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Performance Optimization of Brackish Water Reverses Osmosis Desalination Plants in Gaza Strip

(Yasin and AlManar Plants:Cases study)

الأداء الأمثل لمحطات تحلية المياه الجوفية بنظام التناضح العكسي في قطاع غزة

(محطة ياسين ومحطة المنار: حالتان دراسيتان)

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إقـــــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

PERFORMANCE OPTIMIZATION OF BRACKISH WATER REVERSES OSMOSIS DESALINATION PLANTS IN GAZA STRIP (YASIN AND ALMANAR PLANTS :CASES STUDY)

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الأداء الأمثل لمحطات تحلية المياه الجوفية بنظام التناضح العكسي في قطاع غزة

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Performance Optimization of Brackish Water Reverse Osmosis Desalination Plants in Gaza Strip - Yasin and AlManar plants : Cases study

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﴿شهد الله أنه لا إله إلا هو والملائكة وأولوا

العلم قائما بالقسط لا إله إلا هو العزيز الحكيم﴾

[آل عمران:18]

Dedication

*To the memory of my father "**God's mercy upon**"*

To my beloved mother

To my dear brothers and sisters

This work is affectionately dedicated

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ABSTRACT

Performance Optimization of Brackish Water Reverses Osmosis Desalination Plants in Gaza Strip (Yasin and AlManar Plants:Cases study)

Brackish Water Reverse osmosis (BWRO) has become increasingly attractive source for potable water in the Gaza strip, so the brackish water source is preferable because of the lower investment required for maintenance and operation costs.

More than 90% of Gaza's population depends on desalinated brackish water for drinking purposes by private, public, NGO and governmental BWRO desalination plants. It is important to mention that more than 150 of these plants are in operation throughout Gaza Strip. This research aims to study the optimum performance in BWRO desalination plants in Gaza strip with minimum cost as unit cost by using the most advanced technologies with respect to system configuration, pumping systems, membrane assembly leading to energy and cost saving, so this study focused on role of system configurations and performance of different types of Toray membranes in different stages. The system performance was measured in relation with other operating factors such as recovery ratio, feed concentration, productivity, feed pressure and power consumption.Toray DS, Version 2.5 is a comprehensive RO systems projection software that allows users to analyze and simulate the model and design configuration simpler and easier by using Toray membranes. The analysis results of case one Yasin BWRO plant and case two Al Manar BWRO plant, the energy consumption reduced from 1.0 kWh/m^3 to 0.56 kWh/m^3 and reduced from 1.1 kWh/m^3 to 0.55 kWh/m^3, respectively by using Toray membranes (TM720-440), rearrange system configurations, using high efficiency pump and also resulted the permeate quality. In addition, The optimization of operating parameters (pressure and conversion) and membrane type reduced desalted water as unit cost (US$/m^3) by 42 % and 37 % in Yasin and Al Manar plant, respectively. The study concluded that operating parameters and selection of membranes type and flow configuration BWRO systems can be designed optimally leading to and minimize desalted water unit cost to the system as resulted from 1.04 $/m^3 to 0.59 $/m^3 and 0.65 $/m^3 respectively in Yasin and AlManar desalination Plants.

Key- words: Optimization, BWRO, Brackish, membranes, energy consumption.

الملــخص

الأداء الأمثل لمحطات تحلية المياه الجوفية بنظام التناضح العكسي في قطاع غزة

(محطة ياسين ومحطة المنار: حالتان دراسيتان)

تعتبر المياه الجوفية المصدر الأكثر إقبالا لتحلية مياه الشرب في قطاع غزة حيث يفضل عن غيره من المصادر لانخفاض تكلفة الصيانة والتشغيل فيه, أكثرمن 90% من سكان قطاع غزة يعتمدون على المياه المحلاة عن طريق التناضح العكسي للمياه الجوفية بواسطة المحطات الخاصة والعامة والحكومية والغير حكومية. ومن الجدير ذكره أن هناك أكثر من 150 محطة من هذه المحطات العاملة في قطاع غزة. يهدف هذا البحث إلى دراسة الاداء الامثل لمحطات تحلية المياه الجوفية في قطاع غزة بأقل التكاليف الممكنة باستخدام أحدث التكنولوجيا المتوفرة مع الأخذ بالإعتبار التصميم الأمثل وأنظمة الضخ والمرشحات ذات الجودة العالية التي تؤدي الى توفير الطاقة والتكلفة, لذا ركزت هذه الدراسة على دور تصميم النظام وشكله وعلى الأداء لمختلف أنواع مرشحات Toray في المراحل المختلفة من مراحل التحلية, ثم قياس اداء النظام وذلك بالعلاقة مع عوامل التشغيل مثل نسبة الاسترجاع وتركيز الأملاح في المياه الجوفية والإنتاجية وضغط المياه واستهلاك الطاقة.

يقوم برنامج Toray Ds نسخة 2.5 بالتصميم الشامل لأنظمة التناضح العكسي باستخدام مرشحات Toray ويتيح للمستخدم التحليل والنمذجة والمحاكاة بشكل مبسط وسهل, وأظهرت نتائج الدراسة بالحالة الدراسية الأولي (محطة ياسين) و في الحالة الدراسية الثانية (محطة المنار) أن استهلاك الطاقة انخفض من 1 كيلو وات لكل متر مكعب الى 0.56 كيلو وات لكل متر مكعب الطاقة وانخفض من 1.1 كيلو وات لكل متر مكعب إلى 0.55 كيلو وات لكل متر معب على الترتيب وذلك باستخدام مرشحات Toray نوع (TM720-440) وإعادة هيكلية شكل النظام وإستخدام مضخة ذات كفاءة عالية انعكس ذلك أيضا على جودة المياه المحلاة وأظهرت أيضا أن نمذجة عوامل التشغيل كنسبة الاسترجاع والضغط ونوع المرشحات المناسبة خفض تكلفة سعر الوحدة من المياه بنسبة 42 % ونسبة 37 % في محطة ياسين ومحطة المنار على الترتيب. وخلصت الدراسة الى أن التصميم الامثل للعوامل التشغيلية وإختيار المرشحات المناسبة وأيضا هيكلية نظام التحلية المتبع يقلل من سعر المياه المحلاة من 1 دولار/ متر مكعب إلي 0.59 دولار/ متر مكعب و0.65 دولار/ متر مكعب في محطة ياسين ومحطة المنار على الترتيب.

كلمات مفتاحية: نمذجة, التناضح العكسي للمياه الجوفية, المياه المالحة, مرشحات, استهلاك الطاقة.

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RO	Reverse Osmosis
BWRO	Brackish Water Reverse Osmosis
KWh/m^3	Kilowatt Hour Per Cubic Meter
BWDP	Brackish Water Desalination Plant
PWA	Palestinian Water Authority
CMWU	Coastal Municipalities Water Utility
MOG	Municipality Of Gaza
EQA	Environment Quality Authority
NGO	Nongovernmental Organization
TDS	Total Dissolved Solids
EC	Electrical Conductivity
hr/d	Hour Per Day
M^3	Cubic Meter
ppm	Parts Per Million
$(M_A)_E$	Osmotic Pressure Of Seawater
N_E	Total Element Numbers
Q_p	Permeate Water Flow Rate
$J_{V,ave}$	Average Permeate Flux
HP	High Pressure
TM	Toray Membrane
PV	Pressure Vessels
SDI	Silt Density Index
SEC	Specific Energy Consumption
NPV	Net Present Value

Chapter 1

Introduction

Chapter 1 : Introduction

1.1 General

The problem of inadequacy of fresh water has been faced by most countries because of increasing consumption and population growth. Gaza Strip, in particular, has a problem in terms of water quantity and quality due to depletion of ground water aquifer.

The desalination story in Gaza began with the first established reverse osmosis (RO) brackish desalination plant in 1991 in Deir El-Balah in the central Gaza Strip (El Sheikh, et al., 2003). The plant was built with a capacity of 45 m^3/h by a subsidiary of the Israeli Mekorot water company. Since then, many small- and large-scale desalination plants have been built and operated to provide potable water for the population of Gaza Strip, which suffers shortages in water supplies and depends mostly on groundwater with very high salinity levels (Abuhabib, et al., 2012); (Mogheir, et al., 2013).

Reverse osmosis has become increasingly attractive for brackish water desalination in the Gaza Strip, comparing with sea water desalination; there are two known sources of potable water in the Gaza Strip area: brackish water from wells which have become saline due to dry seasons and over pumping and Mediterranean seawater. Both must be desalinated, but the brackish water source is preferable because of the lower investment required for maintenance, low energy consumption, easier start-up and operation, flexibility in construction and utilization of electrical energy as the only energy source. Since Gaza has no central water supply system for the time being, sub regional systems were considered for immediate implementation (Al Agha, et al., 2005) ; (Abuhabib, et al., 2012).

1.2 Problem Statement

The fresh water production cost in a typical RO desalination plant generally consists of the cost of whole of components plant such as, energy consumption, equipment, membranes, operation and maintenance and financial charges.

In the Gaza strip, six public brackish water desalination plants were built. The desalinated water produced from these plants represents nearly 4% of the total water consumption by the population. In addition, more than 100 private desalination plants produce drinking water with capacity between (100-600) cubic per day, which are represent more than 90% of the total public water consumption (Al Agha, et al., 2005).

These public and private desalination plants haven't reach its optimal work performance, in many functional areas, such as energy consumption, plant operation and plant design, which may have a significant factors in the produced water cost and can reach as high as about 44-50 % of the total permeate production cost as shown in Figure 1.1 (Al Agha, et al., 2005). and there is no doubt that the electricity supply problem in Gaza Strip influence the performance of these plants

Since there is a direct relationship between running time of the plants and its capacity, that will lead to effecting the specific cost. In addition, the design system of the plant including, membrane configuration, number of the stages and passes, and the rate of by-pass and blend, play another an important role in plant performance (Lu, et al., 2006).

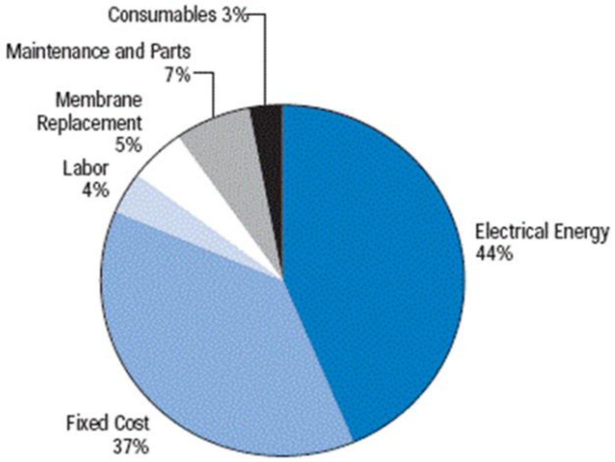


Figure (1.1): Typical costs for a reverse osmosis desalination plant

Source: (Lu, et al., 2006)

1.3 Main Goal:

The main goal of the project is to optimize the performance of (BWRO) in Gaza Strip to reach optimal and economical design leading to minimum unit cost (US$/$m^3$) of potable water.

1.4 Specific Objective:

The research studied brackish water reverses osmosis BWRO operation parameters that influence the performance of the BWRO desalination plants. The research will:

- Study the optimization of the technical parameters in RO process in terms of operating parameters (pressure, conversion rate, flow rate) and unit power consumption (kWh/m^3)

- Determine the economical parameters and cost analysis in RO process in terms of unit cost of product water (US$/$m^3$) such as, annual operating costs (annual membrane replacement cost), annual energy cost, annual chemical cost, annual maintenance cost and annual amortization cost.

1.5 Methodology

It is intended to achieve the objectives of the study by the following steps:

1. Literature review

Revision of accessible references as books, case studies and researches relative to the topic of this research which may include: energy consumption, different design and configurations of BWDP, optimize RO system design, and the optimal operation parameters, that will influence in permeate water cost.

2. Data collection and case study

Data collecting from appropriate authorities such as Palestinian water authority (PWA), Coastal municipalities water utility (CMWU), Municipality of Gaza (MOG) and other Municipalities, ministry of health (MOH), Environment Quality Authority (EQA), BWRO desalination plants and others that includes details and time series data about different parameters (TDS, PH, Plants characterizes such as water, plant capacity ,design system, types of membranes, energy consumption, and others technical parameters) for brackish desalination plants in Gaza Strip, then Study many brackish water desalination plants in Gaza Strip, which have the most influence in the potable water sector.

3. Analysis , modeling and optimization

After collection the data for the main components of the research project, interpretation, investigation and technical analysis and optimal design were precisely implied.

By using projection software such as **Toray DS2** to investigate the interactions and effects of several parameters of BWRO system, this software will enable the development of design within a couple of minutes using the Design Assistant. After the first pass design is completed, one can look at the results and make design adjustments where required or desired, Argo Analyzer feature to select the suitable antiscalant to treat the feed at a given composition and to reach the quality and quantity of permeate product in economical design.

Figure 1.2 shows the flow chart of study methodology start with data collection and cases study, followed by comprehensive analysis of several main components of BWRO system then using design software to optimize the performance of BWRO system leading to optimal unit cost.

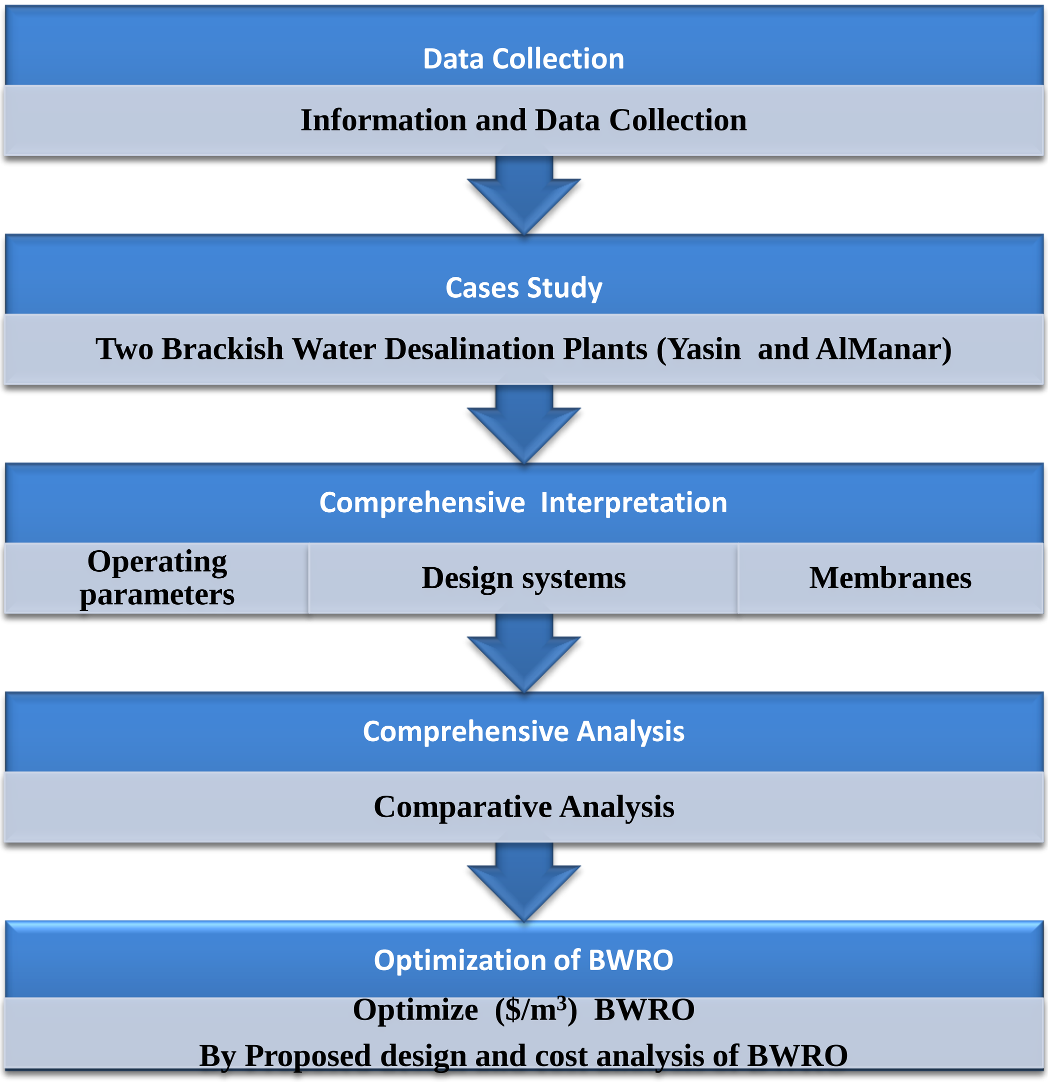


Figure (1.2): Methodology Flow Chart

1.6Thesis Outlines

- **Chapter One (Introduction):**

  General introduction is followed by problem identification, study objectives, methodology, and tools used in order to achieve the objectives and finally, a plan for thesis outline.

