Sustainability assessment and environmental impacts of water supply systems: a case study in Tampa Bay water supply system

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Abstract. Due to the accelerated industrial and urbanization development, climate change, and increasing populations and life quality expectations, the issue of drinking water shortage has raised much public awareness. The desalination system has been widely applied to accommodate the growing demand for clean water resources despite the continuous concerns about its relatively higher energy consumption and environmental footprints. This research conducted a case study in the Tampa Bay Regional Surface Water Treatment Plant and Tampa Bay Seawater Desalination Plant in Florida, U.S. It analysed the performance and environmental impacts of conventional and desalination water supply systems on three sides: energy consumption, carbon footprint, and solid waste. Potential negative effects of both water supply systems are generally associated with surface water ecology, groundwater aquifers, coastal environment, and marine organisms. Various environmental impact mitigation plans have been proposed to prevent or restore the detriments caused by carbon dioxide emissions, plant construction, and concentrated brine discharge. Due to the deficiency in freshwater resources, desalination technology is more promising through proper regulations and regional sustainable development.

1 Introduction

From the 18th century onwards, industrial development and population growth have increased the demand for freshwater. In the last 100 years, the global demand for freshwater has increased sixfold 1. Mesfin M. Mekonnen believes that in 2016, 4 billion people worldwide suffered from water shortages 2. At the same time, the World Water Development Report 2018 predicts that 5 billion people will suffer from water shortages in 2050. This is especially true for landlocked countries in the tropics. The amount of fresh water available is further squeezed by the constant pollution of the Earth's water bodies.

Many freshwater supply methods have been used to obtain usable freshwaters, such as Flocculation by ACTIFLO, fog harvesting, solar-powered water filtration, and desalination. Of which, Flocculation by ACTIFLO and desalination are the most widespread applications. The ACTIFLO flocculation process is one of the conventional water treatment methods. Conventional water treatment is a fresh water supply system consisting of water abstraction, water treatment, and water distribution. Conventional water abstraction systems extract surface or groundwater from natural water bodies and transport it to water treatment plants and individual water users. Its environmental impact comes mainly from water treatment technology. For example, ACTIFLO flocculation uses a micro-sand as a flow inhibitor. It improves conventional flocculation and sedimentation processes and reduces costs. On the other hand, desalination is one of the most extensive methods for water treatment. However, it also has various influences on the environment compared with conventional water treatment.

This study took two typical plants-Tampa Bay Regional Surface Water Treatment Plant and Tampa Bay Seawater Desalination Plant in Florida, as an example to compare their environmental impacts based on different water treatment methods. Florida state has the largest number of water desalination treatment plants in the USA, which is the preliminary rationale behind this selection 3. In addition, this study made an assessment of the sustainability of both conventional and desalination water supply systems, calculated their energy costs, carbon footprint, and solid waste, analyzed these impacts on the environment and summarized problems for both methods and proposed measures.

2 Case background

Two selected plants are located in Florida, a “hot spot” of intense desalination activity in the south-eastern part of the United States (Figure 1). One rationale behind the choice of the study area is the interactions between geological and climatic factors contributing to Florida's unique

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hydrological condition. The region is delineated by a diverse landscape that contains interconnected streams, wetland, estuarine and marine ecosystems 4. It is characterized by the scarcity of freshwater resources but abundance in the seawater resources from the Gulf of Mexico. Moreover, in response to the urgent need for a new freshwater supply source, the state of Florida is leading the U.S. in both the number of desalination facilities (167) and the gallons of potable water produced per day (approximately 515 million gallons) with the lowest cost in SWRO facilities 5.

