Institute of Biodiversity and Environmental Conservation

Perception of Operators on Waste Management Systems in Desalination Plants in the United Arab Emirates

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Perception of Operators on Waste Management Systems in Desalination Plants in the United Arab Emirates

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

The technique of desalinating saltwater is one of the most practical ways to meet the growing need for freshwater in the Gulf countries, especially in the United Arab Emirates (UAE). Desalination offers great benefits in terms of the economy, society, and health; however, there are also negative effects on the environment because of uncontrolled waste disposal. The study aims to determine the perception of operators on waste management systems in desalination plants in the UAE. This study adopted a descriptive research design for collecting data about the impact of unregulated wastewater management and types of unregulated wastes using naturalistic observation and survey. The quantitative data was collected from the respondents using structured and close-ended questionnaires with a 4-point Likert scale. A simple random sampling method was used for selecting respondents in desalination plants. About 150 respondents were included in the study to get their perception of existing control measures and the development of innovative ideas or technology to control the brine impact and contribution of desalination plants to the development of waste management systems in the UAE. Data analysis was done using statistical tools like Chi-square. The results of this study showed that solar power plants benefit the UAE's people and economy. It was also observed that UAE desalination plants kept on trying new techniques like reverse osmosis (RO) and electro dialysis (ED) to reduce the levels of waste production and safeguard the natural surroundings. Hence, UAE desalination plants must adopt proper techniques and waste disposal methods to dispose of harmful brine, which will help preserve and safeguard the environment. It was found that the UAE is taking initiatives to treat and regulate brine discharge from desalination plants in order to provide citizens with safe and clean drinking water. However, the rejected brine and other waste liquids have a negative impact on the marine ecosystem.

Keywords: Desalination, waste management, greenhouse gas emissions, brine disposal, reverse osmosis.

Persepsi Pengendali Terhadap Sistem Pengurusan Sisa di loji Penyahgaraman di UAE

ABSTRAK

Teknik penyahgaraman air masin adalah salah satu cara paling praktikal untuk memenuhi keperluan air tawar yang semakin meningkat di negara-negara Teluk, terutamanya di Emiriah Arab Bersatu (UAE). Penyahgaraman menawarkan faedah yang besar dari segi ekonomi, masyarakat dan kesihatan; namun, terdapat juga kesan negatif ke atas alam sekitar kerana pembuangan sisa yang tidak terkawal. Matlamat kajian ini adalah untuk menentukan persepsi pengendali terhadap sistem pengurusan sisa di loji penyahgaraman di UAE. Kajian ini menggunakan reka bentuk kajian deskriptif untuk mengumpul data tentang kesan pengurusan sisa kumbahan tidak terkawal dan jenis sisa tidak terkawal menggunakan pemerhatian dan tinjauan naturalistik. Data kuantitatif dikumpul daripada responden menggunakan soal selidik berstruktur dan tertutup dengan skala Likert 4 mata. Kaedah persampelan rawak ringkas digunakan untuk memilih responden dalam loji penyahgaraman. Kira-kira 150 responden telah terlibat dalam kajian untuk mendapatkan persepsi mereka terhadap langkah kawalan sedia ada dan pembangunan idea atau teknologi inovatif untuk mengawal kesan air garam dan sumbangan loji penyahgaraman kepada pembangunan sistem pengurusan sisa di UAE. Analisis data dilakukan menggunakan alat statistik seperti kaedah Chi-square. Hasil kajian ini menunjukkan bahawa loji tenaga solar memberi manfaat kepada rakyat dan ekonomi UAE. Ia juga diperhatikan bahawa loji penyahgaraman UAE terus mencuba teknik baharu seperti osmosis terbalik (RO) dan dialisis elektro (ED) untuk mengurangkan tahap pengeluaran sisa dan melindungi persekitaran semula jadi. Oleh itu, loji penyahgaraman UAE mesti menggunakan teknik yang betul dan kaedah pelupusan sisa untuk melupuskan air garam berbahaya, yang akan membantu memelihara dan melindungi alam sekitar. Oleh itu, dapat disimpulkan bahawa

UAE sedang mengambil inisiatif untuk merawat dan mengawal air sisa daripada loji penyahgaraman bagi menyediakan air minuman yang selamat dan bersih kepada rakyat, namun ia memberi kesan negatif kepada ekosistem air laut dan persekitaran semula jadi yang menolak air garam dan air sisa lain.

Kata kunci: *Penyahgaraman, pengurusan sisa, perlepasan gas rumah hijau, perlupusan air garam, osmosis terbalik.*

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LIST OF ABBREVIATIONS

ED/EDR	Electro Dialysis and Electro Dialysis Reversal
ERD	Energy Recovery Device
LTE Desalination	Low-Temperature Evaporation Desalination
MD	Membrane Distillation
MED	Multi-Effect Distillation
MSF	Multi-Stage Flash
RO	Reverse Osmosis
SSD	Single Stage Desalination

CHAPTER 1

INTRODUCTION

1.1 Research Background

Desalination is the process of cleaning and purification of water in a high-power plant. This process of making water clean, pure, and fit to drink is primarily used in Gulf Cooperation Council (GCC) countries. The usage of desalination process is used in these countries because the availability of freshwater sources is very low (Moossa et al., 2022). This water is used as the primary source of freshwater supply to the domestic sector and other industries. Some of the desalination plants could be found in Egypt and Arabian Gulf countries. There are more than 199 desalination plants, and some of them are used in collaboration with power production plants which produce about 5000 million m^3/year of seawater. The United Arab Emirates 35%, Saudi Arabia 34%, Kuwait 14%, Qatar 8%, Bahrain 5%, and Oman 4% accounted for seawater desalination capacity, which is estimated to rise and reach up to 1800 million m^3/year by 2013. An increase from 3000 million m^3/year in 2000 to about 5000 million m^3/year by 2012 could be seen in GCC countries which is estimated to rise to 9000 m^3/year in 2030 (Al-Kaabi, 2021). Hence, it could be cited that desalination of water is an important technique that is used by various arid countries to get access to clean drinking water. To comprehend the study to its fullest, undertaking a complete understanding of facts concerning the water consumption in UAE, its composition, and meaningful statistics of the same is essential. The section also covers the sources of water for the country as well as the challenges it faces due to the crisis of increasing demand. Figure 1.1 shows the country-wise desalination capacity in the Arabian Gulf in m^3/day (Lattemann et al., 2008).

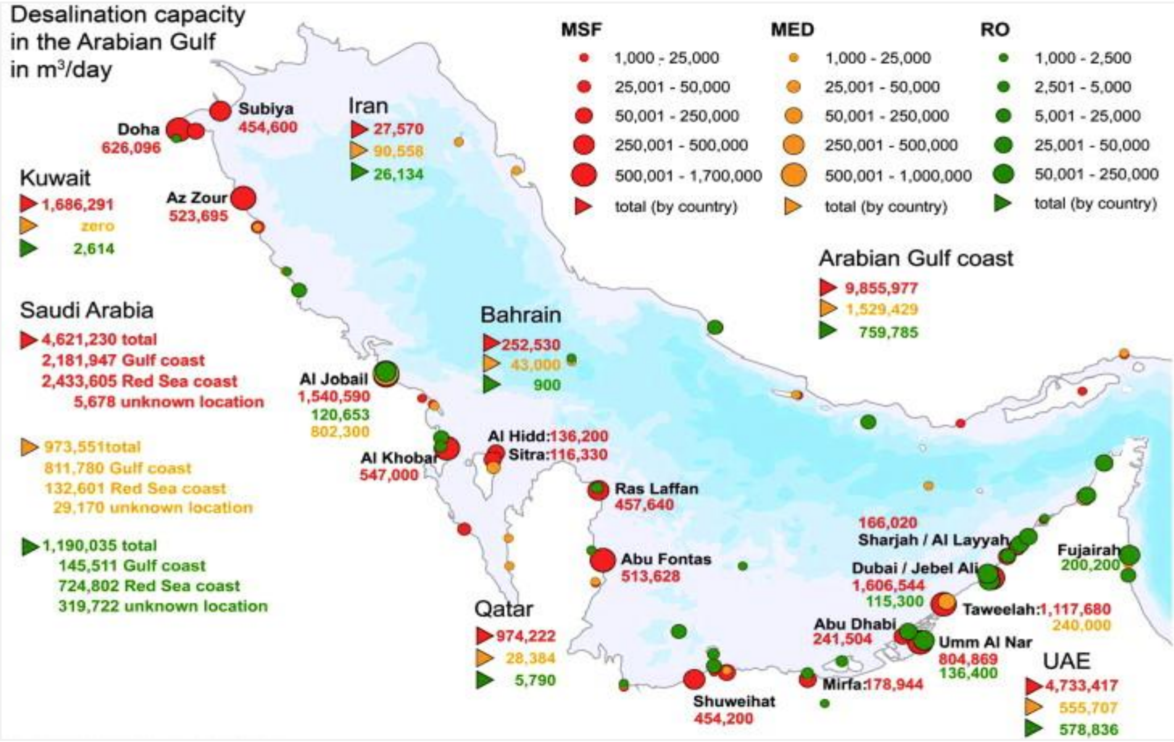

Figure 1.1 Topography of the desalination plants in the Arabian Gulf and its Capacity

1.1.1 Statistics on Water Consumption in UAE

Water consumption in the United Arab Emirates (UAE), owing to its geographical whereabouts, falls under the top 10 most water-scarce countries in the world. This is easily understandable when some light is shed upon its climate, which is exceptionally hyper-arid in nature. The annual average rainfall more than often falls below 100mm. However, when statistics are taken into consideration, UAE also becomes the country with one of the highest per capita water consumption rates in the world, which is 550 liters per day which is easily double the national average at the global level. It is coequally significant to take into consideration the complete understanding of the composition or the mix of this level of water consumption by bringing into light the latest annual report on the same. For this purpose, the Annual Statistics Report of 2017 published by DEWA (Dubai Electricity and Water Authority) under the government of UAE is relied upon. Accordingly, water consumption is the highest among residential, as much as 61.34% of the total (Manju & Sagar, 2017). Commercial consumption comes next with 27.26% of the total, and industrial consumption falls at 3.26%. The remaining 3.26% is allocated to the category of others. This forms a very dynamic group consisting of non-commercial sections and individuals as well, including mosques, police stations, government hospitals, government-run or affiliated educational institutes, DEWA offices, staff premises, and other similar authorities under the government, etc.

When the understanding of water consumption in terms of the number of consumers as opposed to the quantity consumed is undertaken, a slight shift in the statistics is observed. The findings suggest that with respect to the number of consumers, residential constitutes a solid 81.31%, with commercial consumers accounting for 18.08% and industries comprising as low as 0.21% of the entire mix. The remaining 0.40% comprises all the consumers falling under the category of the others already mentioned above. Understanding water consumption based on its source and quantity used is of vital significance. Groundwater consumption accounts for as much as 43.7%, while treated water comes next at 14.5%. Desalinated water holds a prominent place in this country's consumption at 40%. At the same time, surface water accounts for as low as 0.4%. Another statistical gathering of crucial importance in any economy is the understanding of the consumption of water concerning its utilization in different sectors. In this regard, the agricultural sector, owing to the geographical misfortune of the nation, comprises as low as 0.8% of the country’s GDP, but irrigated agriculture consumes the primary water consumer as high as 60% on average (Qureshi, 2020). Of this mix, 39% is put into productive agriculture, while about 11%, an approximation, is used for the inevitable task and purpose of greening and landscaping. The remaining 10% is productively brought into use for the fruitful undertaking of forestry, which, as evident, is non-compromised for a country as such. The remaining amount of about 40% of the consumption is municipal use composed of industrial as well as household purposes.

1.1.2 Different Sources of Water and Challenges Faced by the Country to Meet the Ever-Increasing Demand for Water

The water resources in UAE can be classified under conventional, consisting of surface water and groundwater, and non-conventional resources, i.e., desalinated water, treated water, cloud seeding, etc. Conventional sources are the traditional sources of water. Under this category falls the surface water comprising floodwater, water retained in dams, some very small streams, ponds, and spring water, etc. which are either confined or flowing, depending on the topography, and occasionally replenished by precipitation and groundwater reservoirs. Precipitation is nevertheless scarce due to its pre-existing location in a very dry and humid area, and floodwaters readily seep into the ground, as is typical in sedimentary regions. This makes dam constructions vital here in order to harvest the rainwater and preserve the already less surface water and use it to feed the aquifer. However, the high rate of evaporation in the region makes this task an oddball. UAE’s arid environment makes groundwater an extremely valuable resource for all the social and environmental purposes it serves, along with being valuable for municipal and rural supplies (Ali et al., 2018). It is as high as 640 billion cubic meters, but only 3% is usable and fresh due to its brackish quality and is further subdivided into the category of renewable (shallow aquifers) and non-renewable resources (deep aquifers). The aquifers in the western desert region are saline, but the Bajada region, located in the eastern part, is rich in groundwater resources, consisting of alluvial deposits on the base of Oman and Ras Al-Khaimah Khaymah - mountains. The upper aquifer consists of gravel sand and silts, while the lower aquifer consists of limestone, dolomite, and marl, ranging in thickness from 200 to 800 meters.

Yearly rainfall and surface run-off affect the recharge of shallow aquifers heavily and, thus, are prone to change on an annual basis. Also, being vulnerable to high evaporation and surface water run-off in areas with slopes leaves only 10% to 14% rainfall available to replenish the aquifers. High evaporation rates also increase salt concentration in roots during summers which then, due to excessive irrigation, is carried to the aquifers, which deteriorates the situation. However, adopting sustainable groundwater management and controlling groundwater mining by the government has helped to an extent. Non-conventional sources have come to be crucial to the UAE over the years, and desalinated water deserves a special mention with the second highest capacity in the same after Saudi Arabia. Desalinated water, used either directly or blended with groundwater, meets the qualitative and quantitative requirements for drinking water standards, domestic water supplies, etc. The availability of desalinated water at relatively low costs has also been a big boost to the industrial sector altogether. There are 33 major desalination plants in UAE, most of which use co-generation multi-stage flash (MSF) technology multiple-effect distillation (MED), while only two plants use reverse osmosis (RO) technology. On account of the completion of wastewater treatment facilities and the expansion of urban sewage networks, large quantities of treated wastewater are now available at the disposal of the UAE public for fulfilling various purposes. There are about 79 medium and large wastewater treatment plants discharging as much wastewater, amounting to about 615 million cubic metres (MCM), or around 14% of the total water resources used. The treatment is undertaken, partially or completely, regardless of its intended use, owing to the rising environmental concerns. Currently, UAE owns as well as utilises tertiary and advanced treatment capabilities in the operation of its modern treatment facilities. Municipalities have been made responsible for building and managing sewage systems, creating networks for stormwater collection, and reusing treated wastewater for purposes like irrigating gardens and highway landscaping, etc. However, often enough, almost half of the treated wastewater is discharged into the Arabian Gulf due to inadequate operating networks for transmission and distribution to the end users. Other than this, the difficulty in convincing farmers to bring treated wastewater into utilization acts as a cultural barrier. The UAE is one of the leading countries in cloud seeding and artificial rainmaking, with unseizable improvements achieved over the years (Al Bloushi et al., 2018). This is evident by the 2 million dirhams (around $550,000) spent on cloud seeding operations in 2015. Cloud seeding, up to this day, has been carried out a majority of times in eastern mountain ranges, on the border with Oman. The aims of the same have been to raise the groundwater levels in aquifers and reservoirs in the area. However, some cloud seeding over the cities has also been carried out. With all due respect to its observed success in increasing precipitation, a thorough study on its cost efficiency and availability as a viable option in comparison to other options is yet due.

All of the valuable water resources covered in the previous section are coming under incredibly increasing pressure as the population and its water consumption have been on an in suppressible rise for more than a decade now (Alzaabi & Mezher, 2021). The countrymen's luxury lifestyle has been under frequent criticism for increased water demand and consumption. The high intake of water by people for household and farming purposes is to blame. The fact that the people have a free water supply in the UAE makes them wastewater without much concern. Also, lack of knowledge and, if not knowledge, then will for making any efforts at water conservation on a personal level has been under fire. The water wastage on the farms is observed to be even higher. Irrigation water is more than often used in a wasteful manner, mainly because of the use of traditional flooding and furrow irrigation techniques and for cultivating low-value, high-water-consumption crops. In fact, losses have been seen to be as high as 50% of pumped groundwater. Regarding this, the country's water infrastructure is under agitating pressure which has been further amplified because of other problems such as budget cuts, as a result of falling government revenues due to low oil prices, affecting existing projects. According to environmentalists, the UAE will run out of water resources in 50 years. Hence the country is facing some serious challenges. The depletion of groundwater levels has become a matter of serious concern requiring immediate and uncompromising action on the government’s part. Groundwater levels in different regions of the country have seen a high-paced depletion of about 60 meters on average. This is a serious problem as groundwater in UAE translates as the main source of water resources. The fact that the country's environmental conditions make it more vulnerable to depletion and less convenient to replenish is a scary reality. The salinity level in groundwater has also been seen to be on an upward trend. The environmental circumstances have never been supportive of the UAE water infrastructure anyway. The high evaporation rates, especially during summers, result in the accumulation of salt in root zones, increasing salt concentration (Safdar et al., 2019). However, excessive irrigation results in percolating of water deeper and then acts as a carrier of these accumulated salts to aquifers which in turn further aggravates the already deteriorating groundwater quality condition. Competing sectorial demands is another challenge the UAE is feeling heavily under pressure. Rising population and urbanization growth which is directly related to water demand in the domestic as well as the industrial sector, has become a major problem. Priority clashes in the allocation of limited water resources have been observed. For example, the policy of food self-sufficiency, which aims to increase the UAE’s own food production for domestic consumption, restricts the allocation of water resources to other sectors. The changing environmental conditions have only worsened the prevailing condition in relation to excessive water consumption resulting in a scarcity crisis. Not only does the weather disrupt the sincere attempts made at sustaining water, but it has also been in an evil uproar as problems of desertification and land degradation are on the increase. According to environmentalists, in the succeeding 50 years, rainfall may decrease by 15-20%, and rising temperature is required to increase evaporation rates. It will be vulnerable to severe weather events such as floods and drought cycles. In the UAE, climate change and an increase in water consumption will cause water scarcity (Awadh et al., 2021). Overall, the most challenging aspect that this water infrastructure management has posed in front of the government has been regarded as the budgeting and excessive expenditure demand it has created. The government has been under pressure to invest in infrastructure and water efficiency technology. A limited budget due to falling government revenues with low oil prices has affected existing projects adversely. The realisation that opportunities lie in technology and innovations that can make drinking water production efficient, storage solutions, and wastewater treatment and reuse has been made but at high expenses

1.1.3 Types of Unregulated Wastes from Desalination Plants

It is found that desalination leads to the generation of unwanted substances like pollutants, harmful gases, etc., which leads to environmental change. It was found that the desalination plant was responsible for bringing impurities and pollutants. It was also responsible for bringing changes in the climate and increasing the level of environmental pollution. It was found that the wastewater generated from the desalination plants, when released into seawater, led to an increase in the salinity of the seawater resulting in harming the marine life of the waters and impacting the marine ecosystem. The process of carrying out desalination activity at all the plants that are located in the Gulf regions led to the usage of large quantities of water. This led to the creation of water pollution, which mainly occurred in the coastal regions where most of the desalinated plants were located. Hence, a high concentration of waste disposal was found in these areas due to carrying up various desalination tasks and carrying out procedures related to the pre-treatment of the units (Alsharhan & Rizk, 2020). The cleaning of the plants, pipelines, and storage equipment also required the consumption and discharge of large quantities of chemicals which increased the chemical potency of the coastal regions in comparison to the inland areas. It was found that many of the plants were functioning in collaboration with the thermal power plants, mainly at the stage of Multi-Stage Flash (MSF), which resulted in increasing the temperature of the seawater, salinity, water currents, and turbidity. This led to the concentration of high levels of microelements like Arsenic, Lead, Dioxin, etc., including toxic materials like carbon monoxide, nitrogen dioxide, Sulphur dioxide, etc., in places that were located close to the desalinated plants. The increasing effect of the desalination plants could be seen with the increase in the sea urchins, which mostly occurs due to high salinity and sewage concentrations in the seawater. It must be noted that high-frequency sea urchins negatively affect the growth and development of marine species. The high presence of salinity in seawater has not led to bring about any changes in the growing proportions of the toxicants but however has changed the chemical compositions of the toxicants present in the sewage, which has resulted in a reduction of toxicity components in seawater (Shahzad et al., 2017). Apart from this, it was also found that the desalination of seawater, the drinking water that was made available for human consumption, contained a certain amount of boron which caused several health issues to the individuals. It was also found that when carrying out the procedure of desalination and disposal of wastewater into the sea, the amount of dissolved oxygen present in the seawater gets reduced. It leads to a rise in the temperature of seawater, which affects marine vegetation and species in a harmful way. Hence, it could be cited that the desalination of plants resulted in the generation of many outcomes, which laid an impounding effect on the natural environment and human settlements.

1.1.4 Impact of Unregulated Waste Disposal on the Environment

The environmental impacts of the desalination process in the UAE can be assessed by taking seawater intake into account. The open intake of seawater by desalination plants enormously leads to the loss of aquatic organisms as the collision of intake screens that is impingement and entrainment takes place. Structure piping is used in the construction of the intake, which causes seabed disturbances and the re-suspension of sediments, nutrients, or pollutants into the water column, Sgouridis et al.,(2016). This causes disturbances in the natural structure formation of the seabed. When the exchange of water takes place and sediment is transferred to the seabed, the seabed water is polluted. Desalination of water also leads to the production of large quantities of brine water, which increases the temperature, chemical disposition in water, increase in pre-treatment and cleaning chemical residue quantities, reaction (by-)products, heavy metals, and so on. When this residual water with a high chemical composition enters natural seawater, a high concentration of salt is disposed of into the sea, resulting in an increased level of salinity in the natural seawater. This causes an increase in seawater salinity of about 5% to 15% on average, disrupting the natural 41-45 ppt levels of the seawater (Belkin et al., 2017). It has been discovered that the majority of desalination plants collaborate with thermal power plants, increasing the temperature of the seawater by about 7 to 8 degrees Celsius above the eminent levels of 35 degrees Celsius. This has a significant impact on marine life and leads to long-term changes in species composition and abundance near underwater discharge sites. The new environmental conditions can attract or repel marine organisms. Some organisms acquire the potential to get adapted to new environmental conditions to attain sustainability. Benthic communities like seagrass beds are found to get affected by high salinity levels and chemical residues negatively. Apart from polluting the water to high levels, desalination plants also pollute the air by emitting NOx and SO_2. It occurs due to high-energy consumption by desalination plants. Reduction in the dissolved levels of oxygen could be found in the marine water, which harmfully affects the plant vicinity present under the waters (Saif & Almansoori, 2016). The decrease in the concentration and saturation levels of dissolved oxygen also increases the temperature and salinity quotient of the seawater. The presence of chlorine and other heavy metals like iron, nickel, chromium, and molybdenum gets increased in seawater. It is found that due to desalination, the un-ionised ammonia gets increased in the seawater, which increases the pH level affecting marine life in a harmful manner. Hence, it could be cited that desalination leads to a number of impacts on the natural seawater composition and natural air in a harmful manner.

It was found that the products and by-products that were developed by carrying out the process of desalination led to the rise of coagulants, bisulphites, and chlorine (Al-Abri et al., 2022). When such a high-frequency concentrated waste was dumped into the seawater, it negatively impacted marine life and the natural environment and led to the creation of disturbances in the maintenance of ecological balance. It was found that the intake mechanism that was installed by the desalination plants killed about 3.4 billion fish and other marine organisms in a year. Desalination was also responsible for causing damage to the fisherman community, also reducing and killing about 165 million pounds of fish annually, and is expected to kill about 717.1 million pounds in the future. The desalination process of producing clean drinking water was also found to be responsible for putting drinking water supplies at risk. It was found that seawater was found to be a rich source of chemicals like boron which was not found to be present in the freshwaters. Boron was found to be one of the essential elements present in water which helped in carrying out reproductive activities among the animals (Ruiz-Garcia et al., 2019). It was found that desalination was responsible for reducing the boron content by 50% to 70%, which highly impacted the reproductive activities of marine animals. It was also found that the boron present in water caused irritation among humans by creating troubles in the digestive tract. There was a law or regulation that was related to the presence of boron in the clean drinking that was provided by the desalination units. It was also found that desalination contributed to the rise in temperature and was regarded as one of the major causes that led to the creation of global warming. It was found that the desalination plants used a large sum of energy to carry out the water purification process. The removal of salt from large volumes of water took about nine times the operation of the water treatment process from the surface water; the same procedure was carried out 14 times in the case of groundwater usage (Paleologos et al., 2016). To carry out the extensive water treatment process, the desalination plants had to use huge amounts of energy which led to the creation of harmful gases in the environment and increased the temperature of the atmosphere. It was also found that an emission that was released by the operation of the desalination process led to climate change resulting in the emergence of droughts and scarcity of water in varied places.

1.1.5 Measures and Techniques for Controlling Waste Disposal

To reduce the harmful impacts of desalination plants, the Gulf countries have adopted wastewater treatment procedures. Through this, the water can be used for irrigation purposes in nearby regions (Moossa, 2022). The use of wastewater to carry out irrigation activities has led to the recycling of nutrients leading to the protection of the environment. Reverse Osmosis (RO) techniques are used to purify brackish waters in remote areas, which can be used for drinking water and agriculture. The isobaric Energy Recovery Device (ERD) is used to recover the energy from the high-pressure brine. The use of calcite is done to carry out demineralisation and CO_2 treatment that is released by desalination. The introduction of a comprehensive monitoring plan is recommended in the UAE, which will help to regulate the working of desalinated plants and the various processes carried out by them. This stress is laid down on monitoring pre-treatment residuals so that the turbidity or suspend the ability of solids, chemicals, residual disinfectants, and pH can be maintained (Garg, 2022). The usage of membrane cleaning solutions is monitored so that less use of chemicals would pollute the seawater less. The discharge of TDS, salts, heavy metals, nutrients, temperature, dissolved oxygen (thermal processes), and additives such as antiscalants and antifoaming agents by brine must be monitored. The monitoring regarding the dissolved state of copper, nickel, and iron, dissolved oxygen, and temperature must be done adequately. Surveillance of desalinated water supplies must be done by carrying out audit-based activities, direct testing of samples, designing and implementing WSPs, etc. Measures like the implementation of appropriate legislation, regulations, and standards must be done in order to support the provision of safe potable water (Faour-Klingbeil & CD Todd, 2020). Further to stringent laws related to controlling waste disposal in UAE, the licenses to ensure compliance with water quality standards have been regularized. It has been understated that all the major pipelines that are used to supply fresh drinking must not be contaminated or harm the quality of water. Measures like the publication of water quality information, water monitoring methods, products, and processes that are approved for the production of water are to be monitored and published. In addition to this, water quality regulations are also initiated by the UAE governing bodies. To ensure safe and acceptable drinking water quality control, provision of information, testing of samples, treatment process, and storage facilities, distribution networks are to be monitored regularly. Drinking water supply regulations are implemented by the UAE governing bodies to ensure that the populace gets safe and clean drinking water. For this, monitoring and inspecting of customer storage and plumbing are done. Incident reporting and investigation regulations System operators have been laid out by the UAE governing bodies to sustain the emergency plans that could exercise control over bacteriological contamination and hydrocarbon pollution. The reporting of such incidents to the Bureau was made compulsory. Monitoring of desalination plants was laid down by the governing bodies of the UAE. Sanitary inspection is laid down for carrying out the detection and prevention of contamination done by sewage so that the generation of Pathogenic protozoa, viruses, and bacteria could be reduced. Identification and prevention of impacts of microalgae, cyanobacteria, storm events, industrial discharges, etc., are emphasised by carrying out local conditions assessments. Monitoring exercises related to downstream control measures were initiated so that pre-treatment and treatment could be carried out inadequately. Pre-treatment process related to membranes is laid down, which is carried out by identification and prevention of biofouling or scaling, or precipitation (Garcia-Trinanes et al., 2021). The use of additives like antiscalants and quality control of additives and materials is recommended. For carrying out the pre-treatment process related to thermal processes, the use of additives like antiscalants, antifoaming, quality control of additives and materials, and prevention of microbial fouling are emphasised. The pre-treatment process was carried out, and the use of sodium bisulphate, monochloramine, copper sulphate, and ozone was done.

It was found that in Abu Dhabi, many technological upgrades were done along with the usage of natural gas, which led to the reduction of NO_x and SO_2 emissions. Mudflats and sub-tidal areas were planted to control environmental imbalances and focus on building tidal flats. They were regarded as good for the environment and provided habitat to many species

(Lim et al., 2018). In addition, mangrove swamps were planted on the tidal flats. The combination of tidal and mud flats provided an essential ecosystem for many birds' survival. Seagrass Meadows were extensively in the large areas of Arabian Gulf water. Seagrass was found to be essential in promoting a positive marine environment. Seagrass was also found to be consumed by some of the endangered species, like dugongs. They were also the main source of food for all marine turtle species, especially green turtles. Many species like pearl oysters are found to be using Seagrass as their habitat and promotion of many important fisheries species, like shrimps. They were also found to be responsible for stabilising mobile sands and the creation of stable shorelines. Measures were also laid down by the UAE government to promote the growth of corals at the seaside. Coral reefs were found to be responsible for promoting a diverse environment in the marine realm (Hereher et al., 2022). They were also important for the growth of fisheries. Hence, it was analysed that the governing bodies in UAE had taken various steps and measures to control waste disposal generated while carrying out the desalination process.

1.1.6 Contribution to the Development of a Waste Management System in UAE

Many parts of the world were found to be engulfed in the clutches of drought, which led to the scarcity of water in the region. Many regions were found to be inadequately connected with water supply systems, due to which the water became unfit for consumption and led to the generation of numerous diseases and death (Al Shamsi, 2022). Hence, it was necessary to introduce measures or develop a technique that could provide clean and safe drinking water so that the sustenance of the population could be possible. The desalination plants that were laid down in the various parts of the Gulf regions adequately helped in gaining independent sources of water so that human needs could be met properly. The desalination process has further led to the attainment of essential minerals like gypsum, potassium, magnesium, table salt, etc. Effective measures were laid down through which brine water could be extracted to produce more acceptable drinking water (Loganathan et al., 2017). It was also found that the operation of desalination procedures has led to the generation of a mutilating environment which has led to the promotion of ecological balance systems. It was also found that the Reverse Osmosis (RO) process of desalination techniques has led to the generation and promotion of energy savings and a reduction in the emission of carbon dioxide into the environment resulting in deteriorating pollution levels.

It was found that desalination has also made a breakthrough in the agriculture industry and has pulled down the constraints of releasing wastewater into the seabed (Ibrahim et al., 2018). The desalination practices that were used previously were found to be highly costly and used seawater and brackish water on large scales so that the production of clean and fresh drinking water could be done. However, due to extremely high competition in the markets due to the high consumption of water, desalination costs declined. In place of that, the cost of surface water and groundwater was increased. Despite the impounding efforts laid by the UAE governing bodies to reduce the cost of desalinated water, the cost was still found to be high. Due to the monetary value linked with desalinated water, it was not found to be fit for usage in the regular agricultural process. However, the high-cost wastewater could be effectively used to carry out horticulture activities. The high-value cash crops like vegetables and flowers, which are specially grown under the special care of greenhouses, vegetables that were grown in coastal regions could be extensively grown with the help of desalination wastewater (Gude, 2019). It was found that the wider use of wastewater generated by the desalination process was done in coastal regions as the safe disposal of the yield was more adequately possible in the regions that lay near the sea in place of the inland regions.

For effective use of wastewater generated by desalination, the RO procedure of water management was preferred. The application of the RO procedure led to the effective use of wastewater in the agriculture procedure due to reduced cost. The reduction in the cost of wastewater management was due to advancements in the technologies that were taking place in the segment of desalination procedures. Due to the introduction of new technologies, many improvements could be brought to the membranes, which led to the reduction in water production costs by conducting a desalination process. Specific examples of the application of desalinated water could be seen in Spain. It was found that more than 300 desalination plants were built in Spain (Alonso & Melian-Martel, 2018). It accounted for about 40% of the total number of plants that existed in the world. About 22.4% of the wastewater that was generated by carrying out desalination procedures was used in carrying out irrigational activities. It was found that most of these plants used brackish water for carrying out the desalination process. Only about 10% of water was used for the sea in pursuing the process of desalination in order to generate water. About 1000 m^3/d (11.6 liters/s) of water was provided by the desalination plants for carrying out irrigational activities. It was found that adequate arrangements were made so that the farmers could effectively use the wastewater so that the agriculture process could be carried out adequately (Aliku, 2017).

1.1.7 Hurdles and Outcomes of Integrated Waste Management System in UAE

The benefits and the use of the desalination process could be evidently seen with the rising in the extensive use and expansion of the process in various countries. The high use of desalination to carry out the water purification process has led to an increase in the generation of waste in large numbers. The increased use of the desalination process was due to the high consumption of pure drinking water and an increase in the population of the Gulf countries. The unregulated increase in the quantity of discharge has led to the generation of a number of gases in which methane is found to be a great potent greenhouse gas. It can be generated from organic waste, which takes place in municipal landfills or dumpsites (Nanda & Berruti, 2021). It is found that due to the unconditional rise in the cost of the reprocessing of the waste, some of the portions of the waste are burnt. Additionally, it was also found that the effective management of waste could only be done with the help of regional and local governing bodies. It is found that the introduction of new technologies, modified waste segregation techniques, and use of a high dimensional collection system, correcting the concerns related to the management of waste, etc., was dealt with in an adequate manner. It also included carrying out a process that led to the conversion of unregulated waste into different energy forms and resources. It was also found that the Government of Abu Dhabi took a responsible step towards initiating an institution in Tadweer which mainly dealt with the responsibilities of developing strategies, management policy, development of contractual systems, etc. was done so that waste could be treated adequately across the UAE (Al Bloushi et al., 2020). In addition to this, in Abu Dhabi, through the efforts of governing bodies, an organization named the Abu Dhabi Sewerage Services Company (ADSSC) was launched in the year 2005, which was responsible for carrying out the various waste management activities in an adequate manner. For this proper initiative program, AED was launched with a budget of about "5.7 billion (USD 1.6 billion)" so that waste management activities could be carried out in an adequate manner. Another organization called Tunnel Enhancement Programme (STEP) was set up in the year 2009 and was responsible for carrying out activities like the construction of deep sewer tunnels of about 41 kilometers in length. As per the survey conducted by the Official Portal of the UAE Government 2018, it was found that the program ideally diversified about 85% of the waste that was dumped on the grounds (Dweiri et al., 2018).

It was found that a Dubai Integrated Waste Management Master Plan was initiated in 2012 under the supervision of Dubai Municipality's Waste Management Department, which was responsible for reducing the amount of waste that was being sent to landfills to minimum levels within a span of 20 years of time with the application of the integrated and innovative approach. Additionally, Dubai Municipality was expected to launch the largest plant, which possessed the ability to reduce the emergence of methane gas that increased pollution levels in the air. It was found that the capacity of the plant was to accumulate the waste of the whole Middle East. For carrying out the construction process, an estimated amount of AED 2 billion will be required for the effective implementation of the project. It was found that studies were conducted by Dubai Municipality, in coordination with Dubai Supreme Council of Energy and Dubai Electricity and Water Authority, in order to make arrangements to establish the strategy of Dubai for Clean Energy. The program will contribute toward producing 7% of Dubai's total energy from clean energy sources by 2020 (Salim & Alsyouf, 2020). Additionally, the local municipalities that were functional in UAE were found to be responsible for managing disposing and treatment of wastewater adequately. Abu Dhabi Sewerage Services Company (ADSSC), located in Abu Dhabi, was responsible for carrying out the activities that were related to the collection and treatment of wastewater discharged from all residential and commercial customers (Al Jaziri et al., 2022). The public services Department of Ras Al Khaimah carries out activities related to wastewater management. Many investments were made by the governing bodies in upgrading and extending the system of sewage and drainage operations in Abu Dhabi.

1.2 Problem Statement

The functioning operation of wastewater management in the UAE has grown many folds. This is because the extensive use of desalination plants has caused a number of issues and problems, resulting in harmful effects on the environment (Al-Saidi & Elagib, 2018). It must be noted that the environment is an important part of human civilisation, and if it is not maintained properly, many harmful implications, like drought, famine, etc., can occur. Additionally, it must be noted that if wastewater management is not carried out satisfactorily, impounding negative implications could be seen in nature. The huge amount is due to the marine species along with destruction to air. In many cases, the destruction of flora and fauna could also be seen along with the rise in temperature and noise pollution. Moreover, desalination brine and wastes like hazardous waste, industrial waste, agricultural waste, etc., dumped into the Arabian Sea contribute to ongoing marine pollution, which harms the aquatic life and marine ecosystem. UAE's integrated waste management system needs to be improved and innovated by implementing state-of-the-art desalination technologies. The negative consequences highlight the importance of sustainable desalination. Due to the absence of integrated waste management systems, most of the GCC countries have poor desalination waste management practices. However, some cities in the UAE, have started encompassing integrated waste management and sustainability practices in addition to desalination and other supply chain activities. The greenhouse gas effect, the decline in aquatic life, disruption of the marine ecosystem, poor seawater quality, noise, water, soil, and air pollution, as well as the usage of the non-biodegradable package for processed water, are all effects of by-product disposal into the inland and sea and improper desalination wastes. New desalination technologies have been developing as a result of increased sustainability efforts, with the main objective of transitioning from conventional, unsustainable desalination to modern, green desalination based on circular, green, resilient, agile, and lean supply chain principles. In discussions of supply chain sustainability, desalination has been essential because of its detrimental effects on environmental conditions. It can be noted that there is a vast and constantly expanding body of literature on desalination technologies, frameworks, policies, practices, and their effects. However, there have not been adequate studies conducted on the relationship between desalination plants and supply chain sustainability. Hence, the current research study is necessary to be carried out so that various harmful implications of the desalination plants and improper wastewater management can be understood in a better way.