- **Chapter Two (literature Reviews):**

  Revision of accessible references as books, case studies and researches relative to the topic of this research which may include: energy consumption, different design and configurations of BWDP, Optimize RO system design and operation parameters, that will influence in permeate water cost.

- **Chapter Three (Data collection and Cases study):**

  Whole data of brackish water desalination plant (BWDP) in Gaza strip such configuration PH, chemical, test TDS, conversion rate, type of membranes, flow rate, and other operation parameters, two BW desalination plants in Gaza Strip have been taken as a case study.

- **Chapter Four (Analysis, Modeling and Optimization):**

  Express the computation for main effective elements and factors of reduction in permeate water cost in private plants(brackish water). And using projection software such as **Toray DS2** to investigate the interactions and effects of several parameters of BWRO system.

- **Chapter Five (Results and Discussion):**

  Study plant capacity, design system, types of membranes, energy consumption, and others technical parameters for brackish desalination plants to achieve the optimal design and operation parameters desalination plant is made, according the desired quality and quantity of product water.

- **Chapter Six (Conclusion and Recommendations):**

  The conclusion and recommendations of the study are stated in this chapter of the thesis.

Chapter 2

Literature Review

Chapter 2: Literature Review

2.1. Introduction

Optimization of the Reverse Osmosis (RO) process utilizing a set of implicit mathematical equations which are generated by combining solution-diffusion model with film theory approach. The simulation results were compared with operational data which are in good agreement having relative errors. The sensitivity of different operating parameters (feed concentration, feed flow rate and feed pressure) and design parameters (number of elements, spacer thickness, length of filament) on the plant performance were also investigated, Finally, a nonlinear optimization framework to minimize specific energy consumption at fixed product flow rate and quality while optimizing operating variables (feed flow rate, feed pressure) and design parameters (height of feed spacer, length of mesh filament), leading to Reduction in operating costs and energy consumption up to 50 % (Lu, et al., 2006).

Nowadays, desalination activities based on Reverse are being intensively introduced to combat water scarcity, as they provide a cost-effective solution to produce drinkable water from underground (Baker, 2004).

It has been argued that the specific energy consumption can be lowered by utilizing a large number of RO membrane units in parallel so as to keep the low and operating pressure low (Maskan, et al., 2000). It has also been claimed that the specific energy consumption SEC decreases upon increasing the number of membrane elements in a vessel (Wilf, 2007). In the mid 1990's researchers have suggested that a single-stage RO process would be more energy efficient (Malik, et al., 1996). However, it has been also claimed that a two-stage RO was more energy efficient than single-stage RO (Maskan, et al., 2000). The above conflicting views suggest that there is a need to carefully compare the energy efficiency of RO desalination by appropriately comparing single and multiple-stage RO on the basis of appropriately normalized feed low rate and SEC taking into consideration the feed osmotic pressure, membrane permeability and membrane area.

Minimization of fresh water production cost for desalination processes:

Influential factors in minimizing of water production cost usage in desalination processes using RO membranes can be classified according to:

1. Improved system design.
2. High efficiency operation parameters.
3. Energy consumption.
4. Optimal membrane.

2.2. Improved System Design

The effect of different operating and design parameters such as feed pressure, salinity, spacer geometries, and number of membrane elements in the pressure vessel on the performance of RO performance is studied. An optimization problem incorporating a process model is formulated to optimize the design and operating parameters in order to minimize specific energy consumption constrained with fixed product demand and quality (Lu, et al., 2006).

Membrane processes has vital role in designing RO processes and estimating their performances. A film theory approach which was developed originally by Michaels (1968) is used in this work to describe the concentration polarization. It is simple, analytical, and (reasonably) accurate for most RO separations. Further, film theory can be extended to describe the effect of spacer-filled RO modules on concentration polarization which is inherently used in design and evaluation of the membrane processes. Solution-Diffusion model is used to illustrate solvent and solute transport through the membrane. This model is the most used and is able to provide an accurate prediction of the flow of water and salt through the membrane (Marcovecchio, et al., 2005).

Further reduction in RO desalination cost has been shown to occur from optimal process configuration and control schemes. Theoretical cost minimization framework have been developed and experimentally implemented using a controller to quantify the effect of energy cost with respect to membrane cost, brine management cost, and feed salinity fluctuation (Zhu, et al., 2009b).

In another study, various mixing operations between feed, concentrate, and permeate streams were evaluated to assess their potential on energy usage (Zhu, et al., 2010).

It was determined that various mixing approaches may provide certain operational or system design advantages but they do not provide an advantage from an energy usage perspective in this innovative configuration, Feed water enters the pressure vessel through two feed ports on each end of the pressure vessel in the first stage. The concentrate is collected through a middle port and flows to a similar port on the pressure vessels in the second stage. Thus, the flow path is reduced by half and although the membrane unit has eight elements per pressure vessel, the flow path length is reduced to four elements per stage, creating a lower pressure drop that lowers the feed pressure. A 15% reduction in the feed pressure has been reported using the center port design when compared to a conventional side port design (Wilf, et al., 2010) a novel design modification to reduce pressure drop across membrane elements is the use of a pressure vessel with a center port design (Van Paassen, et al., 2005).

The feed spacer pattern used in most spiral wound membrane elements causes a variation in the flow path of the feed water resulting in a higher axial pressure drop than flow in an open channel, Although feed spacer geometry was found to have a marginal impact on mass transfer, thinner spacer filaments spread apart substantially reduced hydraulic pressure losses. In addition, certain non-circular spacer filament shapes produced lower hydraulic losses when compared to conventional circular spacer filament shapes (Guillen, et al., 2009) Although various feed spacer geometries have been shown to reduce hydraulic pressure loss in RO elements, actual data from pilot-scale and full-scale operation are still minimal since spiral wound elements with novel feed spacer configurations are not readily available. Commercialization of feed spacers that reduce the axial pressure drop across membrane elements could potentially reduce the feed pressure requirements during RO brackish water desalination.

Source water TDS concentration of plants typically ranges between 500 mg/L and 10,000 mg/L. Plants processing source water with salinity between 500 and 2500 mg/L and in a range of 2500 to 10,000 mg/L (or above) are referred to as low salinity and high-salinity brackish water reverse osmosis (BWRO) desalination facilities, respectively. Figure 2.01 illustrates a typical schematic of a low-salinity BWRO desalination plant. For such plants blending a portion (5 to 30 percent) of the source water flow with RO permeate is common practice for remineralization of the desalinated water. Low-salinity BWRO plants often process the source water through a single RO stage (pass) only. However, two-stage BWRO plants configured with 2:1 arrays are also common. Table 2.1 provides an illustrative hypothetical example of the permeate water quality produced by a low-salinity BWRO plant operating at blending ratio of 28.6 percent and permeate recovery of 85 percent (Wilf, 2007). In this specific example, the TDS of the source brackish water and RO permeate are 647.3 and 215 mg/L, respectively (Voutchkov, et al., 2013).

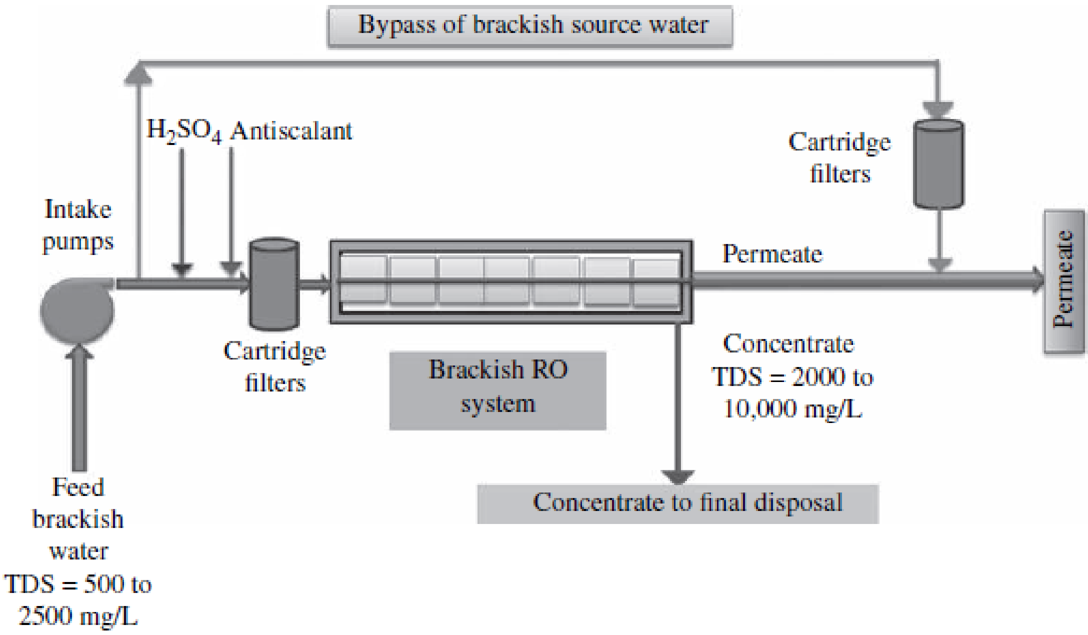


Figure (2.1): Schematic of typical low-salinity BWRO plant

Source : (Voutchkov, et al., 2013)

Table (2.1): Example of Product Water Quality in BWRO Plant

Water Quality Parameter	Source Water Quality	Blended Permeate Water Quality
Temperature, °C	25	25
pH	7	6.6
Ca2+, mg/L	96	29
Mg2+, mg/L	11.7	3.5
Na+, mg/L .	90	32.1
K+, mg/L	6.5	2.4
HCO3-, mg/L	72.6	30.4
SO42-, mg/L	158.4	47.2
Cl-, mg/L	190.7	61
F-, mg/L	0.2	0.1
SiO_2, mg/L	24.3	9.3
TDS, mg/L	647.3	215

Source: (Voutchkov, et al., 2013).

2.3. High Efficiency Operation Parameters

Operating parameters (specially pressure and conversions _feed flows) according to desirable objectives, are spread on the large domains, in the same time, the variables participant in theirs choices, are very numerous. The combination of choices of all this elements is essential and decisive, for desalination costs and water price (Mehdi, et al., 2012).

Energy is predominantly consumed from operation of primary feed pumps, second pass feed pumps (as required), pretreatment pumps, product water transfer pumps, chemical feed pumps, and water distribution pumps. The distribution of power usage in a two-stage brackish water RO system. More than 80% of the power is required for the operation of the primary feed pumps (Wilf, et al., 2004).

Although the flow and head of a pumping system are determined by the design specifications of the RO system, the selection and operation of pumps and other elements of a pumping system play an important role in reducing overall energy usage in the plant to achieve an energy efficient operation, A pump's speed must fall within a specified range for optimal efficiency or the best efficiency point (Veerapaneni, et al., 2007)

2.4. Energy Consumption

To minimize specific energy consumption at fixed product flow rate and quality, optimizing operating variables (feed flow rate, feed pressure) and design parameters (height of feed spacer, length of mesh filament) have to be in consideration Energy cost in desalination plants is about 30% to 50% of the total cost of the produced water based on the type of energy used. Fossil energy is the best type of energy for desalination from an economic point of view. To increase the efficiency of the desalination plant, it must be operated around the clock and should be never idle. Unfortunately, almost all the RO plants in Gaza are operating for only 8 (hr/d), and thus the energy consumption is not optimum (Baalousha, 2006).

2.5. Optimal Membrane

There are further avenues for improving the permeability of RO membranes using novel membrane materials such that the energy consumption is minimized. But, the new generation membranes must provide at least double the permeability of current generation RO membranes. This is based on a recent approach to determine the minimization of energy costs by improving membrane permeability (Zhu, et al., 2010). A dimensionless factor was used to reflect the impact of feed water osmotic pressure, salt rejection requirement, membrane permeability, and purchase price of electrical energy and membrane module and it was estimated that unless the permeability of the RO membrane is doubled and the capital cost of pressure vessels directly impacted by a lower membrane area requirement. New generation RO membrane which show promise in providing more than double the permeability of currently available RO membranes were discussed below. New generation RO membranes offer reduced feed pressure requirements while maintaining rejection. Today's high productivity membrane elements are designed with two features that include more fresh water per membrane element and higher surface area and denser membrane packing (Voutchkov, 2007).

A major impediment in the application of RO membrane technology for desalinating brackish water is membrane fouling. For the RO membrane to have a long life, a good pretreatment is essential. Nonetheless, pretreatment must be backed up by an appropriate cleaning process. The specific RO membrane cleaning procedure is a function of the feed water chemistry, the type of membrane, and the type of fouling. In most cases, the cleaning regimen is based on flushing membrane modules by recirculating the cleaning solution at high speed through the module, followed by a soaking period. This process is repeated several times (Baker, 2004).

Spiral-Wound, Hollow-Fiber, and Flat-Sheet RO Membrane Elements

The two most widely used configurations of membrane elements at present are spiral-wound and hollow-fiber. Until the mid-1990s, hollow-fiber elements were the most prevalent technology used for desalination, but at present the marketplace is dominated by spiral-wound RO membrane elements (Voutchkov, et al., 2013).

Spiral-Wound RO Membrane Elements

Spiral-wound membrane elements (modules) are made of individual flat membrane sheets that have the three-layer structure and micro porous polymeric support; and reinforcing fabric as shown in Figure. 2.2. A typical 8-in.-diameter spiral-wound RO membrane element has 40 to 42 flat membrane sheets. The flat sheets are assembled into 20 to 21 membrane envelopes (leafs), each of which consists of two sheets separated by a thin plastic net (referred to as a permeate spacer) to form a channel that allows evacuation of the permeate separated from the saline source water by the flat sheets (permeate carrier). Three of the four sides of the two-membrane flat-sheet envelope are sealed with glue and the fourth side is left open figure. 2.2 . The membrane leafs are separated by a feed spacer approximately 0.7 or 0.9 mm (28 or 34 mils) thick, which forms feed channels and facilitates the mixing and conveyance of the feed-concentrate stream along the length of the membrane element. Membranes with the wider 34-mil spacers have been introduced relatively recently and are more suitable for highly fouling waters. In order to accommodate the wider spacers, fewer membrane leafs are installed within the same RO membrane module, which results in a tradeoff between reduced membrane fouling and lower membrane element productivity (Voutchkov, et al., 2013).

The plastic caps are perforated in a pattern that allows even distribution of the saline feed flow among all membrane leafs in the element .The plastic caps' flow distribution pattern varies between membrane manufacturers. The reason the plastic caps are often also referred to as seal carriers is that one of their functions is to carry a chevron-type U-cup-style rubber brine seal that closes the space between the membrane and the pressure vessel in which the membrane is installed. This seal prevents the feed water from bypassing the RO element (Fig. 2.2). Membranes with the wider 34-mil spacers have been introduced relatively recently and are more suitable for highly fouling waters. In order to accommodate the wider spacers, fewer membrane leafs are installed within the same RO membrane module, which results in a tradeoff between reduced membrane fouling and lower membrane element productivity (Voutchkov, et al., 2013).

Pressurized saline feed water is applied on the outside surface of the envelope; permeate is collected in the space inside the envelope between the two sheets and directed toward the fourth, open edge of the envelope, which is connected to a central permeate collector tube. This collector tube receives desalinated water (permeate) from all flat-sheet leaves (envelopes) contained in the membrane element and evacuates it out of the element (Voutchkov, et al., 2013).

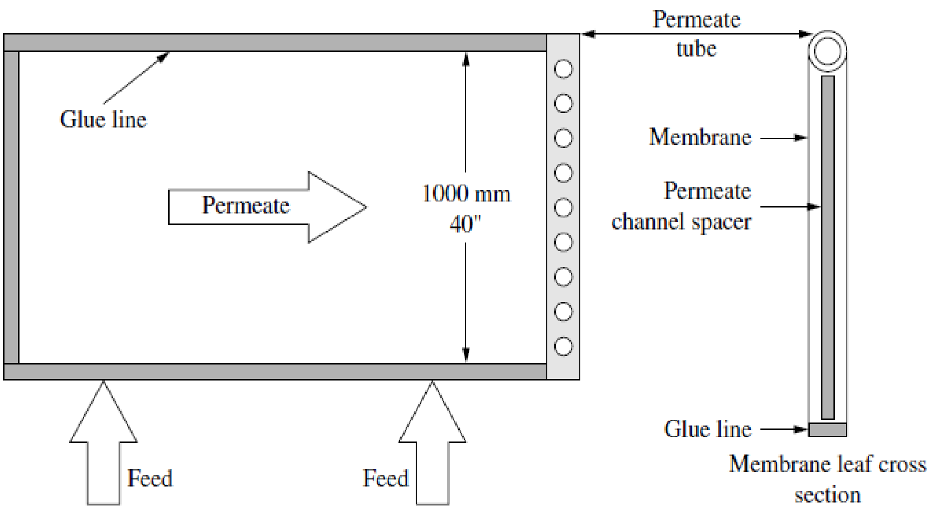


Figure (2.2): Flat-sheet membrane envelope.