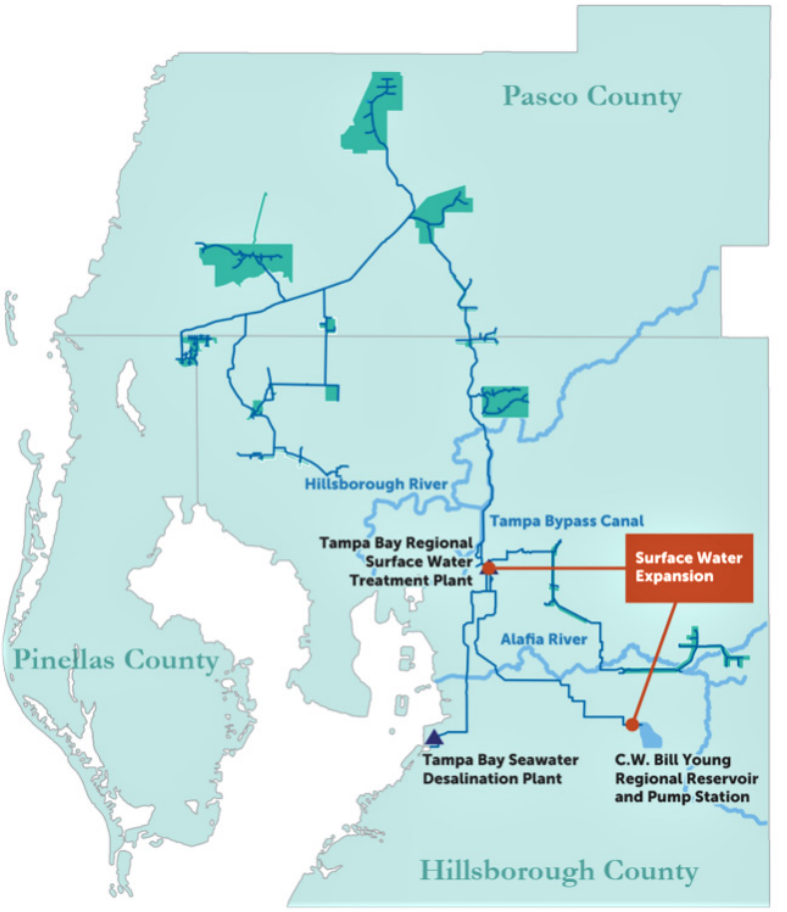


Figure 1. Location of the case study area with the two investigated water plants 6.

Table 1 shows the sphere of sustainability in this research, which is the two selected water treatment plants with their key technologies attached.

Table 1. The selected water treatment plants with their key technologies

Classification	Conventional water supply system	Desalination
Plant	Tampa Bay Regional Surface Water Treatment Plant	Tampa Bay Seawater Desalination Plant
Innovative technology	Flocculation by ACTIFLO	SWRO (seawater reverse osmosis)

The time horizon of this research is one year, which means the numerical results are normalized to an annual average outcome. Meanwhile, the seasonality analysis of energy consumption is also included based on the monthly data within one year. The three parameters utilized to assess environmental impacts are unit energy consumption (kWh/m^3), unit solid waste generated (kg/m^3), and carbon footprint (expressed in CO_2 emissions) (Pounds CO_2/m^3). Of which, the solid wastes are generally defined as sludges from the feed water. Apart from that, they can also include the Natural Organic Matter (NOM) or Dissolved Organic Carbon (DOC), removed from the coagulation or flocculation process in conventional water treatment systems. While in seawater desalination plants, the solid wastes can contain marine microorganisms (e.g., phytoplankton and zooplankton), suspended solids, the sea salt precipitates, and the replaced reverse osmosis membrane.

3 Methods and results

3.1 Source of data

The data relating to the two selected water plants were obtained from Tampa Bay Water's official website, including Energy consumption(kWh) and sludge Hauled (Tons) per month from 2016 to 2019.

Other data, including average water production rate per day and carbon intensity, were obtained from Tampa Bay Water's official website and the U.S. EIA website. In this case study, the average water production rate of conventional water supply is 99 million gallons of water per day, which equals 374,755.8 m^3/day; and the average water production rate of desalination water supply is 25 million gallons of water per day, which equals to 94,635.3 m^3/day. From Table 2, the intensity is assumed to be 2.21 pounds CO_2/kWh 7. Since the water treatment technologies involved in these two plants do not directly generate greenhouse gases, there is no existing data on the parameter of GHG emissions. However, it is investigated that the electrical energy used in the Tampa Bay Water plant comes from a nearby power plant, Tampa Electric's (TECO) Big Bend Power Station. It utilizes coal as its main fuel for power generation, as demonstrated in figure 2 8.

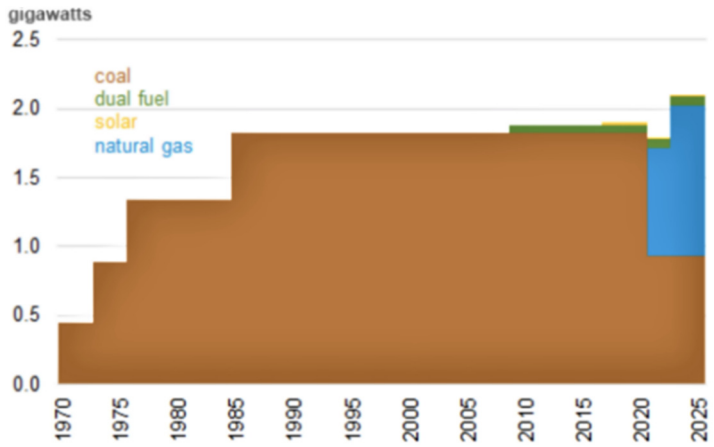


Figure 2. Big bend Power station nameplate capacity by fuel source 8

Table 2. U.S electricity generation and resulting CO_2 emissions by fuel in 2019 7

fuel	Electricity generation million kWh	CO2 emissions million metric tons	million short tons	pounds per kWh
Coal	947,891	952	1,049	2.21
Natural gas	1,358,047	560	617	0.91
Petroleum	15,471	15	17	2.13

3.2 Methods

3.2.1Calculation of energy consumption (kWh/m^3). The first parameter, annual energy consumption per cubic meter water production, can be calculated using equation E= dE/dL, where E is the energy used per cubic meter of water, dE is the energy used per day, dL is water produced per day.