1.3 Research Scope

The discussions of this thesis focus on waste management, desalination plants and their environmental impacts, and the sustainability of the supply chain. This thesis thoroughly explains various desalination technologies used to treat wastewater, brackish water, and seawater. Further, it looks into the conventional techniques, technologies, and methods to eliminate waste, the effects of these methods, and the waste from desalination on climate change and the marine ecosystem. The introduction of suitable desalination technology to the UAE is then covered in more detail. This research also evaluates the Perception of operators' waste management system in a desalination plant and its challenges and mitigation measures. A total of 150 respondents were been involved with different levels and qualifications working in 3 major Desalination plants in the UAE.

1.4 Research Aims and Objectives

The major aim of the study is to assess the impact of the unregulated disposal of wastes from desalination plants in the UAE. To attain this, various desalination plants in

UAE will be taken into consideration, and their waste management system will be examined. Through the study, it will be determined whether the desalination plants in UAE are disposing of waste in a regulated manner, what the current measures adopted by them, and what relevant measures will be developed to make the waste management system more efficient. In addition to this, some other objectives are as follows:

1) To determine whether it is necessary to classify the different technologies in controlling unregulated wastes from desalination plants in the UAE.

2) To investigate the environmental impacts of unregulated waste disposal like global warming, greenhouse effect, marine pollution, and air pollution.

3) To assess currently available control measures in the treatment of unregulated wastes and to reduce the environmental impact.

4) To ascertain how the desalination plants can most effectively adopt and contribute to the creation of an integrated waste management system in the UAE.

5) To identify challenges in the implementation of an integrated waste management system in the UAE and create solutions to control it.

1.4.1 Research Questions

- What are the different types of unregulated wastes disposed of in desalination plants, and what different technologies are used in disposing of unregulated wastes in the UAE?

- How the desalination plant wastes impact the environment in the UAE?

- What are the control measures required to mitigate the unregulated wastes of desalination plants and reduce environmental impact?

- How best can the desalination plants adopt and contribute to the development of an integrated waste management system for the UAE?
- What are the challenges to the implementation of an integrated waste management system, and how it can be controlled?

1.5 Contribution of The Study

The research was necessary to be carried out so that different aspects of the desalination plants and wastewater management techniques that were operating and functional in UAE could be known and understood in a better manner. The current study led to the provision of a great deal of information about the desalination plants that were functional in UAE along with their statistics so that in-depth knowledge and understanding could be availed about the functioning and operations of the desalinated plant units. The study will help to know about the different types of unregulated wastes from desalination plants and hence would get to know about the various harmful effects or positive effects of the use of the desalination process. The research study also provided a great deal of learning about the implications of unregulated waste disposal on the environment. The contribution of desalination plants in the sector of the environment was necessary to be known so that by analysing the different implications necessary corrective measures could be implemented in order to protect the environment. Hence, a comprehensive method that can be used for controlling waste disposal impact could be evinced so that the controlling measures could be carried out satisfactorily. The research study adequately analysed whether the weather waste management techniques had been adopted by the desalination plants or not and if not adopted the research study adequately analysed the challenges and hindrances faced by the desalination plants. This led to acquiring a great deal of knowledge about the wastewater management process that is carried out in the UAE.

1.6 Operational Definitions

1.6.1 Integrated Waste Management

Satori et al. (2018) contended that creating integrated waste management programmes (IWMP) has been the most effective way to address the negative effects of waste management. All waste types and their facets are taken into account in these programmes. Despite the programmes' importance, a lack of funding may make it difficult or impossible to put them into action. The long-term objective behind this programme is to implement this in every country. IWMP makes sure that cross-sectoral solid waste management has been planned ahead of time. The objectives of IWMP, as mentioned by Satori et al. (2018), are (i) Waste management should be optimised, (ii) environmental impacts should be minimised or entirely mitigated, (iii) environmental costs should be kept to a minimum, and income from the environment should be maximised, and (iv) communities should be given the tools they need to create proactive plans for effective waste management.

One of the national regulations for environmental concerns is an integrated waste management system. Further, the regulation stipulates that waste should be minimised, reused, or recycled whenever possible, or/and treated and disposed of in an efficient way when it cannot be entirely avoided (Nanda & Berruti, 2021). Consequently, the four following priorities are part of integrated waste management:

- Minimisation of wastes
- avoiding waste
- treatment of waste and

- Disposal of wastes.

IWM encourages hierarchy-based waste management planning and integrated waste management planning. The main objective of the IWM is to achieve integrated pollution and waste management, which has been a national policy that regulates both the management of waste and pollution. Further, the goal is to fulfill outstanding commitments regarding sustainable development.

1.6.2 Desalination

Desalination is a method used to remove the dissolved mineral salts in the water and convert them to portable water. Currently, this method is been adopted to convert seawater to fresh water for human consumption and agricultural purposes. Many desalination techniques have been used currently, for example, Thermal and Reverse osmosis techniques.

1.6.3 Unregulated Wastes

The waste which is been disposed of from industry, agriculture, municipal waste, and other hazardous waste, which is not been controlled with specific standards by the regulators. For example, Abu Dhabi Quality & Confirmatory Council (ADS 23/2017) Environmental Specifications for Land-Based Liquid Discharges to the Marine Environment states there is an exception for rejected brine that is discharged from the desalination plants and power plants including similar facilities from industrial entities. Abu Dhabi Specifications (ADS) will be developed on subjects that have no or inadequate specifications or are not covered by local legislation.

1.6.4 Waste Treatment

The hierarchy of waste management places waste treatment as the third priority. Countries treat waste using a variety of techniques, including sterilisation, thermal treatment, chemical treatment, and more. The waste treatment and disposal steps are handled concurrently to create good coherence because the former can be utilised as the latter. Although methods for treating or disposing of solid waste differ from nation to nation as well, landfills are still the most popular choice for waste disposal. Incineration is a popular waste treatment and/or disposal method in the nations like Denmark, Sweden, China, and Japan. The majority of developed nations, particularly those with limited land, employ this technique. Waste is burned at extremely high temperatures during incineration, a method of waste treatment. This approach serves as a treatment and disposal strategy. Waste materials are transformed into residual ash, emissions, heat, and gas during the incineration process. Some of the techniques that are frequently used in the nation for the treatment of solid waste include the use of encapsulation, solidification, immobilisation, physical treatment, chemical treatment, and incinerators. However, this method of waste treatment is discouraged due to the detrimental environmental effects associated with incineration processes (Nanda & Berruti, 2021).

1.6.5 Waste Disposal

Waste disposal is the fourth and final option in the waste management hierarchy after the first three priorities have been implemented. There are many ways to dispose of waste, including incineration, encapsulation, and landfilling. Because they have the potential to treat waste and then finally deal with it as a disposal facility, some waste management priorities also fall between waste treatment and waste disposal. Despite the difficulties the nation faces, there has been a notable improvement in the legal system and the execution of the development plans for solid waste management. Since approximately 95% of the world's solid waste is disposed of in landfills, many developed and developing nations continue to use this method for waste disposal (Nanda & Berruti, 2021).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The United Arab Emirates (UAE) is constituted of seven emirates that lie on the eastern coast of the Arabian Peninsula. The Gross Domestic Product (GDP) of the country was about $403.2 billion (AED 1.46 trillion) in 2014, which reached about 385.6 billion USD in the year 2017 (Al Adlani, 2019). The growth rate of the country was recorded to be about 0.8% annually in the year 2017. Likewise, an increase in population could also be seen. As per the UAE Population Statistics 2009, the population of UAE was about 69.4 lakhs which reached 9.54 million in the year 2018. The UAE is experiencing immense industrial growth and a high rise in population. In recent years the demand for water and other basic necessities has increased in the nation. As per the UAE Climate records, the temperature of the region is found to be soaring high each day. The regions that are located near the coast experience hot and humid climates. The region is experiencing a hot arid climate and drought-like conditions. The regions that are located in the interior (deserts) experience a hotter climate than the coastal areas (Kravchenko et al., 2018). UAE receives about 4 to 6 mm of rainfall on an average basis, which accounts for about 100-150 mm of rainfall in a year. The downpour of rainfall also keeps on changing every year. The average temperature in the month of January is about 64 °F (18 °C), while in the month of July, it reaches 91 °F (33 °C). During the summer months, the temperature in the interior reaches up to 120 °F (49 °C), while on the coast, the temperature soars to 115 °F (46 °C) (Al-Fadala, 2019). The immense economic development and increase in industrial and agricultural activities in UAE have increased a huge pressure on water resources. Because of this UAE has to depend upon non-contemporary sources of water to fulfill its increasing demand for water consumption by the human and other living populations (plants, animals, etc.) present in the nation. The non-contemporary sources consist of seasonal rainfall, floods, springs, and groundwater. Seasonal floods account for 125 Mm^3/year; permanent springs account for 3 Mm^3/year, seasonal springs account for 22 Mm^3/year, falaj (water channel supply for irrigation) discharges provide 20 Mm^3/year, and aquifer recharge provides 109 Mm^3/year. In addition to this, about eight desalination plants have been set up in different locations in UAE to meet the water requirements of the population and adequately process the sewage water. The water received from desalination plants is about 475 Mm^3/per year, and reclaimed water is about 150 Mm^3 per year (Khateeb et al., 2011).

There are two major sources of water in the UAE that are desalinated seawater and groundwater. The groundwater is mainly used for agricultural purposes, and the desalinated water is used for drinking purposes. Hence, to meet the increasing demand for water consumption, additional eight desalination plants have been installed, which are Tawilah A, Tawilah B, Umm al Nar plants (five in units), and the Al Mirfa plant (Elsaid, 2020). The desalination plants located in UAE are responsible for 35% of the desalinated water that is generated in the whole of the Gulf region. These desalination plants use seawater as their primary feed to supply clean drinking water to the population. This leads to the generation of high volumes of concentrates and wastes like rejected brine. The brine contains high amounts of salts and harmful chemical compounds. The brine is generally released into the seawater, because of which the groundwater and the nearby regions get contaminated. To avoid the occurrence of such circumstances, the proper disposal of the rejected brine is necessary. For this, the desalination plants dispose of the reject brine in the ponds that are specifically designed to evaporate the reject brine, inject the saline water into deep wells, unload the brine water on the surface of the water bodies, etc. (Dias et al., 2021). The application of the disposal technique of reject brine or the waste depends upon the concentration level or chemical composition of the reject brine, the topographical location of the desalination plants, the location of the waste discharge outlets, legal issues, economic factors, and many more factors. Desalination is boosting its efforts and is continually experimenting with new techniques to lower the production content of rejected brine. However, they face enormous challenges such as the continuous sprouting of desalination plants and improvements in a variety of regulatory processes involved with reject brine disposal, which are related to the appropriate management and disposal of reject brine. The restrictions also result in limited access to non-contemporary disposal options. This has highly affected the innovative practices that are carried out by the desalination plants to reduce the harmful brine concentrate to low levels in a negative manner (Sepulveda et al., 2010). Hence, the governing bodies in UAE are making efforts to reduce the restrictions that are hindering the effective progress of innovative desalination practices.

The current research study describes the Perception of operators on waste management systems in Desalination Plants with special reference to the UAE. The increasing demand for water for human consumption has laid down huge pressures on the water resources that are present in the UAE. Hence, desalination plants have become an important source of water supply in the nation. However, there are certain problems associated with desalination, like the generation of high salt concentrations and a heavy load of different chemicals, such as iron (Fe), nickel (Ni), chromium (Cr), and molybdenum (Mo). The rejected brine released by the desalination plants contains high levels of salts and harmful chemical compounds like H_2S and Cl – which contaminate the soil and water when not disposed of properly. The current study lays stress on the identification of techniques and measures that can be used to exercise control over the improper disposal of rejected brine (Sgouridis et al., 2016). The different types of unregulated wastes in a desalination plant, the impact of unregulated waste disposal on the environment, the development of waste management systems in UAE, hurdles, and outcomes in developing an integrated waste management system in UAE, etc., will be discussed. The research study also includes a research gap and conceptual framework so that the readers could get better learning about the current research topic.

2.1.1 Types of Unregulated Wastes from Desalination Plants

As per the study made by Al-Maaded et al., (2012), the desalination plants provide clean drinking water and meet the water consumption requirements of the increasing population in UAE. There are about 33 desalination plants in the UAE, and about eight new desalination plants have been installed recently to meet the water requirements of the UAE populace. In addition to this, there are about 79 medium and large wastewater treatment plants discharged which provide approximately about 2000 to 3700 million liters per day to meet the water requirements of the people. To produce large amounts of clean drinking water, desalination plants use large amounts of seawater. Because of this, about 615 million cubic meters, or around 14% of the total water resources, reject brine (wastewater) gets generated. The desalination plants operational in UAE are of two types. According to Al-Fadala (2019), the first kind of desalination plant uses a phase-by-phase process of cleaning and purification of water. It involves various stages, from evaporation levels to freeing levels, that are multi-stage flash (MSF), multi-effect distillation (MED), vapor compression distillation, solar distillation, and freezing. The second type of desalination plant uses a single-phase process of cleaning and purification of water. The production process involves the extraction of salts in liquid form. It carries out processes like reverse osmosis (RO), electrodialysis (ED), and its variant, electrodialysis reversal (EDR), in order to remove the salt from the seawater.

According to Iqbal et al. (2018), the processing of seawater by desalination plants leads to the generation of two main types of waste concentrates that are seawater concentrate and solid waste (reject brine). The seawater concentrate is regarded as the filtered seawater which had not been used to carry out the desalination procedure. Therefore, the salts and other chemical compounds that are present in the seawater concentrates are similar to the natural seawater. There is no presence of chemical compounds, and the seawater concentrate is generally released into the seawater again. The production of drinking water by desalination plants leads to the generation of huge amounts of concentrates, also known as reject brine. The amount of generation of brine highly depends upon the amount of feed water used, the amount of salt present in the feed water, and methods chosen for the disposal of waste. The desalination plants which use the thermal process of purification of water like MSF and MED techniques produce fewer quantities of concentrates or reject brine. As per Benaissa et al. (2020) point of view, these desalination plants use low water recoveries and mix the concentrate with cold water before discharging. The mixing of cold water dilutes the rejected brine. This diluted mixture is processed in the final discharge phase, which reduces the salt content of the brine drastically, leaving the salinity levels 15% above the normal salt water levels. Some desalination plants also store the rejected brine separately so that it can be disposed of sufficiently later on. Some desalination plants are found to be using the RO process of processing seawater. These plants are also found to be using brackish water as their initial feed. While carrying out the filtration process, about 25% of rejected brine is generated. The rejected brine is evaporated, which reduces the concentration levels to 2%.

Desalination plants also lead to the generation of unwanted substances like pollutants, harmful gases, etc.

As per Vanclay and Esteves (2011), the concentrates that are generated by desalination plants highly negatively impact the environment. Due to releasing of concentrates in the seawater, the marine life of the sea gets impacted in a harmful manner. In addition to this, the land and the groundwater present in the nearby regions of the desalinated plants get contaminated with high salinity levels. This highly impacts the fertility of the soil and agricultural process adversely. The desalination plant was responsible for bringing impurities and pollutants to the local regions, which increased the level of environmental pollution. The concentration level in reject brine highly depended upon the quality of the feed water, the technology that was used to carry out the desalination process, the levels of recovery gained or made efforts for, and the percentage of chemical additives used while carrying out the processing of seawater to convert it into drinking water, etc.

According to Jawad et al. (2021), the desalination plants carried out different water purification processes in order to gain safe drinking water. This involves a pre-treatment process in which acidification of the feed water is done by using antiscalants chemicals and carrying out the process of chlorination and de-chlorination. In case the feed water quality is poor, the processes like filtration, coagulation, flocculation, ion exchange, and carbon adsorption are carried out. The fed water is taken from various outlets like beach well intake, subsurface water intake, open seawater intake, etc. The conduction of these processes results in the removal of wastes from the basic water levels. Then the membrane process is carried out so that the concentration from the feed water can be removed. Then in the pre-treatment process, certain chemicals are added to purify the water to consumption levels, and finally, in the post-treatment process, the rejected concentrate is collected and separated from the drinkable water. According to Al-Fadala (2019), the rejected brine is collected and treated before disposing of so that it does not harm the surroundings and environment in a harmful manner. The rejected brine collected by the desalination process consists of high total dissolved solids (TDS) levels. The presence of metals like aluminium, arsenic, barium, cadmium, chromium, iron, manganese, nickel, lead, selenium, copper, and zinc was found in the rejected brine concentrate.

As reported by Wang et al. (2019), the cleaning of pipelines, water supply pipes, and storage equipment also requires the usage of chemicals in large quantities. This leads to an increase in the chemical potency of the water that is present in the areas that are located in the nearby regions of desalinated plants. In addition to this, most of the desalination plants that were located in coastal regions used to release the rejected brine into the ocean waters, due to which the chemical composition levels of the water in the coastal regions have increased drastically. Hence, the presence of microelements like arsenic, Lead, Dioxin, etc., including toxic materials like carbon monoxide, nitrogen dioxide, sulphur dioxide, etc., could be found in the water composition levels in these areas. As per the report from the Pacific Institute (2006), most desalination plants return the rejected brine to the seawater due to the increased cost of waste disposal. This highly affects the marine environment in a negative manner, and the long-term process of carrying out seawater desalination could result in the discharge of high levels of rejected brine into the ocean water. Apart from this, the water that is provided for human consumption after the purification process is also found to be containing a low amount of boron. The presence of boron in the water (though very less in percentage) negatively affects human health. It causes several health issues for individuals consuming desalinated seawater.

According to Ikram et al. (2019), the desalination of seawater requires the conduction of various processes through which the seawater is processed to clean and purify and make it compatible and fit to be consumed by individuals. Among the varied desalinated processes chemical dosing system and Clean-In-Place (CIP) system is carried out to clean the water and remove the extra salt and unwanted chemical component present in the water. While carrying out the chemical dosing system, the water that is gained from the pre-treatment plants is pumped into the chemical tanks by using a dosing pump and dosing pipes. The dosing equipment is designed and laid out to carry out the chemical dosing process in an adequate manner. For this, all the chemical dosing equipment is centrally installed so that the distillation of the water can be monitored and supervised concisely. Then the process of the Clean-In-Place (CIP) system is carried out, which cleans the membrane element. Various kinds of pollutants are present at the surface level of the membrane. According to De Vito et al. (2011), the removal of such pollutants is a long-term process that often leads to the generation of pressure between the inlet and outlet systems of water. This helps in cleaning the membrane surfaces and frees them from pollutants that harm the quality of water. Hence, in this process, a huge amount of rejected brine is released into the seawater. The release of high concentrations into the seawater increases the salinity of the seawater and makes it inappropriate for marine consumption.

2.1.2 Impact of Unregulated Waste Disposal on the Environment

As per Sgouridis et al. (2016) view, the continuous discharge of rejected brine, and other solvents, and unregulated water disposal in the seawater have laid negative impacts on the environment and the natural surroundings. The uncontrolled waste disposal has led to the depletion and pollution of freshwater reserves. Sustainable human development and continuous intervention of human activities in the natural working of the ecosystem have led to increased contamination and decreased the quality of water and natural surroundings. According to De Vito et al. (2011), the problem related to the scarcity of fresh water is increasingly felt by the UAE governing bodies and the common people. The increased rate of modernisation, affluence, populace and climate change has resulted in severe loss of freshwater reserves in the UAE. As per the Annual Statistics Report of 2017 published by DEWA (Dubai Electricity & Water Authority), the water consumption levels are highest amongst the residential sectors, which account for about 61.34% of the total water requirement in the UAE. According to Al-Fadala (2019), other sectors, like industrial consumption, account for 27.26% of the water requirement in the UAE. About 3.26% of water is required by various organizations like mosques, police stations, government hospitals, government-run or affiliated educational institutes, DEWA offices, staff premises, and other similar authorities under the government, etc. Hence, in order to meet the daily water consumption requirements, UAE has established more than 33 desalination plants so that the daily water requirement of the citizens of the UAE can be met adequately. The desalination plants are accountable for providing water to America, Australia as well as other Middle East countries. Hence, increased usage of desalination plants could be witnessed, resulting in the formation of large amounts of wastes (reject brine and other wastes) harmful to the environment.

According to Sepulveda et al. (2010), one of the major ill effects of the use of desalination plants is the increased production of rejected brine and other harmful wastes, which adversely affect the natural surroundings and the environment. The brine discharge leads to thermal pollution, which results in increasing the temperature of the seawater. This disturbs the natural balance of the seawater temperature and upsets the distribution of marine flora and fauna. The underwater organisms find it hard to adjust and survive in the changed seawater temperature conditions. The rejected brine that is released from the desalinated plants that are located in the coastal regions of UAE bears high temperatures. Certainly, when the highly heated reject brine gets mixed with the seawater, the heat gets distributed to natural seawater components. The natural temperature of the seawater varies from 10^0c to 25^0c. When the highly heated reject brine is released into the seawater, the temperature of the seawater gets raised to about 60% to 40^0C near the regions where the brine is released. The amount of heat released by the brine highly depends upon the type of desalination plants and the seawater treatment process used by the plants. In addition to this, the location of the desalination plant and the distance of the discharge site also impact the dispensation of rejected brine in the seawater. If the location of the desalination plant is far from the discharge, the rejected brine will take time to reach the outlet, and, in the process, the temperature of the brine will get reduced. However, if the location of the desalination plant is near the discharge outlet, the brine will reach the outlet soon and release the heated waste material into the seawater. In both cases, the temperature of the seawater gets raised by little difference and negatively impacts the marine ecosystem.

As per Ahmed et al. (2019), the rejected brine that is released by the desalinated plant in UAE contains high levels of saline levels. The brine that is discharged by the plants forms a hypersaline layer under the natural surface of the seawater. The hypersaline layer is heavier than the natural water surface levels and gets settled down in the lower levels of sea bedrock. The settlement of hypersaline layers in the seabed region highly impacts the growth and development of local marine biota negatively. The high saline levels change the dissemination activities that are carried by the marine species resulting in a low growth rate of the marine organisms. The Larval stage which is important for the growth of marine species gets disturbed due to the presence of high saline levels in the brine discharge regions in the seawater. The proper growth and development of organisms from the larval stage do not adequately take place. According to De Vito et al. (2011), the sudden increase in the salinity levels of the seawater because of brine discharge degrades the survival propensities of marine species. In addition to this, due to the high density of brine, the formation of plumes takes place along the seafloor. The formation of plumes leads to the increased exposure of brine discharge to the benthic organisms possessing a threat to their survival in the seawater. The brine that is discharged by the desalination in UAE, which carries out a reverse osmosis process, increases the salinity content by almost twice the normal saline content of the seawater. This salinity level of the seawater gets increased by 50 ppt which lays a serious impact on the size of the fish and its survival rate.

According to HodaHosseini et al. (2021), Desalination plants, as well as combined water and power production plants, are becoming more common in Gulf coastal areas as populations and economies grow. Indeed, coastal infrastructure for water, energy, and food supply is increasingly intertwined with some mega plants supplying major cities in the region, posing several threats to coastal populations and marine ecosystems. This is a huge challenge that threatens the health of the Arabian Gulf.

As the ocean warms, the sea becomes more stratified, preventing nutrients from reaching the upper photic layers to feed photosynthetic microorganisms. Due to its high concentration in the air, climate change also causes CO_2 to become soluble in the sea. This has a deleterious impact on calcareous organisms by lowering the pH of the waters. Additionally, as the water temperature rises, oxygen solubility in the water will decrease, impacting aquatic creatures. These changes have an impact on species richness and the structure of marine communities. According to Wabnitz et al. (2018), climate change is increasing pressure on the Arabian Gulf, resulting in the survival of organisms that can withstand high temperatures and salinity. Despite the high adaptability of some organisms, climate change harms them. For example, increased sea temperature in the Arabian Gulf caused massive bleaching and coral death in 1996 and 1998.

Carbon dioxide, which is naturally present in the atmosphere, dissolves in seawater, according to the National Oceanic and Administration, US Department of Commerce (2020). Water and carbon dioxide react to generate carbonic acid (H_2CO_3), a weak acid that breaks down (or "dissociates") into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-). As a result of increased carbon dioxide levels in the atmosphere caused by humans, more CO_2 is dissolving into the ocean. The average pH of the ocean is now around 8.1, which is basic (or alkaline), but when CO_2 levels rise, the pH declines and the ocean acidifies. The pH of the ocean has declined from 8.2 to 8.1 since the industrial revolution and is anticipated to dip another 0.3 to 0.4 pH units by the end of the century. A pH drop of 0.1 may not appear to be significant, but the pH scale is logarithmic, just like the Richter scale for assessing earthquakes. pH 4 is ten times more acidic than pH 5, while pH 6 is 100 times more acidic (10 times 10) than pH 5. If we keep adding CO_2 at current rates, seawater pH might drop another 120 percent by the end of the century, to 7.8 or 7.7, culminating in an ocean more acidic than any seen in the preceding 20 million years or more.

As per Srivastava and Pathak's (2020) view, the rejected brine consists of high alkaline levels, calcium carbonate, calcium sulphate, and other elements in high quantities. The presence of these elements is almost twice the percentage that is present in the natural seawater levels. The discharge of brine into the seawater increases the alkalinity levels of seawater which highly negatively impacts marine life. According to Al-Fadala (2019), the desalination plants in UAE also use antifoaming agents such as fatty acids, alkylated polyglycolic, etc., which increases the chemical composition levels of the rejected brine.

This highly chemical-composed brine, when mixed with the seawater, the aquatic organism that lives around the outlets gets highly impacted adversely.

As per Dias et al. (2021), the desalination plants operational in UAE highly use a substantial amount of seawater as their initial feed. This highly impacts the two-away movements of the impingement and entrainment of the aquatic organisms. Impingement is defined as the collision rate at which the desalination plants screen the seawater as their initial feed. Entrainment is referred to as the actual amount of filtered water that is drawn in the desalination plant for carrying out the process of the filtration of water. When the desalination plants in UAE open outlets to take in the seawater, many marine species and fish go within the outlet and get trapped in the fish screen present in the desalination plant pipe outlet. Because of this, many fish and other aquatic organisms get trapped in the filter covering and get hurt or lose their lives. This causes high rates of impingement and negatively impacts marine life. At times, it happens that many marine organisms that are small in size get passed through the filter covering and enter the intake pipes.

2.1.3 Measures and Techniques for Controlling Waste Disposal Impact

According to Mezher et al. (2011), to reduce the harmful impact of disposal waste UAE has introduced various wastewater treatment processes like reverse osmosis, surface water discharge, evaporation pond, land application, dust control, de-icing agent, etc. By the use of such measures, the wastewater could be effectively used for several purposes like irrigation, suppression of ice, etc. Apart from these, the UAE governing bodies have introduced various plans through which effective monitoring and surveillance of the activities and workings of desalination plants are done. This major focus is laid down on ascertaining the pre and post-treatment and post of residuals so that the harmful effects of the waste brine could be regulated. By doing this, the turbidity levels or presence of chemical components, residual disinfectants, and pH could be monitored. Intensive supervisory activities are carried out by the UAE governing officials in order to control and maintain the Total Dissolved Solids (TDS), salinity, metals, chemical, temperature, and other components before the discharge of brine into the seawater. A special team of wastewater inspection experts and professionals is formed to carry out the audit and monitor activities regarding the testing of waste brine samples, designing and implementing WSPs, etc. The experts evaluate the quantity of dissolved state of various microelements like arsenic, Lead, Dioxin, etc., including toxic materials like carbon monoxide, nitrogen dioxide, sulphur dioxide, etc., and propose measures through which the alkalinity of the wastewater could be reduced. This would help to reduce the levels of toxic contents before discharging the wastewater into the ocean water resulting in less harm to marine life under the water.

According to Inyinbor Adejumoke (2018), recycling brine waste for utilisation purposes helped to reduce the harmful effects of the rejected brine. Many industrial units and manufacturing plants that are functional in UAE require solutions like hydrometallurgy, sodium hypochlorite, lithium carbonate, Chlor-alkali, etc. (part of reject brine) to carry out the industrial process. The use of rejected brine by such units will help to reduce its quantity to a minimum. The manufacturing units reuse the brine waste process and utilise the leftover harmless brine solution for carrying out irrigation or de-icing processes. The Chlor-alkali plants in UAE reuse brine waste which has a high percentage of metals like iron, vanadium, or manganese, to carry out their industrial procedure. For effective utilisation of brine waste, it is treated with chelating resins, which remove the metals and unwanted compounds. According to De Vito et al. (2011), by carrying out this process, the brine waste gets freed from excessive contamination levels, which makes it useful to be used for watering purposes.

However, if high amounts of contaminated solvents are present, then lithium carbonate or lithium hydroxide is used by the plants to reduce the levels of the unwanted metals and other contaminants that are present in the brine waste. Further, the solution is treated with high pressures to distill and purify it for reusable purposes.

As per Ibrahim et al. (2018) point of view, many desalination plants in UAE carry out the process of reverse osmosis (RO) to treat waste disposal. In the reverse osmosis procedure, the excessive salts and contaminants that are present in the rejected brine waste are treated so that the leftover water can be used for industrial and agricultural purposes. While carrying out the reverse osmosis procedure, the two streams of pure water and wastewater are mixed in a ratio of 10:1; that is, the portion of pure water would be ten times more than the portion of wastewater. This dilutes the high levels of contaminants and pollutants present in the brine waste. According to Al-Fadala (2019), high levels of salts and other pollutants are removed from the diluted solution by passing the solution through the reverse osmosis membranes. This procedure reduces the high salinity and harmful metals like silica, heavy metals, hardness, organic compounds, sulfates, nitrates, phosphates, suspended solids, etc. levels to a minimum. The leftover water received after carrying out the reverse osmosis process can be used for irrigation purposes and farming for such crops, which require a high portion of salts to grow properly. The use of such water helps in enhancing agricultural production, reducing the risk of increasing the high salinity of soils and groundwater to a minimum and carrying out an adequate soil drainage process.

As per Kneese and Bower's (2013) point of view, surface water discharge and evaporation ponds helped to reduce the harmful effects of waste disposal in the UAE. Some of the desalination plants in the UAE had been directed to discharge brine waste to the surface water bodies like rivers, lakes, or reservoirs. It helped in reducing the salinity levels of the waste. Further, farming vegetables and flowers are done near the coast so that the salinity levels are reduced to a minimum. It is one of the most effective processes used for inland surface water discharge of waste brine by desalination plants. While carrying out the process of evaporation, the waste brine concentrate is ejected into the pond under the right climatic conditions (when the evaporation rates are the maximum). According to De Vito et al. (2011), a special lining is developed under the strict supervision of UAE governing officials around the water reservoir so that the concentrate does not get mixed with the nearby surrounding and natural soils and environment. The discharge of waste on such surfaces of the ponds leads to the evaporation of excessive salts. When evaporation is carried out, the salt gets separated in the form of a crystallised mass. The UAE water regulatory expert recorded that the application of this process is highly beneficial for drying up the brine filtrates and can be implemented with other waste treatment procedures.

According to Elsaid (2020), deep injection wells could be used to dispose of brine waste in an adequate manner so that the harmful impacts of the brine could be minimised. For this, a deep well ranging from 330-2,600 m is constructed, and entire brine waste is injected into it. The construction of the deep well must be done on the porous subsurface rock formations so that the movement of waste would get restricted to the porous subsurface of the rock. By this, the brine waste would not get mixed with the nearby soils and rocks and would not cause harmful effects on the natural composition of the soils.

Through the use of this method, the brine waste gets collected into underground reserves, because of which its harmful effects get reduced. However, it must be noted that the construction of deep wells is an expensive procedure and requires a lot of permitting and evaluation of the site. The UAE governing bodies take proper care while choosing the site for the construction of deep wells. The UAE governing authorities take care that the location of the deep wells must not be near vulnerable areas where earthquakes or mineral resources, or groundwater reserves are present. By using deep well injection, about 13% of the total brine waste generated by the desalination plants in the UAE can be consumed or utilised effectively.

According to Khateeb et al. (2011), many innovative techniques have been initiated by the UAE governing bodies to reduce the harmful effect of waste disposal and improve the environmental conditions to high levels. A new kind of flat known as tidal and mud flats is constructed, which helps in re-establishing the natural ecosystem. It acts as a habitat for the birds where they can live and flourish, hence helping in adequately restoring natural fauna.

Apart from these, seagrass meadows are grown on the coasts of the Arabian Gulf region in order to promote the marine ecosystem in an effective manner. According to De Vito et al. (2011), seagrass is also found to be well efficient in consuming a harmful chemical that is present in brine waste and helps in reducing the alkalinity levels of seawater. They are also consumed by a number of marine species, like dugongs, green turtles, etc., as their primary feed. Many species like pearl oysters use seagrass as their habitat and help in the promotion of essential fish species, like shrimps. They also help to provide the base to the shorelines and act as land stabilisers.

This helps to reduce seashore sand erosion and helps in controlling floods. Along with that, measures are laid down by the UAE governing bodies to promote the growth of corals in the seaside regions. The coral reefs form by accumulating together and play an important part in establishing a positive environment to promote the marine ecosystem in the seawater. They play an important part in the promotion of fisheries. The application of these natural methods, along with the efforts made by the desalination plants, help in effectively promoting waste disposal in the UAE.

2.1.4 Contribution to the Development of a Waste Management System in UAE

According to Al-Fadala (2019), many countries in the world are facing drought conditions due to immense urbanisation, deforestation, improper use of water, inadequate water supply systems, etc. As per the report by the World Bank, approximately more than 50% of the countries in the world will face issues related to water shortage and scarcity by 2025. It also revealed that more than 75% of the population would be facing issues related to water shortage by 2050. Under such circumstances, the desalination plants would be the only support that would provide drinking water to the needful population. However, with the extensive use of desalination plants, the problem related to the disposal of rejected brine waste would also rise to high levels. The discharge of brine has ill effects on the natural environment and disturbs the ecology of marine life and structure. Hence, it is necessary to implement procedures through which the concentration levels of discharged brine waste could be reduced, or proper disposal of rejected brine could be done. This would help to prevent the harmful effects of brine on the environment and human settlement.

As per El Mahrad et al. (2020) point of view, innovations and technological reforms are introduced by the experts in the operations of desalination plants in UAE so that more extraction of drinkable water could be done from the brine waste. This would help to reduce the quantity of brine and promote healthy work practices. For this, the desalination plants in UAE are recommended to use the reverse osmosis (RO) process to purify the brackish waters so that low levels of waste would be generated. Apart from this Isobaric Energy Recovery Device (ERD) is also suggested to be used by the desalination plants functional in UAE so that the recovery of energy from the high-pressure brine could be done adequately. The use of calcite is done to carry out remineralisation and CO_2 treatment that is released by desalination. Further, desalination plants in UAE are also using dust control techniques to exercise effective control over unregulated waste disposal. In the case of the dust control method, the brine waste is spread over the roadways during the hot, dry seasons so that the harmful chemicals that are present in the brine get evaporated in a quick manner leaving behind the salt residues. De-icing agent technique is also used by some desalination to dispose of the waste cost-effectively. In this process, the brine waste is used as a reducing agent in place of road salt to suppress the ice present on roads during the cold winter months. This helps in suppressing ice and proper use of brine waste. By using both procedures, about 6% of the total brine waste generated in the desalination plants in the UAE can be consumed or utilised effectively.

As per Khan et al. (2019) overview, the UAE governing bodies make sure that the various procedures that are carried out by the desalination plants dispose of the waste are environment friendly. To ensure measures are adequately carried out by desalination plants, appropriate legislation and regulation have been laid down so that safe drinking water can be provided to all without making negative implications on the environment and nature. Stringent laws related to the application of safe disposal techniques have been issued, and licenses of the desalination plants are regularly checked. The process used by them to supply water and dispose of waste is monitored on an alternate weekly basis. As per Al-Maaded et al. (2012) study, the pipelines that are used to supply water are thoroughly checked and cleaned so that the quality of water can be maintained properly. The regular cleaning of the various water supply systems and pipelines is done so that the growth of pathogenic protozoa, viruses, and bacteria can be reduced. According to De Vito et al. (2011), it has been made compulsory by the UAE water regulatory bodies that the desalination plants must publish details about the quality of water, monitoring techniques used by them in order to improve the quality of water, chemical that are used by them for the purification process, procedures used to carry out the filtration of water, etc. so that the authenticity of the application procedure could be done.

As per Epstein's (2018) view, the sewer discharge process is also recommended to be used by the desalination plants by the UAE governing bodies in order to dispose of the brine waste. The brine produced as the end waste at the time of processing of seawater is disposed of in the local sanitary sewer system. For this, the sewage system and desalination plants disposal systems are connected so that the disposal activity can be carried out in an adequate manner. The supervisory officer of the USE sewage discharge system works in collaboration with the discharge head of desalination plants so that no leakage or spill happens in the effective conduction of the discharge process. This mixing of sewage with waste reduces the alkalinity and salinity of the brine before it is finally disposed of in landfill areas or discharged into seawaters. The supervisors inspect the mixing levels and detect and lay down measures to prevent the contamination of sewage and waste solution. By using this procedure, about 8% of the total brine waste generated in the desalination plants in the UAE can be consumed or utilised effectively. This land application process is easy to implement and operate. It can be used for inland as well as coastal desalination plants. Apart from these, the UAE water regulatory body authorities have made it compulsory for the desalination plants to report about the various procedures used by them to treat the waste so that control could be exercised on them. This helps in keeping a vigil on the desalination plants and stops them from using harmful techniques of waste disposal that could negatively harm the environment.

As reported by Al-Ali et al. (2019), the UAE governing bodies that are handling the water regulatory section have made it mandatory that the desalination plants must report and publish about the accidents or abnormal incidents that are occurring at the time of carrying out water cleaning and purification process. In addition to this, measures have been taken by the research and development team of the water regulatory body to introduce a more advanced method and environmentally friendly techniques of water filtration. This would help in acquiring drinkable clean water and reducing the generation of waste to minimum levels. According to De Vito et al. (2011), desalination plants that operate with solar power have been introduced, which convert seawater into drinkable fresh water in an economical and natural manner. The use of such plants also helped in reducing the carbon dioxide emissions that were generally done while carrying out the desalination process. Such kind of development projects initiated by UAE governing bodies also helped in the zero-emission of damaging materials into the natural surroundings and led to the provision of clean drinking water to a large populace. The use of solar desalination plants also helped in reducing the operational cost and enabled the installation of such plants in a wide range so that the drinking water problem in the nation could be removed.