Source: (Hydranautics, 2008)

In a straight tangential path on the surface of the membrane envelopes and along the length of the membrane element as shown in Figure. 2.3. A portion of the feed flow permeates through the membrane and is collected on the other side of the membrane as freshwater. The separated salts remain on the feed side of the membrane and are mixed with the remaining feed water. As a result, the salinity of the feed water increases as this water travels from one end of the membrane element to the other. The rejected mix of feed water and salts exits at the back end of the membrane element as concentrate (brine) (Voutchkov, et al., 2013).

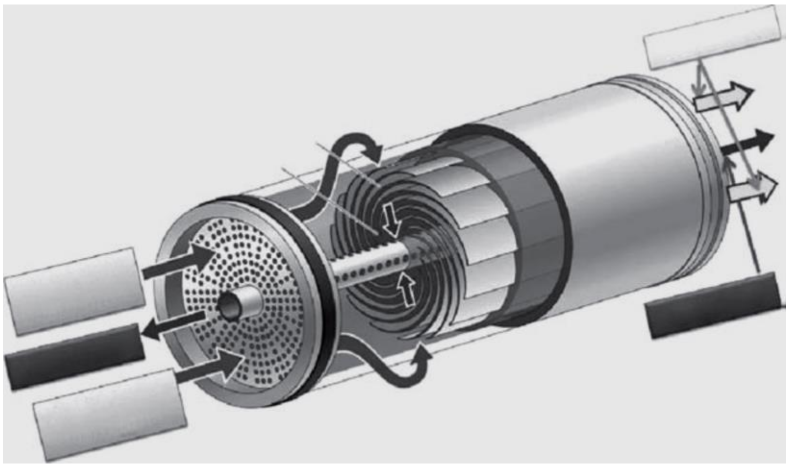


Figure (2.3): Spiral-wound membrane element.

Source: (Voutchkov, et al., 2013)

The subsequent membrane elements are exposed to increasingly higher feed salinity and elevated concentration polarization, which results in progressive reduction of their productivity (flux). As flux through the subsequent elements is decreased, accumulation of particulate and organic foulants on these elements diminishes and biofilm formation is reduced. However, the possibility of mineral scale formation increases, because the concentration of salts in the boundary layer near the membrane surface increases due to the increasingly higher feed salinity. Therefore, in RO systems fouling caused by accumulation of particulates, organic matter, and biofilm formation is usually most pronounced on the first and second membrane elements of the pressure vessels, whereas the last two RO elements are typically more prone to mineral scaling than other types of fouling (Voutchkov, et al., 2013).

Hollow-Fiber RO Membrane Elements

In hollow-fiber membrane elements, the 0.1- to 1.0-µm semipermeable film is applied as a coating to the surface of hollow fibers of diameter comparable to that of human hair (42 µm internal diameter, 85 µm external diameter). The hollow fibers are assembled in bundles and folded in a half to a length of approximately 48 in.

Both ends of the bundle are epoxy-sealed to encapsulate the water introduced in the tube in a way that allows all of the concentrate generated in the tube to exit from only one location—the back end of the membrane as shown in Figure 2.4 (Voutchkov, et al., 2013).

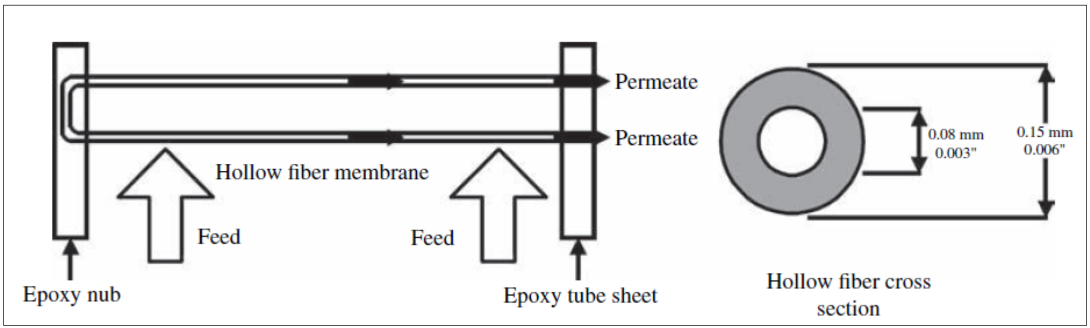


Figure (2.4) Hollow-fiber RO vessel with two membrane elements

Source: (Toyobo, 2012)

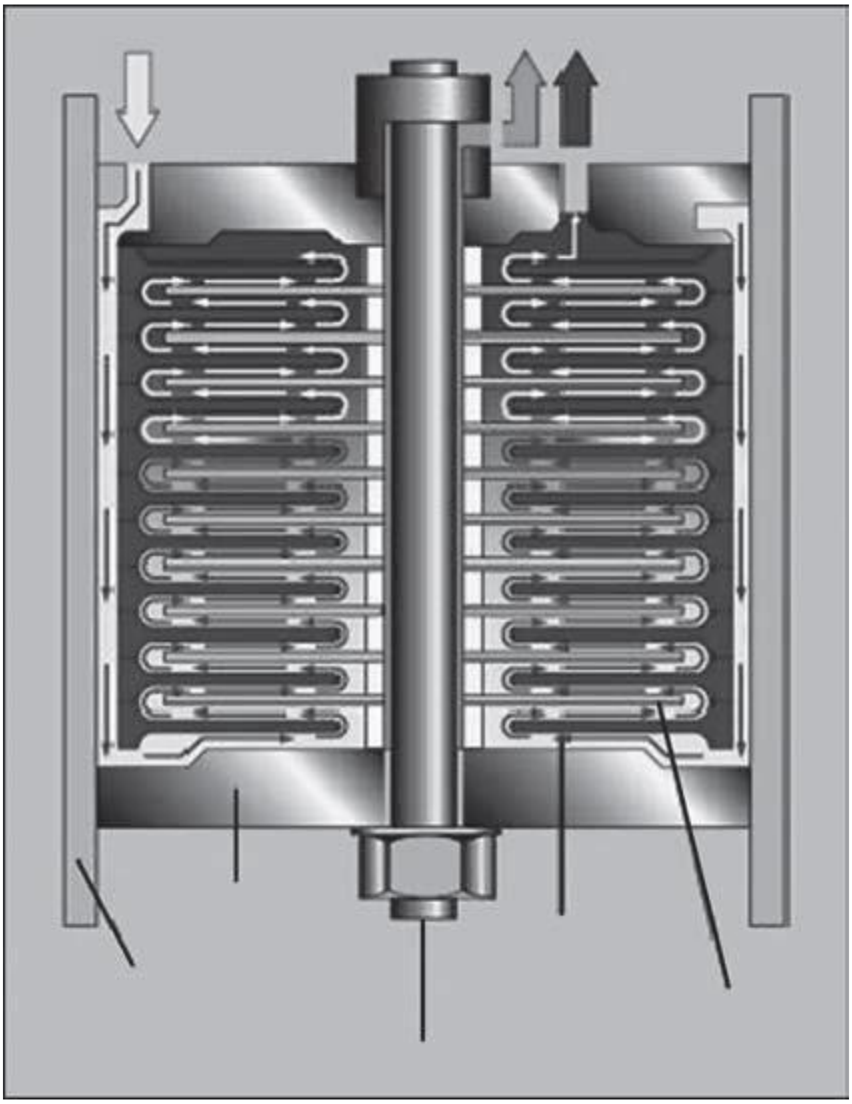
As compared to spiral-wound membrane configuration, hollow-fiber membrane configuration allows approximately 4 times more membrane surface per cubic foot of membrane volume. This higher surface area results in a proportionally lower permeate flux for the same volume of processed water, which in turns reduces concentration polarization and associated scaling potential when the source seawater is of high mineral content.

Because of the lower permeate flux and higher membrane surface area, the feed water flow regime in a hollow-fiber membrane element is laminar (as compared to nearly turbulent flow that occurs in the spiral-wound elements). This low-energy laminar flow results in little to no “scrubbing effect” of the feed flow on the surface of the membranes. This low velocity along the membrane surface allows solids and biofilm (Voutchkov, et al., 2013).

to attach to and accumulate more easily on the membranes, which in turn makes hollow-fiber membranes more susceptible to particulate fouling and biofouling and more difficult to clean. As a result, this type of element requires more enhanced source water pretreatment to remove particulate foulants from the water and it operates better on waters of low turbidity and SDI, such as those obtained from well intakes. For comparison, the turbulent flow on the surface of a spiral-wound membrane element makes that membrane configuration more resistant to particulate fouling and biofouling, but because of the higher permeate flux and concentration polarization, it is more prone to mineral scaling. Currently, the only large company that makes hollow-fiber membrane elements is Toyobo Company, Japan. Their membranes are made of cellulose triacetate (Voutchkov, et al., 2013).

Flat-Sheet RO Membrane Elements

Flat-sheet membrane elements are used in plate-and-frame RO systems as shown in Figure 2.5. In this case, the elements consist of flat membrane sheets similar to those that are rolled to create spiral-wound elements. Typically, two flat-sheet membranes are placed in filtration plates with the membrane film site outward so that they form an envelope. The filtration plates are integral parts of the RO system stacked within its frame structure. Permeate spacers are installed between each pair of membrane sheets, forming an envelope to facilitate permeate collection and prevent the membrane sheets from sticking to each other. Feed water/brine spacers are installed between the membrane envelopes to allow feed water to flow through (Voutchkov, et al., 2013).



Figure(2.5): Plate and frame RO unit

(Hydranautics, 2008)

Because of its low membrane packing density, which is approximately half that of a spiral-wound system. This type of RO system is significantly larger and more costly than a conventional spiral-wound RO system. Therefore, plate-and-frame systems have not found application for municipal water RO desalination. However, under the plate and frame configuration, the flat membrane sheets can easily be removed from the module and can individually be hand-cleaned. This allows for better cleaning and facilitates the use of this type of system for high-solids applications such as food processing (Voutchkov, et al., 2013).

Chapter 3

Data Collection and Case Study

Chapter 3: Data Collection and Case study

3.1. Introduction

More than 90% of the population depends on the desalinated water for drinking purposes by private, public, NGO and governmental RO desalination plants what are established and operated all over the Gaza Strip in the last twenty years as shown in Figure 3.1 and Table 3.1, Where private plants is owned by owners sailing by distributing the drinking water for the consumers or for the distributors, public plants related to PWA, CMWU, Municipalizes and Charities, NGO owned by Non-governmental organization, and governmental Owned by school or university.

Table (3.1): BWDP's classification of the Gaza strip

	Gaza north	Gaza city	Middle area	Khanyunis	Rafah	Total Number
Private	13	28	8	15	6	70
NGO	10	10	8	7	4	39
Public	1	5	11	9	2	28
Governmental	2	8	1	4	1	16
Total Number	26	51	28	35	13	153

Source: (PWA, 2015)

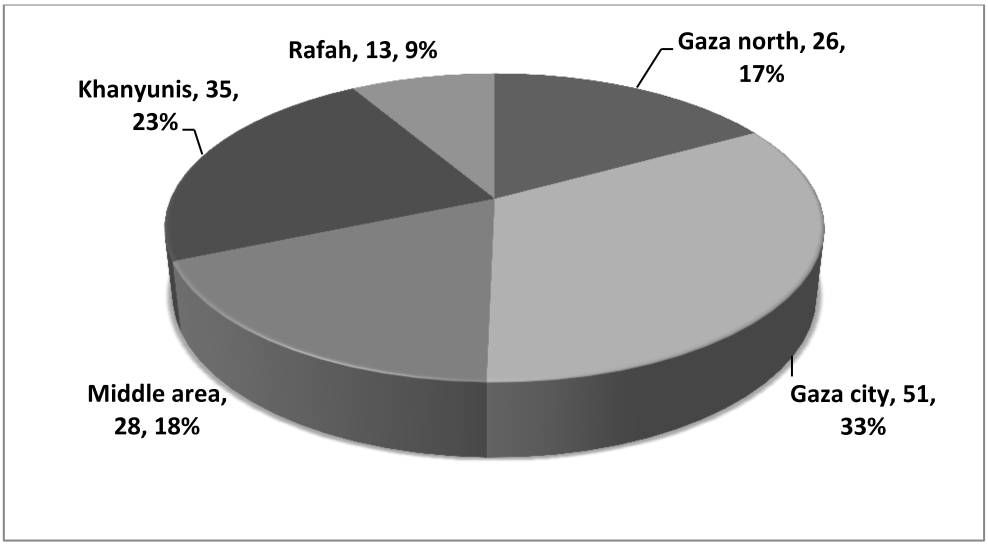


Figure (3.1): Distribution and percentages of the BWDP's of the Gaza strip.

Source: (PWA, 2015)

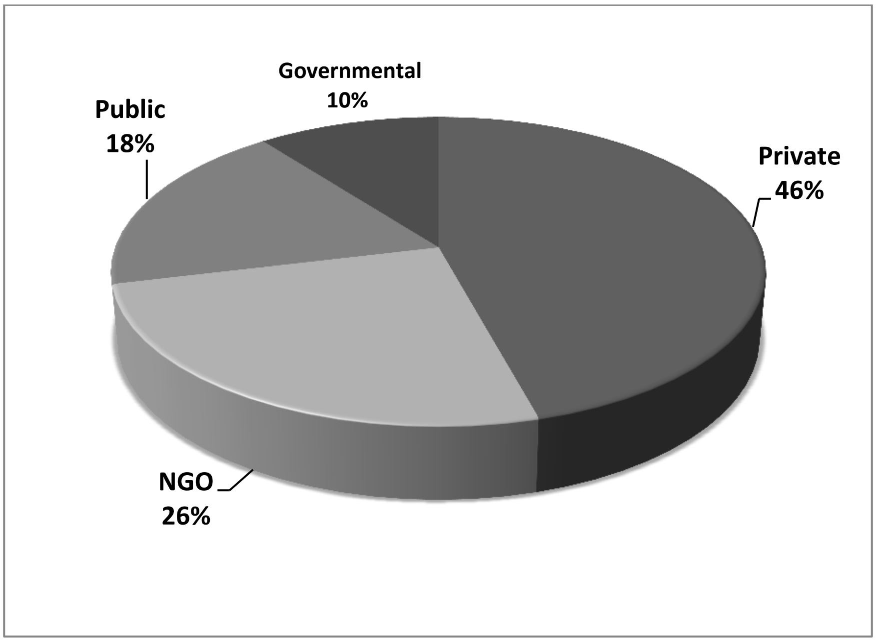


Figure (3.2): Distribution of the BWDP's classification of the Gaza strip

Source: (PWA, 2015)

3.2. BWRO Desalination Plants in Gaza Strip

All of desalination plants which are established in all over the Gaza Strip are brackish water desalination plants except for one seawater RO plant located in the middle area of Gaza Strip, more than 150 BWRO small private or public large scale plants and distribution stations are operating and provide potable water for the population of the Gaza Strip, only 48 of these plants are subjected to PWA licensing and regular monitoring which classified as shown in Table 3.2 and Figure 3.3.

Table (3.2): Licensed and Unlicensed BWDP's of the Gaza Strip

Class	**Gaza north**	**Gaza city**	**Middle area**	**Khanyunis**	**Rafah**	**Total Number**
Licensed	16	18	7	3	4	48
UnLicensed	10	33	21	32	9	105
Total **Number**	26	51	28	35	13	153

Source: (PWA, 2015)

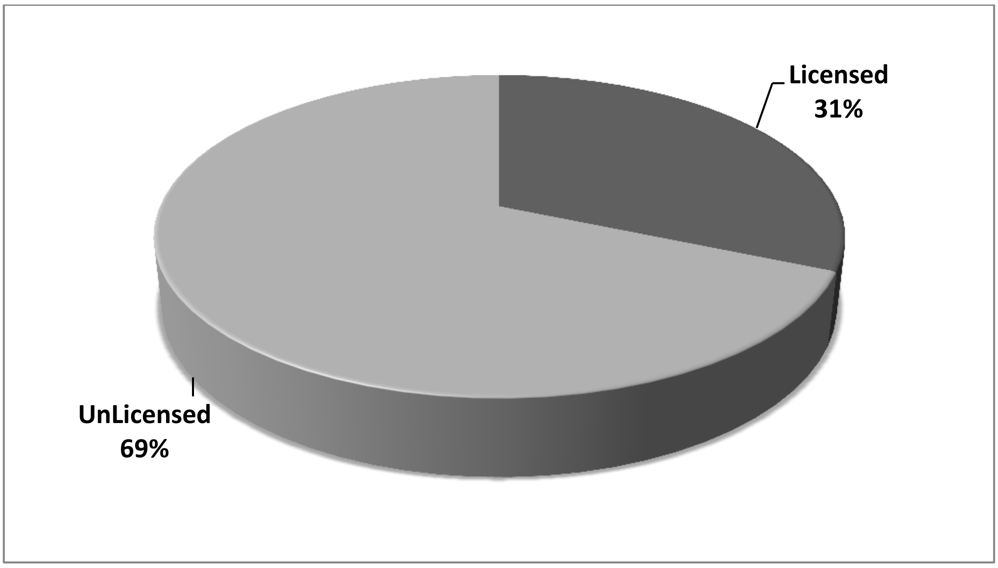


Figure (3.3): Licensed and Unlicensed BWDP's of the Gaza strip

Table 3.3 shows TDS for specific water classifications where the brackish water has arranged between (1500-10000) mg/l and this range was restricted and supposed in the model and required design in this research.