3.2.2 Calculation of solid Waste generated (Sludge Hauled) (kg/m^3). The second parameter, the generated annual solid waste per cubic meter water production, can be calculated by the equation, M_{sludge}=dM / dL, where M_{sludge} is the sludge hauled per cubic meter water, dM is sludge hauled per day.

3.2.3 Calculation of GHG emission (Pounds CO_2/m^3). The third parameter, annual GHG emission per cubic meter the equation can calculate water production, M_{CO_2}=E*I, where I means the carbon intensity (see Table 1).

3.3 Results

According to the calculations, the results of three parameters for both conventional and desalination water supplies are summarized in the following tables. As a result, the conventional water supply system is generally more sustainable than the current desalination technology if only the three calculated parameters are taken into account. The conventional water supply outperforms desalination with SWRO technology regarding water production rate, energy cost, carbon footprint, except for the solid waste generation. However, there is not much solid waste generated, especially in desalination.

3.3.1 Calculation results of the conventional water supply system. The result of the conventional water supply system is stable (Table 3). Energy consumption ranges from 0.083 to 0.094 kWh/m^3 between 2016 and 2019, with an average value of 0.088 kWh/m^3. Solid waste generated ranges from 0.13 to 0.17 kg/m^3, with an average value of 0.153 kg/m^3. GHG emission ranges from 0.18 to

0.21 Pounds CO_2/m^3, with an average value of 0.193 Pounds CO_2/m^3.

Table 3. The results of three parameters from 2016 to 2019 from the conventional water supply

year	2016	2017	2018	2019	average
Energy (kWh/m^3)	0.088	0.094	0.083	0.085	0.088
Solid waste (kg/m^3)	0.14	0.13	0.17	0.16	0.153
GHG emission (Pounds CO_2/m^3)	0.19	0.21	0.18	0.19	0.193

3.3.2 Calculation results of desalination. The desalination water supply system is unstable (Table 4). Energy consumption ranges from 0.331 to 1.207 kWh/m^3 between 2016 and 2019, with an average value of 0.772 kWh/m^3. The solid waste generated ranges from 0.009 to 0.034 kg/m^3, with an average value of 0.024 kg/m^3. GHG emission ranges from 0.73 to 2.67 Pounds CO_2/m^3, with an average value of 1.71 Pounds CO_2/m^3.

The results show that the annual data of three parameters vary greatly and peak in some specific years. For example, in 2017, energy consumption and CO_2 emission are much larger than in any other year. In 2018, the result of solid waste was much more than other years. The average energy consumption is 0.772 kWh/m^3, which is higher than the conventional one. The average CO_2 emission is 1.71 Pounds CO_2/m^3, which is also higher than the conventional water supply. The average solid waste is 0.024, which is lower than the conventional one.

Table 4. The results of three parameters from 2016 to 2019 from the desalination water supply.

year	2016	2017	2018	2019	average
Energy (kWh/m^3)	0.331	1.207	0.678	0.872	0.772
Solid waste (kg/m^3)	0.009	0.034	0.027	0.025	0.024
GHG emission (Pounds CO_2/m^3)	0.73	2.67	1.49	1.93	1.71

*3.3.3 Seasonality Analysis of Energy Consumption. Based on the monthly raw data in both water treatme*nt plants, a temporal chart was plotted to intuitively demonstrate the seasonal pattern of energy consumption changes from 2016 to 2019 (Figure 3).

Compared with energy consumption in conventional water supply, desalination water supply shows a more remarkable fluctuation, peaking in the spring (January to May) and nadir in the fall (July to November). On the contrary, the energy cost in conventional water supply increases in the fall while it decreases in the spring.