According to De Vito et al. (2011), UAE governing bodies have also laid down regulatory measures according to which it is necessary for every water regulatory supervisor to visit and inspect the desalination plant regularly. The supervisors are required to monitor and inspect the various water storage tanks that are used to store water after completing the water purification process. According to a study by Al-Maaded et al. (2012), the supervisor needs to record the status and condition of the water storage tanks and ensure that they are cleaned regularly. This would ensure that the people are provided with clean drinking water without any contamination by algae or protozoa. The supervisor also inspects the quality of fitting materials, storage tank material, tank cleaning equipment, etc., so that no infiltration of clean drinking water occurs. Strict measures are followed regarding the fitting of water meters, automatic water filters, water level detection devices, etc., so that the excessive water flooding in the tanks, leakage, etc., could be reduced. Incident reporting measures and emergency plans are laid down so that any emergency or accident can be controlled and managed effectively. For the effective management of accidental issues, a separate Bureau has been framed in UAE so that such incidents could be directly reported and sorted out speedily. The Bureau also suggests and helps in implementing corrective measures to avoid the occurrence of any accidents in the future.

2.1.5 Hurdles and Outcomes of Integrated Waste Management System in UAE

According to Dawoud (2012), the use of desalination plants has increased over the years. The adequate functioning of the desalination plants has enabled the UAE governing bodies to fulfill the water requirements of the large populace and meet the industrial demands appropriately. However, the incessant increase in the emergence of desalination plants has created environmental and economic issues. The installation of desalination plants is not an easy process. It requires huge investments at multiple stages so that the seawater can be converted into fresh drinkable water in large amounts. It must also be noted that the excessive use of desalination plants has also led to an increase in waste (reject brine) which is negatively impacting the environment. Hence to ensure that the environment and the natural surrounding does not get severely hampered, strict regulatory measures have been laid down by the UAE governing bodies to regulate the process associated with rejected brine disposal.

Hence, to manage the waste disposal methods adequately, capital is required so that the various appropriate measures of waste disposal, like deep-well injection, etc., could be initiated. However, it is found that the desalination plants do not pose a large number of funds to implement adequate waste disposal techniques and require UAE governmental initiatives to implement an adequate waste management system.

As reported by Moossa et al. (2022), limited access to non-contemporary disposal options in UAE has also created hurdles in the effective implementation of waste management systems. The effective management of waste requires effective collection, storage, and disposal techniques. The conduction of these processes in an adequate manner is highly costly, and the desalination plants require investing huge amounts to maintain quality disposal techniques. In addition to this, the absence of an effective regulatory body within the working of the desalination plants hampers the conduction of effective waste management techniques. Due to the lack of a strict and vigilant regulatory body, the adequate functioning of the waste management system does not take place, and the waste (reject brine) is discharged into the seawater, which highly impacts the seawater and marine ecosystem negatively. Due to this, the salinity, chlorine levels, and other heavy metals like iron, nickel, chromium, and molybdenum get increased in the seawater. This leads to the desalination of un-ionised ammonia, because of which the pH level of the seawater gets increased. This highly adversely impacts marine life and reduces its reproductive capacities. Hence, it could be cited that inappropriate waste management creates harmful implications for the natural surroundings and environment.

According to Dost et al. (2019), improved awareness among the masses about the issues associated with the risk to the environment is also creating hindrances in the implementation of adequate waste management techniques. As per Al-Maaded et al. (2012) point of view, apart from this, it was also found that the drinking water that is supplied by the desalination plants contains small quantities of boron which is harmful to human consumption. Upon regular consumption of boron water, issues related to the digestive and respiratory systems may develop among humans. Hence, to reduce the negative implications of waste disposal, effective corrective measures like initiating institutions like Tadweer, etc. and waste management techniques have been laid down by the UAE governing bodies.

As per Attia et al. (2021) point of view, effective waste management techniques have also been initialised by the Dubai Municipality's Waste Management Department. For this, the Dubai Integrated Waste Management Master Plan was introduced in the year 2012. Under this plan, the use of landfills to dispose of waste is reduced to a minimum. It is targeted that no or zero waste would be released into the landfills. In place of this integrated and innovative approach would be used, and the waste would be converted into reusable items or recycled to make new products. In addition to this, efforts have been laid down by the Dubai Municipality to establish the largest plant in the Middle East, which would be capable enough to convert solid waste into usable energy. To establish such a large project, about AED 2 billion is required to be invested in the project that is envisioned to be launched in the Warsan district. Apart from this, the National Agenda has been initialised by the Dubai Municipality to reduce the use of landfills by 75% by the year 2021. The National Agenda also made provisions through which protection of the environment from the methane gas emitted by landfills could be done effectively. Additionally, Dubai Municipality also carried out a research study in coordination with the Dubai Supreme Council of Energy and Dubai Electricity and Water Authority so that effective strategies and programs like Dubai for Clean Energy could be developed. The programme is aimed at producing about 7% of

Dubai's total energy by using the energy generated from waste energy management resources till 2020.

According to Ali et al. (2021), effective waste management techniques are also initiated in the emirate of Sharjah in UAE. Effective municipal waste management company Bee' ah was established in the year 2007 with the help of a public-private partnership so that proper management of waste in the nation. In addition to this, an adequate plan related to the 100% reduction in the use of landfills was also initiated in the year 2011 so that the adequate utilisation and recycling of waste could be done. It also laid stress on 100% diversifying the use of landfills till the year 2015. To attain this, a state-of-the-art waste management center was initiated under the Bee'ah so that process and recycling of waste could be done adequately. As per Al-Maaded et al. (2012) point of view, in addition to this, Bee'ah also introduced the two-stream waste collection in the year 2012 so that waste reduction could be done correctly. Along with that, a new tipping fee structure was also introduced so that adequate incentives could be provided to the various waste reduction schemes so that the regulation of landfill and waste management could be done adequately. For this, the use of blue and green-colored, odour-proof bins has been promoted in the UAE on a large scale. This will help to protect the environment and keep it clean and safe in an adequate manner.

2.2 Desalination Methods in Different Countries

2.2.1 Predicting Future Water Supply-demand Gap for Chennai Megacity, India

The study of Nabaprabhat and Elango (2018) has aimed at using the decision support tool called the 'Water Evaluation and Planning Model' to quantitatively forecast the gap between water demand and supply in the Indian megacity of Chennai through the year 2050 while taking into account various additions to the current supply system and business as usual scenarios. Results from this modelling analysis of Chennai's water resources system show that recycling wastewater will boost water supply reliability by roughly 30 percent, using a new reservoir will raise it by 19 percent, and adding a desalination plant will increase it by 10 percent. The CMWSSB (Chennai Metropolitan Water Supply and Sewerage Board) has made information on desalination plants available online, and it is documented that both of the currently operational plants have been using the 100 MLD generating capacity. WEAP model has been used for forecasting and quantifying water management plans under various scenarios for the megacity of Chennai. A new desalination facility, a new reservoir, reusing wastewater separately, and lastly, the results of simultaneous operation of the scenarios are all the possibilities that are taken into consideration. It is implied that the new reservoir holds more promise than the desalination plant among all the existing augmentation measures. Additionally, the future demand-supply gap can be significantly closed with the maximum level of reliability of 30 percent when compared to all other scenarios, which call for desalination plants to provide 10 percent and additional reservoirs to produce 19 percent of the water needed (Nabaprabhat & Elango, 2018).

Additionally, the proposed water reuse will solely enhance water availability by 50%, 38% with the new reservoir, and 25% with the new desalination plant alone. Therefore, a better water supply in the near future is promised by the combination of the three water source augmentation procedures for Chennai. With these three solutions in place, there will be more water available than needed, at least until the year 2050. Beyond this time, new options must be explored in order to enhance water availability and satisfy the rising water demand brought on by the fast urbanisation of the world. Thus, water planning has been an important component of any city's efficiency and profitability. This component can help gain more significance shortly. Cities will become highly robust and resilient in overcoming their current challenges and establishing effective strategies for tackling any of these concerns utilizing an appropriate planning system. WEAP was thus successfully applied to find better choices for water management in Chennai. Beyond this time, new options must be explored in order to enhance water availability and satisfy the rising water demand brought on by the fast urbanisation of the world. Thus, water planning has been an important component of any city's efficiency and profitability. This component can help gain more significance in the near future. Cities will become highly robust and resilient in overcoming their current challenges and establishing effective strategies for tackling any of these concerns through an appropriate planning system. WEAP was thus successfully applied to find better choices for water management in Chennai (Nabaprabhat & Elango, 2018).

2.2.2 Solar Desalination Plants in Turkey

Water shortage is a problem in many nations, particularly those in semiarid as well as arid areas, as a result of the consumption of freshwater resources and environmental contamination. The issue is also made much more challenging and expensive by climate change. Seawater desalination driven by renewable energy sources like wind or/and solar may present a chance for diminishing future worries of nations about rising water demand. This will help to alleviate the problem of escalating water shortage. When planning the construction of these facilities, solar desalination plants' site assessments has been crucial. Several elements, such as climatic, demographic, economic, and environmental requirements, must have been taken into consideration. Aydin and Sarptas (2020) proposed a GIS-MCE model, which will be composed of three sub-models: logical aggregation of sub-models, analytic hierarchy process-based factor weighting, and fuzzy factor standardisation. The authors focused on a model that evaluates climatic, demographic, and environmental considerations but ignores desalination uncertainties, energy needs, and economic needs.

The proposed GIS-MCE model evaluated the site suitability of Turkey's coastal regions based on six parameters, including water unit cost, population, precipitation, solar radiation, seawater salinity, and seawater temperature. The findings of this study revealed that the cities of Aydin, Izmir, and Istanbul in the Aegean and Marmara regions are the most ideal for solar desalination, while Rize, Trabzon, and Artvin in the Black Sea region are the least suitable (Aydin & Sarptas, 2020).

2.3 Desalination Technologies

Both water supplies of brackish and seawater can be desalinated using a wide range of technologies. Most of these are currently in use for commercial purposes, but some, like membrane distillation, are either in advanced stages of development or close to commercialisation and are not evaluated in the current study. The energy requirements, quality of source water, and the value attached to the recovered water - all have an impact on the selected technology. For instance, brackish water with a salinity of 1600 mg per liter has an osmotic pressure of 140 kPa compared to seawater with a salinity of 35000 mg per liter at 2800 kPa. The needed energy for seawater treatment has been more compared to those for brackish water in reverse osmosis (RO) since when using seawater as feed, considerably a higher pressure needs to be provided to prevent the water's osmotic transfer using the semi-permeable membrane. Although grid energy has been primarily utilised for desalination, various energy sources such as heat, wave or wind power, and solar are also available to supply the power required to power the process of desalination (Burn et al., 2015).

In the Southern Australian region, where high-value crops are grown, solar desalination technology has recently been used to provide heat, energy, and water, and the development of various photovoltaic RO demonstration plants has taken place. In the Netherlands, research on wind energy that converts directly to mechanical energy has been conducted (Karad & Thakur, 2021). Another potential direct mechanical energy source is wave energy, and a system using hydrostatic pressure has been tested (Lacroix et al., 2022). In general, the concentration of salt can be used to examine which process can be suitable, such as scaling and fouling, which have been the functions of the raw water composition. The quality of water has been the essential component that determines the technology type, which has been pertinent to the desalination of different waters. With technologies like RO, the main operational challenges have been related to membrane deterioration, particularly scaling and the biofouling of the membranes (Burn et al., 2015).

2.3.1 Established Commercial Technologies

2.3.1.1 Reverse Osmosis

Reverse Osmosis (RO) desalination eliminates all naturally occurring salts, leaving behind unbuffered water that is deficient in calcium and other vital minerals, necessitating their addition to make the water fit for human consumption. Due to the lack of divalent salts and the presence of CO_2, the pH is low (around 5.5), and the (LSI) Langelier Index is negative, indicating that the water is corrosive and unbalanced. This means that the sodium adsorption ratio (SAR), which affects agriculture, is out of balance, which can lead to soil de-structuring and waterproofing due to sodium and calcium exchange. Although it will be necessary to address the significance of these issues for agricultural purposes, it is anticipated that buffering will take care of the problem. Even though a sizable portion of the input water has been returned to the source or ocean as a concentrated waste stream, RO can be relatively inefficient since every input water needs chemical pre-treatment and filtration.

The RO plant in Perth, Binningup, and the Southern Seawater Desalination, where this brine has been equal to 55 to 60 percent of the input water stream, serves as an example of a typical value (Zarzo & Prats, 2018). The transfer of high boron by means of RO membranes and the boron's toxicity for various crops are two additional major problems in desalination for agriculture. This makes seawater particularly problematic, which is why many plants demand a second pass RO. The desalination plant lifetime, energy costs, qualified labour, the conditions of the desalination plant site, the location of the desalination plant, automation and control, the requirements for pre-treatment, the quality and source of the incoming feed water, and type and size of the desalination plant all have a significant impact on the desalination cost. Less power has been needed, and less anti-scaling chemical dosing has been needed when using feed water with lower salinity. Because of economies of scale, larger plants can use less water per unit of output, and longer plant maintenance intervals and lower energy costs can also lower water costs (Sosa-Fernandez et al., 2018). However, they also concentrate sizable amounts of brine that must be discharged and call for sizable energy plants to be placed close by.

According to Burn et al. (2015), the following categories can be used to categorize the operation costs of desalination:

- treatment (for example, RO)
- pre-treatment
- intake
- product water pumping
- remineralisation
- energy use
- disposal of brine

- civil works and
- post-treatment (Burn et al., 2015).

2.3.1.2 Nanofiltration

There are numerous examples of Nanofiltration (NF) use, particularly in the drinking water industry, and it is thought to be a highly promising technique for the production of high-quality water or highly pre-treated feed water for RO. Dissolved solids like controlled and uncontrolled organic compounds, organic carbon, and inorganic ions are among the impurities that are eliminated. NF membranes have drawn attention as the seawater desalination pre-treatment since they have been primarily used for softening and removing organic compounds from the surface and brackish water. Typically, they are thin-film composite structures based on polyamide that are chemically similar to RO membranes. Their 0.5 to 1.5 nm pore size falls between that of RO and Ultra Filtration membranes (UF). When applied for seawater desalination, the low-pressure NF stage before the RO system removes the multivalent ions as well as some organics and sodium chloride, leaving a feed for the subsequent RO system that has a significantly lower ionic strength than the original raw water. A smaller osmotic pressure effect results in lower applied pressure requirements, which reduces energy consumption and increases water yield. Regrettably, the overall cost of an NF/RO system is typically 10% higher than that of an RO-only system. However, there are some circumstances where the approach has been justified financially because the NF's organics removal results in significantly reduced RO membrane fouling and improved membrane performance.

The advantages of using NF are demonstrated by a large-scale plant in the UAE (Yang et al., 2019). The NF component for the processing of the plant of about 8.6 ML per day,

- Reduces by 17 percent the pressure used in the RO plant.
- Removes 80–95 percent of the divalent cations
- Sulphate rejection to N99 percent
- brings TDS down to 28,260 mg per liter from 45,460 mg per liter and
- Lowers the hardness from 7500 to 220 mg per liter.

2.3.1.3 Electrodialysis

Ions are separated through ion-exchange membranes during electrodialysis (ED), a membrane separation procedure, under the influence of a potential gradient. Ion-selective membranes are arranged in multi-compartmented cells, and in ED, salts that have been dissolved in water are transferred using a direct current electric field. Cation-exchange membranes (CEM) allow only positively charged species to pass through while rejecting negatively charged species. When a potential gradient is applied across the cationic species, electrodes (Na^+, K^+, and $NH4^+$) have a tendency to move toward the cathode. Anion exchange membranes (AEM), which permit only negative species to pass through and reject ions of the positive species, cause anion species (PO_4, SO_4, and Cl) to move in the opposite direction towards the anode. Cations and anions are obtained separately in the concentrated solution through this process. One stack of ED cells can have up to about 100's pairs of CEM and AEM arranged alternately between electrodes on an industrial scale. This technology can be used to treat brackish waters to remove salt, in addition to treating wastewater by removing and concentrating nutrients like phosphorus, potassium, and nitrogen. When removing membrane foulant, EDR has been used. According to the composition of the feed, these foulants are typically magnesium and calcium carbonates, phosphates, or sulphates. Improving performance and lessening scaling and fouling needs the periodical reversal of the current through the membrane stack. EDR makes it possible to operate the brine stream in super-saturated conditions concerning species whose solubility is limited, such as calcium carbonate and sulphate (Stenina et al., 2020). Since the process gives high recovery (85 percent), can utilise fewer chemicals, and handle suspended solids, it has been typically restricted to low salinity feeds with TDS up to 3000 mg/L. Additionally, it has a lower capital cost than RO, which is 637 US dollars/m^3 each day versus 925-2100 US dollars/m^3 each day for RO. It is, however, less adaptable than RO, particularly in terms of feed water salinity.

2.3.1.4 Ion exchange resins

Ion exchange (IX) is used to purify, separate, and decontaminate aqueous and other ion-containing solutions using solid ion exchange resins. They can be replaced by acid, alkali, or brine in the case of softening resins. They can be either anion or cation exchangers. As a result, their regeneration is dependent on chemicals, which generally restricts their use in the desalination of low-salinity waters and the polishing of industrial waters. The application of regenerated heat that has been possible with weak electrolyte resins is one radical departure from the norm. Both Perth and Adelaide had large-scale demonstrations of it, with the latter using deep anaerobic ground waters. IX has drawbacks like the buildup of divalent metal ions on the cation exchanger, which necessitates an earlier softening step, and the anion exchanger being degraded by oxygen in surface waters under hot regeneration conditions. The method was uneconomical due to these additional steps (Burn et al., 2015). The following are the main benefits of IX:

- Recovery of water is high
- product water with high quality
- the volume of wastewater rejection is low
- easily can be operated
- the energy requirement is less

- little need for civil works and a small physical footprint and
- the operational and capital costs are low (Burn et al., 2015).

2.4 Impact of Brine Discharge from Seawater Desalination Plants on Persian / Arabian Gulf Salinity

Around 50 percent of the world's capability to desalinate saltwater is present in the desalination plants that surround the Arabian Gulf (referred to as the Persian Gulf also). The majority of these plants discharge brine, or hypersaline wastewater, into the Gulf via nearshore and surface outfall. Building up salt in brine puts the area's supply of drinkable water at risk since desalination energy rises with saltwater salinity. Additionally, brine encompasses compounds and metals that are not native to the marine environment and can harm marine ecosystems. Here, brine has been added to evaporation-driven residual circulation of the Gulf countries that regulate sub-basin flushing for the first time in order to assess the impact of brine on salinity at regional and basin scales. The study by Ibrahim and Eltahir (2019) reported that basin salinity has not been sensitive to brine as salt build-up only slightly raised average basin salinity annually (40.5 g/kg) by 0.43 g/kg. However, some regions are more sensitive to brine than others, particularly in the southwest Gulf along the Arabian coast, where the largest salt build-up increased salinity by roughly 4.3 g/kg. This study's findings indicated that the brine outfall has a crucial role in determining the effect of brine on the levels of regional salt.

2.4.1. Designing Brine Outfalls in Southwestern Gulf Region

Ibrahim (2017) argued that only around 1.2 percent of the basin’s evaporation of the Gulf that powers the Gulf’s residual circulation has been separated from the Gulf through means of seawater desalination. Particularly, the southwest Gulf region, a slow flushing zone, can have significant benefits from enhancing brine transport to the open ocean from the Gulf by using the flushing properties of residual circulation. The results of Ibrahim and Eltahir (2019) show how brine discharge and residual circulation of the Gulf interact dynamically in the far field. A planned investigation of outfall options for slow-flushing Gulf zones, where brine produced by plants nearby is released into fast-flushing zones where residual circulation flushing has been efficient, will be carried out in the future. This study will be recorded in a design manual (Ibrahim & Eltahir, 2019).

However, the brine discharge far-field analysis provided here for the Arabian coast will be useful for directing the brine outfalls design, particularly in the Southwest Gulf which has been most susceptible to salt build-up. Long brine outfalls are occasionally required although the development and maintenance expenses of ocean outfalls rise rapidly with outfall length to prevent severe environmental harm to the ecosystems in nearshore marines. To ensure that brine is discharged in areas where residual Gulf circulation flushing has been efficient, this study can help use the temporal and spatial salt build-up features due to the discharge of brine that is provided for evaluating potential locations for brine outfalls in the south-western Gulf (Shahvari & Yoon, 2014).

2.4.2. Evaluating Harmful Algal Bloom Population Dynamics

In the Gulf, the harmful algal blooms (HABs) and their formation may have increased due to the brine discharge's slight reduction in the flushing time of the country. Al Shehhi et al. (2014) argued that due to the rapid growth of HAB, which has become more frequent in recent decades, is largely influenced by the movement of newly generated HABs from the Indian Ocean to the Gulf. According to Sale et al. (2011) and Al-Yamani et al. (2012), HABs can have a significant amount of marine life to perish in the Gulf. HABs also contaminate the seawater that desalination plants use as their starting point, which results in abrupt drops in plant output, plant shutdowns, and damage to membranes and other delicate desalination equipment (Zhao & Ghedira, 2014; Al Shehhi et al., 2014; Thu et al., 2014; Ghanea et al., 2016). Additionally, it has been discovered by Roberts et al. (2010) that brine is a source of inorganic fertilizers for hazardous algae. The findings offer temporal and spatial salinity features that might be utilized for examining and tracking Gulf nations that are most at risk for HABs due to the discharge of brines.

2.5 Desalination in the Context of WANA's Water Regime

In the study of El-Khoury (2014), the Arab States League has a dismal reality. Gulf nations only obtain 2.1 percent of the global average yearly precipitation while having 10 percent of the world's land area. Aside from having few lakes and rivers, this region of the planet also contains overused subsurface water resources. Despite this common problem, each country in West Asia and North Africa (WANA) has very different techniques for water policy. Any analysis of the brine mining sector in WANA must take this divergence into account. In order to clarify the differences in water policies and put the problem of brine management in the context of the water regime of the WANA regions, this study has conducted expert interviews. Eight specialists all contributed to this research. Six experts underwent in-depth interviews, and two were contacted through email. The interviews are chosen after taking into account each one's political, professional, and educational background as well as the knowledge that background has given them. In turn, the data gathered shaped the study's analytical framework (El-Khoury, 2014).

2.6 Mining the WANA Seas: The Numbers

The UAE country solely generates 20 percent of the desalinated water globally. By not looking at the UAE, other Gulf countries comprise 43 percent of desalination globally. Even more of WANA, the area of the world with the most water scarcity, would be included when the view has been enlarged. Hence, desalination gained traction, partly as a result of the widespread lack of water. Ciocanea et al. (2013) argued that WANA has been significant for the desalination businesses as it offers over 77 percent of the desalination facilities all around the world. Ulrichsen (2012) argued that one could find a number of policy solutions for seawater desalination difficulties in the WANA using the "Knowledge-Based Development" paradigm. These issues centre on the desalination process's energy costs, the effectiveness of the filtration systems that produce brine after extracting potable water, and potential uses for that brine.

Any saline fluid is typically referred to as brine. However, the toxins, minerals, and other chemical substances present in sea and ocean water differ between various bodies of water (Manasrah et al., 2019). Mining brine concentrate is not a distinct sector of the economy. It is an entirely dependent derivative industry on the desalination sector and the water governance system that oversees desalination. Brine mining has been the subcategory of brine management. Further, as it has been a part of the waste management businesses, it differs from "normal" mining. The mining sector benefits from brine mining as well. Mines consume a lot of water; thus, they could profit from advancements in filtering technology and systems, which are frequently supported by the desalination sector. These upgrades allow for effective water mining usage. Studies on desalination and mining can exchange information more easily due to the IDA. As a result, new global economic connections are made, including those between the mining industry in South America and the desalination industry in the GCC. In WANA, the Arabian-Persian Gulf, Arabian Sea, Gulf of Aden, Red Sea, and the Mediterranean are the principal bodies of water. Each of these bodies of water has unique chemical and physical characteristics that call for a unique strategy for brine management. For instance, due to the prevalence of thermal springs in the sea's deep basins, the Red Sea tends to become "saltier" the deeper one dives (Manasrah et al., 2019). The Arabian-Persian Gulf, a shallow water basin where the salinity rises as one approaches the shore, is an exception to this rule. These slight yet vital nuances of each water body create a divergence in the kinds of risks associated with desalination that depends on the region. Even though each water body in WANA has unique characteristics, the problems brought on by the rising usage of saltwater desalination on the major water bodies are the same. The drastic reduction in water resources per person in WANA is arguably the most concerning issue. Since the 1960s, the region's share of per capita water resources has drastically decreased due to a combination of the growing population, increased per capita water demand, and overexploitation of water resources. The majority of Arabs, according to the UNDP Arab Human Development Report, think that a lack of public investment is the main factor contributing to the deteriorating water and sanitation situation (UNDP, 2013) (Table 2.1 and 2.2). This is not a significant advancement for some regions of WANA, particularly the GCC. Water resources in the GCC were already scarce. The GCC governments foresaw this difficulty and made significant investments in desalination as early as the 1970s. The GCC had risen to prominence as the world's desalination leader by the turn of the century. The GCC has lately invested in water reuse as a response to the environmental effects of the depletion of renewable water resources, but the region has not yet taken any action on the usage of non-renewable groundwater (aka fossil water).

Table 2.1: Decline rate in per capita renewable water resources in different Arab nations (1962-2011) (Source: UNDP, 2013)

State	The decline in per capita renewable water resources (1962 to 2011) (in percentage)
Lebanon	52.4
Tunisia	58.7
Morocco	62
Egypt	64.4
Algeria	68.9
Somalia	69.2
Sudan & South Sudan	72.9
Comoros	73.5
Mauritania	74.5
Iraq	76.3
Syria	76.4
Libya	77.4
Yemen	78.5
Oman	79.5
Jordan	84.7
Saudi Arabia	84.8
Bahrain	87
Djibouti	89.5
Qatar	97
United Arab Emirates	98.7

Table 2.1 Continued

Kuwait	No decline
The average rate of decline (excluding Kuwait)	**72.68%**

In other parts of WANA, the building of river dams by upstream nations (most notably, Ethiopia, Israel, and Turkey) exacerbated the already severe reduction in per capita renewable water resources brought on by population increase and overexploitation. Four sizable desalination facilities in Algeria could cause brine discharge issues along the Mediterranean coastline. Algeria employs "diffusers" to address this problem. Diffusers, as their name implies, disperse the brine discharge across a large region to facilitate mineral dispersion into the sea and prevent salinity levels from rising close to the desalination plants. Egypt is now spending money on building more desalination facilities, and it is swiftly catching up to Algeria (Amitouche et al., 2017). In many desalination facilities, the GCC also uses diffusers. Diffusers can reduce the damaging environmental effects of desalination even though they do not bring in money for the process. Even when diffusers are used, over time, the discharge of highly salinized brine solution from desalination plants will raise the salinity of some shorelines and semi-enclosed water bodies (Ciocanea et al., 2013). This is a result of desalination continuing to spread over the WANA region's semi-enclosed oceans. Around some desalination plants in the WANA region, a zone of dangerously salty seawater already exists. If we continue with our current desalination methods, we run the risk of these radii growing further. While the actual environmental effects are still unknown, it is preferable to act now rather than later.

Table 2.2: Population count in the Arabic Nations League constituents (1992–2018) (Source: UNDP, 2013)

Year	Population count (in millions)
1992-1993	283,142,431
1997-1998	316,149,123
2002-2003	348,052,071
2007-2008	385,604,883
2012-2013	428,690,019
2017-2018	471,814,758

Experts in ocean brine are advancing the management/treatment of wastes and mining innovations. Another inspiration source is the salt business. After all, sodium (Na) and chloride make up 75 to 90 percent of the 4.5 to 5 percent mineral composition of seawater (Cl). Ocean brine mining professionals are enhancing brine mining efficiency by leveraging advances in Zero Liquid Discharge (ZLD). The importance of the UAE in this process is shown by the fact that 20 percent of the desalination globally takes place there. Filtration can be improved, and it might help the mining and desalination sectors. Experts agreed that contained regional seas, such as the Red Sea and the Arabian-Persian Gulf, have been more likely to be impaired by unrestrained disposal of brine than oceans and open seas, even though the actual effects remain unknown. In the 1990s, desalination brine equivalent to 6.4 million cubic metres was released daily into the Red Sea. The amount increased to 6.8 million Cubic Meters in the 2000s (Ciocanea et al., 2013). Israel, Jordan, and Saudi Arabia are the main sources of desalination brine discharge in the Red Sea. Egypt is increasingly a significant donor as well. Due to the explosive and quick debut of Egypt into the desalination business, accurate estimates of the desalination brine discharge volumes in the 2010s differ.

The problem of desalination is made worse by the WANA region's exponentially rising water demand. For instance, Egypt just inaugurated the Al Galalah desalination facility. The Al Galalah desalination plant, which is situated on the Red Sea's northern coasts, will supply 1,000,000 people with 150,000 cubic metres of water each day. President Sisi announced the construction of yet another desalination plant because this is insufficient to meet Egypt's rising water demand. El Arich on the Mediterranean will be the location of this new plant. At 300,000 cubic metres per day, it will have a capacity that is double that of Al Galalah. As a result, the facility in El Arich is both one of the largest desalination operations in the world and the largest in Africa. Desalination became a national security concern for Egypt, particularly in light of Ethiopia's renaissance hydroelectric dam (Takouleu, 2020) (Tables 2.3 and 2.4).

Table 2.3: Quantity of reused water in the GCC (2012-2018), in millions of cubic meters (Source: Takouleu, 2020)

Country	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Bahrain	12.8	13.1	15.1	15.1	14.8	16.1	31.6
GCC	657.45	689.14	863.56	869.97	-	-	-
KSA	194	183	256	229	216	254	302
Kuwait	47	36.2	39.9	44.87	-	-	-
Oman	16.2	-	27.3	31.9	33	46.1	58.25

Table 2.3 continued

Qatar	78.8	80.04	94.01	97.37	104.18	130.53	150.88
UAE	308.65	376.8	431.25	451.73	470	493.9	513

Table 2.4: Quantity of Desalinated Water in the GCC (2000-2018) in millions of cubic meters (Source: Takouleu, 2020)

Country	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**	**2017**	**2018**
Bahrain	61	95.7	188.2	219.2	241.6	241.9	239.2	-
GCC	-	-	-	5,459.56	5,767.67	6,063.12	6,327.99	-
KSA	797.2	1,025	1,485	1,912	2,050	2,241	2,458	2,541
Kuwait	374.9	471.62	593.69	653.08	676.97	712.36	723.45	721.89
Oman	-	-	-	244.1	261.4	306	326.1	340.4
Qatar	147	195	374	482.2	533	557	602	637
UAE	701.9	1,241.30	1,679.60	1,949	2,004.70	2,004.90	1,979.24	2,020.53

Mediterranean’ El Arich will be the location of this new plant. At 300,000 cubic metres per day, it will have a capacity that is double that of Al Galalah. The facility in El Arich is now the biggest desalination operation in Africa and among the biggest in the world. Desalination became a national security concern for Egypt, particularly in light of Ethiopia's renaissance hydroelectric dam. On the Nile, the Renaissance Dam is situated upstream. Ethiopia will have control over the water supply to Egypt as a result. Iraq shares problems with its neighbours Syria and Turkey, who constructed numerous dams on the Tigris and Euphrates rivers. In order to improve its water (and national) security, Iraq is hence interested in expanding its seawater desalination capacity. The window of opportunity to address our brine management issue is closing as more nations turn to desalination as a dependable source of drinking water. Turkey's network of about 1,000 dams has depleted Iraq's water supplies and made it difficult for Syria to receive water from the Euphrates River. Israel, on the other hand, built a dam near Lake Tiberias, which supplies water to the Jordan River. Additionally, it has changed the flow of water from the lake to the valleys. Israel's water policy has had an adverse effect on Palestine and Jordan. Israel now charges a premium for the water that was formerly freely supplied to Jordan Valley locals. With the completion of the Renaissance dam on the Blue Nile, a similar drama is playing out between Egypt, Sudan, and Ethiopia. Jordan is becoming more and more dependent on desalination, just like Egypt. Jordan launched its first RO desalination plant in 2017 and now gets a lot of its water from the Disi subterranean reservoir, which it shares with Saudi Arabia. The plant was constructed by AquaTreat, a Jordanian business that offered desalination and brine management services to oil firms in the GCC. In contrast to its contemporaries, Jordan's desalination experiment is concentrated on the industrial sector rather than on serving households. With a daily output of 15,000 Cubic metres, this factory is quite tiny (Hassanzadeh et al., 2011) (Fig 2.1).

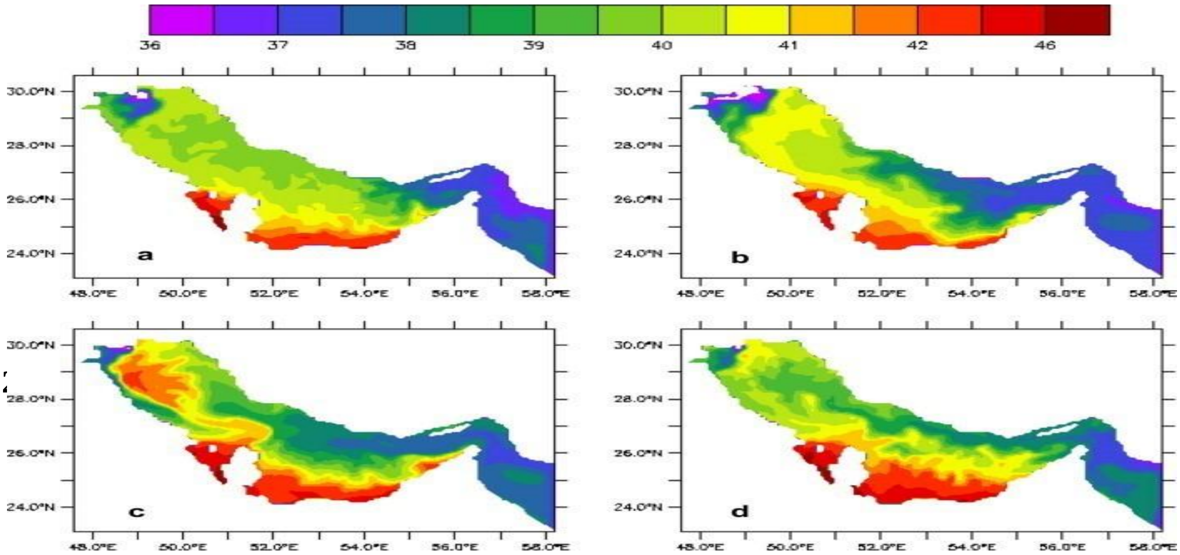

Figure 2.1: Persian Gulf Salinity (Hassanzadeh et al., 2011). The figure shows simulated horizontal salinity (a) January 15, (b) April 15, (c) July 15, and (d) October 15

used for brine disposal throughout WANA (Sezer et al., 2017). This technique wastes the potential profits from brine mining, adds to the (very) long-term salinisation of the oceans, and degrades the quality of future desalination feed water. Other strategies being thought about include:

1. Injection into deep wells
2. evaporation ponds
3. Watering plants that can withstand salt water.
4. Beneficial mineral recovery
5. No liquid discharges.
6. Making of sodium bicarbonate
7. Making use of brine to create coral reefs
8. Solar crystallisation (using photothermal columns or pillars)

These techniques overlap quite a bit as well. For instance, some brine management techniques fall under the solar crystallisation and ZLD categories.

Each of these approaches has benefits and drawbacks. As an illustration, deep well injection is reasonably priced and requires little to no brine processing before injection. Even so, it is only a short-term fix. Evaporation ponds are a low-cost solution for large nations, but they are ineffective for small nations like Qatar that do not have enough land resources. Additionally, in order to prevent harmful contamination of subterranean resources and soil degradation, the beds of the evaporation ponds must be coated with pricey specific materials (Sezer et al., 2017). Another interesting method is to water saline-tolerant plants. The brine discharge from wastewater treatment plants, like the As-Samra facility in Jordan, is fed to a bio-saline species. This demonstrates how mining the brine and waste management are related. There are halophytes that are utilised to make biofuels, despite the fact that few plants that produce vegetables or fruits can withstand salt water (Eshel et al., 2010). These halophytes can withstand extremely saline water, and the need for biofuels has increased recently. Most alternative brine control techniques require fresh advancements in filtering technology. One instance is the recovery of valuable minerals (Gul et al., 2013).

A very promising technique for managing brine is a valuable mineral recovery (VMR). In order to obtain priceless minerals, it includes filtering brine discharge. Sodium and Chloride, Magnesium, Calcium, fluoride, and Bromine are a few of these minerals (Sezer et al., 2017). Although this technique has been around since the 1980s, it is often only used to filter out a single mineral, molecule, or chemical at a time. On the surface, salt seems to be the most sensible option, but other elements have also been harvested on a large scale. For many years, Saudi Arabia has been removing magnesium from its brine. Israel achieved the commercial production of sodium chloride, although its brine production is insufficient to support exports. In the previous century, bromine extraction from the sea was common, but competition with the Dead Sea and other natural bromine reserves generally put an end to this. The GCC region currently imports more salt than it exports. But if its brine is used, it might become a significant global exporter of salt (NaCl) and other minerals extracted from ocean brine. The brine created by desalination in the GCC each year includes much more sodium chloride (NaCl) than is now consumed by humans each year. This indicates that not all of the NaCl in the brine has to be extracted. Instead, each nation is free to take what it requires, store it, or re-deposit it. Another technique for managing brine is Zero Liquid Discharge (ZLD). ZLD could act as a bridge between desalination and VMR in the context of desalination (Gorjian et al., 2019). ZLD lessens the toxicity of salty solutions created during the mining process in conventional mining. ZLD uses brine crystallisation or concentration to completely purge the solution of hydrogen dioxide (ware). This enables the extraction of priceless minerals and, in situations when extraction has no commercial applications, the safe storage of the crystallised/concentrated brine. ZLD brine can also be disposed of in landfills without running the danger of contamination (Sezer et al., 2017).

2.7.1 Efforts to Improve Brine Management in WANA

Most studies on the enhancements of brine mining in the WANA area begin in the GCC due to its dominant position in the desalination industry. For instance, Qatar and the engineering faculty at Texas A&M University's Qatar campus founded the Sustainable Water and Energy Utilization Initiative (QWE). QWE is part of Qatar's "Knowledge-based Development" initiative, which aims to provide homegrown answers to the nation's problems. In the past, Qatar and the GCC paid exorbitant prices to international corporations to resolve such crucial issues. The goal of programmes like QWE is to lower the price of correcting structural issues with Qatar's energy and water systems. In order to provide Qatar with new sources of income, QWE also intends to develop frameworks for solutions that may be exported outside (Hawash, 2021) (Fig 2.2). Other GCC nations also created their own ideas and fixes.