Table (3.3): Water Classification of Total Dissolved Solids

Water type	**TDS (mg/L)**
Potable water	< 500
Fresh water (not treated)	< 1500
Brackish water	1500 - 10000
Saline water	> 10000

Source: (PWA, 2015)

3.3. **Unit cost of the existing plants in Gaza Strip governorates**

After conducting surveying in this research about of cost product desalinated, it's found the mean of unit cost in many plants in Gaza governorates is 1.04 US$/$m^3$ as described in Table 3.4.

Table (3.4): The average of unit cost in several plant in Gaza Strip governorates

Plant	**Governorate**	**Max production capacity (m3/hr)**	**Unit Cost ($/m3)**
Yasin	North	39	1.05
Al Falah	North	3	1.08
Al Manar	Gaza	20	1.11
Al Kheir	Gaza	30	1
Al Sahaba	Gaza	4	1.05
Al Aqsa	Middle area	13	1.18
Al Jazaer	khanynis	8	0.92
Abu Zuhri	Rafah	12	1
Average of unit Cost			**1.04**

(Year-2016)

▪ **Brackish water desalination plants (BWDP's) in Gaza north**

The BWDP's in north Gaza are locating in the different parts of the north governorate and distributed in 26 plant as shown in Figure 3.4, its illuminate in Figure 3.4 that the concentrate of the locations of BWRO plants is close to the high population positions in north governorate. Table A1 in appendix A shows the parameters and measures of permeate product such: pH, TDS, electrical conductivity (EC), turbidity, hardness, chloride, fluoride, nitrates, sulphate, calcium, magnesium, sodium and potassium, additionally the Productivity of permeate water is shown in Table A2 in appendix A.

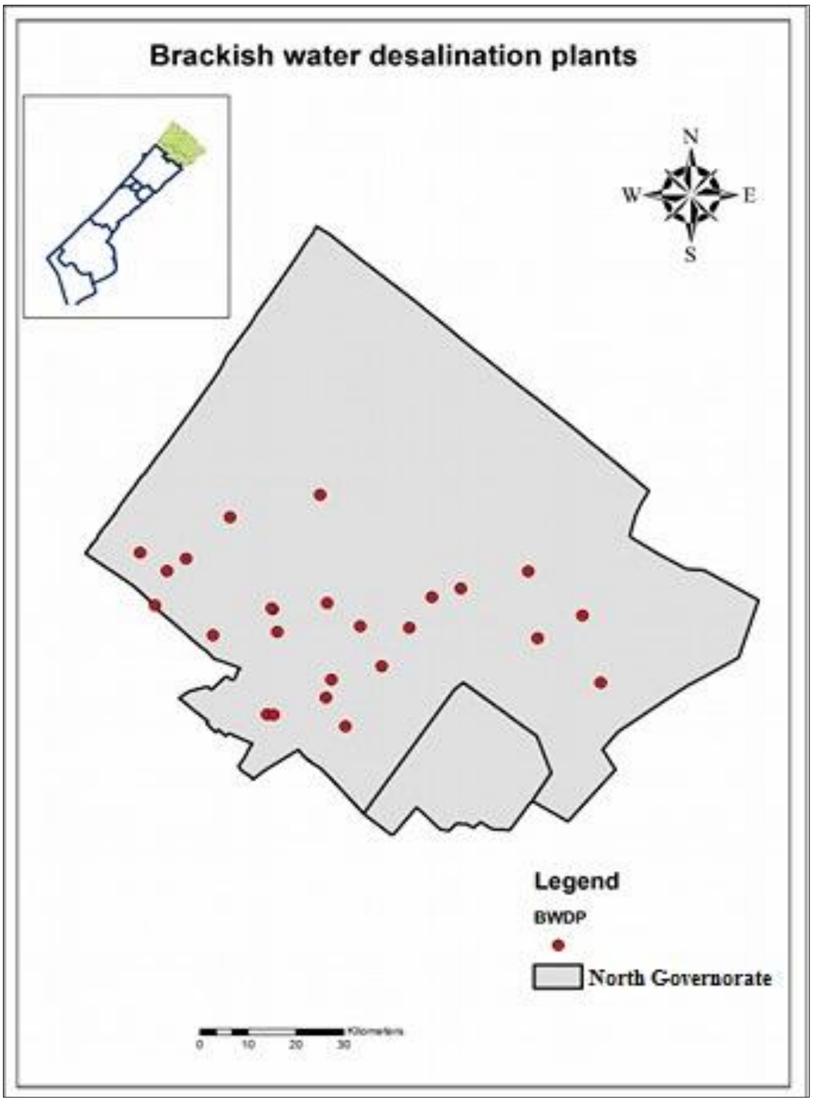


Figure (3.4): Locations of BWDP's in Gaza North

- **Brackish water desalination plants (BWDP's) in Gaza city**

The BWDP's in Gaza city are locating in the different parts of Gaza city governorate and distributed in 51 plant as shown in Figure 3.5, Its illuminate in Figure 3.5, that the concentrate of the locations of BWDPs is close to the high population positions in Gaza governorate. Table A2 in appendix A shows parameters and measures of permeate product such: pH, TDS, electrical conductivity, turbidity, hardness, chloride, fluoride, nitrates, sulphate, calcium, magnesium, sodium and potassium, additionally the Productivity of permeate water is shown in Table A3 in appendix A.

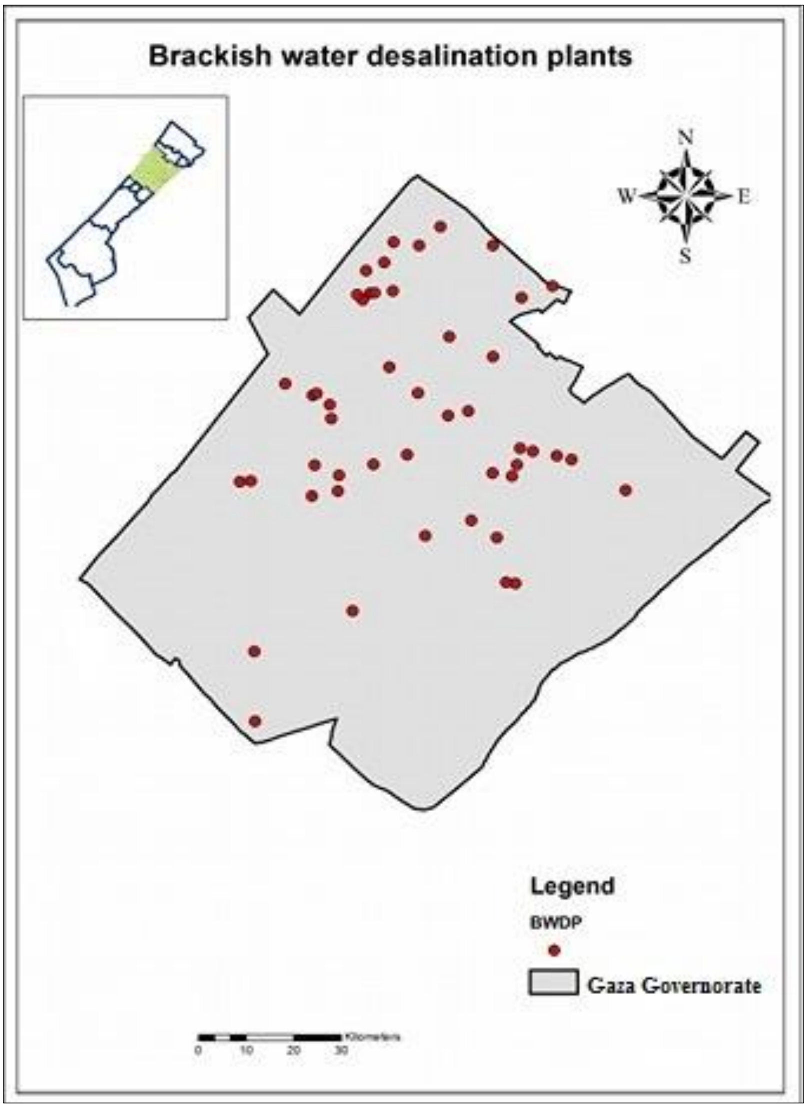


Figure (3.5): Locations of BWRO plants in the Gaza City

▪ **Brackish water desalination plants (BWDP's) in Middle area governorate**

The BWDP's in Middle area are locating in the different parts of the Middle area governorate and distributed in 28 plant as shown in Figure 3.6, Its illuminate in Figure 3.6 that the concentrate of the locations of BWDPs is close to the high population positions in Middle area governorate. Table A5 in appendix A shows parameters and measures of permeate product such: pH, TDS, electrical conductivity, turbidity, hardness, chloride, fluoride, nitrates, sulphate, calcium, magnesium, sodium and potassium , additionally the Productivity of permeate water is shown in Table A6 in appendix A.

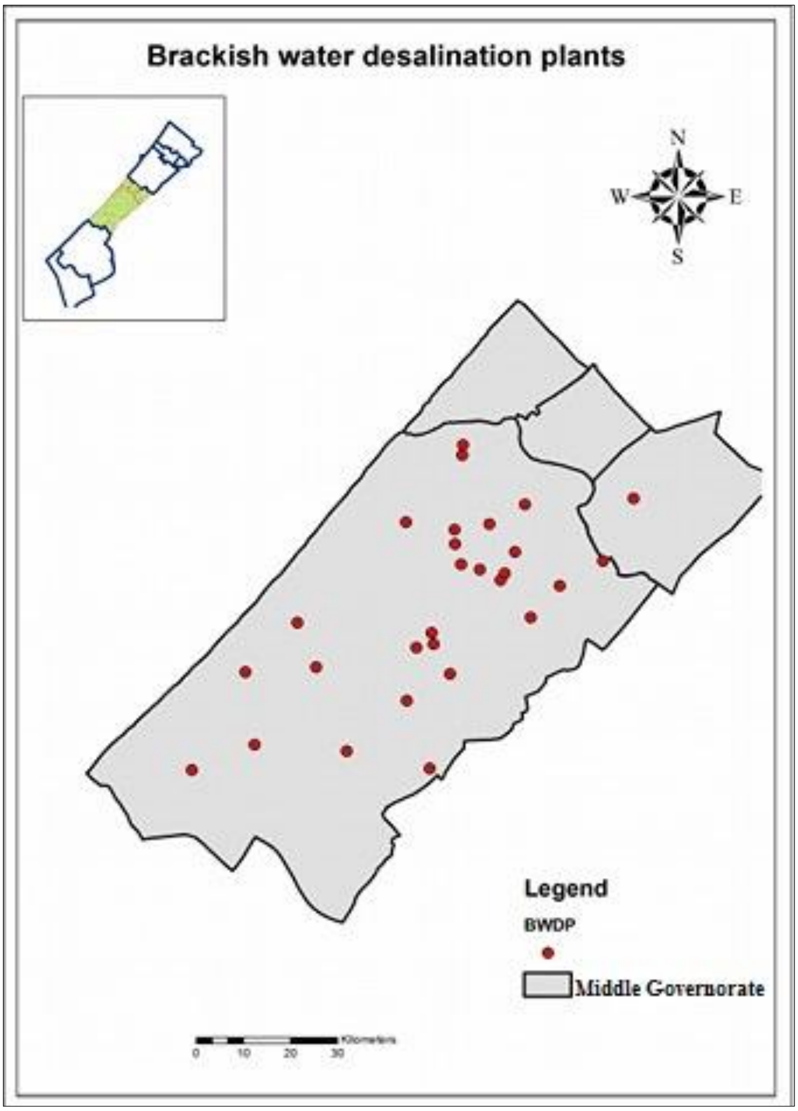


Figure (3.6): Locations of BWRO plants in Middle area Governorate

▪ **Brackish water desalination plants in Khanyounis governorate**

The BWRO plants in Khanyounis governorate are located in the different parts of Khanyounis governorate and distributed in 35 plant as shown in Figure 3.7. Its illuminate in Figure 3.7 indicates that the concentrate of the locations of BWDPs is close to the high population positions in Khanyounis governorate. Table A7 in appendix A shows parameters and measures of permeate product such: PH, TDS, electrical conductivity, turbidity, hardness, chloride, fluoride, nitrates, sulphate, calcium, magnesium, sodium and potassium, additionally the Productivity of permeate water is shown in Table A8 in appendix A.

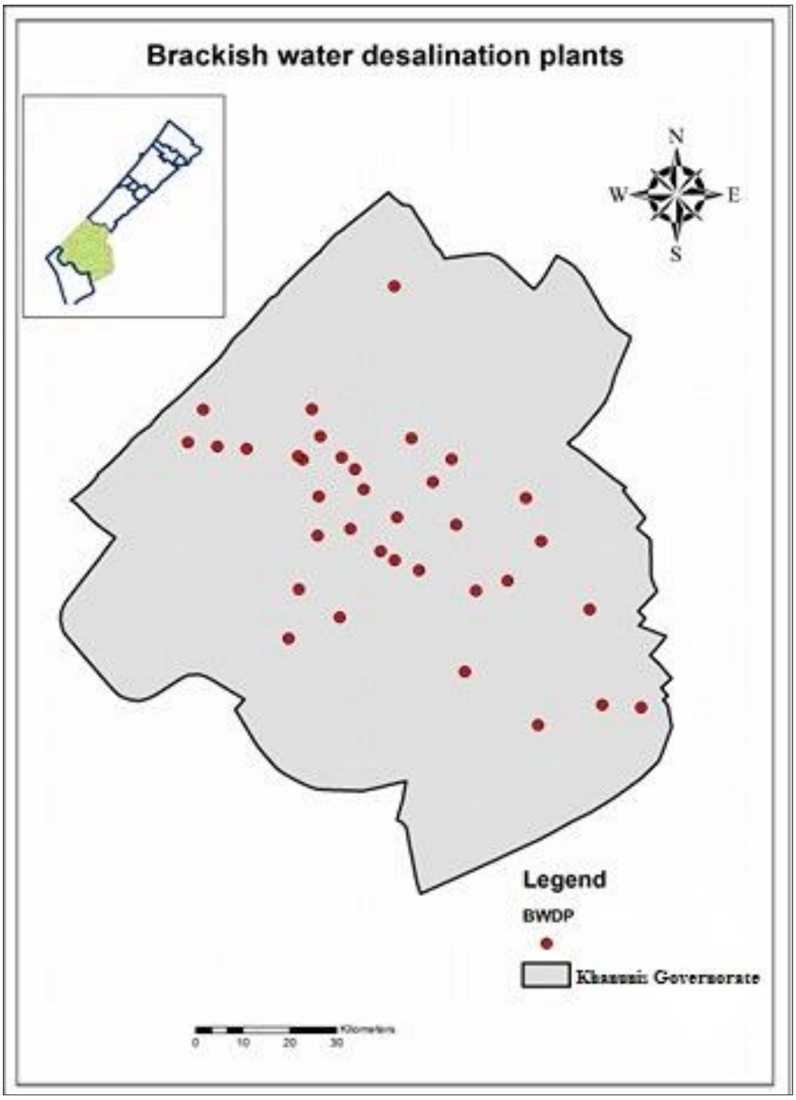


Figure (3.7): Locations of BWRO plants in Khanyounis Governorate

▪ **Brackish water desalination plants (BWDP's) in Rafah governorate**

The BWDP's in Rafah governorate are located in the different parts in Rafah governorate and distributed in 14 plant as shown in Figure 3.8. Its illuminate in Figure 3.8 indicates that the concentrate of the locations of BWDPs is close to the high population positions in Rafah governorate. Table A9 in appendix A shows parameters and measures of permeate product such: pH, TDS, electrical conductivity, turbidity, hardness, chloride, fluoride, nitrates, sulphate, calcium, magnesium, sodium and potassium , additionally the Productivity of permeate water is shown in Table A10 in appendix A.