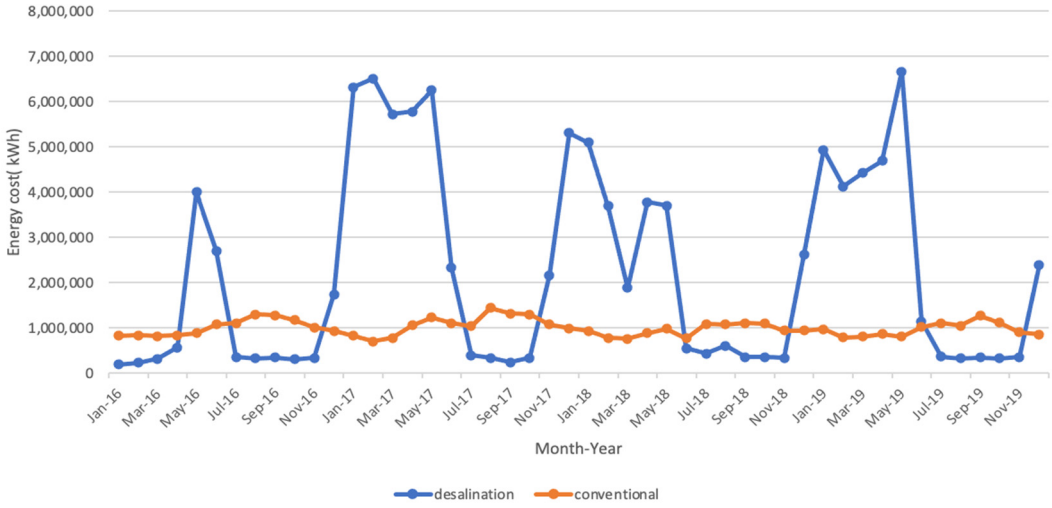


Figure 3. The relationship between energy consumption and seasonal change from conventional and desalination water supply systems

4 Influence of water supply technologies on the environment

4.1 Influence of conventional water supply system

4.1.1 The current status and production process. A typical flow chart below shows the common treatment procedures involved in a conventional water supply plant (Figure 4). Conventional water treatment plants commonly utilize a combination of coagulation, flocculation, sedimentation, filtration, and disinfection procedures to produce safe and clean drinking water for the public. The coagulation and flocculation processes are associated with each other closely, and sometimes can be used interchangeably. It involves adding positively charged coagulants to the water and rapidly mixing to attract the negatively charged dissolved or suspended particles. Then, the larger particles would settle down to the bottom called sedimentation, or they would go through the filtration step directly. This step will decrease a large amount of solid waste.

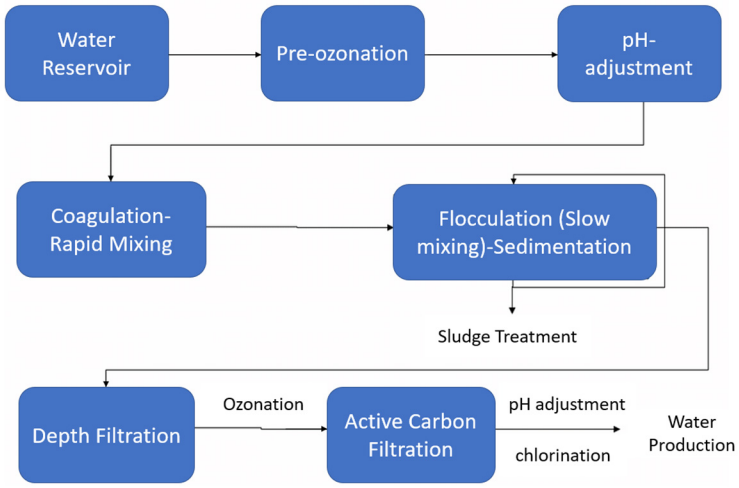


Figure 4. A typical flow chart of conventional water treatment processes.

In this case study, Tampa Bay Regional Surface Treatment Plant utilizes an advanced technology called ACTIFLO® in the flocculation process 9. ACTIFLO® is a high-performance water clarifier, removing the color, suspended solids, colloids and living organisms from the raw water in a high rate and compact process. Flocculation by ACTIFLO process uses Microsand as a flow suppressant, combining traditional flocculation chemistry with inorganic silica Microsand to improve purification efficiency. The high-volume ratio of the Microsand in this process facilitates the binding of stable flocs, resulting in larger volumes of stable flocs with faster settling rates. This method increases the efficiency of water treatment and reduces the area of land used and the total cost 10. Equipped with ACTIFLO®, the treatment plant ensures that water quality is not influenced by seasonal changes, extreme weather, or industrial pollution, even exceeding the demands of Tampa Bay Water's member governments, the Florida Department of Environmental Protection and the EPA.

ACTIFLO® has been applied in municipal and industrial water and wastewater treatment for more than 20 years. Flocculation by ACTIFLO has been used in over 90 plants in the USA in the 20th century with the advantage of dealing with highly variable water qualities. It can work under the condition of rapid raw water or flow fluctuations due to its short hydraulic residence time and quick treatment capability. Additionally, it is particularly efficient in tackling the algal bloom, phosphorus removal, and removing the odor from algae. Apart from conventional surface water treatment plants, ACTIFLO® technology can also be employed in desalination water treatment plants as a pre-treatment procedure. It offers the benefits of life extension of subsequent RO plant membranes, delivery of a continuous and dependable water supply, and maximizing the whole water processing lifecycle to reduce the costs.