Figure 2.2: Ras Laffan desalination plant, situated in Northern Qatar (Source: Hawash, 2021)

The King Abdulaziz University of Science and Technology (KAUST) in Saudi Arabia created a hydrophilic silica-based material that boosts Multi-Stage Flash thermal desalination (MSF) efficiency. This material addresses the issue of overheating at the evaporation-based desalination facilities in Saudi Arabia. At lower temperatures, the silica-based material created at KAUST collects water, and at higher temperatures, it releases it. This procedure, known as "Absorption Desalination" (AD), is Saudi Arabia's scientific achievement. This invention depends on products made from oil, which Saudi Arabia has a lot of. Saudi Arabia can profitably sell this silica-based product to other nations. However, it is impossible to build a whole desalination plant using only AD. Instead, AD is a supplement to the "evaporation/thermal desalination" process, which is energy expensive. This may be deliberate since Saudi Arabia benefits from the spread of the thermal desalination process globally through the sale of UAE gas and oil. It is possible to devote more funds to study the enhancement techniques of absorption, perhaps through WANA-wide collaboration to lighten the burden on individual nations. Solar crystallisation is a different brine management strategy that KAUST supports. ZLD produces solar crystallisation as a by-product. Large photo-thermal pillars that are capable of crystallising enormous amounts of brine in the same way that small photo-thermal discs do so on a modest scale in laboratories were designed with support from KAUST (Zhang et al., 2021). This "next generation" solar crystallisation technology for salt treatment was introduced by Peng Wang, a professor at KAUST and Hong Kong Polytechnic, in April 2021 at a joint webinar of the IDA and the Saline Water Conversion Corporation (SWCC). The inclusion of nitrilotriacetic acid (NTA), which stops the crystals from binding to the photothermal surfaces and preventing additional crystallisation, is the key to scaling up from small photothermal discs to massive photothermal pillars/columns. The fact that this innovative technique requires less energy is crucial.

Wang emphasised that Saudi Arabia generates brine of about 2000 million cubic metres annually through desalination. Mining this substantial volume of brine needs enormous input of energy. Hence, the author made an effort to reduce the cost of energy through means of utilising solar energy to run unique techniques for solar crystallisation. Along with the KAUST study, the SWCC of Saudi Arabia (The Saline Water Conversion Corporation) financed studies on enhanced filtering systems that significantly raise the rate of seawater consumption in the country, as argued by Wang et al. (2011). This made ways for brine mining to develop. The country is not only investing in better filtration systems. The KISR in Kuwait (Kuwait Institute for Scientific Research) modified an existing Reverse-Osmosis membrane system design driven by pressure to increase the rate of recovery of water in certain trial plants from 30-60 percent. The country can drastically lower the desalination costs of energy once this modified system has been put into use on a commercial basis. In addition to NaCl mining, this system helps to investigate mining for brine concentrate on a serious note. The Shuwaikh Desalination Plant in Kuwait solely produces magnesium with an annual worth of about 464 million US dollars. Currently, this magnesium has been re-deposited to the ocean. For the prevention of the loss of valuable brine, certain steps have been taken by other WANA nations. Abu Dhabi built an enormous subterranean cistern for preserving brine and identified a method for increasing the usage of these resources in order to prevent the financial potential of brine from being lost (Wang et al., 2011). A membrane has been used by Sultan Qaboos University's Nanotechnology Research Center in Oman that accepts vapour but excludes solids and liquids. The desalination plants in Oman may function much more effectively due to this membrane. Membrane distillation has been an exclusive area of the desalination industry, where Oman has been quickly gaining competitive benefits. As a result, Oman might be able to dominate the membrane distillation industry and generate income aside from exports of fossil fuels in the future. There has been a lot of room for advancement in membrane distillation as it is used to handle brackish water and wastewater.

2.7.2 WANA-Wide Cooperation in Desalination and Brine Management

If there are still unresolved disputes that prevent WANA-based cooperation, one may start with the GCC and then go on to WANA-based cooperation as the geo-political environment becomes more stable. Polyester reinforced with glass, fiberglass, and steel industries in the GCC has been supervised by this GCC-based cooperation. The next frontier of GCC for coordination and innovation may be desalination. This prospect has been even more pertinent now that Qatar and Saudi Arabia have just gotten along (Lawson, 2012). The "minor constituents" part of (Table 2.5) does not adequately depict the variety of elements that can be found in saltwater, although showing the elements' quantities that have been present in the seawater sample.

It might be challenging to depict the brine elements' diversity when merely considering the content per kg. Consequently, using the per-million cubic meter as an alternate statistic could be preferable. On average, there is rubidium of about 100 kilograms, lithium of about 100 kilograms, uranium of about 3 kilograms, and gold of about 0.3 to 20 grams in seawater for every million cubic meters. These substances have been considered highly distributed in the water to currently support extraction commercially. Takouleu (2020) reported that a million cubic meters of saltwater include potassium of about 500 tonnes, magnesium of about 2000 tonnes, bromine of about 80 tonnes, and sodium chloride of about 35,000 tonnes, in contrast to these rare elements. Other than magnesium, any substances can be used for the extraction of saltwater commercially, as magnesium can be used for extracting seawater for strategic or military applications).

Table 2.5: Composition of Seawater per kilogram (Source: Takouleu, 2020)

Element	Percentage per kg (%)	Amount in grams
Calcium	0.05	0.5
Chloride	2.3	23
Magnesium	0.177	1.77
Other Constituents	0.022	0.22
Potassium	0.046	0.46
Sodium	1.85	18.5
Sulfate (bromine)	0.32	3.2

Takouleu (2020) asserted that by the year 2030, it had been anticipated that the GCC would experience a NaCl shortage of 2.5 tonnes annually. Brine mining has been the perfect solution for dealing with this shortage. Saudi Arabia has started the Shoaiba and Jubail II projects as anticipated to this. A dual brine concentrator and new nanofiltration technologies have been used in these projects. The brine's liquid content can be reduced further by this brine concentrator, increasing the efficiency of the brine mining. The GCC's Chlor-alkali sector get NaCl produced by the new plants, which will have a purity level of about 99.7 percent. The desalination sector collaboration between countries globally, such as Japan, the USA, Arabic nations, and so on, can help development. Fluid Technology Solutions, FEDCO, Khair Inorganic Chemical Industries, Toyobo, Hydranautics, and SABIC Petrokemya are some of the companies in these countries. A global meeting related to brine mining was held in March 2022 in the brine mining and new desalination plant of Jubail. IDA and SWCC organised this meeting. In the sector of mining of brine concentrate, SWCC and IDA have been the pioneers in allocating funds for academic exchange and cross-border knowledge development. This is because of SWCC's control and IDA's mandate over 20 per cent of global brine output. GCC and SWCC collaboratively work via the (WSTA) Water Sciences & Technology Association. The mining of brine concentrate and desalination are two areas where IDA Academy, the academic arm of the organisation, is working to advance knowledge creation. Abdullah Al-Abdul Kareem, the SWCC governor, and John H. Lienhard, the IDA Academy dean, presented a speech at a joint webinar in July 2021 and commended the advancements in the mining of brine concentrate at the desalination plants of Shoaiba and Jubail 2 projects, the IDA directorial board president, gave a speech at the occasion and mentioned the desire to "start producing a value product from the brine". Ahmad Al- Amoudi, general director of (DTRI) Desalination Technologies Research Institute in SWCC, noted that "the cost-effective extraction of precious minerals from brine has been a solution for the economical desalination". The SWCC and IDA executives created the foundation for ongoing cooperation in the mining of brine concentrate with their remarks. In these remarks, the leaders of IDA and SWCC laid the groundwork for further collaboration in brine concentrate mining (Takouleu, 2020). Table 2.6 provides the number of desalination plants in the GCC.

El-Naas (2011) proposed another technique for managing brine that involves putting one of several types of rejected brine into a chemical reaction with ammonia and carbon dioxide to produce sodium bicarbonate. The name "Solvay process" refers to Ernest Solvay, who was credited with creating this technique in 1881. As it has not been economically feasible to produce sodium bicarbonate on a regional scale, this was not the significant solution for the management of brine in WANA countries. This technique might be used for reusing some brine; however, this needs to be used in conjunction with a more effective and financially viable technique for recycling and reusing brine. UAE has recently found a way to create coral reefs with brine. The UAE has been demonstrating brine that is processed may be used for producing corals artificially in controlled circumstances, despite the fact that brine has been demonstrated to harm already existing coral reefs when diffusers have not been used for the distribution of discharge of brine (Sezer et al., 2017). It has been noted as a recent breakthrough, and its potential has not yet been realised. It is possible that some components of ocean brine can act as nutrients for coral reefs. Finally, the term "solar applications for brine disposal" refers to a variety of ways to obtain VMR and ZLD brine. This section's previous examples include solar crystallisation. There is a wealth of information available on how to effectively recycle or reuse salt using solar technologies, which is possibly the least expensive method of brine management.

Table 2.6: Number of Desalination Plants in the GCC countries (Source: Takouleu, 2020)

Country	2000	2005	2010	2013	2014	2015	2016	2017	2018
Bahrain	4	5	5	5	5	5	5	5	-
GCC	69	91	131	143	151	160	169	174	-
KSA	12	13	19	35	37	40	43	45	44
Kuwait	5	5	6	8	9	9	10	10	-
Oman	18	28	40	42	45	50	52	60	65
Qatar	3	4	7	7	7	8	9	10	-
UAE	27	36	44	46	48	48	50	44	-

2.8 Case Studies for Brine Management

Regional data analysis aids in the discovery of recurring problems and generalisations. But it overlooks the subtleties that affect local water administration. This section includes a case study of Jordan, one of the WANA countries, as well as a brief analysis of the other regions in WANA to show how the local environment affects WANA's water policy. Although Jordan faces many of the same problems with brine management and water scarcity as its WANA counterparts, the country's topography, post-colonial borders, and other distinctive features set it apart from its neighbours in the region. Half of the Dead Sea's shoreline is under Jordanian authority. Jordan has significant global influence over the brine mining sector as a result of the Dead Sea's enormous mineral riches. The main cause of the inefficiency of bromine extraction from saltwater is the export of Dead Sea brine extracts (Hawash, 2021). Desalination is best suited to a small number of nations. Brine/seawater concentration mining is only possible in a few numbers of nations. What requirements must a nation fulfill in order to desalinate? What about nations with the resources to invest in concentrate mining? This section examines the situation in Jordan, a nation for whom desalination is not the ideal source of drinkable water. Despite this, Jordan will soon construct a new pipeline to deliver desalinated water from its southern coastlines to its northern towns. This section will examine Jordan's experience with desalination after briefly discussing Jordan's WANA colleagues.

2.8.1 GCC

Most desalination operations worldwide are located in the Arabian-Persian Gulf. The main supply of water for the GCC region is provided by desalination facilities. Nothing else in the world is like this. Salinity levels in the Gulf are rising in part as a result of the withdrawal of potable water from its waterways. The Tigris and Euphrates Rivers' decreasing water flow into the Gulf of Mexico is the other significant factor. The re-depositing of seawater concentrate from desalination plants into the Gulf also has a negligible impact on the salinity of the water, in addition to the extraction of potable water and the decreasing intake from upstream. The semi-enclosed Gulf region between Saudi Arabia, Bahrain, and Qatar is where the effects of growing salinity are most noticeable. Saudi Arabia built dozens of desalination units around the Red Sea. While some increase their production during the Hajj, others operate all year to serve the local communities. Desalination also helps the rest of the Red Sea basin (Hawash, 2021).

GCC should start mining brine right away rather than waiting because of how heavily it depends on desalination. Today, it is simple for a major nation like Saudi Arabia to harvest minerals from brine for commercial use. It is also a good idea to invest in brine concentrate mining in a smaller nation with a high desalination capacity, such as Qatar, but only for military or strategic objectives or to supply a few nearby manufacturing plants. Although

Qatar produces a lot of desalinated water, it does not produce as much as Saudi Arabia. Only because of the pre-existing industrial infrastructure in places like Ras Laffan and Mesaieed is Qatar a way for investing in the mining of brine concentrate. Since much of the necessary infrastructure already exists, there won't be much need for fresh investments to get ready for mining brine concentrate. The union as a whole must start a cooperative effort in order to enable brine management and commercial collaboration for the small countries in GCC. The GCC produces enormous quantities of brine each day, allowing the union to become completely self-sufficient for some elements and an exporter for others. If this is successful, WANA and GCC might work together to implement this approach over the entire region (Hawash, 2021).

2.8.2 Sudan and Egypt

The Renaissance dam being built on the Nile in Ethiopia has recently increased interest in desalination in Egypt. This upstream dam will lessen Egypt's access to freshwater. Egypt is taking action by funding significant desalination projects, as was previously mentioned. However, the amount of water generated by these projects is comparable to a drop in a huge ocean compared to Egypt's water demand. In order to fulfill the growing demand, the government of Sudan, which is right next door, invested in solar-powered desalination. Sudan won't be able to rely on desalination to supply the majority of its water supply like Egypt can. Desalination can always be insufficient to satisfy the water needs of Sudan and Egypt, nor will it ever be necessary. Instead, it can address a few regional issues in both nations. For instance, the El- Arish and El Sokhna desalination plants will meet the water needs of Red Sea coastal resort areas and the water-scarce parts of Sinai, respectively. Water use at non-essential places may eventually require desalination plants. While the exploitation of non-renewable water resources for necessary uses (such as agriculture or domestic consumption) could be acceptable (Hawash, 2021), it should not be allowed for non-essential businesses such as golf courses and beach resorts. Before deciding whether to start a concentrate mining sector, feasibility research on the possibility of mining brine concentrate should be conducted at these desalination plants. Other mining sectors in Sudan and Egypt generate copious volumes of effluent. Prior to examining brine concentrate mining, the governments of Sudan and Egypt would get support from learning more about the ability of Zero Liquid Discharge (ZLD) to handle the wastes generated from mines. The extensive wastewater management system of Egypt might be used to house the brine management programme of the country. It is simple to obtain resources from the neighbourhood GCC nations that might hasten the development of Sudan and Egypt.

2.8.3 The Arab Maghreb Union (AMU) and Algeria

Algeria has no experience of strain from geopolitics on its water sources, unlike Sudan and Egypt. The population centers of the nation have been dispersed along its extensive coastline, while an extensive desert covers its back. The Algerian desert has not connected to any central watercourse. Every river in Algeria has only a few miles long, and they run to the Mediterranean shore from the northern highlands. The desalination plants in Algeria have been dispersed throughout the northern areas. Algeria might work with its neighbours, similar to the GCC, to begin an initiative in brine mining in the Maghreb Union. However, compared to the GCC project, this one would be of lower quality. The Atlas Mountains, which run from Morocco to Algeria, provide the Maghreb Union with a significant watershed (Hawash, 2021).

The population of Tunisia has been supported by a number of water surfaces like rivers, etc. The environment has yet reversible even if dams and excessive watershed exploitation have harmed the renewable water resources of the region in the Maghreb Union.

Only Libya, which has encountered both desertification and civil war greatly, is a member of this union that gets immediate perks from desalination. Presently, diffusers have been used to deposit the discharge of brine from the plants of the Maghreb Union into the Mediterranean Sea. By doing this, the sea's environmental impact can be reduced. The Maghreb Union might gain more from wastewater management investments than it would from spending money on new techniques in brine mining. This is because the Maghreb Union produces significantly more wastewater than it does desalinated water. The water obtained from the lakes, rivers, and Atlas Mountains in the region might be decreased with the aid of treated wastewater (Hawash, 2021).

2.8.4 Jordan

Regarding its brine management and desalination projects, Jordan has been working on these significant water transport projects. Red Sea-Dead Sea Water Conveyance Project is the first one, which has been under development for ten years, and the AAWDC Project is the newly developed second project. There have been numerous delays associated with the first project. However, the allocation of funds for this project was taken off by the World Bank on May 2021. The Roya News of Jordan reported this event as a national emergency. The Jordanian Ministry of Water's spokesperson, Omar Salamah, informed the public the following day in an interview with the Jordan Times. Before addressing this problem, Salamah remarked, "The AAWDC project, which was initiated in February 2020, would carry forward unaltered. Saudi and other countries were closely looking into this problem. The large-scale investment potential of Saudi Arabia in the mining of brine concentrate has depended on the Dead Sea's continued existence. Increasing quantities of numerous minerals can be found in this little body of water. However, Saudi Arabia wants to mine these minerals from the Gulf and the Red Sea; this might not be economically feasible until the Dead Sea has still been mined (Hawash, 2021). The above-mentioned former project, also known as the Red-Dead or Red-Dead Canal, has been an important project to the majority of Jordanians for a variety of reasons. Omar Salamah's remarks shifted the focus of Jordan people from this project to the recently developed AAWDC project.

Jordan is one of the least water-rich nations globally, with only enough renewable freshwater resources to support the 2 million population of the country. Desalination by itself cannot support the entire population of Jordan due to its limited inland and coastline population regions. Jordan communities used to share water resources with their neighbourhood regions before it was colonised (Hawash, 2021). Jordan's capability for establishing a sustainable water governance mechanism was significantly hampered by the effect the western and northern neighbourhood regions had on the surface water flow in Jordan as a result of post-colonial boundaries. As a more sensible non-conventional water resource, particularly for inland communities, this prompted Jordan to make significant investments in municipal wastewater treatment. The Aqaba desalination plant offers benefits to the coastal cities in Jordan and the surrounding Ma'an province. Jordan has spent decades trying to figure out how to get desalinated water to its northern cities from the Red Sea as Syria and Israel control its upstream water resources. The Red Dead Canal came to the attention of the World Bank due to Jordan's intense interest in the project. Since Jordan’s per capita renewable water resources have drastically decreased, water has become an important topic in the country. An effort is being made to "patch up" the water system of the AAWDC. Jordan has been waiting for its western and northern neighbours to achieve long-term social and political stability before working together to find a comprehensive solution to the water shortage in the region. The AAWDC of Jordan is an imitation of the desalination policies adopted in the 1970s by southern neighbours of Jordan, such as GCC and Saudi Arabia.

Other nations in the area and beyond are following suit, including Jordan, Algeria, and Egypt. As a solution to water constraints, nearly every nation in North Africa and West Asia has considered and invested in desalination.

Initially, the Red Dead Conveyance project was conceived as a solution for restoring the declining quality of the Dead Sea. This has been expanded to include a desalination plant that generated drinkable water for the businesses and communities of Jordan, Palestine, and Israel after numerous in-depth investigations and public discussions have been held. To stop further depletion, brine concentrate would be dumped into the Dead Sea. In many respects, the land around the Dead Sea is a treasure trove. The Dead Sea and its underlying aquifers comprise bromine of about a million tonnes in addition to being an important ecoregion. Jordan is the second-largest bromine exporter globally due to the Dead Sea. Al-Ghazawy (2013) reported that the Dead Sea lost a depth of about 0.8-1.2 meters annually. As the Jordan River water, which would have ordinarily fed into the Dead Sea meant for replenishing the evaporating water, has been diverted, the depth level has been decreased. The other reason is the result of Jordan and Israel, the two countries that export the most bromine globally, taking goods and valuable minerals out of the Dead Sea. Dead Sea mud and Bromine are two of these commodities that are possibly the most well-known. Israel and Jordan have institutionalised the Dead Sea exploitation, which is still going strong. Both governments are aware that this needs to change, but they have been unable to work together to put an end to their exploitative tactics (Al-Ghazawy, 2013).

Before the Dead Sea is replaced as a significant source of bromine, neither party wants to "miss out" on the revenues from mining ocean brine concentrate. Palestine's tardy statehood has made it unable to make a significant impact on the Dead Sea and other water-related challenges. Neither side wants to lose out on the profits before ocean brine concentrate mining replaces the Dead Sea as a major source of bromine. Palestine's delayed statehood has prevented it from being an effective actor on the Dead Sea and other water-related issues. The Dead Sea's bromine mining will soon come to an end, driving up the price of bromine and permitting advancements in the commercial usage of brine concentrate. Two possibilities are there that could result in the mining of bromine in the Dead Sea. The first involves the basin of Dead Sea inhabitants "wake up," put an end to the Dead Sea's exploitation and restore freshwater flow to the rivers of Yarmuk in Jordan. The next possibility involved is dystopian and gloomy in comparison to the first. The Dead Sea environment is destroyed as a result of human exploitation, similar to the disaster of the Aral Sea. The Dead Sea has been currently moving quickly towards this possibility. Since the middle of the 20th century, it has lost over 100 meters (Hawash, 2021; Al-Ghazawy, 2013).

The Red Dead Canal project has been proposed as an act of preventing the depletion of the Dead Sea. However, this project does not provide support to the mining business of local bromine, whose profits have been needed to cover the canal's price of about 10 billion US dollars. The Dead Sea's limited bromine reserves cannot be replenished by water from the Red Sea. Despite excavating the new canal from the Dead Sea and investing millions in constructing the desalination plant along the canal, reusing the naturally existing canals that once fed and supplied the Dead Sea has been an optimal solution (like the Yarmouk, Jordan rivers, etc.). Syria and Israel must unleash the dammed upstream water to save the Dead Sea. Jordan would likewise need to alter its water governance structure, but Israel and Syria are more motivated to do so because of the water control that post-colonial political and geographic boundaries have granted them (Al-Ghazawy, 2013). Eventually, the bromine mining sector will move to the oceans and open seas, regardless of which scenario comes true. When that takes place, the top desalination nations worldwide will have the ability to commercially extract bromine from brine. This enables economical seawater concentrate mining to expand beyond NaCl mining. Jordan uses a variety of unconventional water sources in addition to desalination. Jordan has been relying on wastewater as a non-conventional supply of water since 1982 when the As-Samra wastewater treatment plant was built. The post-colonial boundaries of Jordan make desalination less appealing as an unconventional water resource due to its limited coastline and remote location from its population centers. Since it was built in 1982, As-Samra has undergone numerous enlargement projects.

An increase in the plant's capacity to 365,000 cubic meters per day was supported by the (USAID) United States Agency for International Development. Wastewater treatment facilities, like desalination facilities, typically produce potable water as well as certain by-products. As wastewater, Samra's or "brine," was for many WANA nations, municipal wastewater is a superior choice to desalination. Reusing water is possible close to populated areas, which may benefit inland communities. The municipal water supplies in Amman and Zarqa are supplied with As-treated Samra wastewater. Brine from the water treatment process has been utilised for feeding the bio-saline plant that resembles grass. Initially, some of the water was supplied to a tissue factory on a 7-year contract. For the area, As-Samra offers an alternate desalination approach. Jordan is still a long way from realising all of its potential for wastewater treatment. About 40 percent of the water flowing through the pipelines of Jordan has been lost, claimed Zureikat. Larisa Abulghanam reaffirmed this in a different interview. Jordan loses a sizable portion of its water supply due to carelessness, theft, and leaks in usage. Jordan would benefit financially and economically more from these investments than from desalination (Arab Water Council, 2011).

2.9 Research Gap

The functioning conduction of wastewater management in the UAE has grown many folds. This is because the extensive use of desalination plants has caused several issues and problems, resulting in harmful effects on the environment. It must be noted that the environment is an important part of human civilisation, and if it is not maintained properly, many harmful implications, like drought, famine, and scarcity, can occur. The UAE's growing population enlarges the amount of waste produced by industrial and human activity, placing pressure on the country's limited capacity for waste disposal. Additionally, it must be noted that if wastewater management is not carried out adequately, impounding negative implications could be seen in nature. There was also a lack of adequate information about the adequate measures that were initiated by the desalination plants to reduce the harmful impacts of unregulated waste management. It was also found that there were no scientific studies or publications on the policies, laws, and rules governing desalination, desalination waste disposals, or their environmental compliance. The literature on appropriate and integrated waste management of desalination waste, such as brine and other chemicals, was also lacking. UAE's integrated waste management system needs to be improved and updated by implementing contemporary desalination technologies. These negative consequences highlight the importance of modern desalination technologies. In light of this reality, stakeholders ought to reconsider current desalination procedures. Desalination needs to be the central idea of contemporary desalination practices, and operations, designs, and technologies need to be evaluated in light of sustainability. It is important to use contemporary technologies that reduce waste and products. Hence, the current research study is necessary to be carried out so that various harmful implications of the desalination plants and improper wastewater management can be understood in a better way. The research would lay emphasis on generating and creating better waste management techniques so that the negative impact of the waste could be minimised on the land and marine ecosystem. This would also help in the proper disposal of waste generated from desalination plants in the UAE adequately and reduce the harmful effects caused by it on the environment.

2.10 Research Hypothesis

H1(a): Membrane-based technologies used to control the disposal of different unregulated wastes of desalination plants in the UAE.

H1(b): Thermal-based technologies used to control the disposal of different unregulated wastes of desalination plants in the UAE.

H2(a): Desalination plants in the UAE generate wastes that do not have an impact on the environment.

H2(b): Desalination plants in the UAE generate wastes that have an impact on the environment.

H3(a): Existing measures and technologies control the waste disposal and environmental impacts from the desalination plants in the UAE.

H3(b): Existing measures and technologies do not control the waste disposal and environmental impacts from the desalination plants in the UAE.

H4(a): The development of an integrated waste management system in the desalination plant has a positive impact on the development of the UAE.

H4(b): The development of an integrated waste management system in the desalination plant has a negative impact on the development of the UAE.

H5(a): The challenges in implementing an integrated waste management system in the UAE can be controlled.

H5(b): The challenges in implementing an integrated waste management system in the UAE cannot be controlled.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter starts with a conceptual framework supported for this study. Then, it discussed the suitable research philosophy and research design employed; the research methodology/strategy (quantitative/qualitative) adopted; research instrument developed (questionnaire/interview) for this thesis. It included various data collection methods and tools that help to evaluate the existing control measures which are available so that innovative ideas are to be developed and technologies will be implemented for controlling the various impact of unregulated waste from the desalination plants in an effective manner. In addition to this, the research methodology also helps to determine 3 desalination plants that are adopted and make effective contributions to the integrated waste management system for the UAE. It also helps to determine the hindrance by implementing an integrated waste management system for the UAE so that the country will be able to measure its outcome in the right way. In addition to this, the section also includes strategies that were undertaken by the researcher for collaborating the findings and ethical considerations so that the research could be carried out in an adequate manner.

3.2 Conceptual Framework

Figure 3.1 In the current study conceptual process related to the desalination plants is discussed in a concise manner. In carrying out the desalination processes, various methods and approaches involved in the disposal of unregulated wastes can be discussed. The environmental impacts of these desalination plants and the mitigation measures are outlined in the above diagram. The hindrances to the implementation of an integrated waste management system for the UAE and measures to overcome them are also outlined.

Figure 3.1: Conceptual Framework

3.2.1 Unregulated Waste Disposal and Technologies Used in it the UAE Desalination Plant

According to Sgouridis et al. (2016), the continuous discharge of rejected brine, other insolvents, and unregulated water disposal in the seawater have laid negative impacts on the environment and the natural surroundings. The uncontrolled waste disposal has led to the depletion and pollution of freshwater reserves. Many desalination plants in the UAE carry out various chemical decomposition processes at the pre-and post-treatment procedures which leads to the increase of anti-scaling elements such as polyphosphates, polymers of maleic acid, sulphuric acid, etc. in the seawater. Accordingly, the following hypotheses were formulated:

H1(a): Membrane-based technologies used to control the disposal of different unregulated wastes of desalination plants in the UAE.

H1(b): Thermal-based technologies used to control the disposal of different unregulated wastes of desalination plants in the UAE.

3.2.2 Environmental Impacts of Desalination Plants in the UAE

Desalination is a procedure where a lot of energy has been used for creating potable water from salt water and sending the brine back to the ocean. Globally, the increasing number of large desalination facilities and new desalination activities have raised concerns about potentially unfavourable environmental impacts (Fane, 2018; Esrafilian & Ahmadi, 2019). Desalination's primary environmental issues can be broadly divided into direct and indirect environmental impacts. The direct effects have been primarily associated with the pollution caused by brine, air pollution like increased energy use, and emission of greenhouse gas. Land usage, noise pollution, and effects associated with construction sectors are some of the indirect effects. Further, it has to be noted that the desalination process itself can be impacted by the environment. For example, the desalination process can be considerably impacted by the water quality provided to desalination plants. Accordingly, the following hypotheses were formulated:

H2(a): Desalination plants in the UAE generate wastes that do not have an impact on the environment.

H2(b): Desalination plants in the UAE generate wastes that have an impact on the environment.

3.2.3 Currently Available Mitigation Strategies Help Control Water Wastes of Desalination Plants in the UAE

Environmental impact assessments can be used to examine the potential effects of desalination and provide the best ways to prevent, mitigate, and/or lessen the negative impacts of desalination plants in the UAE. Numerous strategies can be used to enhance the desalination process while mitigating the environmental impacts. The strategies can be source water intake, site selection, discharge of brine (energy and water recovery, materials extraction), etc., Accordingly, the following hypotheses were formulated:

H3(a): Existing measures and technologies control the waste disposal and environmental impacts from the desalination plants in the UAE.

H3(b): Existing measures and technologies do not control the waste disposal and environmental impacts from the desalination plants in the UAE.

3.2.4 Integrated Waste Management System of Desalination Plants in the UAE

Integrated waste management system (IWMS) encourages hierarchy-based waste management planning and integrated waste management planning. The main objective of the IWMS is to achieve integrated pollution and waste management, which has been a national policy that regulates both the management of waste and pollution. Further, the goal is to fulfil outstanding commitments regarding sustainable development. There are four stages involved in IWMS such as minimizing, avoiding, treating, and disposing of wastes. Accordingly, the following hypotheses were formulated:

H4(a): The development of an integrated waste management system in the desalination plant has a positive impact on the development of the UAE.

H4(b): The development of an integrated waste management system in the desalination plant has a negative impact on the development of the UAE.

3.2.5 Challenges in the Implementation of Integrated Waste Management System

However, the IWMS in desalination plants of UAE contributes to the better development of the country, but there involve certain challenges in implementing it. The challenges can be poor infrastructure, unavailability of resources, lack of public awareness, and commitment to national laws and policies. Accordingly, the following hypotheses were formulated:

H5(a): The challenges in implementing an integrated waste management system in the UAE can be controlled.

H5(b): The challenges in implementing an integrated waste management system in the UAE cannot be controlled.

3.3 Research Philosophy

Researchers have research philosophies for how they gather, analyze, and interpret data about phenomena. It encompasses various research philosophies based on positivism, which refers to what has been thought to be true, and epistemologies, which refer to what has been recognized to be true. So, the process of changing what is thought into what is recognized - from doxa to episteme - is the goal of science. Research philosophy is crucial and there are two philosophies used commonly by researchers such as positivism and interpretivism (Galliers & Huang, 2012). The current study, helped the researcher to identify the various types of unregulated waste which are disposed of from desalination plants in the UAE by adopting determined assumptions and beliefs.

A positivism research paradigm was adopted in this study, as it is mostly used as a quantitative strategy, so it was best suited for this research. With the help of positivism research paradigm, it helped to identify the various unregulated waste which is generated from the various desalination plants in UAE by making the focus on a single reality that could be measured easily. The current positivist research paradigm also helped to make effective control measures by identifying various environmental aspects and their impacts in an effective way. Hence, it was necessary to carry out the research in this respect so that better learning about the integrated waste management in Desalination Plants in UAE could have been known by using a positivism approach with the help of personal interviews, individual participation, etc. The positivism research paradigm also helped to identify various issues and challenges that were experienced by the desalination plants regarding the disposal of waste that was generated while carrying out the seawater purification process. As a result, the study mainly focused on identifying the various impounding factors by using information and reports from laboratory results through face-to-face interviews, so that they could be rectified in order to safeguard marine life by identifying various issues that are faced by desalination plants in UAE in the disposal of the waste in an adequate manner.

3.4 Research Design

Using research design, research provides the methods and procedures drawn into a framework that addresses the research problem. being investigated Effective research design protects against bias and enhances validity and reliability. Various research designs are there such as Explanatory research design, Descriptive research design, Correlational research design, Experimental research design, etc., (Baker & Edwards, 2017).

In the current research study, which is related to the Perception of operators on waste management in Desalination plants in the UAE, the descriptive research design was used. As the research is quantitative in nature, it helped in collecting various facts related to the waste management issues in desalination plants in UAE adequately. The descriptive research design helped in gaining complete facts about the types of unregulated wastes, the impact of unregulated waste management, and its contribution to the development of a waste management system with the help of naturalistic observations and surveys in an organized manner. With respect to this, exploring and analysing the facts related to the measures and techniques for controlling waste disposal impact in UAE, face-to-face interviews were conducted by asking questions from the employees who are involved/working in the desalination waste management plan logically.

3.5 Research Strategy

Research strategy enhances the validity and credibility of research in a thesis that narrows down from broad assumptions to detailed analysis consisting of data collection, data analysis, and interpretation that provides the researcher with a decision to study the research topic. It is guided by designing a research philosophy that helps a researcher to meet the research objectives and answer the research questions properly. Below mentioned are the three research approaches commonly used by researchers: Quantitative research approach, Qualitative approach, and mixed method approach (Amaratunga et al., 2002).

In the current research study, which is related to the Perception of operators on waste management in Desalination plants in the UAE, the research adopted a quantitative research approach. It is best suited for the research study in order to determine the best desalination plants and their contribution to the development of a waste management system for the UAE with the help of a data collection approach. It helped in testing the generated hypotheses by using mathematical expressions like mean, descriptive statistics, etc. It also evaluated the results by establishing a comparison between the waste management system and its outcome in an effective manner. Additionally, the research also recognized and evaluated the protocols in order to determine various control measures and technologies for effectively measuring the impacts and outcomes. The quantitative evaluation of the various data helped in assessing the need to identify the different types of unregulated waste from desalination plants in the UAE. It also helped in numerically presenting the facts. The quantitative research approach also helped in analysing the various challenges that were faced by the desalination plants in UAE. It also helped in authenticating the generated hypotheses and deducing results so that the acceptance or rejection of the hypotheses could be done in a precise manner.

3.6 Instrument Development

A tool that has been developed for collecting, quantifying, and evaluating information in a study is called an instrument. It can be an interview, questionnaire, survey, test, checklist, or poll. It can be either online or offline. For this study, both structured questionnaires and interviews were performed. This study used the study of Bryman (2016) to conduct the interview method and collect the data. The interview process includes: (i) developing an interview structure according to the research questions, (ii) avoiding questions that could have multiple or dual concepts, (iii) finding the potential interview subjects or themes, (iv) estimating the likelihood of the number and type of participants from the target populations, (v) choosing the method to record the interview, (vi) obtaining consent from the participants for performing the interview, and (vii) planning suitable time and location for the interview.

3.6.1 Interviews

Interviews were conducted face-to-face to collect information on the unregulated waste, suitable desalination techniques, the environmental effect on the desalination process, techniques to reduce the adverse effect of desalination plants on the environment, mitigating measures, and techniques to improve the desalination process and finally, employee's perception towards environment aspects and impacts of brine waste disposal during the process of desalination. People who are experts (specialists) such as the QHSE managers, plant managers, lab analysis specialists, waste management engineers, and production engineers working in the following three desalination plants (Jebel Ali desalination plant, Taweelah A1 Power and Desalination Plant, and Fujairah F2 Plant) were the participants of this interview. These close-ended interviews.

3.6.2 Questionnaire

For the effective collection of data and information, structured questionnaires that had close-ended questions with a 4-point Likert scale (1 = Strongly Agree; 2 = Agree; 3 = Disagree; 4 = Strongly Disagree) were used in the research. The questionnaire was designed with easy and simple questions to understand. The quantitative questionnaire had also been designed according to the proposed objectives so that relevant information about the current research topic could be collected in multiple types of questions so that respondents do not feel any kind of difficulty while sharing their reviews. The questionnaire framed for this study was provided with all the basic information, including types of chemicals used, kinds of waste management systems followed, and their effect. Further, the respondents were provided with the assurance that their data will stay individual and confidential through a cover letter. They were mentioned to answer questionnaires as precisely as conceivable by guaranteeing the security of their answers and anonymity. A total of 150 respondents were involved in the survey using the Questionnaire. Refer to Appendix -1 (Questionnaire).

3.6.3 Pilot Study

A pilot study can be conducted as a preliminary version of a major study with the same respondents. It is used to test the reliability and validity of the questionnaires developed. The results of the pilot study can be used to modify the questionnaire. A pilot study of 32 participants was analyzed for the Cronbach alpha values to ensure the reliability and correlation between the variables.

3.7 Population

The UAE currently has 70 major desalination plants. However, for this study, the target desalination plant was three desalination plants in UAE such as Jebel Ali desalination plant, Taweelah A1 Power and Desalination Plant, and Fujairah F2 Plant. Moreover, the target population was the QHSE managers, plant managers, lab analysis specialists, waste management engineers and production engineers working there. In this process, each participant had a uniform opportunity. Individuals who reside within the area of study only were chosen as respondents. The total number of respondents planned for this study was 240. However, exclusively 150 people participated in the survey. From this total population, 47 were Laboratory Analysis Specialists, 39 were Waste Management Engineers, 30 were plant managers, 28 were QHSE managers, and 6 were production engineers at different desalination plants, as shown in Table 3.1, which reflects the plant name, location, the technology used, and capacity.

Table 3.1: Plant name, location, the technology used and its capacity (Source: Saif, 2012)

Plant Name	Location	Capacity (m^3/d)	Technology
Al Fujairah 1	Qidfa', Fujairah, UAE	170000	RO cogeneration
Al Fujairah 1		284000	MSF
Al Fujairah 2		136260	RO cogeneration
Al Fujairah 2		454200	MED
Jebel Ali G	Jebel Ali, Emirate of Dubai, UAE	273000	MSF cogeneration
Jebel Ali M Station		636440	MSF cogeneration
Jebel Ali		127200	MSF
Jebel Ali K2		182000	MSF cogeneration
Jebel Ali L1		317800	MSF cogeneration
Jebel Ali L2		250000	MSF cogeneration
Al Taweelah A1	The coastal area of Taweelah, Abu Dhabi	98000	MED cogeneration
Al Taweelah A1		240000	MSF cogeneration

Table 3.1 continued

Al Taweelah A2		227000	MSF cogeneration
Al Taweelah B1		340950	MSF cogeneration
Al Taweelah B2		104400	MSF cogeneration
Al Taweelah B3		314600	MSF cogeneration

3.8 Sample Frame

A sampling frame is simply the collection of source materials from which the sample has been drawn. The primary function of the sampling frame is to offer participants a way to select which specific individuals of the target population to speak with. In this study, the experts (specialists) such as the QHSE managers, plant managers, Laboratory analysis specialists, Waste management engineers, and Production engineers working in three desalination plants were chosen as samples.