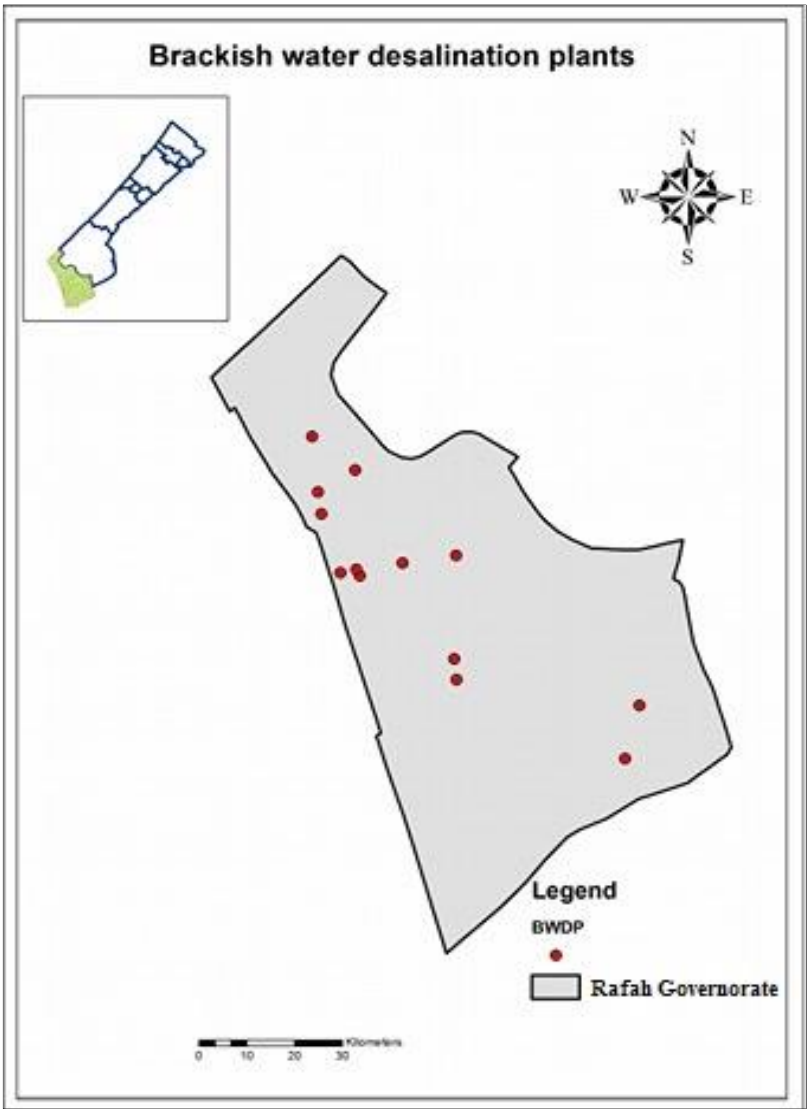


Figure (3.8): Locations of BWRO plants in Rafah governorate

3.4. Cases Study

Two cases studies have been chosen based on different flow rates and salinity of raw feed water.

The first case study represents (Yasin plant) located in north of Gaza Strip, with flow rate 960 m^3 /day and feed water salinity 1502 ppm, which is relatively large comparing with other existing plants.

The second case study represents (Al Manar Plant) located in East of Gaza City with flow rate 360 m^3/day and feed water salinity 2105 ppm.

3.4.1. Case study 1: Gaza North -Yasin plant

It was constructed in the 1st of January,2009 at private sector, the area of the station 300 m^2 , the Total Capacity Storage is estimated 300 cubic meters. it's one of the largest stations that feed the northern area of the Gaza Strip. Figure 3.10 shows the configuration, design of pumping system and plant storage.

The Water that produced is sailing for the distributors and bringing to the consumer, Table 3.5 describe the main parameters of Yasin plant.

Table (3.5): Design Characteristics of Yasin plant

Capacity of desalination plant	960 m^3/day
Feed water salinity	1502 ppm
Permeate water salinity	80 ppm
Temperature	25°
Recovery rate	75%
PH	7.7
No of stages	4
No of elements / vessel	3
No of vessels	10
Total No of elements	30
Membrane element Model	DOW-BW 30HR
Power consumption	1.0 kWhr/m^3

Figure 3.9 shows the existing design configuration of Yasin plant which consist of four stages, each pressure vessel have three membrane from DOW-BW 30HR model, that will be gathered 30 membrane in ten pressure vessel by series connection in the staging and passing in the plant system.

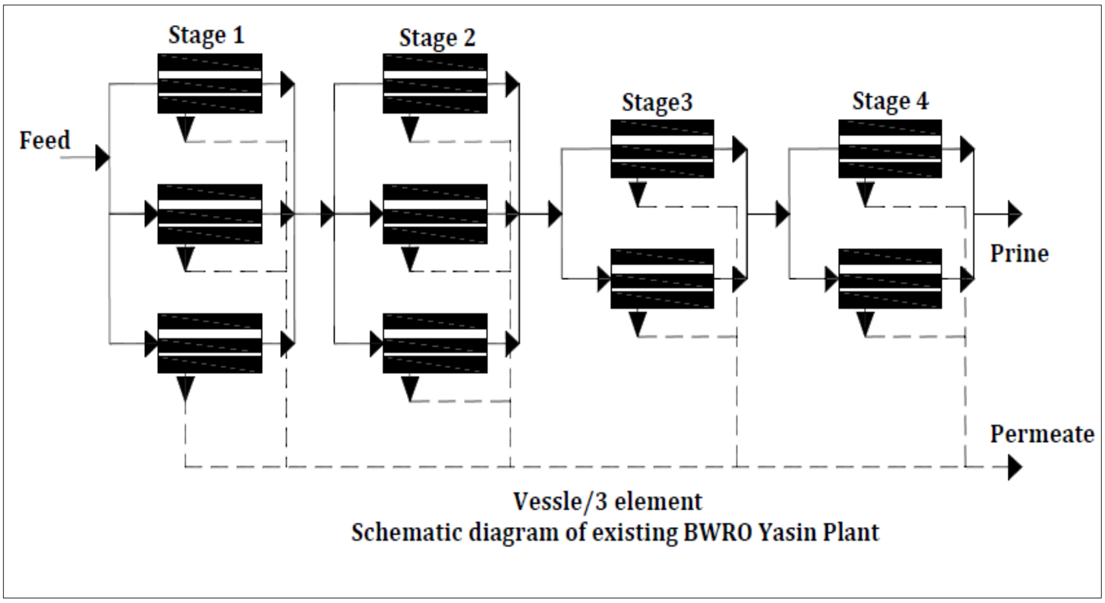


Figure (3.9): Schematic diagram of configuration in Yasin plant

Figure (3.10): Pumping and storage in Yasin plant

3.4.2. Case study 2: Gaza City –Al Manar plant

It was constructed in 1st of January, 2003 at private sector, the area of the station 200 m^2 , the estimated total capacity storage is 130 cubic meters. It's one of the largest stations that feed the Eastern area of the Gaza city. Figure 3.12 shows the configuration , the design of pumping system and the plant storage.

The Water that produced is for both self-distribution to the local consumer and sale at a wholesale price for the distributors and bringing to the consumer, Table 3.6 describe the real main parameters in Al Manar plant.

Table (3.6): Design Characteristics of Al Manar plant

Capacity of desalination plant	360 m^3/day
Feed water salinity	2105 ppm
Permeate water salinity	116 ppm
Temperature	27°
Recovery rate	70%
PH	7.5
No of stages	3
No of elements / vessel	2
No of vessels	8
Total No of elements	16
Membrane element model	Hydranautics ESPA2, CPA3
Power consumption	1.1 kWhr/m^3

Figure 3.11 shows the existing design configuration of AlManar plant which consist of three stages, each pressure vessel have two membrane from Hydranautics ESPA2, CPA3 model, that will be gathered 16 membrane in eight pressure vessel by series connection in the staging and passing in the plant system.

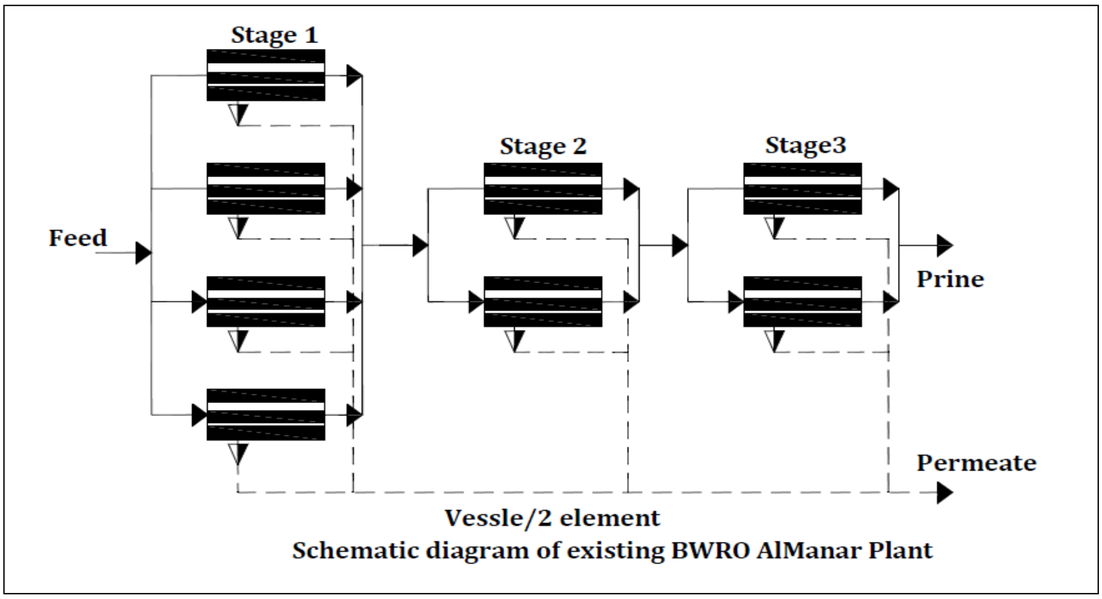


Figure (3.11): Schematic diagram configuration in Al Manar plant

Figure (3.12): Pumping and storage in Al Manar plant

Chapter 4

Analysis, Modeling and Optimization

Chapter 4 : Analysis, Modeling and Optimization

4.1. Introduction

This chapter estimates the optimization performance of BWRO system by modeling and performance evaluations of technical parameters. The optimization performance process was restrained to a limited number of stages and specifications of plant configurations, the choice of optimal operating parameters of RO system is also assured by the suitable (water resource quality, pressure, conversion, flow rate, temperature and energy system). The design and operation parameters optimization of desalination plant is made, according the desired quantity and quality of produced water will be achieved.

The specific methodology was in availability of database of BWRO membrane models and Performing the systematic generation of all feasible RO process configurations (process layout and operating conditions) with respect to project specifications and local context then optimizing the RO process configuration. a focus is made on spiral-wound membranes in accordance with actual market trends.

4.2. Design Safety Margin Considerations

- The recommended pump pressure is higher than the feed pressure by 10% of Net Driving Pressure +3 Psi (0.2 bar) for entry losses.
- A safety margin of 10% should be used for system design whenever the fouling rate cannot be predicted.
- A design should include as a contingency number of elements 10% higher than calculated.
- The feed pressure should be specified as required for the given product flow with 90% of the calculated membrane elements.

Equation 5.1 represent one of basic equations for performance evaluation of BWRO system, taking into consideration feed source, feed quality, feed/product flow, and required product quality.

$$N_E = Q_P / J_{V,ave} X (M_A)_E \quad \text{......5.1}$$

Where;

N_E = total element numbers .

Q_p = product flow rate .

J_V, ave = average permeate flux .

$(MA)_E$ = membrane area of element (as shown in data sheet).

4.3. Sizing of the BWRO System

The approximate RO system size (e.g. Number of membrane elements and pressure vessels, etc.) required to produce a quantity of product water can be determined by the following general steps:

1. Selection the membrane type and corresponding model number.

2. Selection the flux rate (l/m^2h) according to expected feed water quality.

3. Divide the desired plant capacity by the design flux rate and by membrane element surface area.

4. Divide total number of elements by the number of elements per pressure vessel. Round result up to the nearest integer.

5. Select the appropriate array to achieve the desired recovery percentage and increase number of pressure vessels if necessary.

Before utilizing the projection software, some hand calculations should be performed. These will provide a basic insight into the results of the projections, and make optimization task of the required design less time consuming.

4.4. Preliminary Design

Case Study 1: (Gaza North-Yasin plant)

It's one of the largest BWRO stations in northern area of the Gaza Strip. The average proposed capacity is 960 m^3/day.

Step 1: Consideration the source (feed) water quality.

The membrane system design depends on the available feed water and its required application. Therefore, the system design information shall be according to the feed water analysis.

A) Feed source well brackish supply water, with SDI <5.

B) Choosing overall feed water concentration in TDS =1502 ppm.

Step 2: Select the flow configuration

The standard flow configuration for water desalination where the feed volume is passed once through the system. Concentrate is directly discharged and not recirculate .

Step 3: Select membrane element type

Elements are selected according to feed water salinity, feed water fouling tendency, rejection and energy requirements. The standard element size for systems greater than 10 gpm (2.3 m^3/hr) is 8-inch in diameter and 40-inch long and Table 4.1 shows the types of different models membranes, where selected membrane is TM720-440. BW element with active membrane area of 440 ft^2 (41 m^2).

Table (4.1): Membranes Trademarks and theirs models

Element Type	Models
Filmtec: brackish water	BW30-440*I*, BW30-400/34*I*, BW30-400, BW30-365, BW30-4040, TW30-4040, BW30-2540, TW30-2540, TW30-4021, TW30-4014, TW30-2521, TW30-2514, TW30-2026.
Hydranautics: Brackish water	ESPA1-4040, ESPA2-4040, ESPA3-4040, ESPA4-4040, ESPA1, ESPA2, ESPA2-365, ESPA2+*, ESPA3, ESPA4**, ESPA-B*, CPA2-4040, CPA2, CPA3, CPA4, LFC1, LFC3, LFC3-LD.
Toray: Brackish water	TM710, TM720-370, TM720-400, TM720-430, **TM720-440.**
Koch: Brackish water	TFC-XR, TFC-XR MAGNUM, TFC-HR, TFC-HR MAGNUM, TFC-HR MEGAMAGNUM.
Toyobo Brackish water	HA3110, HA5110, HA5230, HA5330, HA8130.

Step 4: Select average membrane flux

Select the design flux, f, (gfd or l/m^2-h) based on pilot data, customer experience or the typical design fluxes according to the feed source found.

Availability and Redundancy of operation of RO system

Availability: number of operation hours in a year after reducing the downtime.

Redundancy: spare production ability.

The plant daily capacity = 960 m^3/day.

The plant yearly capacity = 960*365 = 350,400 m^3.

Number of hours in a year = 365*24 = 8,760 hour.

Plant average flow = $\frac{350,400}{8,760} = 40 \ m^3$/hour.

The number of operation hours in a year are 8, 000 hours. Where 760 hours are for downtime due to maintenance etc.).

Plant flow with availability factor = $\frac{350,400}{8000} = 43.8 \text{ m}^3$/hr

Plant flow with availability and redundancy factors of 10% = 43.8*1.1= 48.18 m^3/hr.

Step 5: Select number of stages

The number of stages defines how many pressure vessels in series that feed water will pass throughout the membranes until to system exist (permeate) and is discharge saline water as concentrate. Every stage consists of a certain number of pressure vessels in parallel. The number of stages is a function of the planned system recovery, the number of elements per vessel, and the feed water quality. The higher the system recovery and the lower the feed water quality, the longer the system will be with more elements in series. For example, a system with four 6-element vessels in the first and two 6-element vessels in the second stage has 12 elements in series. A system with three stages and 4-element vessels, in a 4:3:2 arrangement has also 12 elements in series. Typically, the number of serial element positions is linked with the system recovery and the number of stages as shown in Table 4.2 for brackish water systems.

Table (4.2): Number of stages of a brackish water system

System recovery (%)	Number of serial element positions	Number of stages (6-element vessels)
40 - 60	6	1
70 - 80	12	2
85 - 90	18	3

In this Case study No. 1 (Gaza north-Yasin plant) as shown in Table 4.2 the number of stages is 2, which the system recovery ratio more than 84 %.

Step 6: Calculate the number of elements and pressure vessels needed

1. Required permeate flow = 960 m^3/d.
2. Six-element pressure vessels to be used

- Brackish surface supply water with SDI < 5; total permeate flow = 960 m^3/d.
- TM720-440 (BW element with active membrane area of 440 ft^2 (41 m^2)).
- Recommended average flux for surface supply water feed with SDI <5 = 15.0 gfd (25 $L/m^2/h$).

- Total number of elements =

$$\frac{\left(960\ \frac{m^3}{day}\right) * \left(41.67\ \frac{L}{hr}\right) / \left(\frac{m^3}{day}\right)}{(44\ m^2)/\ (25\ L/m^2/h)} = 36 \text{ element.}$$

Number of pressure vessels:

- Total number of pressure vessels = 36/6 = 6
- Number of stages for 6-element vessels and 84% recovery = 2 according to table 4.2
- Staging ratio selected: 2:1. Appropriate stage ratio = 4:2

Step 7: Selection of high pressure feed pump

The feed Pump with capacities of 43.8 m^3/hr each and rated efficiency 80%.