4.1.2 Environmental impacts. The environmental impacts of conventional water supply mostly involve hydrogeological alterations to the surroundings. For instance, the excess groundwater abstraction would decrease groundwater level and land subsidence, and surface water extraction can disrupt the natural flow of streams, rivers, or lakes and further impact the aquatic ecosystems 11.

When water is pumped from groundwater well, a cone of depression around the well is formed since water near the well itself is drawn down the furthest. Excessive pumping from shallow groundwater sources can lead to numerous environmental impacts, such as diverting the groundwater away from the baseflow to which they are originally supposed to contribute. As a result, the perennial streams might become intermittent, while intermittent streams even become ephemeral. In addition, the degradation of stream water quality and deterioration of adjacent aquatic habitats can be caused by the decline

of baseflow contribution. Another outcome of excessive pumping of groundwater is the increased susceptibility of the watersheds to climate changes, indicating a slower recovery from flooding or drought 11.

In this case study, however, Tampa Bay Water's Enhanced Surface Water System extracts the surface water from the Alafia River, Hillsborough River, and Tampa Bypass Canal as an alternative to groundwater sources. It cleans it to drinking water standards at the Tampa Bay Regional Surface Water Treatment Plant. Researchers and engineers have proposed several plans to expand the current service scale and production capacity without increasing extraction from the rivers or canal to avoid further environmental impacts. For example, expanding the ACTIFLO technology and secondary disinfection chemical systems, or adding more ozone contactors and biologically active filters, can contribute to millions of more drinking water production per day.

In addition to the impact that conventional water supply plants have on local soil, surface water, and groundwater when built, the sludge produced is also an important factor in environmental pollution. Sludge contains a large number of pathogens, microorganisms, and organic matter, and heavy metals such as chromium, cadmium, and mercury. When they are not properly treated, they will impact soil, groundwater, surface water ETC 12. They can be detrimental to the soil, groundwater, and surface water if not properly treated 12.

4.2 Influence of desalination technology

4.2.1 The current status and production process. Currently, the gap between water supply and demand is growing increasingly larger due to factors like limited available surface water, high population growth and urbanization development, deficient institutional arrangements, poor management practices, water depletion, and deterioration of quality, especially in shallow groundwater aquifers[12]. A desalination water supply system is developed to relieve the stress of freshwater scarcity by transforming the seawater or brackish water into freshwater resources. Desalination of seawater is estimated to produce approximately 5000 million m^3 of water annually. It prevails in arid or semi-arid regions like the Middle East areas (e.g., Israel, Saudi Arabia, and the United Arab Emirates) with the advantage of providing stable drinking water productions regardless of time, space and climate. The Arabian Gulf is a "hot spot" of intense desalination activity. Meanwhile, other regional centers of activity are becoming more prominent in the Mediterranean Sea and the Red Sea, or coastal areas of California, China, and Australia 13. Moreover, the desalination technology has developed to provide a reliable source of drinking water at a price comparable to that from conventional sources, especially in Tampa Bay Seawater Desalination Plant. Therefore, it is considered the most achievable and promising alternative to meet current and future domestic water requirements.

There was sold and installed reverse osmosis desalination technology with a purification capacity of up to 1,050,600 m^3 /day from 1960 to 1980. During the past four decades, reverse osmosis (RO) membrane technology has gradually prevailed in desalting production, occurring in 80% of the global desalination plants. It has been widely applied in municipal drinking water supply and industrial or agricultural usages, with an increasing water production rate that is attributable to the decline in cost and advances in technology 14.

Processes in a typical desalination plant with the SWRO technology usually include seawater intake, pretreatment, reverse osmosis (RO), and post-treatment (Figure 5). The reverse osmosis process pressurizes the incoming water through the membrane, which results in a pressure difference between the incoming and outgoing water on either side of the membrane. The incoming water is pushed to flow through that membrane. In effect, the incoming water first enters a closed container through a pump, pressuring the membrane. This is opposed to osmotic pressure. But the salinity of the remaining feed water and brine solution becomes increasingly concentrated when there is water passing through the reverse osmosis membrane. The remaining concentrated brine requires further treatment before it is discharged, for example, removing a portion of the concentrated brine solution for disposal or utilizing it. The reverse osmosis system incorporates four major procedures: (1) feed water pretreatment, (2) pressurization, (3) membrane separation and (4) post-treatment stabilization 14.