3.9 Sampling Technique

Sampling is a technique in research in which information about a specific population is gained by the researcher based on obtained results from the subset without conducting any investigation on the individual traits of the population. The sampling technique has been categorized into probability and non-probability sampling techniques explained below: Probability Sampling and Non-Probability Sampling (Acharya et al., 2013).

In the current study, the simple random sampling method under the probability sampling method was used to select participants. The simple random sampling method was selected to choose the sample from which the large populace was used. The simple random sampling method was used for the selection of participants who are the workers or (specialists) in chosen desalination plants. The use of this sampling method helped to select the participants for the current research study in a uniform and unbiased manner.

3.10 Sampling Size

The sample size is known as the number of study participants or observations selected by the researcher denoted by "n" called the representative of the entire population. The formula used to determine the size of the sample for this study:

$$n = N / [1 + N (e)^{2}]$$

Where ‘N’ denotes the size of the population, ‘n’ denotes the sample size, ‘e’ denotes margin error, and ‘1’ denotes the unit or a constant. With a 95% level of confidence allowing a margin error ‘e’ of ±5% (Krejci & Morgan, 1970), and N = 240, the sample size ‘n’ was found to be 150 (approximately). Hence, 150 final samples were chosen for this study.

3.11 Unit Analysis

The highly important element of any study is the unit of analysis. This discloses what qualities need to be inspected in a study. The unit of analysis in a study can cluster people into assorted groups, societies, nations and to associations, and so forth from where the study conducts the data collection process.

3.12 Data Collection

Data collection is the most essential part of the research conduction process which is used to collect the evidence and proofs concerning the research study (Sapsford & Jupp, 2006). Data collection methods are categorized into two types explained below: Primary data collection method; Secondary data collection method (Driscoll et al., 2007).

In the current study, the primary data collection method was adopted. The questionnaires developed were sent to the respondents through email. It consists of questions that took only about 25-30 minutes to complete. From the questionnaire, a large amount of data was collected effectively. In the first part of the questionnaire, the demographic profile of the respondents like their educational qualifications, and the designation was taken. About 240 respondents had been given the questionnaire and explained every question before attempting to answer the question. Hence, using the primary data collection method, helped to identify the different types of unregulated waste with their percentage, the working of desalination plants in UAE, and the impact on the environment explained effectively. A face-to-face quantitative interview with experts (specialists) such as the QHSE managers, plant managers, lab analysis specialists, waste management engineers, and production engineers working in three desalination plants was also conducted.

3.13 Pilot Study

According to Lackey and Wingate (1997), and Kim et al. (2011), a pilot study can be defined as a preliminary version of a major study performed with the same respondents. Its objectives include orienting the researcher to the issue at hand and evaluating the reliability and validity of the measurement tools. In this study, a pilot study was conducted to ensure that the developed questionnaires and their content were reliable. Pilot studies of 32 participants were analysed for the Cronbach alpha values to ensure the reliability and correlation between the variables.

3.14 Validity and Reliability

However, the validity and reliability concepts have distinct characteristics of measuring instruments, and both have been closely associated with each other. In general, there is no relation between a measuring instrument's reliability and validity, but a measuring instrument's validity is likely to make it reliable. Validity cannot be ensured by reliability alone. In spite of the fact that a test may be reliable, it may not be accurate in indicating the expected quality or behaviour. Hence, a study should ensure that the measuring instruments are both valid and reliable. The measuring instrument must meet both of these requirements. A healthy interpretation of research findings will not be possible otherwise.

3.14.1 Validity

Validity is a measure of how well the measuring instrument fulfils its purpose by determining if it assesses the quality or behaviour that it has been designed to measure. The relevant and suitable interpretation of the data gathered from the measurement instrument as a result of the analysis determines validity. Different validity types have been proposed in the literature to determine the instrument’s validity (Oluwatayo, 2012). They are internal validity, external validity, construct validity, criterion-related validity, content validity, concurrent validity, predictive validity, consequential validity, systemic validity, translation validity, statistical conclusion validity, evaluative validity, descriptive validity, interpretive validity, and cultural validity.

In this study, all the data and facts related to the desalination plants and integrated waste management system in UAE were collected from valid sources i.e., desalination plants in UAE in the form of questionnaires. All data were collected based on experience and personnel involved in the process.

3.14.2 Reliability

The consistency and stability of the measurement devices used over time are referred to as reliability. Reliability is also defined as the capability of a measurement system to yield consistent results when used at various points in time. The reliability of scales used in empirical research can be assessed using a variety of methodologies. The techniques that are most commonly used are internal consistency tests, alternate forms, and test-retest reliability. Further, there are three techniques to apply internal consistency tests (alpha reliability, item-total correlations, and split-half coefficient).

As the study mainly focused on the integrated waste management system in UAE for managing unregulated waste, all the data and facts collected are reliable in nature. While collecting data from the desalination plant, permission was taken from the desalination plant authority, so that they would be able to organize the data collected from the specialists who are working in the desalination plants in UAE.

For testing the validity and reliability, the SPSS software has used Cronbach Alpha. Cronbach Alpha is a kind of reliability measure. A reliability test has been conducted with the help of Cronbach alpha, which depicts the internal reliability of the items and enlightens that those are interconnected alongside this it can likewise determine the singular construct. The high value for the Cronbach alpha is 0 to 1. The reliability measurement has been viewed as highly reliable when the alpha's value is greater than 0.6; on the other hand, it has been noted as less reliable when it is lesser than 0.6.

3.15 Data Analysis Techniques

Data analysis in research is the structuring of data systematically so that meanings can be drawn from the data collected. It is organized and arranged in such a manner that information is conveyed to the readers fulfilling the research aims and objectives. Qualitative data analysis is conducted in which the words, expressions, or quotes of the study participants are deduced into themes, categories of themes known as thematic analysis that also provides possible relationships between these recognized patterns. Numerical interpretation is done for the quantitative data collected from questionnaires by using statistical and descriptive methods like correlations, deviations, and presentations in the form of charts, graphs, and bar diagrams (Johnson et al., 2010).

In the current study to determine the final result based on the previously collected data, thematic representation was used by plotting the collected value in a tabular manner and presenting the figures in the form of pie charts, bar diagrams, etc. In the current research study, which is related to the Perception of operators on waste management in Desalination plants in the UAE, statistical tools like Chi-square and SPSS methods were taken into consideration so that the quantitative analysis of the obtained data could be more accurate. SPSS Factor Analysis has been conducted for finding variables and putting them in common scores and the Coefficient of correlation analysis was conducted to evaluate the level of reliability of a research tool.

SPSS: SPSS stands for Statistical Package for Social Science. SPSS Software has been used in the current study to verify the available facts in a quantifiable manner. The application of SPSS enabled the research to present the collected and analyzed facts in a mathematical format in a more accurate manner (Johnson & Turner, 2003).

3.16 Summary

A detailed description of the research strategy, design, philosophy, and sampling technique adopted for conducting this study was provided in this chapter. The research study which is related to the Perception of operators on waste management in Desalination plants in the UAE is quantitative in nature and so a positivist research paradigm was used. The deductive research approach was applied so that quantitative analysis and factor analysis could be carried out adequately. The research design and sampling designs were descriptive research design and simple random sampling method respectively. The collection of data related to the operator's perceptions of waste management systems in desalination plants in UAE had done by using primary means like a quantitative questionnaire consisting of close-ended questions including the use of 4 Likert's scale specifications so that the negative impact of improper disposal of integrated waste by the desalination plants on the Environment could be analyzed effectively. Furthermore, in order to analyze the collected facts, statistical tools like descriptive statistics and SPSS software were used. In addition to this, the validity and reliability were checked by running pilot studies. In the research, ethical norms were maintained, so that the research study could be conducted well without any complications or any external interferences.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Using descriptive analysis, the study evaluated the effects of the UAE's brine disposal of desalination plant waste. It comprises demographic information like designation, qualification, participant responses to questions about how desalination plant waste is disposed of, and other details that are analyzed. The sample size taken for the study is n=150 respondents.

Table 4.1 and Figure 4.1 reveals the designation of the respondents. While focusing on designation, it was found that 31.3% of the respondents were working as laboratory analysis specialists, 26.0% of respondents were employed as waste management engineers, 20.0% of the respondents were engaged as plant managers and 18.7% of the respondents were QHSE managers. The percentage of production engineers was found to be the lowest with only 4% of respondents belonging to this category.

Table 4.1: Frequency of Designation

	Frequency	**Percentage**
QHSE manager	28	18.7
Plant manager	30	20.0
Lab analysis specialist	47	31.3
Waste management Engineer	39	26.0
Production Engineers	6	4.0
Total	**150**	**100.0**

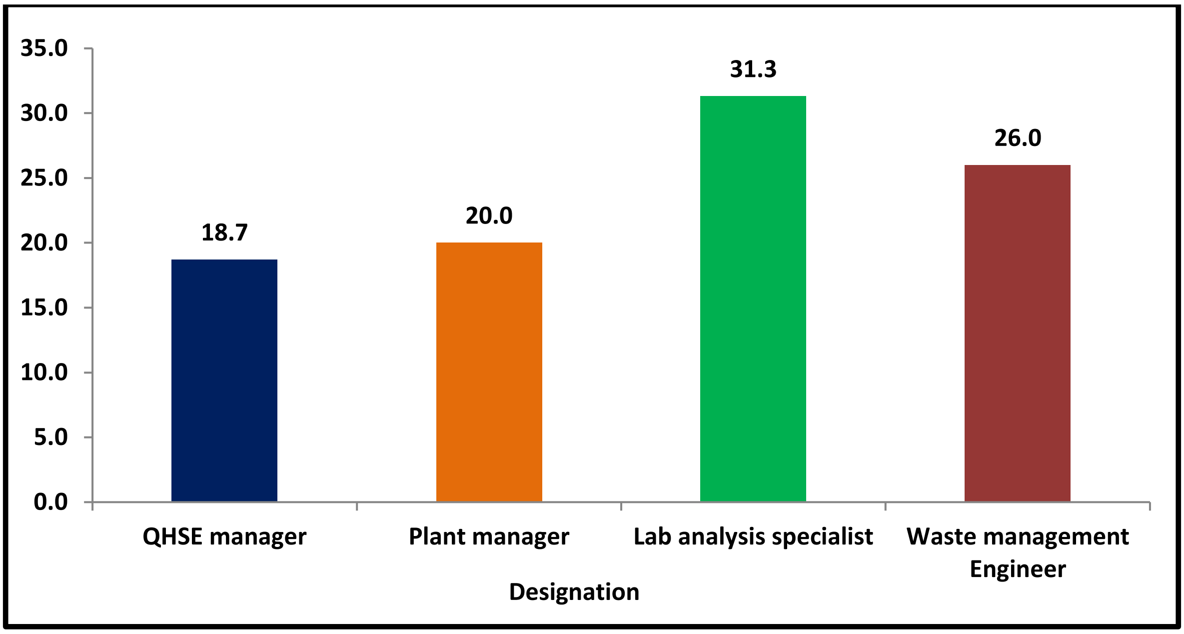

Figure 4.1: Percentage of Designation

Table 4.2 and Figure 4.2 reveals the frequency and percentage of the qualification of the respondents. The facts related to the qualification of the respondents were also included and it was ascertained that 48.0% of respondents had a Master's Degree, 40% of respondents had Bachelor's degree and 8% of respondents had a Diploma certification. The percentage of respondents who had a Doctorate was found to be the lowest with only 4% of participants belonging to this category.

Table 4.2: Frequency of Qualification

	Frequency	**Percentage**
Diploma	12	8.0
Bachelor	60	40.0
Master	72	48.0
Doctorate	6	4.0
Total	**150**	**100.0**

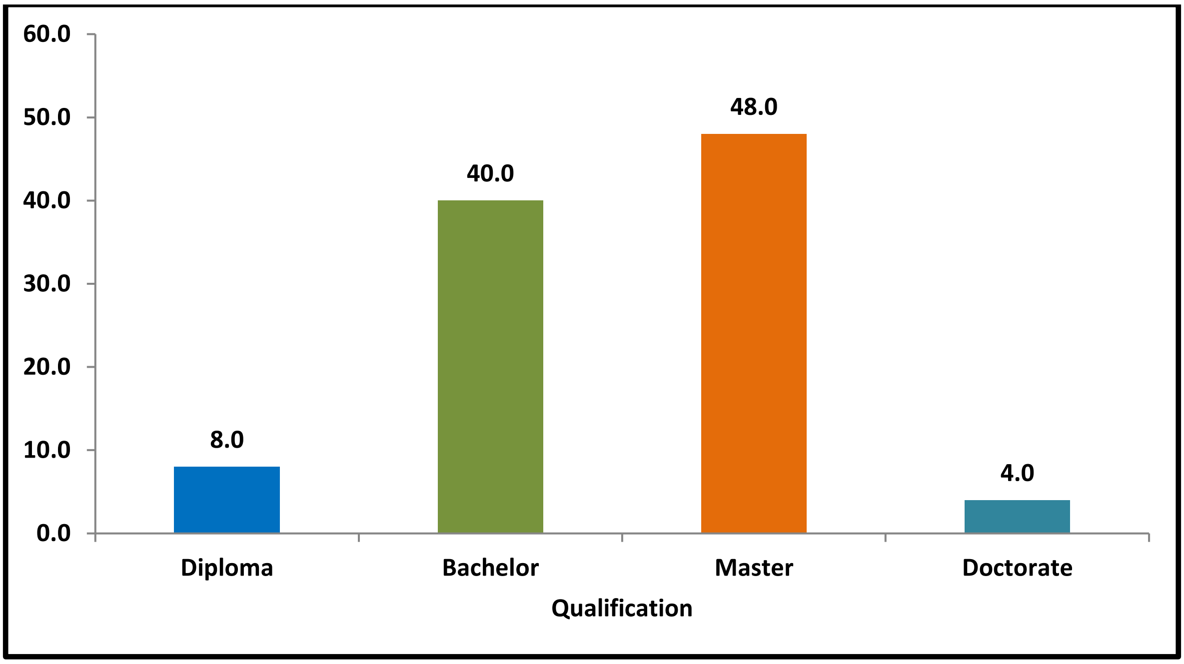

Figure 4.2 Percentage of Qualification

Table 4.3 and Figure 4.3 shows that in the UAE, desalination facilities are the main source of disposal for that kind of waste. After questioning the respondents and reviewing the information regarding the waste types that were primarily discharged from desalination plants in the UAE, it was discovered that 81.3% of the respondents agreed that brine discharge was the waste type that was primarily discharged from desalination plants in the UAE, followed by 10.7% of the respondents who said that chemical discharge was the waste type and 1.3% of the respondents who responded that metal discharge was the waste type that was primarily discharged from desalination plants in the UAE. Consequently, it can be concluded that desalination facilities are very helpful in supplying water to fulfill the growing demand from industry and people.

Table 4.3: Frequency of type of waste is mostly disposed of desalination plants in UAE

	Frequency	**Percentage**
Brine discharge	122	81.3
Emission of gases	10	6.7
Metal Discharge	2	1.3
Chemical discharge	16	10.7
Total	**150**	**100.0**

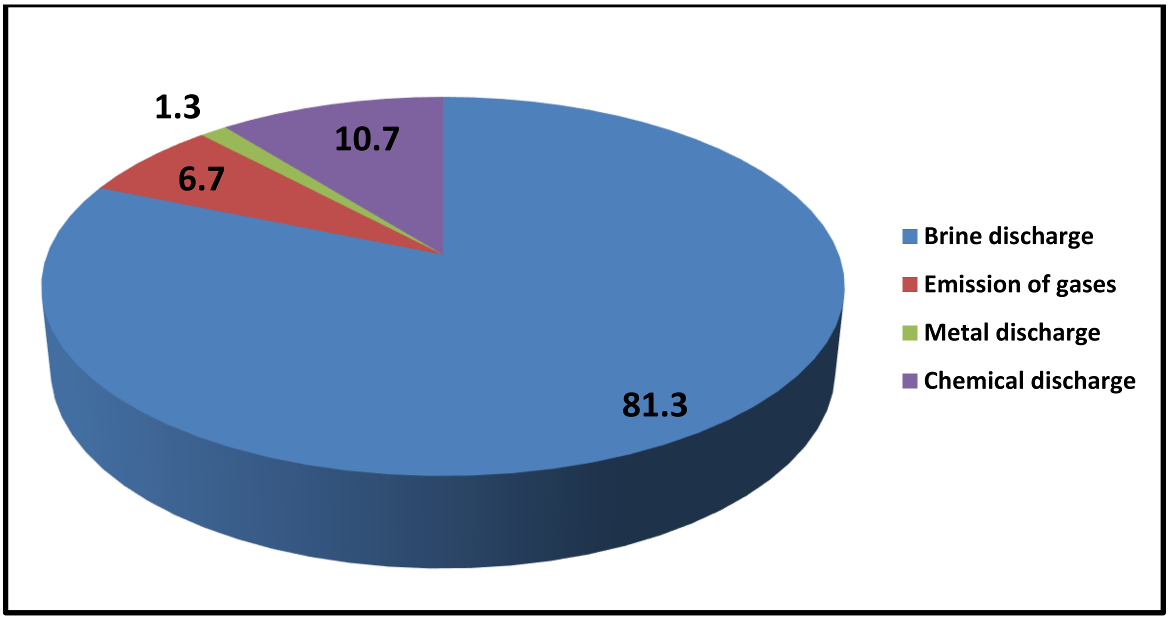

Figure 4.3: Percentage of type of waste mostly disposed of desalination plants in UAE.

Table 4.4 and Figure 4.4 depicts the type of waste disposed of from the respondents' desalination plants. During the interview, the respondents examined facts about the type of waste disposed of from your desalination plant and it was found that 72.7% of the respondents said that brine discharge was the mostly disposed of desalination plants followed by 14% of them explored the chemical discharge while 2.7% of the respondents answered that metal discharge was disposed from desalination plants.

Table 4.4: Frequency of type of waste disposed of from the respondents' desalination plant

	Frequency	**Percentage**
Brine discharge	109	72.7
Emission of gases	16	10.7
Metal discharge	4	2.7
Chemical discharge	21	14.0
Total	**150**	**100.0**

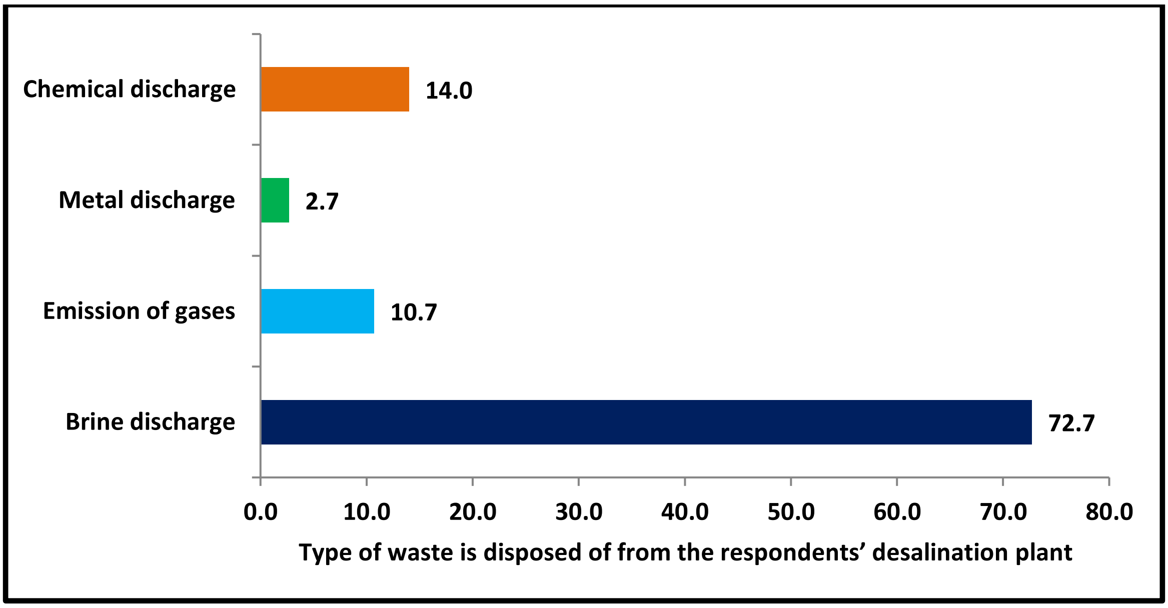

Figure 4.4: Percentage of type of waste disposed of from the respondents' desalination plant.

Table 4.5 and Figure 4.5 reflects the frequency and the percentage of waste disposal that has the most harmful effects on the environment. While analyzing waste disposal facts associated with the most harmful effects on the environment, it was ascertained that 34% of the respondents confirmed that brine discharge had the most harmful effects on the environment, 30% of them explored the Emission of gases, while 14.7% of the respondents answered that metal discharges had the most harmful effects on the environment.

Table 4.5: Frequency of waste disposal has the most harmful effects on the environment

	Frequency	Percentage
Brine discharge	51	34.0
Emission of gases	45	30.0
Metal Discharge	22	14.7
Chemical discharge	32	21.3
Total	**150**	**100.0**

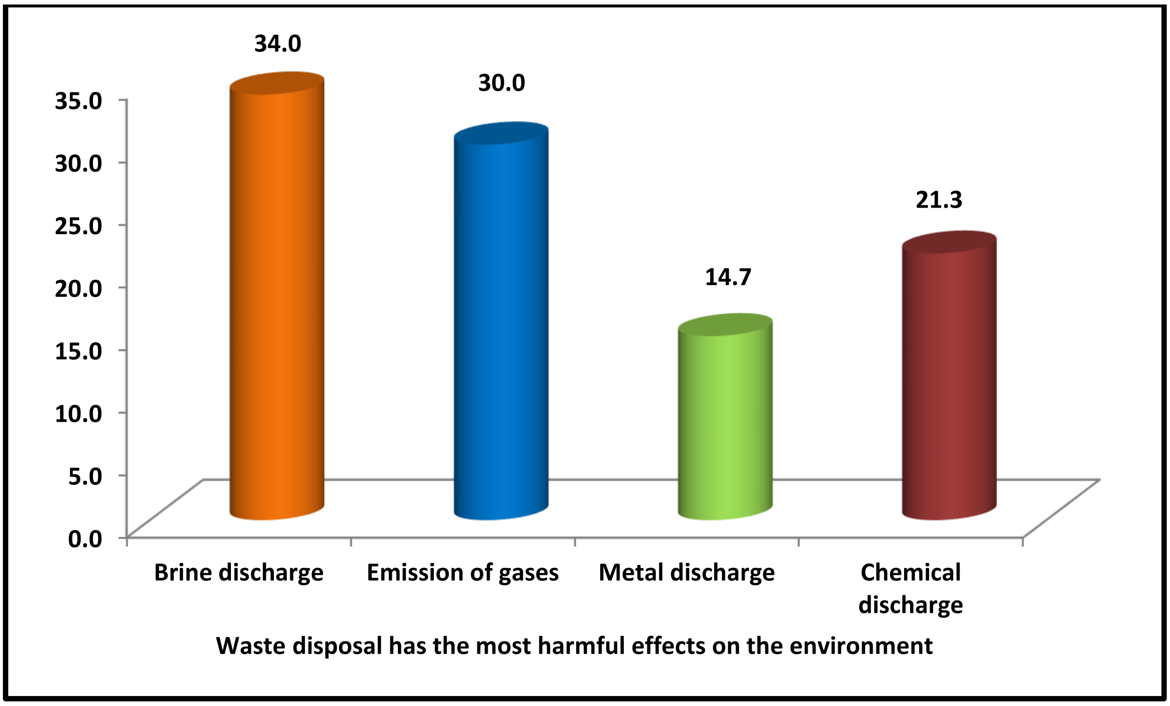

Figure 4.5: Percentage of waste disposal has the most harmful effects on the environment.

Table 4.6 and Figure 4.6 depicts that waste disposal has a complex treatment process. The study also included the facts that were related to the examination of waste disposal which had a complex treatment process. It was determined that 35.3% of the respondents agreed that chemical discharge had a complex treatment process followed by 24.7% of them explored Metal discharge while 17.3% of the respondents said that Brine discharges had a complex treatment process.

Table 4.6: Frequency of waste disposal has a complex treatment process

	Frequency	Percentage
Brine discharge	26	17.3
Emission of gases	34	22.7
Metal Discharge	37	24.7
Chemical discharge	53	35.3
Total	**150**	**100.0**

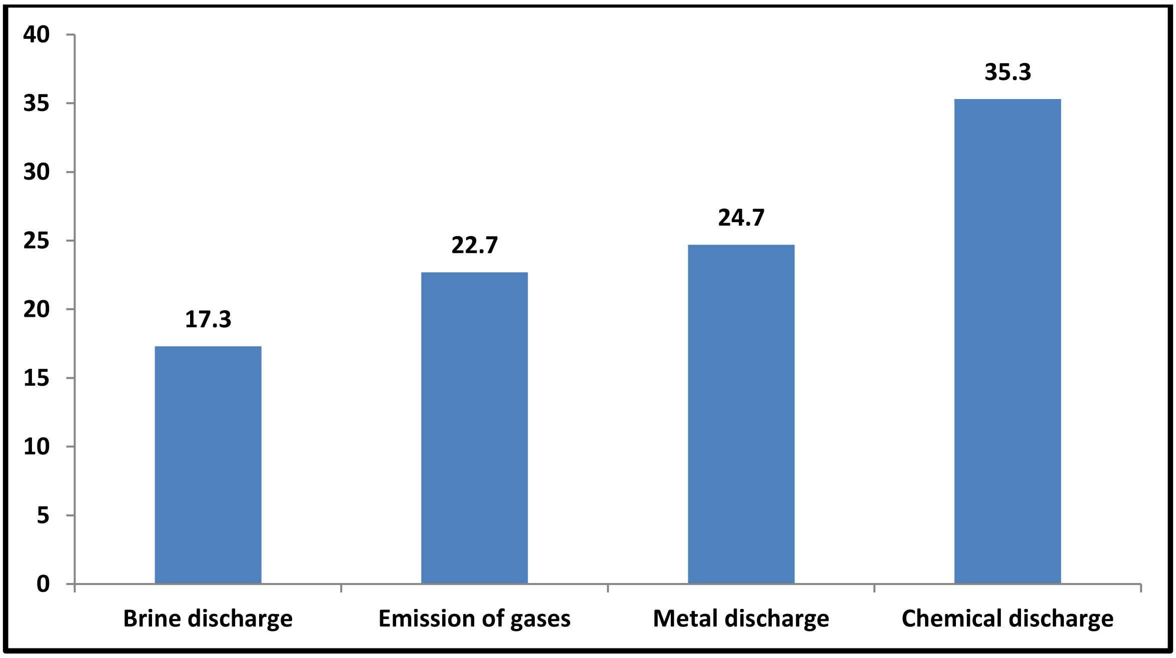

Figure 4.6: Percentage of waste disposal has a complex treatment process

Table 4.7 and Figure 4.7 reflects the facts that were related to the method that was generally used in disposing of unregulated wastes from desalination plants in the UAE were analyzed and found that 53.3% of respondents answered that Reverse osmosis was generally used in disposing of unregulated wastes from desalination plants in the UAE. About 4.0% of respondents confirmed that Vapour compression Distillation was generally used in disposing of unregulated wastes from desalination plants in the UAE.

Table 4.7: Frequency of which method is generally used in disposing of unregulated wastes from desalination plants in the UAE

	Frequency	**Percentage**
Multi-stage flash distillation	64	42.7
Vapour compression Distillation	6	4.0
Reverse osmosis	80	53.3
Total	**150**	**100.0**

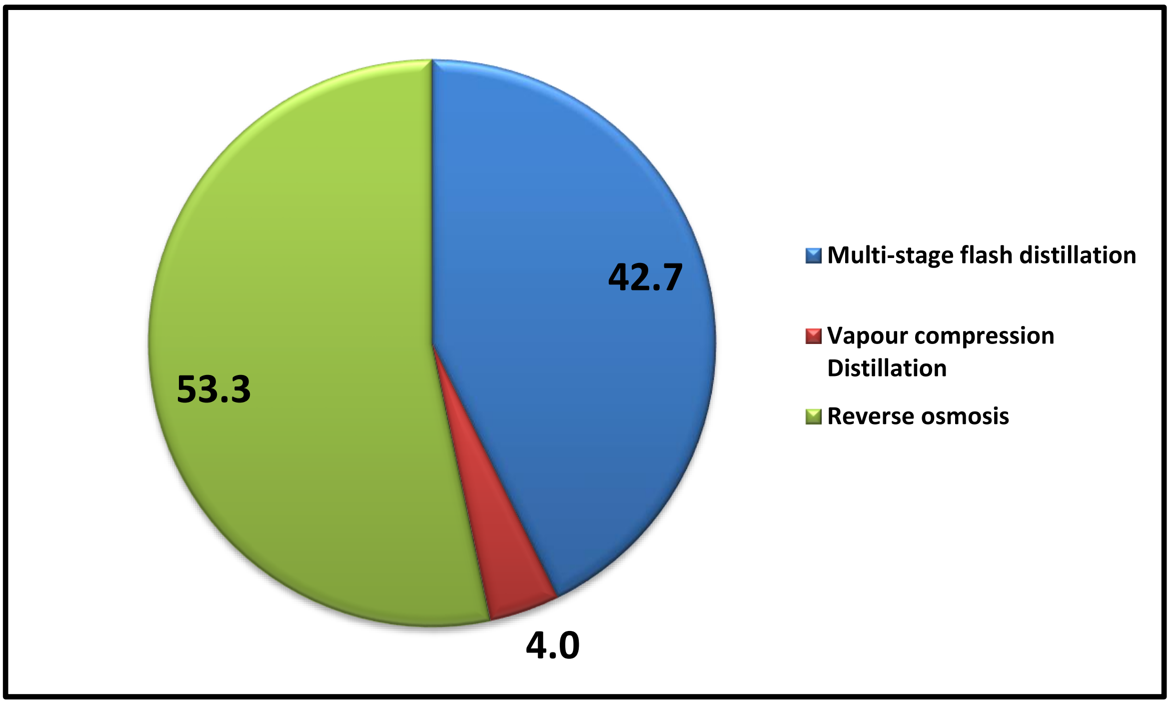

Figure 4.7: Percentage of which method is generally used in disposing of unregulated wastes from desalination plants in the UAE

Table 4.8 and Figure 4.8 shows respondents telling about which desalination process technology is primarily used in the facility. The study also included facts that were related to the examination of desalination process technology that was primarily used in the facility. It was determined that 58.7% of the respondents answered that the thermal process was used in the facility as the desalination process technology, while 41.3% of respondents said that the membrane process is in the facility as the desalination process technology.

Table 4.8: Frequency of which desalination process technology is primarily used in the facility

	Frequency	**Percentage**
Thermal process	88	58.7
Membrane process	62	41.3
Total	**150**	**100.0**

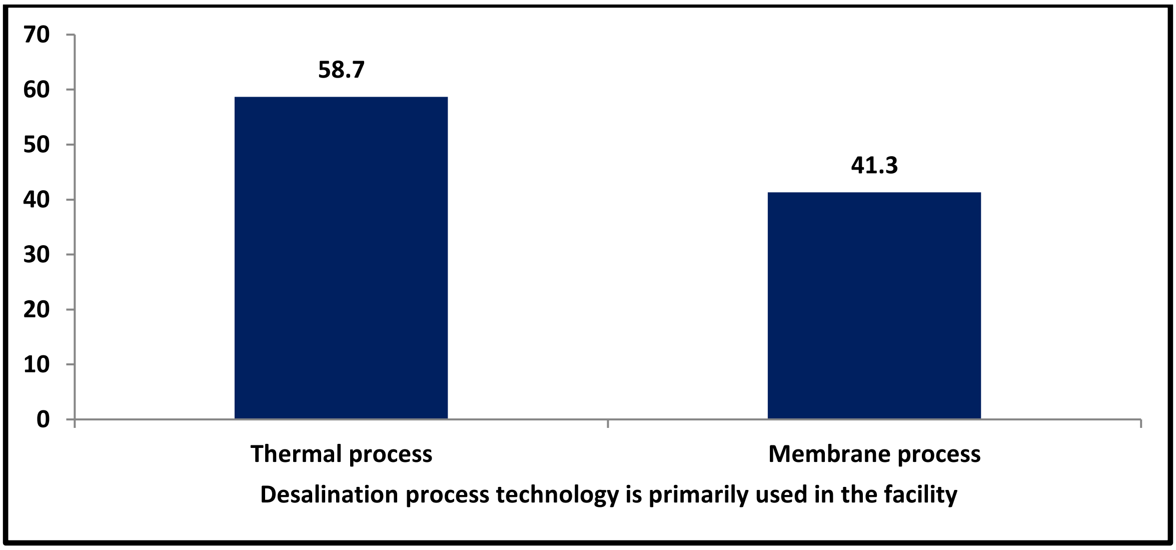

Figure: 4.8: Percentage of which desalination process technology is primarily used in the facility

Table 4.9 depicts the frequency of which technology is used in the thermal process. The researcher interrogated the respondents and analyzed facts associated with technology that was used in the thermal process. The majority 34.7% of respondents confirmed that Multi-Stage Flash Distillation using waste heat could be used as technologies in the thermal process while 2.7% of them confirmed that Solar Desalination and LTE Desalination using waste heat could be used as technologies in the thermal process.

Table 4.9: Frequency of which technology is used in the thermal process

	Frequency	**Percentage**
Solar Desalination	4	2.7
Multi-Effect Distillation	24	16.0
Multi-Stage Flash Distillation	52	34.7
LTE Desalination using waste heat	4	2.7
Vacuum freeze Desalination	5	3.3
Sub Total	**88**	**100.0**

Table 4.10 depicts the frequency at which technology is used in the membrane process. While analyzing that technology is used in the membrane process, it was found that 58.7% of respondents confirmed that there was no technology applicable to the membrane process. The majority 37.3% of respondents answered that membrane distillation is used in the membrane process and 1.3% of respondents answered that reverse osmosis is used in the membrane process.

Table 4.10: Frequency of which technology is used in the membrane process

	Frequency	**Percentage**
Membrane Distillation	2	1.3
Reverse Osmosis	56	37.3
Electrolysis	4	2.7
Sub Total	**62**	**100.0**

Table 4.11 and Figure 4.9 reveals which technique of membrane process energy consumption is less. The researcher interviewed the respondents and analyzed the facts about the technique of the membrane process that consumed less energy. It was determined that 29.3% of the respondents said that forward osmosis was the membrane process that consumed less energy while 1.3% of respondents confirmed that electrolysis was the membrane process that consumed less energy.

Table 4.11: Frequency of technique of membrane process energy consumption is less

	Frequency	**Percentage**
Forward Osmosis	44	29.3
Reverse Osmosis	25	16.7
Rapid Spray Evaporation	43	28.7
Electrolysis	2	1.3
Capacitive Deionisation	36	24.0
Total	**150**	**100.0**

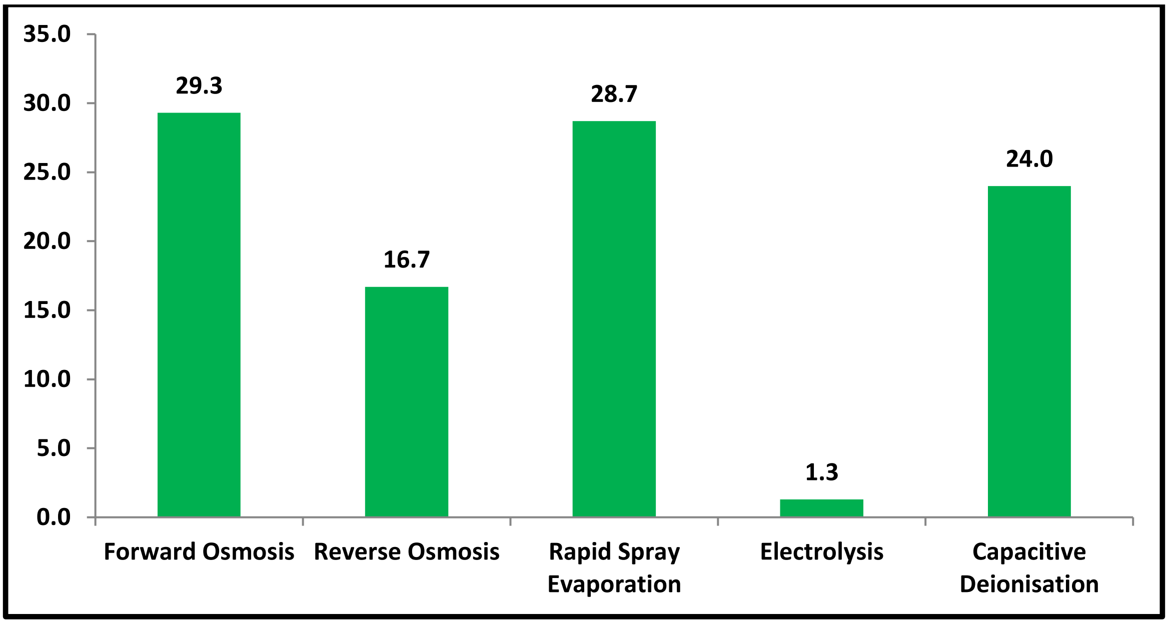

Figure 4.9: Percentage of the technique of membrane process energy consumption is less

Table 4.12 and Figure 4.10 reveals which technique of thermal process energy consumption is less. The researcher interviewed the respondents and analyzed the facts about the technique of the thermal process that consumed less energy. It was ascertained that 49.3% of the respondents said that Solar Desalination was the thermal process that consumed less energy while 2.7% of respondents confirmed that Multi-Effect Distillation was the thermal process that consumed less energy.