Step 8: Analysis and optimization the membrane system.

The chosen system was analyzed and refined using the TORAY releases software for RO progress design and optimized to the optimal design and system configuration .

4.5. Software Design System

The design software is Called **TorayDS ,Version 2.5** was used, it's a comprehensive RO membrane projection software that allows users to design an RO system using the company's membranes. The user interface and reports provide design engineers with detailed data about the type and quantity of membranes, operating pressure, recovery and product quality (TORAY, 2016).

- **Model Description**

Among key features are: text output in multiple languages, and multiple views for detailed performance tracking; "Teach Mode" for short learning curve and quick production of required results; intuitive design screen for complex multipass systems and permeate blending options; and graphical and text-based performance projection output, including trendlines for performance vs. time and temperature (TORAY, 2016).

- **TorayDS, version 2.5**

The RO performance software TorayDS can now be used to finalize and optimize the plant design, provide details for selecting a feed pump, and provide information, It's have Design guidelines for RO system elements as described in Table 4.3. TorayDS program has four input pages, as following:

1. Project Information.
2. Feed Data (stream information and feed parameters).
3. RO Design (System Configuration ,system and cost analysis).
4. Detail Report (output).

Table (4.3): Design guidelines for Toray RO system elements

for TORAY RO Elements			Original Feed Water Source (All values are related to RO Feed before Catridge Filters)									
Design Guideline			RO Permeate	RO Permeate (High pH)	Brackish Well	Brackish Surface MF/UF	Brackish Surface	Sea Well	Sea Open	Tertiary Waste (Filtered)	Tertiary Waste MF/UF	Dimension
Parameter	Condition	Dimens										
Feed SDI @ 15 min.	Range	%/min	< 1	< 1	1 - 2	1 - 2	< 3	1 - 2	< 3	3 - 4	2 -3	
	Limit	%/min	< 1	< 1	< 3	< 3	< 4	< 3	< 4	< 5	< 3	
Typical average system flux	Range	l/m2/hr	30 39	30 39	25 32	23 29	18 23	15 19	12 16	9 13	13 19	
	Limit	l/m2/hr	< 45	< 45	< 34	< 30	< 25	< 20	< 17	< 14	< 21	
Max. lead element flux	Limit	l/m2/hr	48	48	43	39	31	35	28	19	25	
Min.Brine: Permeate Ratio, la...		-	3:1	3:1	4:1	5:1	6:1	7:1	7:1	7:1	7:1	
Max. element Recovery	Limit	%	30%	30%	20%	17%	15%	13%	13%	12%	12%	
Max.feed flow	8"	m3/hr	17	17	16	15	13	15	13	12	13	
	4"	m3/hr	3.6	3.6	3.4	3.2	2.8	3.2	2.8	2.6	2.8	
Min. brine flow	8"	m3/hr	2.4	2.4	3.0	3.0	3.6	3.6	3.6	3.6	3.6	
	4"	m3/hr	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.7	
Max. dP / vessel	Design	bar	< 3	< 3	< 3	< 3	< 2	< 3	< 2	< 2	< 2	
	Oper.limit	bar	4	4	4	4	4	4	4	4	4	
Max. dP / element	Design	bar	1	1	1	1	1	1	1	1	1	
Fouling Factor (3-5years)	Design	%	95 - 94	95 - 94	85 - 80	85 - 80	81 - 75	88 - 84	85 - 80	73 - 65	77 - 70	
Typical SP increase/year 1)	Design	%	5%	10%	10%	10%	15%	7%	7%	20%	15%	
Concentr. Polarization Index (ß)	Limit	-	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	

* different membrane types will be considered by determining the "recommended pump pressure"

1) Parameters can be adjusted in the Toray Design System design program

FLUX: ☐ gfd ☑ l/m2/h ☐ l/m2/d

FLOW: ☐ ltr/min ☑ m3/hr ☐ m3/day ☐ Gal/day ☐ Gal/min ☐ kGal/day

PRESSURE: ☑ bar ☐ MPa ☐ KPa ☐ Kg/cm2 ☐ psi

Chapter 5

Results and Discussion

Chapter 5 : Results and Discussion

5.1. Introduction

The optimization process coupled between physical parameters such as (temperature and concentration of feed, permeate flow and salinity), technical parameters such as (total product concentration of salt, total permeate flow, total plant recovery, total reject concentration of salt), parameters of each stage (number of modules, operating pressure, recovery, bypass/blend rate, product flow of module, product flow, reject flow, product concentration, Reject concentration), and economic parameters such as unit power consumption, investment costs (intake and pretreatment costs, membrane costs, pumping and power recovering system costs.

The software is realized on the basis of a physical modeling of various RO membranes performances, its input data are: capacity and life plant, total concentration of salts, and chemicals concentration of brackish water, like its temperature, and efficiencies of pumps and energy recuperation system.

The principal objective of optimizing in Toray model and other criteria and procurers is to conceive a desalination system able to minimize desalted water cost that will found in cost analysis and cost percentages in the two cases study where the aim of the research realized.

5.2. Results and Discussion of Case 1 : Yasin Plant

5.2.1. Feed water parameters BWRO Yasin Plant

To optimize the performance of BWRO systems, it is necessary to study and describe real chemical parameters of well feed water as shown in Table 5.1, After that, these data have be used as an inputs of Toray model as shown in Figure 5.1.

Table (5.1): Feed water chemical composition in BWRO Yasin plant.

Cations			
Brackish water Constituents	**mg/l**	**mEq/L**	**CaCo3 ppm**
Ca	146	7.2854	364.6
Mg	85	6.9944	350.04
Na	234	10.179	509.4
K	3.1	0.0793	3.97
Ba	1	0.0146	0.73
Sr	1	0.0228	1.14
NH4	1	0.0554	2.77
Fe	1	0.0358	1.79
Totals	**472.11**	**24.667**	**1234.44**
Anions			
Iron	**mg/l**	**mEq/L**	**CaCo3 ppm**
HCO3	165	2.7042	135.33
Cl	587	16.584	829.96
SO4	170	3.5394	177.13
NO3	100	1.6128	80.71
F	2	0.1053	5.27
Br	1	0.0125	0.63
B	1	0.0925	4.63
SiO2	2	0.0333	1.67
PO4	0.5	0.0158	0.79
Totals	**1029.5**	**24.7**	**1234.8**

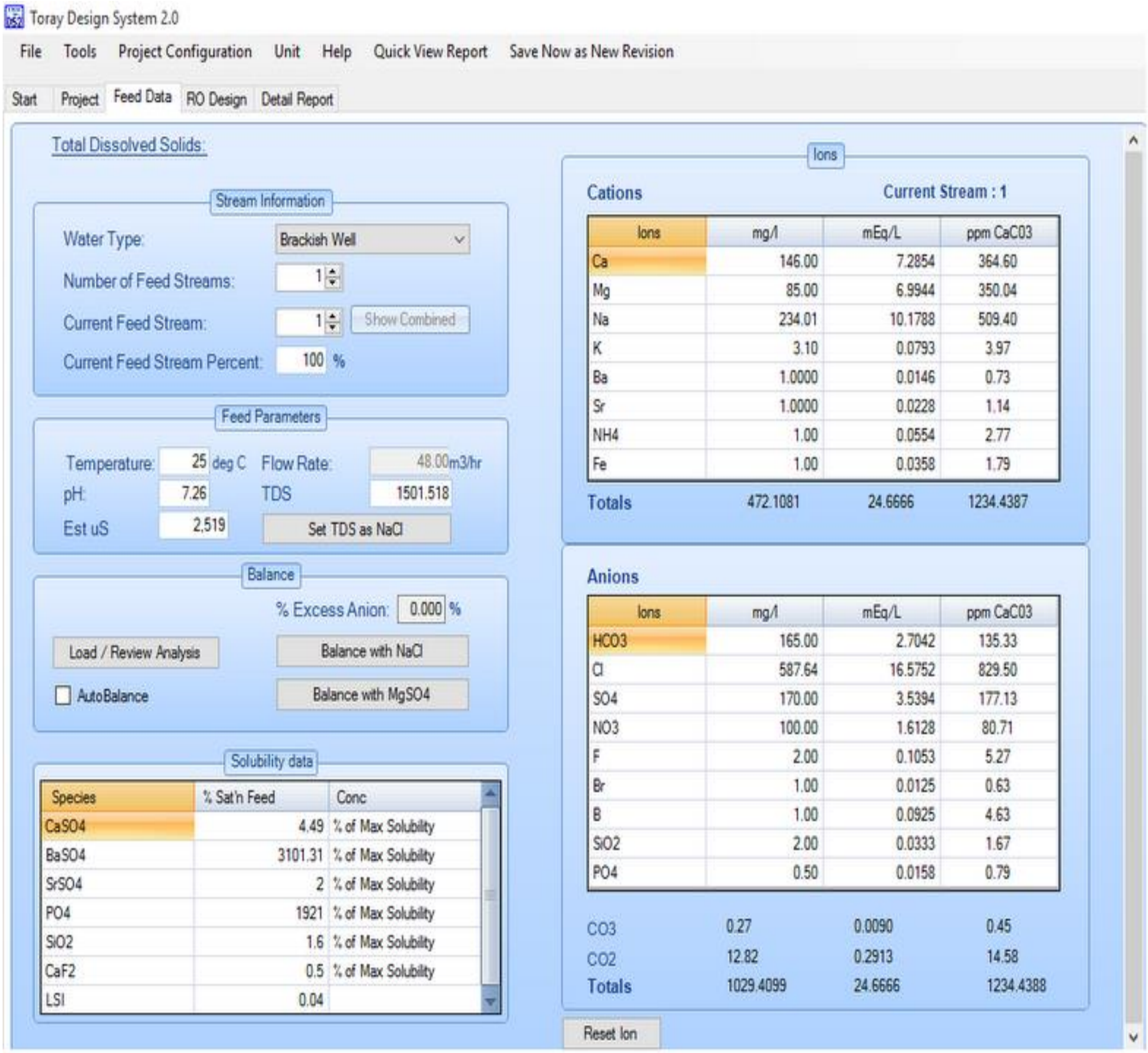


Figure (5.1): Feed water composition input in BWRO Yasin plant

5.2.2. Configurations of proposed BWRO system in Yasin Plant

The optimization performance of BWRO systems evaluated with different design configurations and membrane elements as shown in Figure 5.2 (Toray membrane - TM720-440) and working under varying operational parameters where recovery rate is 84%, and flow feed water 45 m^3/hr as shown in Figure 5.3.

Two stages contains four pressure vessels in first stage and two pressure vessels in the second stage where each pressure vessel have six elements (Tapered Configuration) and the chemical result and other parameters as shown in Figure 5.4. and results Toray in appendix B.