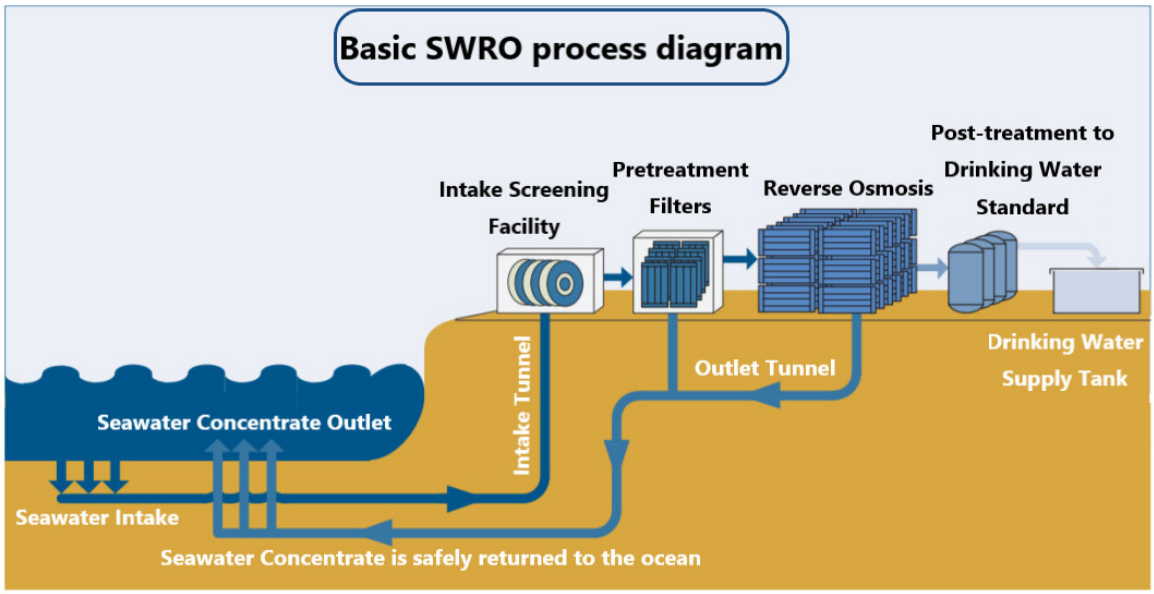


Figure 5. A diagram of a typical SWRO process 15

RO can be further divided into SWRO (Seawater Reverse Osmosis) or BWRO (Brackish Water Reverse Osmosis) based on the salinity or origin of the feed water. This research particularly focuses on the Seawater Reverse Osmosis (SWRO) technology, which is relatively more economical and has the most potential to dominate the future desalination market 13. SWRO has become an emerging alternative desalination technology due to its lower energy consumption compared with other processes like multiple-effect distillation (MED), multi-stage flash (MSF), mechanical vapor compression (MVC), and thermal vapor compression (TVC) (Table 5).

Table 5. Energy consumption of the main desalination processes 16

Properties	MSF	MED	MVC	TVC	SWRO	BWRO	ED
Typical unit size(m^3/day)	70,000	15,000	3,000	30,000	128,000	98,000	145,000
Thermal energy consumption (MJ/m^3)	190-282	145-230	None	227	None	None	None
Total electricity consumption(kwh/m^3)	19.58-27.25	14.45-21.35	7-12	16.26	4-6	1.5-2.5	2.64-5.5
Product water quality(ppm)	≈ 10	≈ 10	≈ 10	≈ 10	400-500	200-500	150-500

4.2.2 Environmental impacts. Compared with traditional water supply systems, more public concerns about SWRO are raised due to its potential environmental impacts, despite various human health and socio-economic benefits, it brings about by producing a stable and unlimited high-quality drinking water without impairing natural freshwater ecosystems 17. The environmental impacts of SWRO technology generally include the energy consumptions with its associated greenhouse gas (GHG) emissions, the disturbance and impingement of marine organisms through the seawater intake process, the possible, solid waste pollution by landfill leakage, and the contamination by concentrate discharge through seawater outfalls 18.

In addition to the GHG emissions, other gaseous emissions from desalination stacks like sulfur dioxide (SO_2), carbon monoxide (CO), nitric oxide (NO), and nitrogen dioxide (NO_2) can also do detriments to public health 19. During the construction of water intake pipelines where feedwater and concentrate discharge are transported, disturbances on the seabed can results in the resuspension of sediments, nutrients, or pollutants into the water column, especially in environmentally sensitive areas [13]. While taking in the feed water, impingement often occurs, which means the losses of aquatic organisms when they collide with the intake screens, or entrainment of the organisms, which further burdens the pretreatment process and impacts the watershed ecology.