Table 4.12: Frequency of which technique of thermal process energy consumption is less

	Frequency	**Percentage**
Solar Desalination	74	49.3
Multi-Effect Distillation	4	2.7
LTE Desalination using waste heat	14	9.3
Vacuum freeze Desalination	29	19.3
Vapour Compression Distillation	29	19.3
Total	**150**	**100.0**

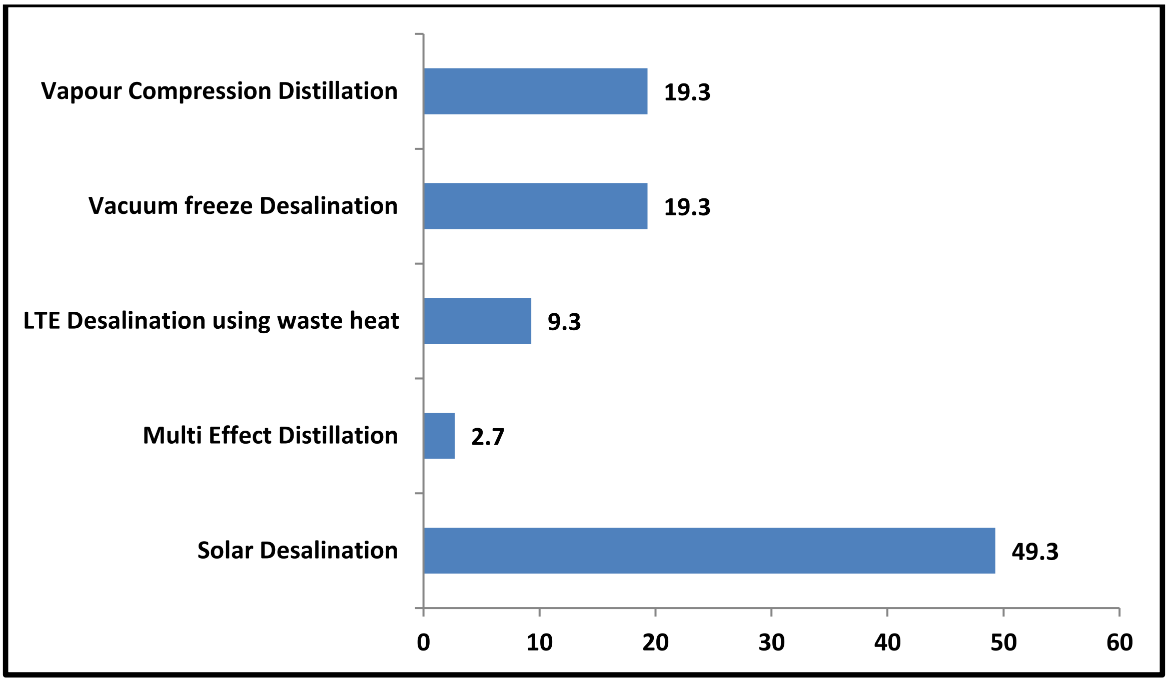

Figure 4.10: Percentage of which technique of thermal process energy consumption is less

4.1.1 Suitable Desalination Technique

Table 4.13 reveals the following, facts related to the low water output and consequent large land requirements that were carefully considered if Single Stage Desalination (SSD) was pursued as a desalination option were analyzed. It was ascertained that 64% of the respondents strongly agreed that it was essential that low water output and consequent large land requirements were carefully considered if SSD was pursued as a desalination option. However, 9.3% of the respondents strongly disagreed with the notion and did not consider that it was essential that low water output and consequent large land requirements were carefully considered if SSD was pursued as a desalination option. While analyzing whether high capital cost needed to be carefully considered if SSD was pursued as a desalination option, it was ascertained that 64.7% of respondents strongly agreed that it was important that high capital cost was carefully considered if SSD was pursued as a desalination option and 9.3% of respondents strongly disagreed and said that it was not important that high capital cost was carefully considered if SSD was pursued as a desalination option.

Table 4.13: Frequency of Suitable Desalination Technique

	SD	D	A	SA
	n(%)			
It is essential that low water output and consequent large land requirements are carefully considered if SSD is pursued as a desalination option.	14 (9.3)	23 (15.3)	17 (11.3)	96 (64.0)
It is important that high capital cost is carefully considered if SSD is pursued as a desalination option.	14 (9.3)	23 (15.3)	16 (10.7)	97 (64.7)
Multi-stage flash is suitable for producing distilled quality water products good for power plants, for industrial processes.	16 (10.7)	18 (12.0)	22 (14.7)	94 (62.7)
Forward osmosis is an emerging membrane-based desalination technology which allows for the use of thinner membranes in the system.	17 (11.3)	25 (16.7)	11 (7.3)	97 (64.7)
Forward osmosis helps minimize membrane fouling and clogging compared with RO.	14 (9.3)	23 (15.3)	14 (9.3)	99 (66.0)
Electro dialysis and electro dialysis reversal (ED/EDR) can also be easily adapted to be powered directly by photovoltaic, making them environmentally sustainable and technically feasible for off-grid communities.	14 (9.3)	23 (15.3)	15 (10.0)	98 (65.3)
Membrane distillation (MD) can produce high-quality distillate at relatively low temperatures (<100°C).	17 (11.3)	25 (16.7)	13 (8.7)	95 (63.3)
Membrane distillation (MD) reduces pre-treatment requirements compared with pressure-based membrane processes.	14 (9.3)	23 (15.3)	16 (10.7)	97 (64.7)
Membrane distillations (MD) use low-grade heat (solar or waste heat) for operation.	14 (9.3)	23 (15.3)	18 (12.0)	95 (63.3)

It was determined that 62.7% of the respondents strongly agreed that multi-stage flash was suitable for producing distilled quality water products good for power plants, for industrial processes. While, 10.7% of respondents strongly disagreed that multi-stage flash was suitable for producing distilled quality water products good for power plants, for industrial processes. While interviewing the respondents and it was analyzed, the facts related to forward osmosis was an emerging membrane-based desalination technology that allows for the use of thinner membranes in the system. It was ascertained that 64.7% of respondents strongly agreed with the notion while 11.3% of the respondents strongly disagreed with the same aspect. It was examined whether Forward osmosis helped in minimizing membrane fouling and clogging compared with RO. It was found that 66% of respondents strongly agreed that Forward osmosis helped in minimizing membrane fouling and clogging compared with RO while 9.3% of respondents strongly disagreed.

Facts related to Electro dialysis and electro-dialysis reversal (ED/EDR) could also be easily adapted to be powered directly by photovoltaics, making them environmentally sustainable and technically feasible for off-grid communities were analyzed and determined that 65% of respondents strongly agreed with the fact while 9.3% of respondents strongly disagreed with the fact. The researcher interrogated the respondents and examined the facts associated with Membrane distillation (MD) that could produce high-quality distillate at relatively low temperatures (<100°C). It was determined that 63.3% of respondents strongly agreed while 11.3% of respondents strongly disagreed. The study also examined the facts that were related to membrane distillation (MD) reduced pre-treatment requirements compared with pressure-based membrane processes. It was ascertained that 64.7% of respondents strongly agreed that Membrane distillation (MD) reduced pre-treatment requirements compared with pressure-based membrane processes. However, 9.3% of respondents disagreed and strongly disagreed that Membrane distillation (MD) reduced pre-treatment requirements compared with pressure-based membrane processes. During the interview, respondents analyzed the facts that were related to Membrane distillation (MD) using low-grade heat (solar or waste heat) for operation. It was found that 63.3% of respondents strongly agreed that Membrane distillation (MD) used low-grade heat (solar or waste heat) for operation. While 9.3% of respondents disagreed and strongly disagreed that Membrane distillation (MD) used low-grade heat (solar or waste heat) for operation.

4.1.2 Environment Effects of the Desalination Process

Table 4.14 shows the facts that were associated with brine produced in the desalination process being disposed of properly and found that 82% of respondents strongly agreed that brine produced in the desalination process was disposed of properly while 4.7% of respondents agreed that brine produced in the desalination process was disposed of properly. The study examined the fact that the salinity of seawater was increased due to the discharge of a high concentration of salt through the outfall of desalination plants. It was analyzed that 74% of respondents strongly agreed that the salinity of seawater was increased due to the discharge of a high concentration of salt through the outfall of desalination plants and 1.3% of respondents strongly disagreed that the salinity of seawater was increased due to the discharge of a high concentration of salt through the outfall of desalination plants. Facts associated with the coastal and marine environment were significantly less affected by concentrate disposal due to a high level of concentrate dilution were examined. It was found that 84% of respondents strongly agreed with the fact while 2.7% of respondents agreed and strongly disagreed with the notion.

Table 4.14: Frequency of Environment Effects of the desalination process

	SD	D	A	SA
	n(%)			
Brine produced in the desalination process is disposed of properly.	11 (7.3)	9 (6.0)	7 (4.7)	123 (82.0)
The salinity of seawater is increased due to the discharge of high concentrations of salt through the outfall of desalination plants.	12 (8.0)	2 (1.3)	25 (16.7)	111 (74.0)
Coastal and marine environments are significantly less affected by concentrate disposal due to a high level of concentrate dilution.	13 (8.7)	4 (2.7)	7 (4.7)	126 (84.0)
Waste concentrate disposal is a very significant problem in inland areas.	7 (4.7)	14 (9.3)	6 (4.0)	123 (82.0)
There is a significant effect on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents.	12 (8.0)	4 (2.7)	18 (12.0)	116 (77.3)
If the desalination plant is combined with a power Plant the temperature of the ambient water in the plant vicinity will increase its seawater temperature	12 (8.0)	4 (2.7)	18 (12.0)	116 (77.3)
An increase in the concentration of residual chlorine affects the water quality of the ambient water.	7 (4.7)	14 (9.3)	6 (4.0)	123 (82.0)
By the effluent discharges from the plant, dissolved oxygen in the water in the plant vicinity is affected.	12 (8.0)	4 (2.7)	18 (12.0)	116 (77.3)
The concentration of unionized ammonia affects marine life.	12 (8.0)	4 (2.7)	18 (12.0)	116 (77.3)

The researcher interviewed the respondents and analyzed facts about whether waste concentrate disposal was a very significant problem in inland areas. It was found that 82% of respondents strongly agreed that waste concentrate disposal was a very significant problem in inland areas and 4% of respondents agreed with the fact. It was examined whether there was a significant effect on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents. It was established that 77.3% of respondents strongly agreed with the fact and 2.7% of respondents disagreed with the notion. The study examined the facts that were associated with the desalination plant combined with power; it was found that 82% of respondents strongly agreed with the combination of a desalination plant with power. However, 4% of respondents agreed with the fact of the combination of a desalination plant with power.

When interviewing the respondents and evaluating the facts about an increase in the concentration of residual chlorine that affects the water quality of the ambient water. It was determined that 82% of respondents strongly agreed that an increase in the concentration of residual chlorine affects the water quality of the ambient water while 4% of respondents strongly disagreed. Facts about the plant's effluent discharge and dissolved oxygen in the water near the plant were investigated. It was discovered that 77.3% of respondents strongly agreed with the notion, while 2.7% disagreed with the fact. The study examined the facts concerning the concentration of unionized ammonia that affected marine life. According to the results, 77.3% of respondents strongly agreed that the concentration of un-ionized ammonia affected marine life, while 2.7% disagreed.

4.1.3 Techniques to Reduce the Adverse Effect of Desalination Plants on the Environment.

Table 4.15 reveals, the frequency of techniques to reduce the adverse effect of desalination plants on the environment. Water levels, current flow velocities, and directions and flow discharges are some of the facts associated with measurements that could be performed in the plant's vicinity. It was discovered that 62.7% of respondents strongly agreed with the fact, while 6% disagreed with the notion. While asking respondents and validation facts related to water quality measurements could be carried out during the study to evaluate the concentrations of substances important to water quality and aquatic species. It was discovered that 64.7% of respondents agreed that water quality measurements could be performed to assess the concentrations of substances important to water quality and aquatic species, while 10% strongly disagreed.

Table 4.15: Frequency of Techniques to Reduce the adverse effect of desalination plants on the Environment

	SD	**D**	**A**	**SA**
	n(%)			
Measurements can be carried out in the plant vicinity and can include water levels, current flow velocities, and directions and flow discharges.	15 (10.0)	9 (6.0)	32 (21.3)	94 (62.7)
Water quality measurements can be carried out to evaluate the concentrations of the substances of importance to the water quality and aquatic species.	15 (10.0)	16 (10.7)	22 (14.7)	97 (64.7)
A biological survey can be carried out in the Plant vicinity to evaluate the ecosystem in the area.	15 (10.0)	9 (6.0)	37 (24.7)	89 (59.3)
A detailed sampling grid can be constructed in the plant vicinity and surveyed by the ecologist.	16 (10.7)	16 (10.7)	20 (13.3)	98 (65.3)
The configuration of the intake and outfall of the plant should be developed and calibrated with field measurements.	17 (11.3)	10 (6.7)	22 (14.7)	101 (67.3)
The water quality model helps to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant.	15 (10.0)	16 (10.7)	21 (14.0)	98 (65.3)

Table 4.15 continued

The Effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity.	15 (10.0)	16 (10.7)	23 (15.3)	96 (64.0)
Hydraulic structures are used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents.	15 (10.0)	16 (10.7)	23 (15.3)	96 (64.0)

The facts related to a biological survey could be carried out in the desalination plant and it was determined that 59.3% of respondents strongly agreed that a biological survey could be carried out in the desalination plant. However, 10% of respondents disagreed that a biological survey could be carried out in the desalination plant. The researcher interrogated the respondents and examined the facts that were associated with a detailed sampling grid that could be constructed in the plant vicinity and surveyed by the ecologist. It was found that 65.3% of respondents strongly agreed that a detailed sampling grid could be constructed in the plant vicinity and surveyed by the ecologist. While 13.3% of respondents agreed that a detailed sampling grid could be constructed in the plant vicinity and surveyed by the ecologist. Facts related to the configuration of the intake and outfall of the plant should be developed and calibrated with the field measurements analyzed. It was determined that 67.3% of respondents strongly agreed with the notion while 6.7% of respondents strongly disagreed with the fact. The study also analyzed the facts that were related to the water quality model that helped to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant.

It was found that 65.3% of respondents strongly agreed that the water quality model helped to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant, while 10% of respondents strongly disagreed with the fact. The effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity facts that were examined in the study. It was ascertained that 64% of respondents agreed with the statement. However, 10% of respondents strongly disagreed that the effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity. When interviewing the respondents and analyzing facts that were associated with hydraulic structures that are used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents. It was found that 64% of respondents agreed with the fact while 10% of respondents strongly agreed with the statement.

4.1.4 Mitigating Measures

Table 4.16 reveals the study examined the facts that were associated with the desalination plant brine could be pre-diluted with seawater or power plant cooling water. It was found that 67.3% of respondents strongly agreed that the desalination plant brine could be pre-diluted with seawater or power plant cooling water and 6% of respondents disagreed that the desalination plant brine could be pre-diluted with seawater or power plant cooling water. Facts about outfall could achieve maximum heat dissipation from the waste stream by using cooling waters that were examined in the study. It was determined that 72% of respondents strongly agreed that outfall could achieve maximum heat dissipation from the waste stream by using cooling waters examined in the study while 6% of respondents agreed with the statement. When interviewing the respondents and assessing the facts about the negative impacts of chemicals that could be minimized by treatment before discharge, it was ascertained that 67.3% of respondents strongly agreed that the negative impacts of chemicals could be minimized by treatment before discharge and 6% of the respondents disagreed with the statement.

Table 4.16: Frequency of Mitigating Measures

	SD	D	A	SA
	n(%)			
The desalination plant brine can be pre-diluted with seawater or power plant cooling water.	15 (10.0)	9 (6.0)	25 (16.7)	101 (67.3)
Outfall can achieve maximum heat dissipation from the waste stream by using cooling waters.	15 (10.0)	18 (12.0)	9 (6.0)	108 (72.0)
The negative impacts of chemicals can be minimized by treatment before discharge.	15 (10.0)	9 (6.0)	25 (16.7)	101 (67.3)
The negative impacts of chemicals can be reduced by the substitution of hazardous substances	16 (10.7)	18 (12.0)	8 (5.3)	108 (72.0)
The adverse impact of chemicals can be minimized by implementing alternative treatment options.	16 (10.7)	13 (8.7)	11 (7.3)	110 (73.3)
Chlorine can be replaced or treated before discharge.	15 (10.0)	18 (12.0)	9 (6.0)	108 (72.0)
The potential for renewable energy use can be investigated to minimize impacts on air quality and climate.	16 (10.7)	18 (12.0)	8 (5.3)	108 (72.0)
Proper selection of sites can be done to minimize to offset the loss of this open space land.	16 (10.7)	13 (8.7)	11 (7.3)	110 (73.3)
Brine water dilution with seawater or cooling water can be used to reduce the salinity and control temperature.	15 (10.0)	18 (12.0)	9 (6.0)	108 (72.0)

The study examined the facts that were associated with the negative impacts of chemicals that could be reduced by the substitution of hazardous substances. It was found that 72% of respondents agreed that the negative impacts of chemicals could be reduced by the substitution of hazardous substances. 10.7% of respondents strongly disagreed that the negative impacts of chemicals could be reduced by the substitution of hazardous substances. The facts about the adverse impact of chemicals could be minimized by implementing alternative treatment options were evaluated. It was ascertained that 73.3% of respondents strongly agreed that the adverse impact of chemicals could be minimized by implementing alternative treatment options. However, 10.7% of respondents strongly disagreed with the notion. During my interview of the respondents and examined the facts that were associated with chlorine that could be replaced or treated before discharge. It was found that 72% of respondents strongly agreed with the statement while 10% of respondents disagreed with whether Chlorine could be replaced or treated before discharge.

Facts about the potential for renewable energy used can be investigated to minimize impacts on air quality and the climate was examined. It was determined that 72% of the respondents strongly agreed that the potential for renewable energy used can be investigated to minimize impacts on air quality and climate. However, 10.7% of respondents strongly disagreed with the fact. The study analyzed the facts that were associated with the proper selection of sites that could be done to minimize the loss of this open space land and found that 73.3% of respondents disagreed with the notion. However, 10.7% of respondents strongly agreed and strongly disagreed that the proper selection of sites could be done to minimize the loss of this open space land. Facts related to brine water dilution with seawater or cooling water that could be used to reduce the salinity and control temperature were assessed in the study. It was determined that 72% of respondents strongly agreed that brine water dilution with seawater or cooling water could be used to reduce the salinity and control temperature. While 10.7% of respondents disagreed that brine water dilution with seawater or cooling water could be used to reduce the salinity and control temperature.

4.1.5 Techniques to Improve the Desalination Process

Table 4.17 reveals the Frequency of Techniques to Improve the Desalination process. During the interrogation of the respondents, the facts that were linked with desalinating briny water CO_2 greenhouse gas emissions that could be used were evaluated. It was found that 69.3% of respondents strongly agreed that desalinating briny water, CO_2 greenhouse gas emissions could be used. While 8.7% of respondents disagreed with the fact and did not ascertain that desalinate briny water, CO_2 greenhouse gas emissions could be used. The study estimated the facts that were associated with reducing capital, operation, and maintenance costs hybrid desalination process could be developed. It was ascertained that 65.3% of respondents strongly agreed with the statement while 10% of respondents strongly disagreed that reducing capital, operation, and maintenance costs hybrid desalination process could be developed. The study examined the facts that were related to water security and reduction in energy consumption, renewable Energy Desalination Programme could be used. It was determined that 58% of respondents strongly agreed that water security and reduction in energy consumption, and renewable Energy Desalination programs could be used. However, 9.3% of respondents strongly disagreed with the notion.

Table 4.17: Frequency of Techniques to Improve Desalination Process

	SD	**D**	**A**	**SA**
	n(%)			
1. To desalinate briny water CO2 greenhouse gas emissions can be used.	15 (10.0)	13 (8.7)	18 (12.0)	104 (69.3)
2. To reduce capital, operation, and maintenance costs hybrid desalination process can be developed.	15 (10.0)	18 (12.0)	19 (12.7)	98 65.3)
3. For water security and reduction in energy consumption, the renewable Energy Desalination Programme can be used.	18 (12.0)	14 (9.3)	31 (20.7)	87 (58.0)

Table 4.17 continued

4. To prevent the membrane from scaling more efficient ultra-permeable membranes can be developed with anti-scaling elements.	14 (9.3)	22 (14.7)	18 (12.0)	96 (64.0)
5. To improve the shelf life of the membrane more efficient ultra-permeable membranes can be developed with anti-scaling elements.	15 (10.0)	13 (8.7)	27 (18.0)	95 (63.3)
6. Solar-powered desalination plants can be used for electricity consumption issues of the desalination process.	15 (10.0)	19 (12.7)	22 (14.7)	94 (62.7)
7. Desalination process can be improved by improvising the method of RO by using forward osmosis.	18 (12.0)	14 (9.3)	35 (23.3)	83 (55.3)
8. Desalination process can be driven by enhancing the method of RO by using electrodialysis.	15 (10.0)	13 (8.7)	26 (17.3)	96 (64.0)
9. Desalination process can be driven by improving the method of RO by using pressure reverse osmosis.	15 (10.0)	13 (8.7)	23 (15.3)	93 (62.0)
10. Low-maintenance, reliable evaporative technologies can be developed.	18 (12.0)	14 (9.3)	36 (24.0)	82 (54.7)
11. Hot exhaust gases from a power plant can be used to desalinate water in a distillation plant for increasing energy efficiency.	14 (9.3)	22 (14.7)	22 (14.7)	92 (61.3)

The researcher interviewed the respondents and investigated facts that were associated with preventing the membrane from scaling a more efficient ultra-permeable membrane that could be developed with anti-scaling elements. It was found that 64% of respondents strongly agreed with the statement while 9.3% of respondents disagreed that preventing the membrane from scaling a more efficient ultra-permeable membrane could be developed with anti-scaling elements. Facts related to improving the shelf life of the membrane, a more efficient ultra-permeable membrane could be developed with anti-scaling elements that were evaluated. It was determined that 63.3% of respondents strongly agreed that improving the shelf life of the membrane more efficiently ultra-permeable membrane could be developed with anti-scaling elements while 8.7% of respondents strongly disagreed with the statement. The study included facts related to solar-powered desalination plants that could be used for the electricity consumption issue of the desalination process.

It was examined that 62.7% of respondents strongly agreed with the statement while 10% of respondents strongly disagreed that solar-powered desalination plants could be used for electricity consumption issues of the desalination process. The facts about the desalination process could be improved by improvising the method of RO by using forward osmosis were analyzed and found that 55.3% of respondents strongly agreed with the statement. However, 9.3% of the respondents disagreed that the desalination process could be improved by improvising the method of RO by using forward osmosis. While interviewing the respondents, I analyzed the facts that were associated with the desalination process that could be driven by enhancing the method of RO by using electrodialysis. It was determined that 62% of respondents strongly agreed that the desalination process could be driven by enhancing the method of RO by using electrodialysis. However, 8.7% of respondents strongly disagreed that the desalination process could be driven by enhancing the method of RO by using electrodialysis. The facts about low-maintenance, reliable evaporate technologies that could be developed were included and examined in the study.

4.1.6 Employee Perception Towards Environment Aspects and Impacts of Brine Waste Disposal

Table 4.18 reveals the facts related to respondent's perceptions were examined whether they were aware of environmental aspects and the impact of brine water disposal was included and assessed in the study and found that 56% of respondents strongly agreed with an awareness of environmental aspects and impact of brine water disposal while 10.7% of respondents strongly disagreed with an awareness of environmental aspects and the impact of brine water disposal. The facts about the respondent's perceptions were analyzed regarding whether they thought effective training was required for all employees. It was ascertained that 60.7% of respondents strongly agreed that effective training was required for all employees while 10.7% of respondents strongly disagreed that effective training was required for all employees. The facts associated with their perception of the latest technique could be integrated into the brine waste management system. It was determined that 59.3% of respondents strongly agreed that the latest technique could be integrated into the brine waste management system. While 12.7% of respondents disagreed that the latest technique could be integrated into the brine waste management system.

Table 4.18: Frequency of Employee Perception Towards Environment Aspects and Impacts of Brine Waste Disposal

	SD	**D**	**A**	**SA**
	N (%)			
I am aware of the environmental aspects and the impact of brine water disposal.	16 (10.7)	24 (16.0)	26 (17.3)	84 (56.0)
I think effective training is required for all employees.	17 (11.3)	16 (10.7)	26 (17.3)	91 (60.7)
The latest technique can be integrated into the brine waste management system.	21 (14.0)	19 (12.7)	21 (14.0)	89 (59.3)
Dilution of brine discharge helps in preventing marine animals.	21 (11.3)	26 (17.3)	25 (16.7)	82 (54.7)
More awareness is to be provided on brine waste disposal.	16 (10.7)	24 (16.0)	29 (19.3)	81 (54.0)
Training will provide a better understanding of waste disposal treatment to employees.	16 (10.7)	14 (9.3)	30 (20.0)	90 (60.0)
Awareness will help in developing standards for brine waste disposal.	21 (14.0)	19 (12.7)	28 (18.7)	82 (54.7)
Mitigating measures are effective in brine waste disposal.	17 (11.3)	26 (17.3)	28 (18.7)	79 (52.7)

The study examined facts that were related to the dilution of brine discharge and helped in preventing marine animals and found that 60% of respondents strongly agreed with the statement. However, 9.3% of respondents strongly disagreed that the dilution of brine discharge helped in preventing marine animals. While interviewing the respondents, I analysed their perception about more awareness to be provided on brine waste disposal. It was found that 54.7% of respondents strongly agreed that more awareness is provided on brine waste disposal. While 12.7% of respondents differed in their opinion and disagreed that more awareness is to be provided on brine waste disposal. The researcher interviewed the respondents and analysed the facts that were related to mitigating measures that were effective in brine waste disposal. It was found that 52.7% of respondents strongly agreed that mitigating measures were effective in brine waste disposal. While 11.3% of respondents strongly disagreed that mitigating measures were effective in brine waste disposal.

4.2 Reliability Test

When a scale of measurement is used repeatedly, its reliability can be determined by looking at the overall consistency of the data. In this study, dependability is assessed using Cronbach's alpha, the most widely used consistency indicator (Bajpai & Bajpai, 2014). When doing a reliability analysis, a scale's amount of systematic variation is determined by administering the scale in various ways and analyzing the correlation between the results.

Cronbach’s alpha**:**

Internal dependability, or how closely connected a group of items is to one another, is measured by Cronbach's alpha. It is regarded as a gauge of scale dependability. Alpha values that are "high" do not necessarily imply that the measure is one-dimensional. One technique for determining dimensionality is exploratory factor analysis. We show the formula for the standardized Cronbach's alpha below for conceptual purposes:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Here N denotes the number of items, the c-bar denotes the average inter-item covariance among the items, and the v-bar denotes the average variance.

The internal consistency of the data is examined before beginning the analysis using Cronbach's alpha (α) value. One of the metrics used in reliability analysis is Cronbach's alpha value. Cronbach's alpha and correlation have a relationship. When the item correlation grows, Cronbach's alpha typically rises.

We came up with the following findings about the information based on Cronbach's alpha value:

- If $\alpha \geq 0.9$ – Excellent
- If $0.7 \leq \alpha < 0.9$ – Good
- If $0.6 \leq \alpha < 0.7$ – Acceptable
- If $0.5 \leq \alpha$ 0.6 – Poor
- If $\alpha < 0.5$ – unacceptable
- Cronbach's alpha value – what amount of internal consistency exists among the data of items.
- Cronbach's alpha of the item deleted – it gives the information about which item appeared to have low consistency among other items.

The reliability analysis results for each factor are presented in Table 4.19. Using Cronbach's alpha approach, the pilot study assesses the data's internal consistency for each variable. Cronbach's alpha scores range from 0.92 to 0.98, indicating that each and every factor has a high level of internal consistency.

Table 4.14: Reliability Analysis

	No. of items	**Mean**	**SD**	**Cronbach's Alpha**	**Status**
1. Suitable Desalination Technique	9	3.29	1.01	0.988	**Excellent**
2. Environment Effects of the desalination process	9	3.61	0.75	0.959	**Excellent**
3. Techniques to reduce the adverse effect of desalination plants on the environment	8	3.35	0.97	0.986	**Excellent**
4. Mitigating Measures	9	3.41	1.00	0.991	**Excellent**
5. Techniques to Improve the Desalination Process	11	3.30	0.95	0.984	**Excellent**
6. Employee Perception Towards Environment Aspects and Impacts of Brine Waste Disposal	8	3.19	0.86	0.924	**Excellent**

4.3 Factor Analysis

To separate the factors from independent variables, factor analysis is utilized. Typically, questions are created using the analysis. Let's say there are a lot of variables in the data. In that case, we may make use of this technique to eliminate some of the variables from the data. This analysis combines variables with related characteristics. Further analysis can be done using the reduced factors.

The Factor Analysis of Performance Management System Variables is shown in Table 4.20, Eighteen of the twenty-four statements are used in the factor analysis. The fifty-four questions are divided into six variables using principal component analysis. The six factors are Suitable Desalination Technique, Environment Effects of the desalination process, Techniques to reduce the adverse effect of desalination plants on the environment, Mitigating Measures, Techniques to Improve Desalination process, and Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal.

Table 4.20: Factor Analysis

	Factor						**% of Variance**
	1	**2**	**3**	**4**	**5**	**6**	
1. Techniques to Improve the Desalination Process							**34.287**
1. To reduce capital, operation, and maintenance costs hybrid desalination process can be developed.	.950						
2. To desalinate briny water CO2 greenhouse gas emissions can be used.	.944						
3. Solar-powered desalination plants can be used for electricity consumption issues of the desalination process.	.939						
4. The desalination process can be driven by improving the method of RO by using pressure reverse osmosis.	.931						

Table 4.20 continued

5. the process can be driven by enhancing the method of RO by using electrodialysis.	.929						
6. To improve the shelf life of the membrane more efficient ultra-permeable membranes can be developed with anti-scaling elements.	.923						
7. For water security and reduction in energy consumption, the Renewable Energy Desalination Programme can be used.	.904						
8. The desalination process can be improved by improvising the method of RO by using forward osmosis.	.896						
9. Low-maintenance, reliable evaporative technologies can be developed.	.892						
10. To prevent the membrane from scaling more efficient ultra-permeable membranes can be developed with anti-scaling elements.	.810						
11. Hot exhaust gases from a power plant can be used to desalinate water in a distillation plant for increasing energy efficiency.	.794						
2. Mitigating Measures							
1. Brine water dilution with seawater or cooling water can be used to reduce the salinity and control temperature.		.968					
2. Outfall can achieve maximum heat dissipation from the waste stream by using cooling waters.		.967					
3. Chlorine can be replaced or treated prior to discharge.		.966					**13.908**
4. The potential for renewable energy use can be investigated to minimize impacts on air quality and climate.		.961					
5. The negative impacts of chemicals can be reduced by the substitution of hazardous substances		.960					

Table 4.20 continued

6. The adverse impact of chemicals can be minimized by implementing alternative treatment options.		.914					
7. Proper selection of sites can be done to minimize to offset the loss of this open space land.		.910					
8. The negative impacts of chemicals can be minimized by treatment before discharge.		.906					
9. The desalination plant brine can be pre-diluted with seawater or power plant cooling water.		.906					
3. Suitable Desalination Technique							
1. Forward osmosis helps minimize membrane fouling and clogging compared with RO.			.947				**11.215**
2. rodialysis and electro-dialysis reversal (ED/EDR) can also be easily adapted to be powered directly by photovoltaics, making them environmentally sustainable and technically feasible for off-grid communities.			.946				
3. The high capital cost must be carefully considered if SSD is pursued as a desalination option.			.944				
4. Membrane distillation (MD) reduces pre-treatment requirements compared with pressure-based membrane processes.			.942				
5. Low water output and consequent large land requirements must be carefully considered if SSD is pursued as a desalination option.			.941				
6. Membrane distillation (MD) uses low-grade heat (solar or waste heat) for operation.			.931				
7. Forward osmosis is an emerging membrane-based desalination technology that allows for the use of thinner membranes in the system.			.897				

Table 4.20 continued

8. Membrane distillation (MD) can produce high-quality distillate at relatively low temperatures (<100°C).			.892				
9. Multi-stage flash is suitable for producing distilled quality water products good for power plants, for industrial processes.			.885				
4. Techniques to reduce the adverse effect of desalination plants on the environment							
1. The water quality model helps to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant.				.937			**10.955**
2. The Effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity.				.935			
3. Hydraulic structures are used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents.				.927			
4. A detailed sampling grid can be constructed in the plant vicinity and surveyed by the ecologist.				.926			
5. Water quality measurements can be carried out to evaluate the concentrations of the substances of importance to the water quality and aquatic species.				.921			
6. Measurements can be carried out in the plant vicinity and can include water levels, current flow velocities, and directions and flow discharges.				.882			
7. A biological survey can be carried out in the Plant vicinity to evaluate the ecosystem in the area.				.871			
8. The configuration of the intake and outfall of the plant should be developed and calibrated with field measurements.				.854			

Table 4.20 continued

5. Environment Effects of the desalination process							
1. The concentration of unionized ammonia affects marine life.					.893		**7.898**
2. There is a significant effect on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents.					.893		
3. If the desalination plant is combined with a power Plant the temperature of the ambient water in the plant vicinity will increase its seawater temperature					.892		
4. By the effluent discharges from the plant, dissolved oxygen in the water in the plant vicinity is affected.					.891		
5. The salinity of seawater is increased due to the discharge of high concentrations of salt through the outfall of desalination plants.					.817		
6. and marine environments are significantly less affected by concentrate disposal due to a high level of concentrate dilution.					.802		
7. Brine produced in the desalination process is disposed of properly.					.780		
8. Waste concentrate disposal is a very significant problem in inland areas.					.684		
9. An increase in the concentration of residual chlorine affects the water quality of the ambient water.					.681		
6. Employee Perception Towards Environment Aspects and Impacts of Brine Waste Disposal							
1. Dilution of brine discharge helps in preventing marine animals.						.859	
2. I am aware of the environmental aspects and impact of brine water disposal.						.850	**6.659**
3. More awareness is to be provided on brine waste disposal.						.839	

Table 4.20 continued

4. Mitigating measures are effective in brine waste disposal.						.832	
5. The latest technique can be integrated into the brine waste management system.						.748	
6. Awareness will help in developing standards for brine waste disposal.						.724	
7. Training will provide a better understanding of waste disposal treatment to employees.						.681	
8. I think effective training is required for all employees.						.654	

Table 4.21 depicts the association between types of waste that are mostly disposed of from desalination plants in UAE and the desalination process technology that is primarily used in the facility. It is observed that the majority 81.3% of the respondents confirmed that brine discharge was mostly disposed of from desalination plants in UAE while 1.3% of the respondents answered that metal discharge was disposed of from desalination plants in UAE. Further, the majority, 77.3% of respondents said that the thermal process is in the facility as the desalination process technology and also stated that brine discharge was mostly disposed of from desalination plants in UAE. From the above outcomes, it is evident that, the chi-square value (9.382) and p-value ($p=0.025<0.05$) which is less than 0.05 significant level. Hence, we conclude that there is an association between the types of waste that are mostly disposed of from desalination plants in UAE and the desalination process technology that is primarily used in the facility.

Table 4.21: Association between types of waste is mostly disposed of desalination plants in UAE and desalination process technology is primarily used in the facility

Which type of waste is mostly disposed of from desalination plants in UAE?	Which desalination process technology is primarily used in the facility?		Total (%)	Chi-Square (p-value)
	Thermal process	Membrane process		
Brine discharge	68 (77.3)	54 (87.1)	122 (81.3)	9.382 (0.025)*
Emission of gases	10 (11.4)	0 (0.0)	10 (6.7)	
Metal Discharge	2 (2.3)	0 (0.0)	2 (1.3)	
Chemical discharge	8 (9.1)	8 (12.9)	16 (10.7)	
Total	88 (100.0)	62 (100.0)	150 (100.0)	

p<0.05

Table 4.22 depicts the association between waste disposal as a complex treatment process and desalination process technology primarily used in the facility. It is observed that the majority 35.3% of the respondents agreed that chemical discharge had a complex treatment process while 2.7% of the respondents said that metal discharges had a complex treatment process. Further, the majority, 54.8% of respondents said that the membrane process is in the facility as the desalination process technology and also agreed that chemical discharge had a complex treatment process. From the above outcomes, it is evident that, the chi-square value (20.882) and p-value (p=0.000<0.01) which is less than 0.01 significant level. Hence, we conclude that there is an association waste disposal has a complex treatment process, and desalination process technology is primarily used in the facility.

Table 4.5: The association between waste disposals has a complex treatment process and desalination process technology is primarily used in the facility

Waste disposal has a complex treatment process	Desalination process technology is primarily used in the facility.		Total (%)	Chi-Square (p-value)
	Thermal process	Membrane process		
Brine discharge	20 (22.7)	6 (9.7)	26 (17.3)	20.882 (0.000)**
Emission of gases	20 (22.7)	14 (22.6)	34 (22.7)	

Table 4.22 Continued

Metal discharge	29 (33.0)	8 (12.9)	37 (2.7)	
Chemical discharge	19 (21.6)	34 (54.8)	53 (35.3)	
	88 (100.0)	62 (100.0)	150 (100.0)	

*****p<0.01***

Table 4.23 depicts the association between Waste disposal having the most harmful effects on the environment and desalination process technology being primarily used in the facility. It is observed that the majority 34% of the respondents confirmed that brine discharge had the most harmful effects on the environment, while 14.7% of the respondents answered that metal discharges had the most harmful effects on the environment. Further, the majority, 30.7% of respondents said that the thermal process in the facility was the desalination process technology and also agreed that the brine discharge had the most harmful effects on the environment. From the above outcomes, it is evident that, the chi-square value (10.558) and p-value ($p=0.012<0.05$) which is less than 0.05 significant level. Hence, we conclude that there is an association between Waste disposal having the most harmful effects on the environment and desalination process technology being primarily used in the facility.