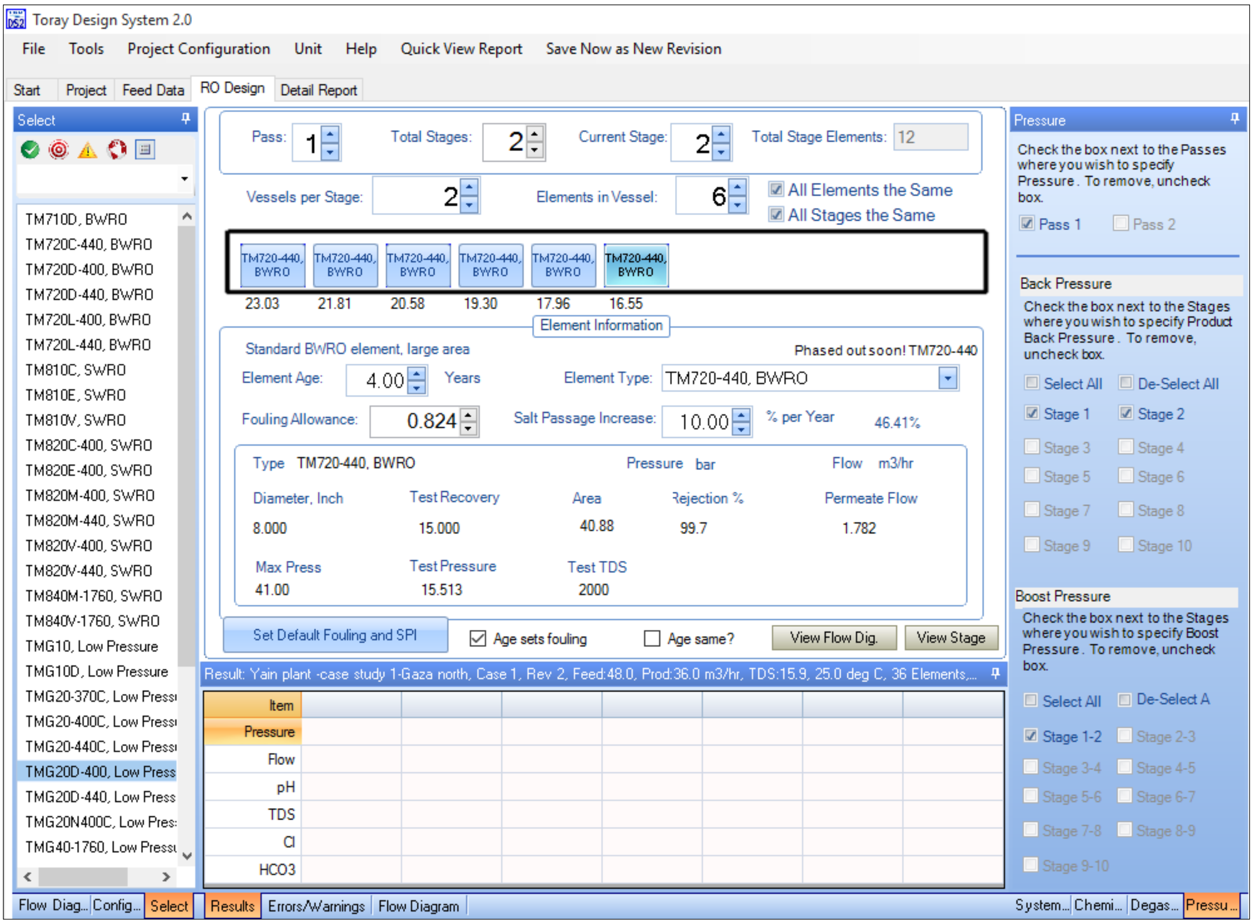


Figure (5.2): System design configuration BWRO Yasin plant

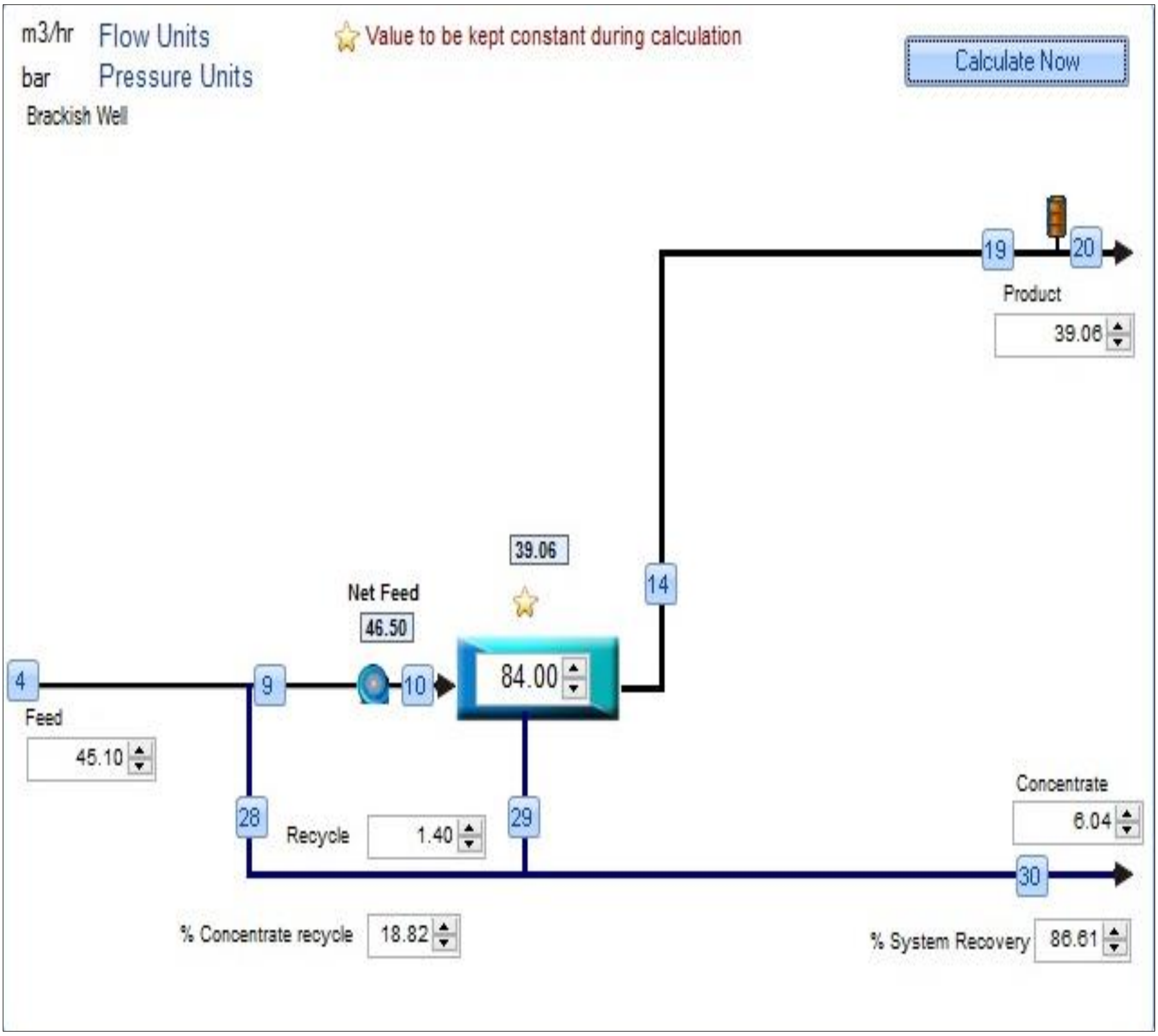
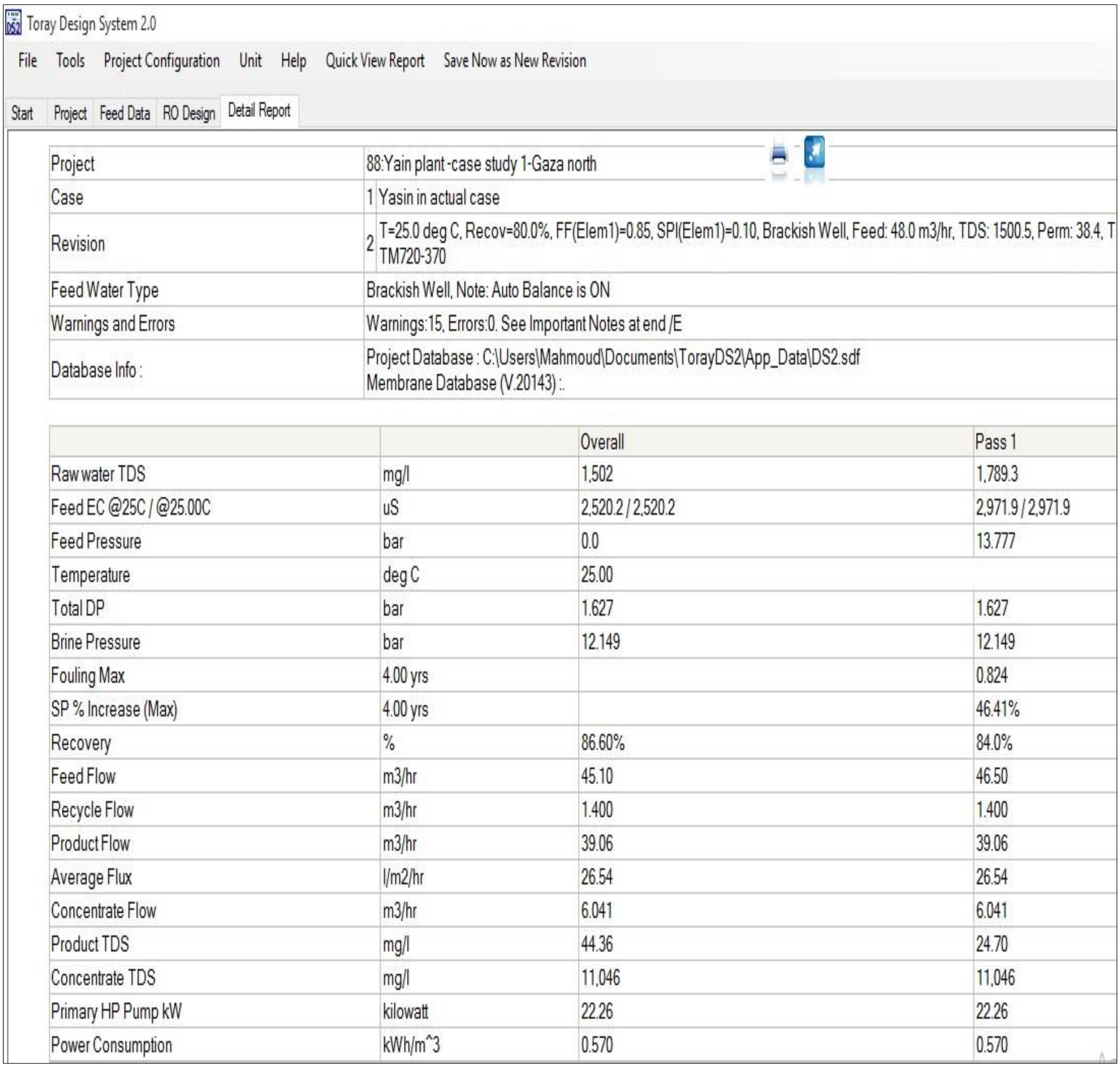


Figure (5.3): Schematic diagram of design configuration in BWRO Yasin plant.

The output of optimized Toray model in Yasin Plant

This output table shows the results by Toray of optimized model for BWRO in Yasin Plant as shown in Figure 5.4, where its explain feed flow, product flow, product TDS, concentrate TDS, and power consumption.



Toray Design System 2.0

File Tools Project Configuration Unit Help Quick View Report Save Now as New Revision

Start Project Feed Data RO Design Detail Report

Project	88:Yain plant -case study 1-Gaza north
Case	1 Yasin in actual case
Revision	2 T=25.0 deg C, Recov=80.0%, FF(Elem1)=0.85, SPI(Elem1)=0.10, Brackish Well, Feed: 48.0 m3/hr, TDS: 1500.5, Perm: 38.4, T TM720-370
Feed Water Type	Brackish Well, Note: Auto Balance is ON
Warnings and Errors	Warnings:15, Errors:0. See Important Notes at end /E
Database Info :	Project Database : C:\Users\Mahmoud\Documents\TorayDS2\App_Data\DS2.sdf Membrane Database (V.20143) :.

		Overall	Pass 1
Raw water TDS	mg/l	1,502	1,789.3
Feed EC @25C / @25.00C	uS	2,520.2 / 2,520.2	2,971.9 / 2,971.9
Feed Pressure	bar	0.0	13.777
Temperature	deg C	25.00	
Total DP	bar	1.627	1.627
Brine Pressure	bar	12.149	12.149
Fouling Max	4.00 yrs		0.824
SP % Increase (Max)	4.00 yrs		46.41%
Recovery	%	86.60%	84.0%
Feed Flow	m3/hr	45.10	46.50
Recycle Flow	m3/hr	1.400	1.400
Product Flow	m3/hr	39.06	39.06
Average Flux	l/m2/hr	26.54	26.54
Concentrate Flow	m3/hr	6.041	6.041
Product TDS	mg/l	44.36	24.70
Concentrate TDS	mg/l	11,046	11,046
Primary HP Pump kW	kilowatt	22.26	22.26
Power Consumption	kWh/m^3	0.570	0.570

Figure (5.4): Main characteristics and parameters of BWRO in Yasin plant

5.3. Relationships between the parameters in the design model in Yasin plant (BWDP)

5.3.1. Recovery rate and Brine/Product Concentration Ratio

The relation between Recovery rate and Brine/Product Ratio is decreasing, as shown in Figure 5.5, where the modeling cases describe the effect of the recovery rate on the Brine/Product Ratio in Yasin plant modeling, leading to the optimal Brine/Product Ratio equal or more than 4 as a range of (TM720-440) membrane ,the optimal value of the recovery rate which adjust with the suitable Brine/Product Ratio is 84 % .

Where Brine/Product Ratio is design condition in Toray which it's limited in (4 ratio and more) .

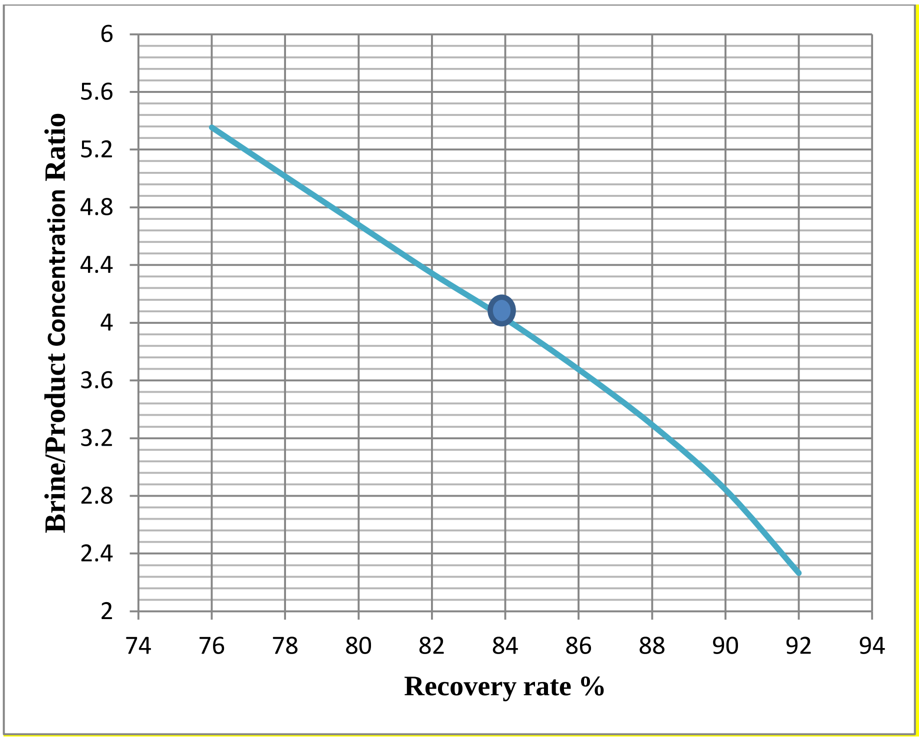


Figure (5.5): Relationship between recovery rate and Brine/Product Ratio (Yasin Plant)

5.3.2. Recovery rate and Feed Pressure

The relation between Recovery rate and Feed Pressure is increasing because of the increasing of Brine/Product Ratio and reaching to optimal ratio as shown in Figure 5.6, but it's clear that the certain feed pressure related in the optimized molding in Yasin plant is 13.59 bar.

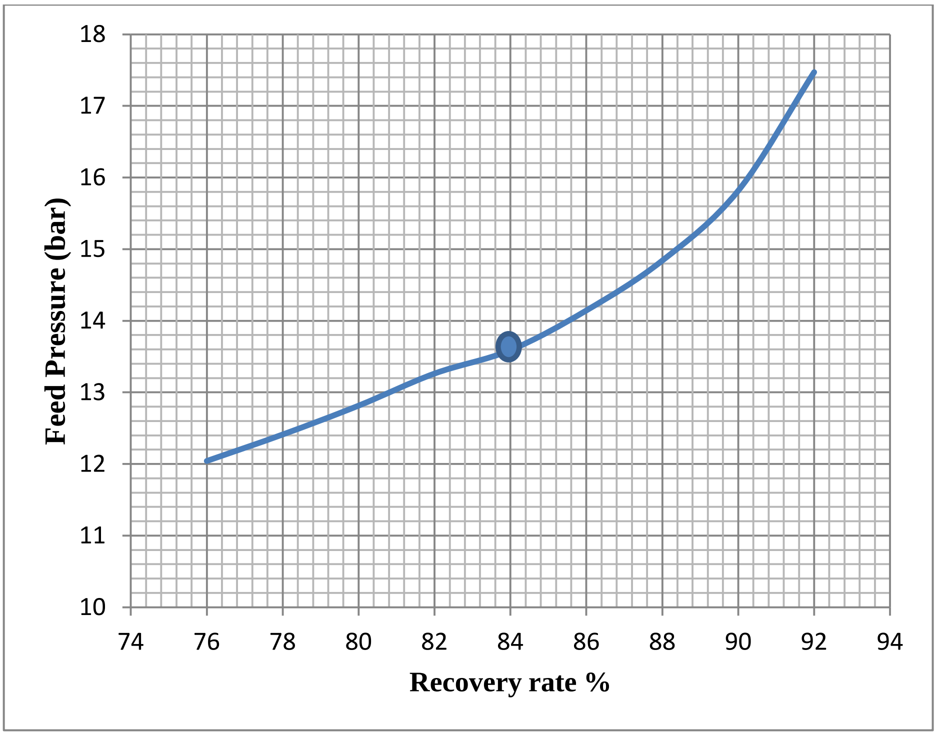


Figure (5.6): Relationship between recovery rate and Feed Pressure (Yasin Plant)

5.3.3. Feed Pressure and power consumption

The relation between feed pressure and power consumption is increasing as shown in and Figure 5.7, where the power consumption affect with the increasing of the feed pressure which related with the recovery rate.

It's found the optimal power consumption in Yasin plant is 0.562 kWh/m^3 , where having the suitable rang of quantity and quality for the using membrane (TM720-440).

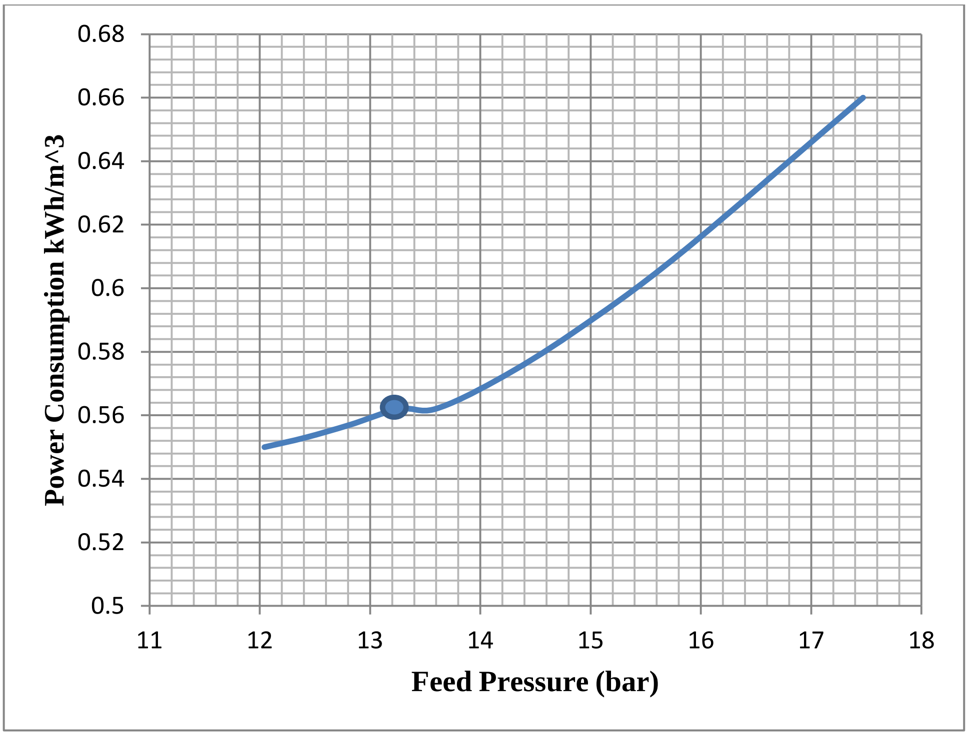


Figure (5.7): Relationship between recovery rate and Power Consumption (Yasin Plant)

5.3.4. Recovery rate and Product Flow

The relation between recovery rate and product flow is increased as shown in Figure 5.8, which having the allowed percentage and range of recovery rate and pressure respectively, which is the optimal flow rate is 39.06 m^3/hr, and this flow rate is the optimal and suitable rate for the chosen design membrane in the best case.

The data source in these figures as result of design cases to reach the optimal case from the desirable objective function in the best design.