In contrast with the conventional water treatment process, desalination processes do not produce much sludge. However, discharged concentrates pose another serious challenge to the adjacent marine habitats and impair the coastal water quality, due to the high salinity, a certain amount of toxic chemicals, and elevated temperatures of the concentrates. The salinity of concentrated seawater produced by membrane desalination systems is 1.3 to 1.7 times higher than that of raw seawater. Even though the concentrated seawater is diluted after discharge, the salinity of the seawater in the vicinity of the outfall is still high. Concentrated seawater significantly increases the salinity of the seawater in the vicinity of the outfall. It creates a high salinity zone in a certain area, thus seriously affecting the marine ecosystem. At the same time, the acidic seawater may lower the pH of the seawater, resulting in localized acidification of the seawater 10. At the same time, the acidic seawater may lower the pH of the seawater, resulting in localized acidification of the seawater. The temperature of the

concentrated seawater produced by the reverse osmosis process is usually 3°C to 5°C higher than the ambient temperature [20]. Increased temperature can lead to lower dissolved oxygen concentrations, harming local organisms in the discharge area.

Furthermore, there is a potential risk of pipe leakage that the concentrated brines ejected from the desalination plant would infiltrate the underground and contaminate the groundwater aquifers due to the toxic chemical residues and by-products in the treated water 21. The chemicals utilized in the desalination process for pre- and post-treatment include sodium hypo chloride (NaOCl) for chlorination to prevent bacterial growth in the desalination facility; ferric chloride ($FeCl_3$) or aluminum chloride ($AlCl_3$) as flocculants for the removal of suspended matter from the water; anti-scale additives such as sodium hexametaphosphate $(NaPO_3)_6$ to prevent scale formation on the pipes and membranes; and acids such as sulfuric acid (H_2SO_4) or hydrochloric acid (HCl) to adjust the pH of the seawater 13. Moreover, chemical pretreatment and cleaning are indispensable in most desalination plants, typically dealing with biofouling, scaling, foaming and corrosion in thermal plants, and biofouling, suspended solids, and scale deposits in membrane plants.

5. Discussion

5.1 limitations of conventional and desalination water supply systems

According to the case study results in the Tampa Bay Region, the conventional water supply is less energy-intensive and thus causes less environmental impacts than desalination. However, its production is limited by the shortage of freshwater resources, the weather and location. Moreover, traditional drinking water treatment shows limited ability to remove micropollutants 22.

The seawater desalination, though widely investigated and accepted, still pose several challenges in practical application. For instance, the energy consumption of desalination is generally higher than that of conventional water supply, which leads to more CO_2 emission. Additionally, the concentrate discharge, if unproperly handled, can have localized impacts on marine ecosystems. In light of the huge storage of seawater resources on Earth, desalination is undoubtedly a predominant alternative to the conventional water supply when considering sustainability. Considering the recent release of Fukushima's nuclear wastewater into the ocean, which largely detriments the marine organisms and water quality, researchers have to develop new methods to treat seawater contaminated by radioactive substances.

5.2 Best Management Plans on RO plants

Several solutions and recommendations based on the limitations mentioned above are summarized, supporting the global implementation of desalination technology. If properly sited, designed, and operated, RO plants are capable of minimizing the energy demand and environmental footprint 23.

Firstly, as a result, found in 3.33, selecting the plant location prudently can enable the seasonal supplementary water supply between conventional and desalination plants, which optimizes the performance of water supply systems. The next step is to employ a tailored treatment system to reduce the environmental impacts, minimizing the constructions as much as possible. If the fuel resources and there will be less disruption to the environment [24]. For example, the Tampa Bay Seawater Desalination Plant takes the advantage of existing water connections pipes to receive both the raw water and cooling water from the Tampa Electric's (TECO) Big Bend Power Station (Figure 6).