Table 4.23: Association between Waste disposals has the most harmful effects on the environment and desalination process technology is primarily used in the facility

Waste disposal has the most harmful effects on the environment	**Desalination process technology is primarily used in the facility.**		**Total (%)**	**Chi-Square (p-value)**
	Thermal process	**Membrane process**		
Brine discharge	27 (30.7)	24 (38.7)	51 (34.0)	10.558 (0.012)*
Emission of gases	35 (39.8)	10 (16.1)	45 (30.0)	
Metal discharge	12 (13.6)	10 (16.1)	22 (14.7)	
Chemical discharge	14 (15.9)	18 (29.0)	32 (21.3)	
	88 (100.0)	62 (100.0)	150 (100.0)	

**p<0.05*

Table 4.24 depicts the association between technologies used in the thermal process and desalination process technology primarily used in the facility. It is observed that the majority 38.7% of the respondents confirmed that Solar desalination was mostly suitable technology is primarily to be used in the facility, while 2.7% of the respondents answered that Multi-effect Distillation and Vaccum compression distillation can be used for desalination. Further, 36% of respondents said that LTE Desalination using waste heat can be used in the desalination plants in UAE. From the below outcomes, it is evident that, the chi-square value (137.094) and p-value (p=0.00) which is less than 0.01 significant level. Hence, we conclude that there is an association between technologies used in the thermal process and desalination process technology primarily used in the facility.

Table 4.24: Association between technologies is used in the thermal process and desalination process technology is primarily used in the facility

Which technology is used in the thermal process?	**Which desalination process technology is primarily used in the facility?**		**Total (%)**	**Chi-Square (p-value)**
	Thermal process	**Membrane process**		
Solar Desalination	2 (2.3)	56 (90.3)	58 (38.7)	134.094 (0.000)**
Multi-Effect Distillation	0 (0.0)	4 (6.5)	4 (2.7)	
Multi-Stage Flash Distillation	24 (27.3)	0 (0.0)	24 (16.0)	
LTE Desalination using waste heat	52 (59.1)	2 (3.2)	54 (36.0)	
Vacuum freeze Desalination	4 (4.5)	0 (0.0)	4 (2.7)	
Vapour Compression Distillation	6 (6.8)	0 (0.0)	6 (4.0)	
Total	88 (100.0)	62 (100.0)	150 (100.0)	

$p<0.01$

Table 4.25 depicts the difference in means of factor between technologies used in the thermal process and desalination. Since the p values for Suitable Desalination Technique ($p=0.000<0.01$), Environment Effects of the desalination process ($p=0.011<0.05$), Techniques to reduce the adverse effect of desalination plants on the environment (p=0.000<0.01), Mitigating Measures (p=0.035<0.05), Techniques to Improve Desalination process (p=0.002<0.01) and Employee perception towards Environment Aspects and Impacts of Brine waste Disposal (p=0.000<0.01) are less than 0.05 significant levels. Hence, there is a difference in means of factor between technologies used in the thermal process and desalination.

Table 4.25: Difference in means of factor between technologies used in the thermal process and desalination.

	Desalination process technology is primarily used in the facility	**N**	**Mean**	**SD**	**SE**	**t value**	**p-value**
Suitable Desalination Technique	Thermal process	88	3.30	1.01	0.11	2.304	**0.000****
	Membrane process	62	3.28	1.01	0.13		
Environment Effects of the desalination process	Thermal process	88	3.55	0.80	0.08	4.232	**0.011***
	Membrane process	62	3.71	0.68	0.09		
Techniques to reduce the adverse effect of desalination plants on the environment	Thermal process	88	3.26	1.00	0.11	3.215	**0.000****
	Membrane process	62	3.47	0.92	0.12		
Mitigating Measures	Thermal process	88	3.44	1.02	0.11	2.675	**0.035***
	Membrane process	62	3.37	0.97	0.12		
Techniques to Improve the Desalination Process	Thermal process	88	3.31	0.99	0.11	3.456	**0.002****
	Membrane process	62	3.29	0.92	0.12		

Table 4.25 continued

Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal	Thermal process	88	3.15	0.89	0.09	1.343	**0.000****
	Membrane process	62	3.25	0.84	0.11		

*****p<0.01, *p<0.05***

4.4 Pearson's Coefficient of correlation

A validity test evaluates the level of reliability or reliability of a research tool. Using the Pearson product-moment coefficient of correlation, a validity test was run. The Pearson correlation coefficient evaluates the strength and the direction of the relationship between two variables. It is necessary to measure the two variables on a continuous (interval) scale (Srmuniv, 2018). Between -1 and 1, the correlation coefficient (r) lies. We can draw the following conclusions based on the direction of the correlation coefficient (Gogtay & Thatte, 2017).

- When r is -1, we say there is a perfect negative correlation.
- When r is a value between -1 and 0, we say that there is a negative correlation.
- When r is 0, we say there is no correlation.
- When r is a value between 0 and 1, we say there is a positive correlation.
- When r is 1, we say there is a perfect positive correlation.

Table 4.26 presents the correlation between the Suitable Desalination Technique, Environment Effects of the desalination process, Techniques to reduce the adverse effect of desalination plants on the environment, Mitigating Measures, Techniques to Improve the Desalination process and Employee perception towards Environment Aspects, and Impacts of Brine Waste Disposal. The analysis shows the linearity between the variables and the strength of association between dependent and independent variables represented by r and p-value, while r is a degree of correlation and p signifies significance level (Al-Meshal &

Almotairi, 2013). From the above results, it shows Risk Acceptance showed a significant positive linear relationship between the Suitable Desalination Technique, Environment Effects of the desalination process, Techniques to reduce the adverse effect of desalination plants on the environment, Mitigating Measures, Techniques to Improve Desalination process, and Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal.

Table 4.26: Correlation Analysis

	Suitable Desalination Technique	Environment Effects of the desalination process	Mitigating Measures	Techniques to Improve the Desalination Process	Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal	Techniques to reduce the adverse effect of desalination plants on the environment
Suitable Desalination Technique	1.000					
Environment Effects of the desalination process	.260**	1.000				
Mitigating Measures	.242**	.301**	1.000			
Techniques to Improve the Desalination Process	.328**	.291**	.215**	1.000		
Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal	.252**	.360**	.241**	.288**	1.000	
Techniques to reduce the adverse effect of desalination plants on the environment	.278**	.453**	.301**	.225**	.279**	1.000

*****p<0.01***

4.5 Findings

4.5.1 Discussion on Statistical Data

A sample size of 150 was used for this study. The participants included experts (specialists) working at the following three desalination plants: Jebel Ali desalination plant, Taweelah A1 Power and Desalination Plant, and Fujairah F2 Plant. With a focus on designation, it was discovered that 18.7% were QHSE managers, 20.0% of respondents were plant managers, 26.0% were waste management engineers, and 31.3% were lab analysis specialists at their places of employment. With only 4% of respondents falling into this category, production engineers were found to have the lowest percentage of respondents. The information regarding the respondents' qualifications was also included, and it was determined that 47.0% of respondents held master's degrees, 38% held bachelor's degrees, and 8% held diploma certifications. Only 7% of participants were found to have a doctoral degree, which was the lowest percentage of respondents. Refer to Appendix – II for the data.

4.5.2 Disposal of Unregulated Waste

After interviewing the respondents and reviewing the data on the waste types that were primarily discharged from desalination plants in the UAE, it was found that 81.3% of them agreed that brine discharge was the waste type, followed by 10.7% who said that chemical discharge was the waste type, 6.7% who said that emission of gases was the waste type and 1.3% who said that metal discharge was the waste type. On the type of waste disposed of in the respondents' desalination plant, it was found that 72.7% of the respondents said that brine discharge was mostly disposed of in their desalination plants, followed by 14% of them who said that the waste disposed of in their desalination plant was chemical discharge while 10.7% and 2.7% of the respondents answered that emission of gases and metal discharge were disposed from their desalination plants respectively.

While analyzing waste disposal facts associated with the most harmful effects on the environment, it was ascertained that 34% of the respondents confirmed that brine discharge had the most harmful effects on the environment, 30% of them expressed the emission of gases as associated with the most harmful effects on the environment, while 21.3% and 14.7% of the respondents answered that the chemical discharge and the metal discharges had the most harmful effects on the environment respectively. The study also included information about the examination of waste disposal, which involved a difficult treatment procedure. According to the results, 35.3% of the respondents agreed that chemical discharges had a complex treatment process, followed by 24.7% of them who felt it was metal discharges, while 22.7% of them said that emission of gases and 17.3% of them said brine discharges did as well.

Reverse osmosis was cited by 53.3% of respondents as the method that was typically used to dispose of unregulated wastes from desalination plants in the United Arab Emirates. 42.7% of respondents said it was true that multi-stage flash distillation was typically used in the UAE to dispose of unregulated waste from desalination plants. A mere 4.0% said that Vapour compression Distillation was generally used in disposing of unregulated wastes from desalination plants in the UAE. This information was analyzed in relation to the facts and revealed that there are no regulations on the disposal of unregulated wastes from desalination plants in the UAE.

The study also included information about the desalination technology that was primarily employed in the facility. It was revealed that 58.7% of respondents indicated that the facility used the thermal process as the desalination process technology, while 41.3% of respondents indicated that the facility uses the membrane process. Regarding the technology applied to the thermal process, solar desalination, multi-effect distillation, multi-stage flash distillation, LTE desalination using waste heat, and vacuum freezing appeared to be in practice. While only 2.7% of respondents claimed that solar desalination and LTE desalination using waste heat were the technologies used in the thermal process, 34.7% of respondents confirmed the use of multi-stage flash distillation. Multi-Effect Distillation and Vacuum freeze Desalination were the technologies used for the thermal process by 16.0% and 3.3% respectively. Analysis of the technology used in the membrane process revealed that 58.7% of respondents agreed that no technology was used in the procedure. Reverse osmosis was mentioned by 37.3% of respondents, while membrane distillation and electrolysis were mentioned by 1.3% and 2.7% of respondents respectively.

The researcher interviewed the respondents about the technique of the membrane process that consumed less energy. The following was given as responses: Forward Osmosis, Reverse Osmosis, Rapid Spray Evaporation, Electrolysis, and Capacitive Deionization. While Forward Osmosis was considered to consume the least energy by 29.3%, an almost equal percentage felt Rapid Spray Evaporation consumed less. 24.0%, 16.7%, and 1.3% felt that Capacitive Deionization, Reverse Osmosis, and Electrolysis respectively were the techniques that consumed the least energy.

Similarly, in the thermal process, among the techniques used, 49.3% claimed that Solar Desalination consumed less energy. While 2.7% said Multi-Effect Distillation consumed less energy, 9.3% felt LTE Desalination using waste heat consumed the least energy. 19.3% claimed that Vacuum freeze Desalination and Vapour Compression Distillation consumed less energy.

Principal component analysis was used to divide fifty-four questions into six variables: (1) Suitable Desalination Technique, (2) Environment Effects of the desalination process, (3) Techniques to reduce the adverse effect of desalination plants on the environment, (4) Mitigating Measures, (5) Techniques to Improve Desalination process and (6) Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal.

4.5.3 Suitable Desalination Technique

Suitable desalination techniques included Small-Scale Desalination (SSD), Multi-stage flash, Forward Osmosis, Electro dialysis, and Membrane Distillation. It was determined that 64.7% of respondents strongly agreed that it was important that high capital costs needed to be carefully considered if SSD was pursued as a desalination option. Whereas, it was determined that 64% of the respondents strongly agreed that, if SSD were to be pursued as a desalination option, careful consideration of the low water output and ensuing high land requirements would be necessary. 62.7% of the respondents strongly agreed that multi-stage flash was suitable for producing distilled quality water products good for power plants, for industrial processes. The facts about forward osmosis and a new membrane-based desalination technology that permits the use of thinner membranes in the system were discovered during the interviewing of the respondents and analysis of the data. In comparison, 11.3% of respondents strongly disagreed with the same concept, while 64.7% of respondents strongly agreed with it.

In comparison to RO, it was investigated whether forward osmosis assisted in reducing membrane fouling and clogging. Forward osmosis was found to help in minimizing membrane fouling and clogging in comparison to RO, according to 66% of respondents, while 9.3% of respondents strongly disagreed. 65% of respondents strongly agreed with the fact that electro-dialysis and electro-dialysis reversal (ED/EDR) could be easily adapted to be powered directly by photovoltaics, making them environmentally sustainable and technically feasible for off-grid communities. However, 9.3% of respondents strongly disagreed with the fact.

The research looked into the information regarding membrane distillation (MD), which could generate high-quality distillate at only about 100°C. According to the results, 63.3% of respondents strongly agreed, while 11.3% strongly disagreed. The study also looked at the evidence that membrane distillation (MD) requires less pre-treatment than pressure-based membrane processes. 64.7% of respondents strongly agreed that membrane distillation (MD) reduced the need for pre-treatment. Similarly, 63.3% of respondents said they strongly agreed that membrane distillation (MD) operated with low-grade heat (solar or waste heat).

4.5.4 Environment Effects of Desalination Process

The research looked into the environmental effects of the desalination process. The question of whether the desalination process' produced brine was properly disposed of was put to the respondents. It was discovered that 82% of survey participants strongly agreed that the desalination process produced brine was disposed of properly. 74% of respondents strongly agreed, compared to 1.3% who strongly disagreed, that the high concentration of salt discharged through desalination plant outfalls caused an increase in seawater salinity. The study looked into whether a high level of concentrate dilution made the coastal and marine environment significantly less affected by concentrate disposal. It was discovered that 84% of respondents strongly agreed with the statement, compared to 2.7% who agreed and strongly disagreed.

It also ascertained if waste concentrate disposal is a very significant problem in inland areas and it was found that 82% of respondents strongly agreed to this. Also, it was established that 77.3% of respondents strongly agreed with the fact there is a significant effect on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents, while 2.7% of respondents disagreed with the notion.

In addition, 82% of respondents strongly agreed with the fact that when a desalination plant is combined with a power plant, the temperature of the ambient water in the plant vicinity will increase its seawater temperature. 82% of respondents strongly agreed that an increase in the concentration of residual chlorine affects the water quality of the ambient water. 77.3% of respondents strongly agreed that by the effluent discharges from the plant, dissolved oxygen in the water in the plant vicinity is affected and 77.3% of respondents strongly agreed that the concentration of the un-ionized ammonia affects marine life.

4.5.5 Techniques to Reduce the Effect of Desalination Plants on the Environment

The study looked at techniques to reduce the adverse effect of desalination plants on the environment. 62.7% of respondents strongly agreed for measurements to be carried out in the plant vicinity that can include water levels, current flow velocities, and directions and flow discharges. 64.7% of respondents wanted water quality measurements to be carried out to evaluate the concentrations of the substances of importance to the water quality and aquatic species. 59.3% of respondents strongly agreed that a biological survey could be carried out in the plant vicinity to evaluate the ecosystem in the area. Again, 65.3% of respondents strongly agreed that a detailed sampling grid could be constructed in the plant vicinity and surveyed by the ecologist. 67.3% of respondents strongly agreed with the notion that the configuration of the intake and outfall of the plant should be developed and calibrated with the field measurements, while 6.7% of respondents strongly disagreed with it. The configuration of the intake and outfall of the plant should be developed and calibrated with field measurements.

65.3% of respondents strongly agreed that the water quality model helped to simulate the water quality of the water around the plant, as influenced by the discharges from the power and desalination plant. 64% of respondents agreed with the statement that the effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity. Lastly, it was found that 64% of respondents agreed with the fact that hydraulic structures are used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents.

4.5.6 Mitigation Measures

The study examined the mitigating measures for the environmental effects of desalination plants. 67.3% of respondents strongly agreed that the desalination plant brine could be pre-diluted with seawater or power plant cooling water. Further, 72% of respondents strongly agreed that outfall could achieve maximum heat dissipation from the waste stream by using cooling waters.

When the information regarding the negative effects of chemicals that could be minimized by treatment before discharge was evaluated, it was observed that 67.3% of respondents strongly agreed with this statement. Similarly, 72% of respondents agreed that the negative impacts of chemicals could be reduced by the substitution of hazardous substances. Interestingly, 73.3% of respondents believed that the adverse impact of chemicals could be minimized by implementing alternative treatment options. Similarly, 72% of respondents believed that Chlorine can be replaced or treated prior to discharge.

It was found that 72% of respondents strongly agreed that it is possible to investigate the use of renewable energy to reduce negative effects on climate change and air quality. The study examined the data related to the appropriate site selection that could be carried out to lessen the loss of this open space land and discovered that 73.3% of respondents agreed with the idea. As one of the mitigating measures, 72% of respondents firmly agreed that dilution of brine water with cooling water or seawater could be used to lower salinity and regulate temperature.

4.5.7 Techniques to Improve Desalination Process

The study analyzed the preference for techniques that are used to improve the desalination process. 69.3% of respondents strongly agreed that to desalinate briny water CO2 greenhouse gas emissions could be used. 65.3% of respondents were in favour of developing a hybrid desalination process that could reduce capital, operation, and maintenance costs. Similarly, 58.0% strongly supported the use of the renewable Energy Desalination Programme for water security and reduction in energy consumption. While about 64% felt more efficient ultra-permeable membranes can be developed with anti-scaling elements to prevent the membrane from scaling, 63.3% agreed that more efficient ultra-permeable membranes can be developed with anti-scaling elements to improve the shelf life of the membrane. 62.7% went for Solar powered desalination plants to tackle the electricity consumption issue of the desalination process. A mere 55.3% felt that the desalination process can be improved by improvising the method of RO by using forward osmosis.

Around 64% of respondents think that the desalination process can be improved by using electrodialysis to enhance the reverse osmosis (RO) method, while 62% believe that it can be improved by using pressure reverse osmosis. A little over half of the respondents strongly agree that low-maintenance; reliable evaporative technologies can be developed. In contrast, 61.3% believe that hot exhaust gases from a power plant can be used to desalinate water in a distillation plant, which would increase energy efficiency.

4.5.8 Employee Perception Towards Environment Aspects and Impacts of Brine Waste Disposal

The study investigated the respondents' awareness and perceptions of environmental aspects and the impact of brine water disposal. It was found that 56% of respondents strongly agreed that they were aware of these issues, while 10.7% strongly disagreed. The study also looked at the respondents' opinions on the need for effective training for all employees, with 60.7% strongly agreeing and 10.7% strongly disagreeing. Finally, the study examined the respondents' views on the feasibility of integrating the latest techniques into the brine waste management system, with 59.3% strongly agreeing and 12.7% disagreeing.

With regard to examining the effectiveness of diluting brine discharge in preventing harm to marine animals, 60% of respondents strongly agreed with this statement, while 9.3% strongly disagreed. When asked about the need for more awareness of brine waste disposal, 54.7% of respondents strongly agreed that more awareness is needed, while 12.7% disagreed. The research also looked into the effectiveness of mitigating measures for brine waste disposal, finding that 52.7% of respondents strongly agreed that these measures were effective, while 11.3% strongly disagreed.

4.6 Reliability of the Study

Cronbach's alpha is a measure of the survey's or questionnaire's internal consistency or reliability. It is a metric with a scale of 0 to 1, with higher values indicating greater dependability. Based on Cronbach's alpha scores ranging from 0.92 to 0.98, it was determined that the questionnaire had high levels of reliability and that the responses to the questions were consistent.

The majority of waste generated by desalination plants in the UAE is disposed of using desalination process technology. According to survey results, 80.7% of respondents confirmed that brine discharge from desalination plants was disposed of in this manner, while 1.3% reported that metal discharge was disposed of in this manner. Furthermore, 77.3% of respondents stated that the membrane process is the primary desalination process technology at their facility, and brine discharge is the primary type of waste disposed of from their plant. The chi-square value (9.382) and p-value (0.05) support the conclusion that there is a significant relationship between the types of waste disposed of from UAE desalination plants and the desalination process technology used at these facilities.

The treatment of waste disposal is a complex process that involves the use of desalination technology. According to a survey, 35.3% of respondents agreed that chemical discharges have a complex treatment process, while 2.7% agreed that metal discharges have a complex treatment process. Furthermore, 54.8% of respondents stated that the facility uses the membrane process for desalination and that chemical discharge has a complex treatment process. The survey data analysis revealed a significant relationship between the complexity of waste treatment and the use of desalination technology, with a chi-square value of 20.882 and a p-value of 0.000, which is less than the significant level of 0.05. Therefore, it can be concluded that the process of treating waste disposal is complex and involves the use of desalination technology.

According to survey results, 34% of respondents believe brine discharge has the most harmful effects on the environment, while 14.7% believe metal discharges have the most harmful effects. Furthermore, 30.7% of respondents stated that the thermal process was the primary desalination technology in the facility and agreed that brine discharge had the most negative environmental effects. The chi-square value of 10.558 and the p-value of 0.012 (less than the 0.05 significance level) support the conclusion that there is an association between waste disposal having the most harmful effects on the environment and the facility's use of desalination process technology. Similarly, it was concluded that there was an association between technologies used in the thermal process and desalination process technology primarily used in the facility.

Furthermore, the p values for Suitable Desalination Techniques, Environment Effects of the Desalination Process, Techniques to Reduce the Negative Impact of Desalination Plants on the Environment, Mitigating Measures, Techniques to Improve the Desalination Process, and Employee Perception of Environmental Aspects and Impacts of Brine Waste Disposal are all less than 0.05. This indicates that there is a statistically significant difference in the means of these factors between the thermal process and desalination technologies. It was also discovered that the majority of respondents were aware of environmental issues and the consequences of brine water disposal. They did, however, emphasize the importance of effective training for all employees in order to raise awareness.

The relationship between appropriate desalination techniques and the environmental effects of the desalination process, as well as techniques to reduce the negative environmental effects of desalination plants and mitigating measures, is significant and positive. This means that selecting an appropriate desalination technique, implementing measures to mitigate the process's environmental impacts, and employing techniques to mitigate the negative effects of desalination plants can lead to a higher level of risk acceptance. Furthermore, the linear relationship between employee perception of environmental aspects and the impact of brine waste disposal implies that a positive perception of the environment can lead to a greater willingness to accept the risks associated with brine waste disposal. Overall, the analysis demonstrates the importance of considering the environmental impacts of desalination and taking steps to minimize them in order to achieve a higher level of risk acceptance.

4.7 Discussion

The purpose of this study was to evaluate the effects of the UAE's unrestricted disposal of desalination plant waste. In order to achieve this, different desalination plants in the UAE were considered, and their waste management system was evaluated. The study also determined whether the desalination plants in the UAE were disposing of waste in a controlled manner, what measures they had already taken, and what appropriate measures were needed to be developed to improve the waste management system.

The study had five main objectives: to ascertain whether categorizing the various technologies for regulating unregulated wastes from desalination plants in the UAE is necessary, to research how unregulated waste disposal affects environmental factors such as air pollution, marine pollution, global warming, and greenhouse effect, to evaluate the current options for environmental impact reduction and the management of unregulated wastes, to determine the most efficient way for desalination plants to adopt and contribute to the development of an integrated waste management system in the UAE and lastly to recognize obstacles to integrated waste management system implementation in the UAE and develop solutions to overcome them.

This research study, which is about waste management in desalination plants in the UAE, used a descriptive research design. With the aid of systematic naturalistic observations and surveys, the descriptive research design assisted in gaining all the information necessary to understand the different types of unregulated wastes, their effects, and their contribution to the creation of a waste management system.

The study used a quantitative research methodology. It is most appropriate for the research study to identify the top desalination facilities and their contribution to the creation of an integrated waste management system for the United Arab Emirates. The need to identify the various types of unregulated waste from desalination plants in the UAE was determined by the quantitative evaluation of the various data. It also aided in the numerical presentation of the facts. The quantitative research methodology was also helpful in analyzing the various difficulties that the desalination plants in the UAE faced. It also aided in validating the generated hypotheses and drawing conclusions, enabling precise acceptance or rejection of the hypotheses.

Both structured questionnaires and interviews were conducted for the benefit of this study. Face-to-face interviews were conducted to gather information on unregulated waste, appropriate desalination techniques, the impact of the environment on the desalination process, mitigation measures, and techniques to improve the desalination process, and finally, employee perception of environmental issues and the effects of brine waste disposal during the desalination process.

The study led to the conclusion that brine was typically the waste discharged from the majority of the desalination plants in the UAE. It was followed by chemical discharge and other waste types such as the emission of gases and metal discharge. According to Ikram et al. (2019), the process of desalination involves a series of steps to purify seawater and make it safe for human consumption. These steps may include chemical dosing and CIP cleaning systems to remove excess salt and other unwanted chemicals from the water.

The study by Iqbal et al. (2018) stated that seawater desalination plants produce two main types of waste: seawater concentrate and solid waste (reject brine). The seawater concentrate is made up of filtered seawater that was not used in the desalination process and therefore contains similar levels of salts and other chemical compounds as natural seawater. It is usually released back into the ocean. However, the production of drinking water through desalination creates large amounts of rejected brine, also known as concentrates. The amount of rejected brine generated depends on the amount of feed water used, the salt content of the feed water, and the chosen method of waste disposal. Also, according to Wang et al. (2019), the use of chemicals in large quantities for cleaning pipelines, water supply pipes, and storage equipment can increase the chemical potency of nearby water sources. Many desalination plants located in coastal regions also release reject brine into the ocean, leading to a significant increase in chemical composition levels in these areas.

The study findings showed that the brine discharge produced the most harmful effects on the environment. Nonetheless, even the emission of gases, chemicals, and metal discharge impacted the environment negatively. As a mitigating measure, Inyinbor Adejumoke (2018) suggests that recycling brine waste for practical purposes can decrease the negative impacts of rejected brine. Industrial plants and factories in the UAE often use components of rejected brine, such as hydrometallurgy, sodium hypochlorite, lithium carbonate, and Chlor-alkali, in their processes. Similarly, the study by Al-Fadala (2019) showed that rejecting brine from the desalination process has high levels of total dissolved solids (TDS). This rejected brine can be collected and treated before disposal to prevent harmful effects on the environment. Elsaid (2020) suggested that deep injection wells can be used to dispose of brine waste in a way that minimizes negative effects. This involves constructing a deep well ranging from 330 to 2,600 meters and injecting all of the brine waste into it.

According to the results, chemical discharges required complex treatment for waste disposal, followed by metal discharges, gas emissions, and brine discharges. Reverse osmosis was the method typically used to dispose of unregulated waste from desalination plants in the UAE, followed by multi-stage flash distillation and vapor compression distillation. This is substantiated in the study by Ibrahim et al. (2018) that many desalination plants in UAE carry out the process of reverse osmosis (RO) to treat waste disposal. Al-Fadala (2019) notes that reverse osmosis is effective at removing high levels of salts and other pollutants. The purified water is then collected on the other side of the membrane, while the concentrated waste is disposed of.

According to the analysis of the responses, there are no regulations on the disposal of unregulated waste from desalination plants in the UAE. However, the study by Khan et al. (2019) showed that the UAE government ensures that desalination plants follow environmentally friendly waste disposal practices. To ensure that desalination plants comply with these standards, appropriate legislation and regulation have been put in place to provide safe drinking water without harming the environment. The use of safe disposal techniques is strictly regulated, and the licenses of desalination plants are regularly reviewed. The process of supplying water and disposing of the waste is also monitored weekly.

The data indicated that most of the facilities that partook in the study used the thermal process for desalination, and the membrane process came next. The technologies used in the thermal process included solar desalination, multi-effect distillation, multi-stage flash distillation, LTE desalination using waste heat, and vacuum freezing. In the membrane process, it was reverse osmosis, membrane distillation, and electrolysis. Interestingly, many claimed no technology was used in the membrane process.

Desalination plants that use the thermal process of water purification, such as MSF and MED techniques, produce smaller quantities of concentrates or reject brine. According to Benaissa et al. (2020), these plants use low-water recoveries and mix the concentrate with cold water before releasing it. This dilutes the rejected brine and reduces the salt content during the final discharge phase, leaving the salinity levels 15% higher than normal saltwater levels. According to Al-Fadala (2019), there are two types of desalination plants. The first type uses a multi-stage process to purify water, including stages such as evaporation, multi-stage flash (MSF), multi-effect distillation (MED), vapour compression distillation, solar distillation, and freezing. The second type uses a single-phase process, which involves extracting salts in liquid form using techniques such as reverse osmosis (RO), electrodialysis (ED), and electrodialysis reversal (EDR) to remove salt from seawater.

The extensive water treatment process used by desalination plants requires a large amount of energy, leading to the production of harmful gases and an increase in atmospheric temperature. The emissions released by the operation of the desalination process also contribute to climate change. The responses were varied concerning the membrane process technique that consumed the least energy such as Forward Osmosis followed by Rapid Spray Evaporation, Electrolysis, and Capacitive Deionisation. Similarly, in the thermal process, many believed Solar Desalination consumed the least energy followed by Multi-Effect

Distillation, LTE Desalination using waste heat, Vacuum freeze Desalination, and Vapour Compression Distillation. According to Sosa-Fernandez et al. (2018), larger desalination plants can be more cost-effective due to economies of scale, as they use less water per unit of output and have longer maintenance intervals and lower energy costs.

In the Netherlands, research on the use of wind energy to directly convert into mechanical energy has been conducted (Karad & Thakur, 2021). This type of technology has the potential to significantly reduce reliance on fossil fuels, which contribute to climate change and air pollution. By harnessing the power of the wind, a cleaner, more sustainable energy source that can help to reduce carbon footprint can be used in desalination plants. Another potential source of direct mechanical energy is wave energy, and a system using hydrostatic pressure has been tested (Lacroix et al., 2022). This technology has the potential to harness the power of ocean waves to generate electricity, providing a renewable and sustainable energy source. In addition to reducing our reliance on fossil fuels, wave energy can also help to reduce the cost of electricity production, making it more affordable and accessible for people.

During the interviews and data analysis, information about forward osmosis and a new membrane-based desalination technology that allows the use of thinner membranes in the system was uncovered. Forward osmosis is a desalination technology that uses a thin membrane to separate salt and other impurities from water. The process involves passing seawater or other saline water through a semi-permeable membrane, which allows water molecules to pass through but blocks the passage of salt and other impurities. According to Jawad et al. (2021), in order to produce safe drinking water, desalination plants typically employ a number of purification processes, including pre-treatment with antiscalant chemicals, acidification, chlorination, de-chlorination, filtration, coagulation, flocculation,

ion exchange, and carbon adsorption. These processes are used to remove impurities and contaminants from the feed water, which is often of poor quality. Forward osmosis is a relatively new and innovative technology that has the potential to revolutionize the way we produce drinking water, especially in areas where traditional methods are not feasible or cost-effective.

According to the study, electrodialysis and electrodialysis reversal (ED/EDR) can be powered by photovoltaic energy, making them environmentally sustainable and feasible for use in off-grid communities. The adaptability of these technologies to photovoltaic power makes them a promising solution for producing clean drinking water in areas where traditional grid-based power is not available. This is particularly important for isolated or remote communities that rely on desalination as a source of clean water, as it allows them to produce drinking water in an environmentally sustainable and technically feasible way. According to Zhang et al. (2021), large photo-thermal pillars were designed with the support of KAUST that are capable of crystallizing large amounts of brine in the same way that small photo-thermal discs do so on a smaller scale in laboratories. These pillars have the potential to significantly improve the efficiency and effectiveness of brine crystallization for desalination purposes.

The research found evidence that membrane distillation (MD) requires less pre-treatment than pressure-based membrane processes and that it can be powered by low-grade heat sources such as solar or waste heat. These characteristics make MD an attractive option for desalination, as it can produce clean drinking water efficiently and with a low environmental impact. According to Al-Fadala (2019), there are two main types of desalination plants: those that use a multi-stage process to purify water, and those that use a single-stage process. The multi-stage process involves several steps, including evaporation, multi-stage flash (MSF), multi-effect distillation (MED), vapour compression distillation, solar distillation, and freezing. The single-stage process involves the extraction of salt in liquid form and uses techniques such as reverse osmosis (RO), electrodialysis (ED), and electrodialysis reversal (EDR) to remove salt from seawater.

The high level of dilution of the concentrate from the desalination process had a significant positive impact on the coastal and marine environment, reducing the negative effects of concentrate disposal. By diluting the concentrate to a high level, the negative impacts on the surrounding ecosystem were significantly reduced, helping to protect and preserve the health of the coastal and marine environment. According to Al-Fadala (2019), the brine produced during the desalination process is collected and treated before being disposed of in order to minimize any negative impacts on the surrounding environment.

Waste concentrate disposal is a very significant problem in inland areas. According to Dias et al. (2021), desalination plants may use methods such as evaporation ponds, deep well injection, or surface release to dispose of rejected brine. These methods are designed to safely and effectively manage the waste generated during the desalination process and minimize any negative impacts on the environment.

The study found the need for effective training for all employees towards awareness and perceptions of environmental aspects and the impact of brine water disposal. According to Dost et al. (2019), a lack of awareness about the risks to the environment associated with improper waste management can also hinder the implementation of effective techniques for managing waste from desalination plants. The study showed that the majority of the respondents wanted measurements of water levels, current flow velocities, and directions and flow discharges in the plant vicinity to be carried out to minimize the environmental impacts of desalination plants. They also wanted the configuration of the intake and outfall of the plant to be developed and calibrated based on field measurements, and a biological survey to be conducted to evaluate the local ecosystem.

The study advocated the use of a water quality model to simulate the impact of discharges from a power and desalination plant on the surrounding water. According to El Mahrad et al. (2020), experts in the United Arab Emirates are introducing innovations and technological reforms to improve the efficiency of desalination plants and extract more drinkable water from brine waste. These efforts aim to improve the sustainability and environmental impact of desalination as a source of clean drinking water.

The results of the study indicate that implementing a hybrid desalination process would be beneficial in terms of reducing capital costs, operational costs, and maintenance costs. Additionally, the study recommends the use of renewable energy sources, such as the Renewable Energy Desalination Programme, to improve water security and reduce energy consumption. One specific suggestion made by the study is the use of solar-powered desalination plants to address the issue of electricity consumption during the desalination process. Another potential solution that the study suggests is using hot exhaust gases from power plants to desalinate water through a distillation process, which would increase the overall energy efficiency of the desalination process. To mitigate the environmental impacts of desalination plants, one effective measure is to pre-dilute the plant's brine with seawater or power plant cooling water. This can help to reduce the concentration of salts and other pollutants in the waste stream. The use of Nanofiltration (NF) technology, as demonstrated by a large-scale plant in the United Arab Emirates (Yang et al., 2019), can also be an effective means of mitigating the environmental effects of desalination. Another approach is zero liquid discharge (ZLD), which has been shown to effectively reduce the toxicity of salty solutions produced during conventional mining processes (Gorjian et al., 2019). ZLD can also serve as a bridge between desalination and vacuum membrane distillation (VMD) in the context of desalination.

Seawater can become more saline if desalination plants release high levels of salt into the water through their outfall. While coastal and marine environments can usually handle the dilution of concentrated waste, proper disposal of brine produced during the desalination process is still important. Inland areas, on the other hand, may face more significant problems with the disposal of concentrated waste. Additionally, an increase in residual chlorine concentrations can negatively impact the overall water quality of the surrounding area. According to Takouleu (2020), one million cubic meters of saltwater contains approximately 500 tons of potassium, 2,000 tons of magnesium, 80 tons of bromine, and 35,000 tons of sodium chloride. These elements are considered rare in comparison to the other components found in saltwater.

Approximately 35% of all desalinated water is produced by plants located in the United Arab Emirates (UAE). These plants take seawater and purify it for use as drinking water for the local population. However, the process of desalination also produces a byproduct called brine, which is often disposed of into the sea due to cost-effectiveness. While this is sometimes permitted by regulations, it can have negative impacts on the environment. To mitigate these impacts, it is necessary to invest in better infrastructure for brine disposal and to alter the properties of the brine before it is released. According to Awad et al. (2021), an effective waste management system has been developed in Abu Dhabi, UAE to properly dispose of and manage waste. Attia et al. (2021) also report that effective waste management techniques have been implemented by the Dubai Municipality's Waste Management Department. Ali et al. (2021) also mention that effective waste management practices have been implemented in the emirate of Sharjah in UAE.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study aimed to assess the impact of unregulated waste disposal from desalination plants in the UAE and determine the current measures in place for waste management. The study considered various desalination plants in the UAE and examined their waste management systems to determine whether they were disposing of waste in a regulated manner and what relevant measures could be developed to improve the efficiency of the waste management system.

One objective of the study was to determine whether it is necessary to classify the different technologies for controlling unregulated waste from desalination plants in the UAE. This is an important consideration because different technologies may have different levels of effectiveness and efficiency in controlling waste. Classifying the technologies could help to identify the most effective options for controlling waste and ensure that the most appropriate measures are put in place.

While focusing the second objective of the study was to investigate the environmental impacts of unregulated waste disposal, such as global warming, the greenhouse effect, marine pollution, and air pollution. Unregulated waste disposal can have serious consequences for the environment, and it is important to understand the full extent of these impacts to take appropriate action to address them. The study also ascertained that desalination plants generate reject brine that is highly concentrated and contains large quantities of chemicals, heavy metals, and reaction (by-) products. All these constituents are highly harmful and when brine is released in water, all these harmful chemicals and metals dissolved in seawater. Hence, there is a reduction in concentration and saturation levels of dissolved oxygen which increases the salinity of the natural water and temperature to high levels. The study examined that due to the conduction of the desalination process, there is a generation of coagulants, bisulfites, and chlorine that disturbs the natural composition of seawater

While focusing on the third objective the study also aimed to assess currently available control measures for reducing the environmental impact of unregulated waste and to identify the most effective ways for desalination plants to adopt and contribute to the creation of an integrated waste management system in the UAE. An integrated waste management system considers the entire life cycle of waste, from generation to disposal, and aims to minimize waste and maximize the efficient use of resources. Implementing such a system can help to reduce the environmental impact of waste disposal and improve the overall sustainability of the region.

Examining the fourth objective, the study aimed to identify challenges in the implementation of an integrated waste management system in the UAE. Moreover, with the adoption of innovative processes such as Reverse Osmosis (RO) desalination techniques, there has been an increase in the workings of the desalination plants and a reduction in the emission of harmful gases, metals, and chemicals. The study examined that the desalination plants have made it possible to use seawater and brackish water for drinking and agriculture purposes by cleaning and purifying them.

Finally, the study aimed to develop solutions to address these challenges and overcome them to implement a waste management system for UAE. There may be various obstacles to implementing an integrated waste management system, including logistical, financial, and regulatory challenges. Identifying these challenges and developing solutions to overcome them is essential to the successful implementation of such a system. The study examined that the major issue faced by desalination plants in UAE is related to waste management which could only be made efficient by involving regional and local governing bodies in the waste management system of the desalination plants

In conclusion, the study aimed to assess the impact of unregulated waste disposal from desalination plants in the UAE and determine the current measures in place for waste management. It also sought to classify the different technologies for controlling waste, investigate the environmental impacts of unregulated waste disposal, assess control measures for reducing environmental impact, and identify challenges and create solutions for implementing an integrated waste management system in the UAE. By addressing these objectives, the study aims to help ensure that waste from desalination plants in the UAE is managed sustainably and responsibly.