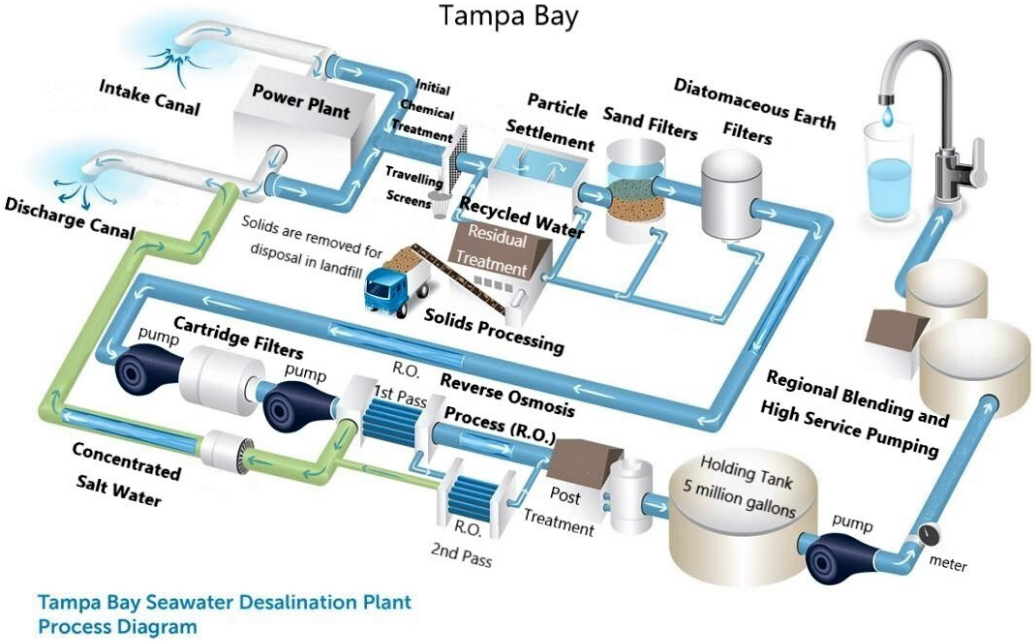


Figure 6. Diagram of Tampa Bay Seawater Desalination Plant Process 25

Furthermore, operational improvements can augment sustainability by using clean energy to reduce CO_2 emissions or improving the performance of RO membranes. Wind and solar energies are common clean energy sources in coastal areas and high potential in electricity generation 26. As a renewable and clean energy source, Tidal energy can generate electricity for RO plants with more predictability. There are many other options like biomass energy and ocean thermal energy conversion (OTEC). As for the RO membranes, heating the feed water to an optimal temperature can improve the efficiency and performance of RO membranes. For example, the extracted seawater in the Tampa Bay Seawater Desalination Plant is blended with the cooling water from the nearby power plant to reach the optimal temperature. In addition, regular maintenance by chemical cleaning the biofouling on the RO membranes can extend its life cycle and reduce the replacement cost. The fouling in SWRO plants is mainly attributable to the deposition of particulate matter, organic compounds, and biological growth 27. Therefore, operational interruption is essential to reverse the fouling.

Various mitigation plans have been summarized in terms of concentrate management, including surface disposal, sewer system blending, land application, deep well injection, evaporation ponds, and zero liquid discharge (Table 6). According to Höpner and Lattemann 27, almost half of the desalination facilities in the U.S. employ the surface water disposal plan. A variety of factors should be considered before determining the optimal disposal plan, such as volume of the concentrate, quality or salinity of the concentrate, the location of the desalination plant, capital, and operational costs, and local environmental regulations 21.

Table 6. A summary of concentrate discharge options and environmental impacts mitigation methods 21.

Discharge Options	Environmental Impacts Mitigation Methods
Surface disposal	Use non-toxic additives; raise pH before discharge; diffusers, bending, mixing zones
Sewer system blending	Reduce recovery; membrane type selection
Land application	Reduce recovery; lending membrane type selection
Deep well injection	Move disposal location or change means of disposal when well leakage occurs
Evaporation ponds	Double lining with leachate collection systems when pond leakage or landfill leakage occurs
Zero liquid discharge	

Specifically speaking, the brines can be pre-diluted with power plant cooling water to reduce the high salinity. The outfall needs to reach maximum heat dissipation before effluents discharge to avoid impacts from high temperature, and hazardous chemical substances particularly the biocides, should be treated before discharge to minimize the negative effects on non-target organisms. A more sustainable, cost-effective and environmental-friendly solution was proposed by El-Naas 28, which coastal and inland desalination plants can use. The reject brine can be converted to reusable sodium bicarbonate solids, and the treated brackish water can be utilized for irrigation. Even the carbon dioxide gas can be captured in pure form or as a mixture of exhaust or flue gases.

Above all, the desalination activity should be integrated into regional management plans that supervise the site selection of RO plants, the water resources and energy utilization, and implementation of advanced desalination technology to avoid an unruly and unsustainable development of coastal areas.

6 Conclusion

Conventional water supply is less energy-intensive and more widely applied than the desalination identified by the sustainability parameters calculated in the case study of Tampa Bay water supply systems. Still, it is also limited by the deficiency in freshwater resources. Conventional water supply mainly impacts the aquatic ecology or watershed hydrology by feed water intake from both surface streams and groundwater extraction. Implementing ACTIFLO technology in the flocculation process can help enhance the pre-treatment performance and reduce the environmental footprints.

Currently, the desalination technology can provide stable and clean drinking water and needy populations as an expedient solution to freshwater scarcity worldwide, which prevails the potential negative environmental impacts. The proposed environmental issues are discussed with their corresponding solutions or recommendations. Site selection of the RO desalination plants should be based on environmental and engineering factors to reduce the construction costs and impacts. Moreover, operational improvements on clean energy and membrane performance can augment the sustainability of the plant. Concentrate management plans and plans mentioned above should be considered under the context of regional sustainable development.

In conclusion, desalination has a promising outlook regarding drinking water supply, and technological advancements would gradually overcome the potential adverse effects.

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