5.2 Limitation

There were several limitations to the research conducted. One major issue was collecting data, facts, and figures from different sources, which was limited. The research also had to rely on the participation of respondents for the collection of more information, but some respondents were not very participative. Additionally, the respondents were found to be varied. The research was also limited by time constraints, and the sample size for the study was small due to monetary constraints, which may not be sufficient to draw general conclusions about all such desalination plants. Finally, the research was only limited to desalination plants and the waste disposal measures adopted by them.

5.3 Recommendation

The desalination industry has made some progress in becoming more sustainable by reducing energy consumption, but there are still negative impacts at various stages of the process, such as intake, pre-treatment, and chemical input, as well as the harmful output of brine. While desalination can play a role in addressing the demand for freshwater, improvements are needed to make the process more sustainable. Rather than just focusing on energy reduction, a holistic approach that considers all aspects of the process is necessary. Recommendations for improving the sustainability of desalination include improving intake infrastructure, setting higher standards for energy use, researching and developing green chemicals, researching and developing green membranes, optimizing the discharge of brine, and improving the characteristics of brine to make it safe to discharge.

Renewable energy sources, such as solar, wind, biomass, hydroelectric power, and ocean energy, are used to power desalination plants. However, these sources can be unreliable due to their dependence on weather and climate. To address this issue, batteries are often used for energy storage, but they have low storage life, high maintenance costs, and can cause environmental damage. Researchers have recently explored the use of fuel cells combined with electrolyzing as a more reliable and environmentally friendly alternative. To optimize the efficiency and cost of using renewable energy in the desalination process, it is important to carefully size and capacity the system.

Desalination plants are currently very expensive and have high energy consumption, which makes them less affordable and less economical. Researchers are working on ways to make these plants more efficient to reduce costs. One area of focus is the use of renewable energy sources such as wind or solar to power desalination plants, which can reduce energy costs. Another area of focus is the use of new materials for the construction of thermal desalination devices, which can reduce corrosion, reduce the size and weight of the assembly, and lower construction costs. Additionally, the development of antifouling materials for both membrane and thermal methods can increase the freshwater production capacity of these devices.

There is a trend in research showing that desalination systems are continually improving and have the potential for further development. This focus on improving desalination systems is driven in part by the depletion of fossil fuel reserves and the increasing importance of renewable energy sources. Future directions for research and development in this field include studying the effects of bio-organic molecules on membrane materials to reduce the cost and improve the performance of desalination systems, examining the real-world applications of high-performance reverse osmosis membranes, and looking into the stability and efficiency of hybrid systems that combine reverse osmosis with renewable energy sources. Additionally, there is potential for the use of hybrid renewable energy systems, including solar-powered evaporation, in desalination processes, and the increased adoption of indirect freeze desalination systems. Another promising approach is the use of ocean thermocline energy for freshwater production. Overall, the goal of future developments in this field is to improve sustainability in terms of energy, economic, and environmental factors.

The research is highly beneficial in the future because it provides relevant information about the different aspects of the desalination plants and wastewater management techniques that are used by them in the UAE. The study provides valuable information about the different types of unregulated wastes that are generated by desalination plants along with the harmful effect caused by them. As a result, there is the attainment of high levels of learning about the functioning and waste management by the desalination plants in UAE. The study also proposes necessary corrective measures that are implemented by desalination plants to protect the environment. It also provides an overview of the comprehensive method that can be used by desalination plants for controlling waste disposal impact. Additionally, the study will also be highly beneficial for the policymakers and regulators to understand the workings of the desalination plants and make rulings accordingly that it protects the industry, humanity, and the environment. The study will also be beneficial to other scholars and researchers who are carrying out the study on a similar topic. As a result, they will be able to take relevant references from the current study and carry out their research process effectively.

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APPENDICES

I - Questionnaire

Demographic Profile:

1. Name (optional)	: ________________________________
2. Designation :	QHSE manager ☐ Plant manager ☐ Lab analysis specialist ☐ Waste management Engineer ☐ Production Engineer ☐
3. Qualification:	Diploma ☐ Bachelor ☐ Master ☐ Doctorate ☐

PART I - Types of waste disposed

1. **Which type of waste is mostly disposed of from desalination plants in UAE?**
   a. Brine discharge
   b. Emission of gases
   c. Metal Discharge
   d. Chemical discharge

2. **Which type of waste is disposed of from your desalination plant?**
   a. Brine discharge
   b. Emission of gases
   c. Metal Discharge
   d. Chemical discharge

3. **Which waste disposal has the most harmful effects on the environment?**
   a. Brine discharge
   b. Emission of gases
   c. Metal Discharge
   d. Chemical discharge

4. **Which waste disposal has a complex treatment process?**
   a. Brine discharge
   b. Emission of gases
   c. Metal Discharge
   d. Chemical discharge

PART II - <u>Disposal of unregulated wastes</u>

1. **Which method is generally used in disposing of unregulated wastes from desalination plants in the UAE?**
    a. Multi-stage flash distillation
    b. Vapour compression Distillation
    c. Reverse osmosis
    d. Electro dialysis
2. **Which desalination process technology is primarily used in the facility?**
    a. Thermal process
    b. Membrane process
3. **Which renewable source of energy is used for the desalination process?**
    a. Geothermal
    b. Solar Photovoltaics
    c. Wind
    d. Solar thermal

(If the answer for the 2 questions is a)

4. **Which technology is used in the thermal process?**
    a. Solar Desalination
    b. Multi-Effect Distillation
    c. Multi-Stage Flash Distillation
    d. LTE Desalination using waste heat
    e. Vacuum freeze Desalination
    f. Vapour Compression Distillation

(If the answer for the 2 questions is b)

5. **Which technology is used in the membrane process?**

   a. Forward Osmosis

   b. Membrane Distillation

   c. Reverse Osmosis

   d. Rapid Spray Evaporation

   e. Electrolysis

   f. Capacitive Deionisation

6. **In which technique of membrane process energy consumption is less?**

   a. Forward Osmosis

   b. Membrane Distillation

   c. Reverse Osmosis

   d. Rapid Spray Evaporation

   e. Electrolysis

   f. Capacitive Deionisation

7. **In which technique of thermal process energy consumption is less?**

   a. Solar Desalination

   b. Multi-Effect Distillation

   c. Multi-Stage Flash Distillation

   d. LTE Desalination using waste heat

   e. Vacuum freeze Desalination

   f. Vapour Compression Distillation

PART III - Suitable desalination techniques

The table below consists of statements related to best-suited desalination techniques. On a scale of 1-4, based on your experience please indicate the degree to which you agree to the statements given below. (1-StronglyAgree, 2-Agree, 3-Disagree, 4-Strongly Disagree)

Statements	**1**	**2**	**3**	**4**
1. Low water output and consequent large land requirements must be carefully considered if SSD is pursued as a desalination option.				
2. High capital cost must be carefully considered if SSD is pursued as a desalination option.				
3. Multi-stage flash is suitable for producing distilled quality water products good for power plants, for industrial processes.				
4. Forward osmosis is an emerging membrane-based desalination technology that allows for the use of thinner membranes in the system.				
5. Forward osmosis helps minimize membrane fouling and clogging compared with RO.				

6. Electro-dialysis and electro-dialysis reversal (ED/EDR) can also be easily adapted to be powered directly by photovoltaics, making them environmentally sustainable and technically feasible for off-grid communities.				
7. Membrane distillation (MD) can produce high-quality distillate at relatively low temperatures (<100°C).				
8. Membrane distillation (MD) reduce pre-treatment requirements compared with pressure-based membrane processes.				
9. Membrane distillation (MD) use low-grade heat (solar or waste heat) for operation.				

PART IV - Environmental effects of the desalination process

The table below consists of statements related to the environmental effects of the desalination process. On a scale of 1-4, based on your experience please indicate the degree to which you agree to the statements given below. (1-Very Satisfied, 2- Satisfied, 3-Dissatisfied, 4-Very Dissatisfied)

Statements	**1**	**2**	**3**	**4**
1. Brine produced in the desalination process is disposed of				

properly.				
2. Salinity of seawater is increased due to the discharge of high concentrations of salt through the outfall of desalination plants.				
3. Coastal and marine environments are significantly less affected by concentrate disposal due to a high level of concentrate dilution.				
4. Waste concentrate disposal is a very significant problem in inland areas.				
5. There is a significant effect on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents.				
6. If the desalination plant is combined with a power Plant the temperature of the ambient water in the plant vicinity will increase its seawater temperature.				
7. Increase in the concentration of residual chlorine affects the water quality of the ambient water.				
8. By the effluent discharges from the plant, dissolved				

oxygen in the water in the plant vicinity is affected.				
9. The concentration of the un-ionized ammonia affects marine life.				

PART V - <u>Techniques to reduce the adverse effect of desalination plants on the environment</u>

The table below consists of statements related to techniques used to reduce the adverse effects of desalination plants on the environment. On a scale of 1-4, based on your experience please indicate the degree to which you agree to the statements given below. (1-StronglyAgree, 2-Agree, 3-Disagree, 4-Strongly Disagree)

Statements	**1**	**2**	**3**	**4**
1. Measurements can be carried out in the plant vicinity and can include water levels, current flow velocities, and directions and flow discharges.				
2. Water quality measurements can be carried out to evaluate the concentrations of the substances of importance to the water quality and aquatic species.				
3. A biological survey can be carried out in the the Plant vicinity to evaluate the ecosystem in the area.				

4. A detailed sampling grid can be constructed in the plant vicinity and surveyed by the ecologist.				
5. The configuration of the intake and outfall of the plant should be developed and calibrated with field measurements.				
6. Water quality model helps to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant.				
7. The Effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity.				
8. Hydraulic structures are used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents.				

PART VI - <u>Mitigating Measures</u>

The table below consists of statements related to mitigating measures adopted for the treatment of waste. On a scale of 1-4, based on your experience please indicate the degree to which you agree to the statements given below. (1-StronglyAgree, 2-Agree, 3-Disagree, 4-Strongly Disagree)

Statements	**1**	**2**	**3**	**4**
1. The desalination plant brine can be pre-diluted with seawater or power plant cooling water.				
2. Outfall can achieve maximum heat dissipation from the waste stream by using cooling waters.				
3. Negative impacts of chemicals can be minimized by treatment before discharge.				
4. Negative impacts of chemicals can be reduced by the substitution of hazardous substances				
5. Adverse impact of chemicals can be minimized by implementing alternative treatment options.				
6. Chlorine can be replaced or treated prior to discharge.				
7. The potential for renewable energy use can be investigated to minimize impacts on air quality and climate.				
8. Proper selection of sites can be done to minimize to offset the loss of this open space land.				
9. Brine water dilution with seawater or cooling water can be used to reduce the salinity and control temperature.				

PART VII - <u>Techniques to improve the desalination process</u>

The table below consists of statements related to techniques used to improve the desalination process. On a scale of 1-4, based on your experience please indicate the degree to which you agree to the statements given below. (1-StronglyAgree, 2-Agree, 3-Disagree, 4-Strongly Disagree)

Statements	1	2	3	4
1. To desalinate briny water CO2 greenhouse gas emissions can be used.				
2. To reduce capital, operation, and maintenance costs hybrid desalination process can be developed.				
3. For water security and reduction in energy consumption, the renewable Energy Desalination Programme can be used.				
4. To prevent the membrane from scaling more efficient ultra-permeable membranes can be developed with anti-scaling elements.				
5. To improve the shelf life of the membrane more efficient ultra-permeable membranes can be developed with anti-scaling elements.				
6. Solar-powered desalination plants can be used for electricity				

consumption issues of the desalination process.				
7. Desalination process can be improved by improvising the method of RO by using forward osmosis.				
8. Desalination process can be driven by enhancing the method of RO by using electrodialysis.				
9. Desalination process can be driven by improving the method of RO by using pressure reverse osmosis.				
10. Low-maintenance, reliable evaporative technologies can be developed.				
11. Hot exhaust gases from a power plant can be used to desalinate water in a distillation plant for increasing energy efficiency.				

Part – VII - <u>Employee perceptions towards Environment aspects and Impacts of brine waste Disposal:</u>

The table below consists of statements related to employee perception towards environmental aspects and impacts of brine water disposal. On a scale of 1-4, based on your experience please indicate the degree to which you agree to the statements given below. (1-StronglyAgree, 2-Agree, 3-Disagree, 4-Strongly Disagree).

	Statements	1	2	3	4
1.	I am aware of environmental aspects and the impact of brine water disposal.				
2	I think effective training is required for all employees.				
3	The latest technique can be integrated into the brine waste management system.				
4	Dilution of brine discharge helps in preventing marine animals.				
5	More awareness is to be provided on brine waste disposal.				
6	Training will provide a better understanding of waste disposal treatment to employees.				
7	Awareness will help in developing standards for brine waste disposal.				
8	Mitigating measures are effective in brine waste disposal.				

II - Percentage Analysis

Designation:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	QHSE manager	28	18.7	18.7	18.7
	Plant manager	30	20.0	20.0	38.7
	Lab analysis specialist	47	31.3	31.3	70.0
	Waste management Engineer	39	26.0	26.0	96.0
	Production Engineer	6	4.0	4.0	100.0
	Total	150	100.0	100.0	

Qualification:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Diploma	12	8.0	8.0	8.0
	Bachelor	57	38.0	38.0	46.0
	Master	70	46.7	46.7	92.7
	Doctorate	11	7.3	7.3	100.0
	Total	150	100.0	100.0	

Part -1

1. Which type of waste is mostly disposed of from desalination plants in UAE?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Brine discharge	122	81.3	81.3	81.3
	Emission of gases	10	6.7	6.7	88.0
	Metal discharge	2	1.3	1.3	89.3
	Chemical discharge	16	10.7	10.7	100.0
	Total	150	100.0	100.0	

2. Which type of waste is disposed of from your desalination plant?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Brine discharge	109	72.7	72.7	72.7
	Emission of gases	16	10.7	10.7	83.3
	Metal discharge	4	2.7	2.7	86.0
	Chemical discharge	21	14.0	14.0	100.0
	Total	150	100.0	100.0	

3. Which waste disposal has the most harmful effects on the environment?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Brine discharge	51	34.0	34.0	34.0
	Emission of gases	45	30.0	30.0	64.0
	Metal discharge	22	14.7	14.7	78.7
	Chemical discharge	32	21.3	21.3	100.0
	Total	150	100.0	100.0	

3. **Which waste disposal has a complex treatment process?**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Brine discharge	26	17.3	17.3	17.3
	Emission of gases	34	22.7	22.7	40.0
	Metal discharge	37	24.7	24.7	64.7
	Chemical discharge	53	35.3	35.3	100.0
	Total	150	100.0	100.0	

Part-II

1. Which method is generally used in disposing of unregulated wastes from desalination plants in the UAE?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Multi-stage flash distillation	64	42.7	42.7	42.7
	Vapour compression Distillation	6	4.0	4.0	46.7
	Reverse osmosis	80	53.3	53.3	100.0
	Total	150	100.0	100.0	

2. Which desalination process technology is primarily used in the facility?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Thermal process	88	58.7	58.7	58.7
	Membrane process	62	41.3	41.3	100.0
	Total	150	100.0	100.0	

3. Which technology is used in the thermal process?

		Frequency	Percent	Valid Percent	Cumulative percent
Valid	Solar Desalination	58	38.7	38.7	38.7
	Multi-Effect Distillation	4	2.7	2.7	41.3
	Multi-Stage Flash Distillation	24	16.0	16.0	57.3
	LTE Desalination using waste heat	54	36.0	36.0	93.3
	Vacuum freeze Desalination	4	2.7	2.7	96.0
	Vapour Compression Distillation	6	4.0	4.0	100.0
	Total	150	100.0	100.0	

4. Which technology is used in the membrane process?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Forward Osmosis	88	58.7	58.7	58.7
	Reverse Osmosis	2	1.3	1.3	60.0
	Rapid Spray Evaporation	56	37.3	37.3	97.3
	Capacitive Deionisation	4	2.7	2.7	100.0
	Total	150	100.0	100.0	

5. In which technique of membrane process energy consumption is less?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Forward Osmosis	44	29.3	29.3	29.3
	Reverse Osmosis	25	16.7	16.7	46.0
	Rapid Spray Evaporation	43	28.7	28.7	74.7
	Electrolysis	2	1.3	1.3	76.0
	Capacitive Deionisation	36	24.0	24.0	100.0
	Total	150	100.0	100.0	

6. In which technique of thermal process energy consumption is less?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Solar Desalination	74	49.3	49.3	49.3
	Multi-Effect Distillation	4	2.7	2.7	52.0
	LTE Desalination using waste heat	14	9.3	9.3	61.3
	Vacuum freeze Desalination	29	19.3	19.3	80.7
	Vapour Compression Distillation	29	19.3	19.3	100.0
	Total	150	100.0	100.0	

PART III

1. Low water output and consequent large land requirements must be carefully considered if SSD is pursued as a desalination option.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	23	15.3	15.3	24.7
	Agree	17	11.3	11.3	36.0
	Strongly Agree	96	64.0	64.0	100.0
	Total	150	100.0	100.0	

2. High capital cost must be carefully considered if SSD is pursued as a desalination option.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	23	15.3	15.3	24.7
	Agree	16	10.7	10.7	35.3
	Strongly Agree	97	64.7	64.7	100.0
	Total	150	100.0	100.0	

3. Multi-stage flash is suitable for producing distilled quality water products good for power plants, for industrial processes.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	18	12.0	12.0	22.7
	Agree	22	14.7	14.7	37.3
	Strongly Agree	94	62.7	62.7	100.0
	Total	150	100.0	100.0	

4. Forward osmosis is an emerging membrane-based desalination technology that allows for the use of thinner membranes in the system.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	17	11.3	11.3	11.3
	Disagree	25	16.7	16.7	28.0
	Agree	11	7.3	7.3	35.3
	Strongly Agree	97	64.7	64.7	100.0
	Total	150	100.0	100.0	

5. Forward osmosis helps minimize membrane fouling and clogging compared with RO.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	23	15.3	15.3	24.7
	Agree	14	9.3	9.3	34.0
	Strongly Agree	99	66.0	66.0	100.0
	Total	150	100.0	100.0	

6. Electrodialysis and electro-dialysis reversal (ED/EDR) can also be easily adapted to be powered directly by photovoltaics, making them environmentally sustainable and technically feasible for off-grid communities.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	23	15.3	15.3	24.7
	Agree	15	10.0	10.0	34.7
	Strongly Agree	98	65.3	65.3	100.0
	Total	150	100.0	100.0	

7. Membrane distillation (MD) can produce high-quality distillate at relatively low temperatures (<100°C).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	17	11.3	11.3	11.3
	Disagree	25	16.7	16.7	28.0
	Agree	13	8.7	8.7	36.7
	Strongly Agree	95	63.3	63.3	100.0
	Total	150	100.0	100.0	

8. Membrane distillation (MD) reduce pre-treatment requirements compared with pressure-based membrane processes.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	23	15.3	15.3	24.7
	Agree	16	10.7	10.7	35.3
	Strongly Agree	97	64.7	64.7	100.0
	Total	150	100.0	100.0	

9. Membrane distillation (MD) use low-grade heat (solar or waste heat) for operation.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	23	15.3	15.3	24.7
	Agree	18	12.0	12.0	36.7
	Strongly Agree	95	63.3	63.3	100.0
	Total	150	100.0	100.0	

PART IV

1. Brine produced in the desalination process is disposed of properly.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	11	7.3	7.3	7.3
	Disagree	9	6.0	6.0	13.3
	Agree	7	4.7	4.7	18.0
	Strongly Agree	123	82.0	82.0	100.0
	Total	150	100.0	100.0	

2. Salinity of seawater is increased due to the discharge of high concentrations of salt through the outfall of desalination plants.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	12	8.0	8.0	8.0
	Disagree	2	1.3	1.3	9.3
	Agree	25	16.7	16.7	26.0
	Strongly Agree	111	74.0	74.0	100.0
	Total	150	100.0	100.0	

3. Coastal and marine environment are significantly less affected by concentrate disposal due to a high level of concentrate dilution.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	13	8.7	8.7	8.7
	Disagree	4	2.7	2.7	11.3
	Agree	7	4.7	4.7	16.0
	Strongly Agree	126	84.0	84.0	100.0
	Total	150	100.0	100.0	

4. Waste concentrate disposal is a very significant problem in inland areas.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	7	4.7	4.7	4.7
	Disagree	14	9.3	9.3	14.0
	Agree	6	4.0	4.0	18.0
	Strongly Agree	123	82.0	82.0	100.0
	Total	150	100.0	100.0	

5. There is a significant effect on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	12	8.0	8.0	8.0
	Disagree	4	2.7	2.7	10.7
	Agree	18	12.0	12.0	22.7
	Strongly Agree	116	77.3	77.3	100.0
	Total	150	100.0	100.0	

6. If the desalination plant is combined with a power Plant the temperature of the ambient water in the plant vicinity will increase its seawater temperature

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	12	8.0	8.0	8.0
	Disagree	4	2.7	2.7	10.7
	Agree	18	12.0	12.0	22.7
	Strongly Agree	116	77.3	77.3	100.0
	Total	150	100.0	100.0	

7. Increase in the concentration of residual chlorine affects the water quality of the ambient water.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	7	4.7	4.7	4.7
	Disagree	14	9.3	9.3	14.0
	Agree	6	4.0	4.0	18.0
	Strongly Agree	123	82.0	82.0	100.0
	Total	150	100.0	100.0	

8. By the effluent discharges from the plant, dissolved oxygen in water in the plant vicinity is affected.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	12	8.0	8.0	8.0
	Disagree	4	2.7	2.7	10.7
	Agree	18	12.0	12.0	22.7
	Strongly Agree	116	77.3	77.3	100.0
	Total	150	100.0	100.0	

9. The concentration of the un-ionized ammonia affects marine life.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	12	8.0	8.0	8.0
	Disagree	4	2.7	2.7	10.7
	Agree	18	12.0	12.0	22.7
	Strongly Agree	116	77.3	77.3	100.0
	Total	150	100.0	100.0	

PART V

1. Measurements can be carried out in the plant vicinity and can include water levels, current flow velocities, and directions and flow discharges.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	9	6.0	6.0	16.0
	Agree	32	21.3	21.3	37.3
	Strongly Agree	94	62.7	62.7	100.0
	Total	150	100.0	100.0	

2. Water quality measurements can be carried out to evaluate the concentrations of the substances of importance to the water quality and aquatic species.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	16	10.7	10.7	20.7
	Agree	22	14.7	14.7	35.3
	Strongly Agree	97	64.7	64.7	100.0
	Total	150	100.0	100.0	

3. A biological survey can be carried out in the Plant vicinity to evaluate the ecosystem in the area.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	9	6.0	6.0	16.0
	Agree	37	24.7	24.7	40.7
	Strongly Agree	89	59.3	59.3	100.0
	Total	150	100.0	100.0	

4. A detailed sampling grid can be constructed in the plant vicinity and surveyed by the ecologist.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	16	10.7	10.7	21.3
	Agree	20	13.3	13.3	34.7
	Strongly Agree	98	65.3	65.3	100.0
	Total	150	100.0	100.0	

5. The configuration of the intake and outfall of the plant should be developed and calibrated with the field measurements.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	17	11.3	11.3	11.3
	Disagree	10	6.7	6.7	18.0
	Agree	22	14.7	14.7	32.7
	Strongly Agree	101	67.3	67.3	100.0
	Total	150	100.0	100.0	

6. Water quality model helps to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	16	10.7	10.7	20.7
	Agree	21	14.0	14.0	34.7
	Strongly Agree	98	65.3	65.3	100.0
	Total	150	100.0	100.0	

7. The Effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	16	10.7	10.7	20.7
	Agree	23	15.3	15.3	36.0
	Strongly Agree	96	64.0	64.0	100.0
	Total	150	100.0	100.0	

8. Hydraulic structures are used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	16	10.7	10.7	20.7
	Agree	23	15.3	15.3	36.0
	Strongly Agree	96	64.0	64.0	100.0
	Total	150	100.0	100.0	

PART VI

1. The desalination plant brine can be pre-diluted with seawater or power plant cooling water.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	9	6.0	6.0	16.0
	Agree	25	16.7	16.7	32.7
	Strongly Agree	101	67.3	67.3	100.0
	Total	150	100.0	100.0	

2. Outfall can achieve maximum heat dissipation from the waste stream by using cooling waters.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	18	12.0	12.0	22.0
	Agree	9	6.0	6.0	28.0
	Strongly Agree	108	72.0	72.0	100.0
	Total	150	100.0	100.0	

3. Negative impacts of chemicals can be minimized by treatment before discharge.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	9	6.0	6.0	16.0
	Agree	25	16.7	16.7	32.7
	Strongly Agree	101	67.3	67.3	100.0
	Total	150	100.0	100.0	

4. Negative impacts of chemicals can be reduced by the substitution of hazardous substances

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	18	12.0	12.0	22.7
	Agree	8	5.3	5.3	28.0
	Strongly Agree	108	72.0	72.0	100.0
	Total	150	100.0	100.0	

5. Adverse impact of chemicals can be minimized by implementing alternative treatment options.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	13	8.7	8.7	19.3
	Agree	11	7.3	7.3	26.7
	Strongly Agree	110	73.3	73.3	100.0
	Total	150	100.0	100.0	

6. Chlorine can be replaced or treated before discharge.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	18	12.0	12.0	22.0
	Agree	9	6.0	6.0	28.0
	Strongly Agree	108	72.0	72.0	100.0
	Total	150	100.0	100.0	

7. The potential for renewable energy use can be investigated to minimize impacts on air quality and climate.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	18	12.0	12.0	22.7
	Agree	8	5.3	5.3	28.0
	Strongly Agree	108	72.0	72.0	100.0
	Total	150	100.0	100.0	

8. Proper selection of sites can be done to minimize to offset the loss of this open space land.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	13	8.7	8.7	19.3
	Agree	11	7.3	7.3	26.7
	Strongly Agree	110	73.3	73.3	100.0
	Total	150	100.0	100.0	

9. Brine water dilution with seawater or cooling water can be used to reduce the salinity and control temperature.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	18	12.0	12.0	22.0
	Agree	9	6.0	6.0	28.0
	Strongly Agree	108	72.0	72.0	100.0
	Total	150	100.0	100.0	

PART VII

1. To desalinate briny water CO2 greenhouse gas emissions can be used.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	13	8.7	8.7	18.7
	Agree	18	12.0	12.0	30.7
	Strongly Agree	104	69.3	69.3	100.0
	Total	150	100.0	100.0	

2. To reduce capital, operation, and maintenance costs hybrid desalination process can be developed.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	19	12.7	12.7	22.7
	Agree	18	12.0	12.0	34.7
	Strongly Agree	98	65.3	65.3	100.0
	Total	150	100.0	100.0	

3. For water security and reduction in energy consumption, the renewable Energy Desalination Programme can be used.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	18	12.0	12.0	12.0
	Disagree	14	9.3	9.3	21.3
	Agree	31	20.7	20.7	42.0
	Strongly Agree	87	58.0	58.0	100.0
	Total	150	100.0	100.0	

4. To prevent the membrane from scaling more efficient ultra-permeable membrane can be developed with anti-scaling elements.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	22	14.7	14.7	24.0
	Agree	18	12.0	12.0	36.0
	Strongly Agree	96	64.0	64.0	100.0
	Total	150	100.0	100.0	

5. To improve the shelf life of the membrane more efficient ultra-permeable membrane can be developed with anti-scaling elements.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	13	8.7	8.7	18.7
	Agree	27	18.0	18.0	36.7
	Strongly Agree	95	63.3	63.3	100.0
	Total	150	100.0	100.0	

6. Solar-powered desalination plants can be used for electricity consumption issue of the desalination process.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	19	12.7	12.7	22.7
	Agree	22	14.7	14.7	37.3
	Strongly Agree	94	62.7	62.7	100.0
	Total	150	100.0	100.0	

7. Desalination process can be improved by improvising the method of RO by using forward osmosis.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	18	12.0	12.0	12.0
	Disagree	14	9.3	9.3	21.3
	Agree	35	23.3	23.3	44.7
	Strongly Agree	83	55.3	55.3	100.0
	Total	150	100.0	100.0	

8. Desalination process can be driven by enhancing the method of RO by using electro dialysis.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	13	8.7	8.7	18.7
	Agree	26	17.3	17.3	36.0
	Strongly Agree	96	64.0	64.0	100.0
	Total	150	100.0	100.0	

9. Desalination process can be driven by improving the method of RO by using pressure reverse osmosis.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	10.0	10.0	10.0
	Disagree	19	12.7	12.7	22.7
	Agree	23	15.3	15.3	38.0
	Strongly Agree	93	62.0	62.0	100.0
	Total	150	100.0	100.0	

10. Low-maintenance, reliable evaporative technologies can be developed.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	18	12.0	12.0	12.0
	Disagree	14	9.3	9.3	21.3
	Agree	36	24.0	24.0	45.3
	Strongly Agree	82	54.7	54.7	100.0
	Total	150	100.0	100.0	

11. Hot exhaust gases from a power plant can be used to desalinate water in a distillation plant for increasing energy efficiency.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	9.3	9.3	9.3
	Disagree	22	14.7	14.7	24.0
	Agree	22	14.7	14.7	38.7
	Strongly Agree	92	61.3	61.3	100.0
	Total	150	100.0	100.0	

PART VIII

1. I am aware of the environmental aspects and impact of brine water disposal.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	24	16.0	16.0	26.7
	Agree	26	17.3	17.3	44.0
	Strongly Agree	84	56.0	56.0	100.0
	Total	150	100.0	100.0	

2. I think effective training is required for all employees.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	17	11.3	11.3	11.3
	Disagree	16	10.7	10.7	22.0
	Agree	26	17.3	17.3	39.3
	Strongly Agree	91	60.7	60.7	100.0
	Total	150	100.0	100.0	

3. The latest technique can be integrated into the brine waste management system.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	21	14.0	14.0	14.0
	Disagree	19	12.7	12.7	26.7
	Agree	21	14.0	14.0	40.7
	Strongly Agree	89	59.3	59.3	100.0
	Total	150	100.0	100.0	

4.Dilution of brine discharge helps in preventing marine animals.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	17	11.3	11.3	11.3
	Disagree	26	17.3	17.3	28.7
	Agree	25	16.7	16.7	45.3
	Strongly Agree	82	54.7	54.7	100.0
	Total	150	100.0	100.0	

5. More awareness to be provided on brine waste disposal.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	24	16.0	16.0	26.7
	Agree	29	19.3	19.3	46.0
	Strongly Agree	81	54.0	54.0	100.0
	Total	150	100.0	100.0	

6.Training will provide a better understanding of waste disposal treatment to employees.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	16	10.7	10.7	10.7
	Disagree	14	9.3	9.3	20.0
	Agree	30	20.0	20.0	40.0
	Strongly Agree	90	60.0	60.0	100.0
	Total	150	100.0	100.0	

7.Awareness will help in developing standards for brine waste disposal.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	21	14.0	14.0	14.0
	Disagree	19	12.7	12.7	26.7
	Agree	28	18.7	18.7	45.3
	Strongly Agree	82	54.7	54.7	100.0
	Total	150	100.0	100.0	

8. Mitigating measures are effective in brine waste disposal.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	17	11.3	11.3	11.3
	Disagree	26	17.3	17.3	28.7
	Agree	28	18.7	18.7	47.3
	Strongly Agree	79	52.7	52.7	100.0
	Total	150	100.0	100.0	

III - Factor Analysis

	Factor					
	1	2	3	4	5	6
Technique to Improve Desalination Process						
2. To reduce capital, operation, and maintenance costs hybrid desalination process can be developed.	.950					
1. To desalinate briny water CO2 greenhouse gas emissions can be used.	.944					
6. Solar-powered desalination plants can be used for electricity consumption issue of the desalination process.	.939					
9. Desalination process can be driven by improving the method of RO by using pressure reverse osmosis.	.931					
8. Desalination process can be driven by enhancing the method of RO by using electro dialysis.	.929					
5. To improve the shelf life of the membrane more efficient ultra-permeable membrane can be developed with anti-scaling elements.	.923					
3. For water security and reduction in energy consumption, the renewable Energy Desalination Programme can be used.	.904					
7. Desalination process can be improved by improvising the method of RO by using forward osmosis.	.896					
10. Low-maintenance, reliable evaporative technologies can be developed.	.892					

4. To prevent the membrane from scaling more efficient ultra-permeable membranes can be developed with anti-scaling elements.	.810					
11. Hot exhaust gases from a power plant can be used to desalinate water in a distillation plant for increasing energy efficiency.	.794					
Mitigating Measures						
9. Brine water dilution with seawater or cooling water can be used to reduce the salinity and control temperature.		.968				
2. Outfall can achieve maximum heat dissipation from the waste stream by using cooling waters.		.968				
6. Chlorine can be replaced or treated prior to discharge.		.968				
7. The potential for renewable energy use can be investigated to minimize impacts on air quality and climate.		.960				
4. Negative impacts of chemicals can be reduced by the substitution of hazardous substances		.960				
5. Adverse impact of chemicals can be minimized by implementing alternative treatment options.		.914				
8. Proper selection of sites can be done to minimize to offset the loss of this open space land.		.914				
3. Negative impacts of chemicals can be minimized by treatment before discharge.		.906				
1. The desalination plant brine can be pre-diluted with seawater or power plant cooling water.		.906				
Suitable Desaliantion Technique						

5. Forward osmosis helps minimize membrane fouling and clogging compared with RO.			.947			
6. Electro dialysis and electro dialysis reversal (ED/EDR) can also be easily adapted to be powered directly by photovoltaics, making them environmentally sustainable and technically feasible for off-grid communities.			.946			
2. high capital cost must be carefully considered if SSD is pursued as a desalination option.			.944			
8. Membrane distillation (MD) reduce pre-treatment requirements compared with pressure-based membrane processes.			.942			
1. low water output and consequent large land requirements must be carefully considered if SSD is pursued as a desalination option.			.942			
9. Membrane distillation (MD) use low-grade heat (solar or waste heat) for operation.			.931			
4. Forward osmosis is an emerging membrane-based desalination technology that allows for the use of thinner membranes in the system.			.897			
7. Membrane distillation (MD) can produce high-quality distillate at relatively low temperatures (<100°C).			.892			
3. Multi-stage flash is suitable for producing distilled quality water products good for power plants, for industrial processes.			.885			

Techniques to reduce the adverse effect of desalination plants on the environment						
6. Water quality model helps to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant.				.937		
7. The Effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity.				.935		
8. Hydraulic structures are used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents.				.927		
4. A detailed sampling grid can be constructed in the plant vicinity and surveyed by the ecologist.				.926		
2. Water quality measurements can be carried out to evaluate the concentrations of the substances of importance to the water quality and aquatic species.				.926		
1. Measurements can be carried out in the plant vicinity and can include water levels, current flow velocities, and directions and flow discharges.				.882		
3. A biological survey can be carried out in the Plant vicinity to evaluate the ecosystem in the area.				.871		
5. The configuration of the intake and outfall of the plant should be developed and calibrated with the field measurements.				.854		
Environment Effects of the desalination process						

9. The concentration of the un-ionized ammonia affects marine life.					.893	
5. There is a significant effect on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents.					.893	
6. If the desalination plant is combined with a power Plant the temperature of the ambient water in the plant vicinity will increase its seawater temperature					.893	
8. By the effluent discharges from the plant, dissolved oxygen in water in the plant vicinity is affected.					.893	
2. Salinity of seawater is increased due to the discharge of high concentration of salt through outfall of desalination plants.					.817	
3. Coastal and marine environment are significantly less affected by concentrate disposal due to a high level of concentrate dilution.					.802	
1. Brine produced in the desalination process is disposed of properly.					.780	
4. Waste concentrate disposal is a very significant problem in inland areas.					.684	
7. Increase in the concentration of residual chlorine affects the water quality of the ambient water.					.681	
Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal						

Dilution of brine discharge helps in preventing marine animals.						.859
I am aware of the environmental aspects and impact of brine water disposal.						.850
More awareness to be provided on brine waste disposal.						.839
Mitigating measures are effective in brine waste disposal.						.832
The latest technique can be integrated into the brine waste management system.						.748
Awareness will help in developing standards on brine waste disposal.						.724
Training will provide a better understanding of waste disposal treatment to employees.						.681
I think effective training is required for all employees.						.654

IV- Correlation Analysis:

Correlations

		Suitable Desalination Technique	Environment Effects of the desalination process	Mitigating Measures	Techniques to Improve the Desalination Process	Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal	Techniques to reduce the adverse effect of desalination plants on the environment
Suitable Desalination Technique	Pearson Correlation	1	.260**	.242**	.328**	.252**	.278**
	Sig. (2-tailed)		.001	.003	.000	.002	.001
	N	150	150	150	150	150	150
Environment Effects of the desalination process	Pearson Correlation	.260**	1	.301**	.291**	.360**	.453**
	Sig. (2-tailed)	.001		.000	.000	.000	.000
	N	150	150	150	150	150	150
Mitigating Measures	Pearson Correlation	.242**	.301**	1	.215**	.241**	.301**
	Sig. (2-tailed)	.003	.000		.008	.003	.000
	N	150	150	150	150	150	150
Techniques to Improve the Desalination Process	Pearson Correlation	.328**	.291**	.215**	1	.288**	.225**
	Sig. (2-tailed)	.000	.000	.008		.000	.006
	N	150	150	150	150	150	150
Employee perception towards Environment Aspects and Impacts of Brine Waste Disposal	Pearson Correlation	.252**	.360**	.241**	.288**	1	.279**
	Sig. (2-tailed)	.002	.000	.003	.000		.001
	N	150	150	150	150	150	150

Techniques to reduce the adverse effect of desalination plants on the environment	Pearson Correlation	.278**	.453**	.301**	.225**	.279**	1
	Sig. (2-tailed)	.001	.000	.000	.006	.001	
	N	150	150	150	150	150	150

**. Correlation is significant at the 0.01 level (2-tailed).