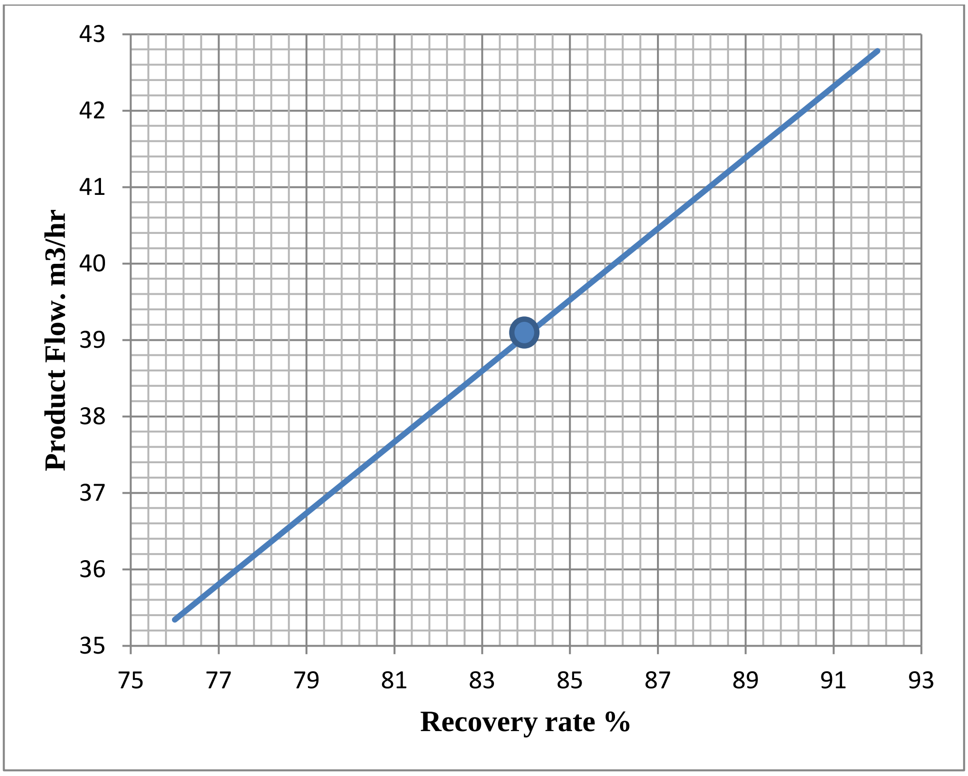


Figure (5.8): Relationship between recovery rate and Product Flow (Yasin Plant)

5.4. Comparison between the Actual and Optimized Model in Yasin Plant

As shown in Figure 5.2, Figure 5.9 and Table 5.6, the system configuration in case 1 consists of 36 membrane elements inside 6 pressure vessels where each vessel consists of 6 elements , four pressure vessel in first stage and tow pressure vessel in the second stage, the membrane element type TM720-440 (Active area = 41.9 m^2, flow rate 42.6 m^3/day), with flow factor 0.85. and appendix B shows more details.

The energy consumption of the system is 0.57 kWhr /m^3 as shown in Toray results in Figure 5.4 and the type of membrane (TM720-440), system configuration and recovery rate leading to reduction energy consumption (0.57 kWhr /m^3) and enhanced the permeate quality (44 ppm).

Table (5.2): Comparison between the actual and optimized model in Yasin plant

Design characteristics	**Real parameters**	**Optimized parameters**
Capacity of desalination plant	960 m^3/day	960 m^3/day
Feed water salinity	1500 ppm	1502 ppm
Permeate water salinity	80 ppm	44 ppm
Temperature	25^o	25^o
Recovery rate	75%	84%
PH	7.7	7.5
No of stages	4	2
No of elements / vessel	3	6
No of vessels	10	6
Total No of elements	30	36
Membrane element Model	DOW-BW 30HR	TM720-440
Power consumption	1.0 kWhr /m^3	0.57 kWhr/m^3
Membrane Age	1.2 year	4 year

Then it have recycling 18.82% from the concentrate flow about 1.4 m^3/hr, leading to recovery ratio 86.61%, as a whole system that will be useful by decreasing the brine flow which draing to sewerage.

The core element (membrane) characteristics playing main role in life time cycle of system and control fouling, flow rate of water and salt rejection and passage.as shown in Figure 5.3.

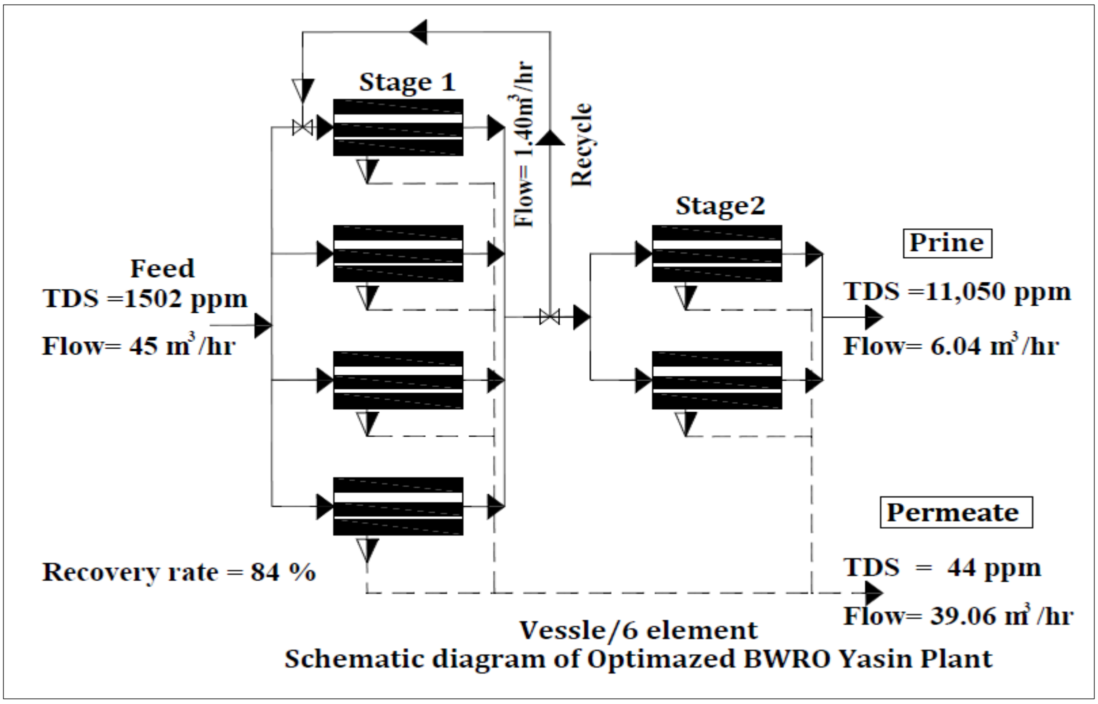


Figure (5.9): Schematic diagram of optimized design in Yasin plant

5.5. Cost analysis of unit cost in Yasin Plant (PWDP)

There are many factors which has an effect on water production cost of the desalination plant as shown in cost analysis in Table 5.3. These are as following:

1. Capital expense: which includes vessels and membranes, operating expense which includes pumping power and chemical operating at certain interest rate (4% - 7%) as percentage for small brackish water desalination plants and project life as assumption 15 year (Al Karapholi, et al., 2012) ,
2. labor.
3. Maintenance and parts.
4. Amortization expense which includes well water cost and licensing and rents
5. Membrane replacement.

The resulted unit cost in the analysis cost in Yasin plant is 0.59 $/m^3 ,these value has reduced by 43 % comparing with 1.04 US$/m^3 as unit cost in Table 3.4 in the existing plants in chapter three.

Net present value is used in formula by excel sheet and resulted unit cost in US$/m^3 in Cost analysis of Yasin plant.

Table (5.3): Cost analysis per unit cost of the optimized case in Yasin plant

Plant Economic Variables	**Yasin plant**				
Project Life (years)	15				
Interest rate (%)	5				
Power cost ($/kWh)	0.14				
Capital Expense					
	Total No	Per year	cost ($)	**Annual cost ($)**	**Total annual cost ($)**
Pressure vessels	6	1.2	2500	3500	
Total elements	36	9	1050	9450	
Pre-treatment (membrances)		24	450	10800	23750
Operating Expense					
	m3/year	Specific energy (kWh/m³)	Unit energy cost ($/kWh)		
Pumping power	312000	0.57	0.14	24,897.60	
Energy expense NPV ($)				258,428.57	17,228.57
Chimichals Operating	m3/year	Rang (litre/m3)	Cost($/litre)		
	312000	0.02	4.2	26,208.00	
Chimichals Operating NPV ($)				272,030.08	18,135.34
	Man power	Month number	$/year		
Labor	2	12	900	10,800.00	
Labor NPV ($)				112,100.31	7,473.35
Miantinance and parts	1	12	850	10,200.00	
Miantinance and parts NPV ($)				105,872.51	7,058.17
Amortization Expense					
Class	Well feed water m3/year		cost ($)/m3		
Well water expence	384000		0.4	153,600.00	
Well water expenceNPV ($)				1,594,315.5	106,287.70
			$/year		
Licencing and returns			5500	5,500.00	
Licencing and returns NPV ($)				57,088.12	3,805.87
Membranes replacement	No of elemnt	Element /year	Replacement price ($/element)		
Class	36	12	150	1,800.00	
Membranes replacement NPV ($)				18,683.38	1,245.56
			Total annual cost ($)		184,985
			Annual Product(m3)		312,000
			Unit Cost NPV ($/m3)		0.59

- **Costs percentages in Yasin plant**

The major percentage cost as shown in Table 5.4 and Figure 5.10 is Amortization Expense 59.5 % which the costs of water well, licensing and returns, then the Operating Expense is 19.12 %, and remains percentage are distributed in the other costs.

Table (5.4): Costs percentages in Yasin plant

Class	Cost $/year	Percentage %
Capital Expense	23750	12.9
Operating Expense	35,363.91	19.12
Labor	7,473.35	4.04
Maintenance and parts	7,058.17	3.82
Amortization Expense	110,093.57	59.52
Membranes replacement	1,245.56	0.67
Total annual cost ($)	**184984.56**	**100**

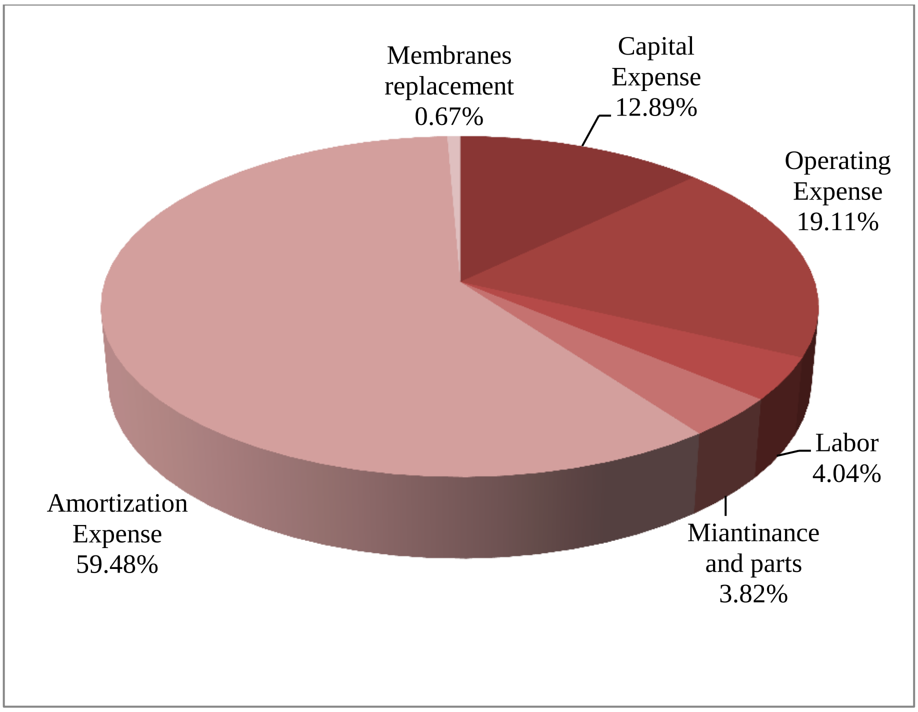


Figure (5.10): Costs percentages in Yasin plant

5.6. Results and Discussion of Case 2 : AlManar plant

5.6.1. Feed water parameters in BWRO AlManar Plant

To optimize the performance of BWRO systems, it is necessary to study and describe real chemical parameters of well feed water as shown in Table 5.5. After that, these data have be used as an input of Toray model as shown in Figure 5.11.

Table (5.5): Feed water chemical composition in Al-Manar Plant.

Cations			
Brackish water Constituents	**mg/l**	**mEq/L**	**CaCo3 ppm**
Ca	70	3.493	174.81
Mg	93	7.6527	382.98
Na	520	22.6349	1132.7
K	4	0.1023	5.12
Ba	1	0.0146	0.73
Sr	1	0.0228	1.14
NH4	0.5	0.0277	1.39
Fe	1	0.0358	1.79
Totals	690.87	33.9838	1700.72
Anions			
Iron	**mg/l**	**mEq/L**	**CaCo3 ppm**
HCO3	246	4.0316	201.76
Cl	833	23.519	1177.01
SO4	200	4.164	208.39
NO3	130	2.0966	104.92
F	1	0.0526	2.63
Br	1	0.0125	0.63
B	0.5	0.0462	2.31
SiO2	1	0.0166	0.83
PO4	1	0.0316	1.58
Totals	1414.32	33.9707	1700.06

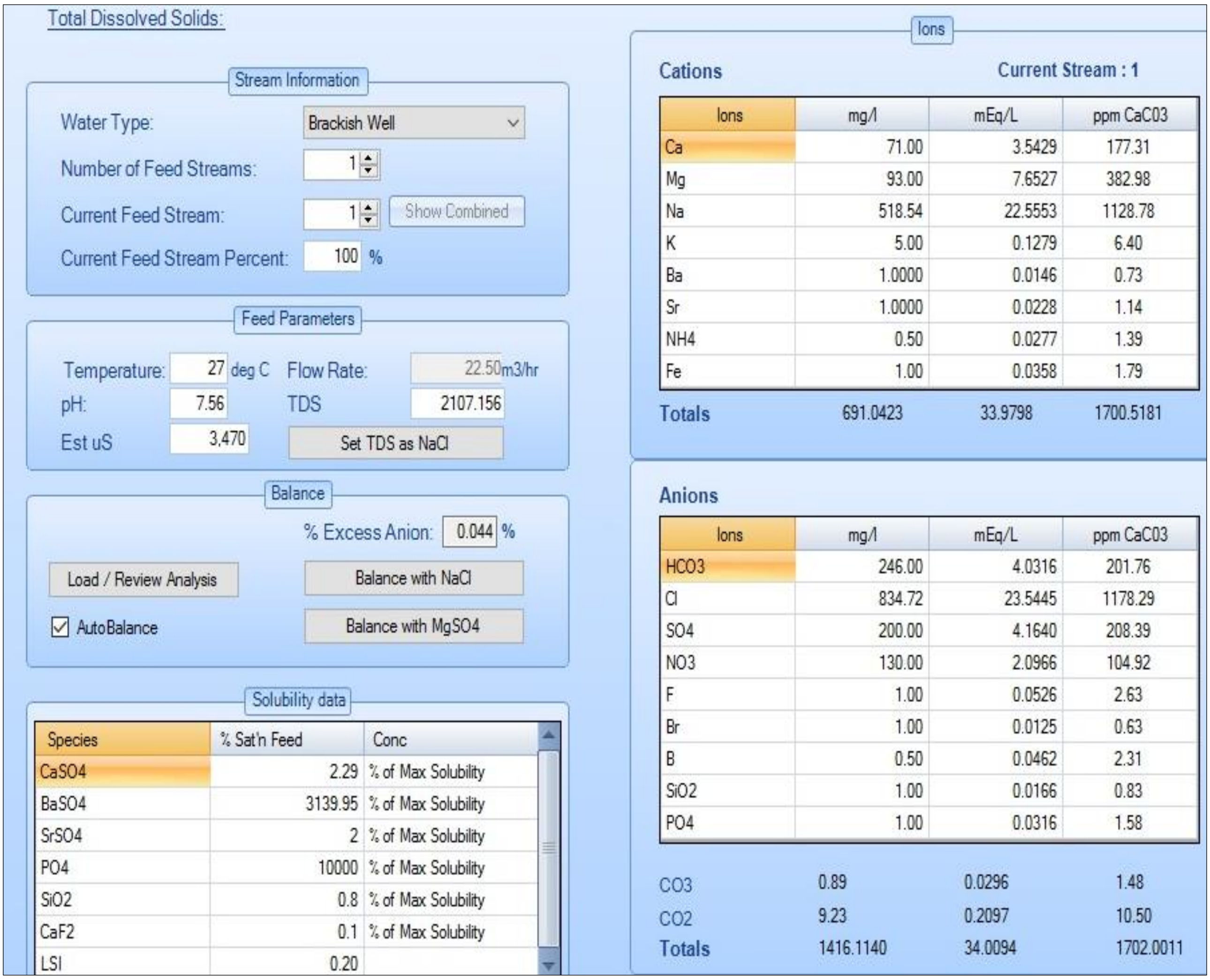


Figure (5.11): Feed water composition input in BWRO Al-Manar Plant

5.6.2. Configurations of proposed BWRO system in Al-Manar plant

The optimization performance of BWRO systems evaluated with different design configurations and membrane elements as shown in Figure 5.12 (Toray membrane - TM720-440) and working under varying operational parameters where recovery rate is 75%, and feed flow water 23 m^3/hr as shown in Figure 5.13.

Three stages contains three pressure vessels in first stage, two pressure vessels in the second stage and one pressure vessel in the third stage, where each pressure vessel have three elements (Tapered Configuration) and the chemical result and other parameters as shown in Figure 5.14 and results Toray in appendix B.

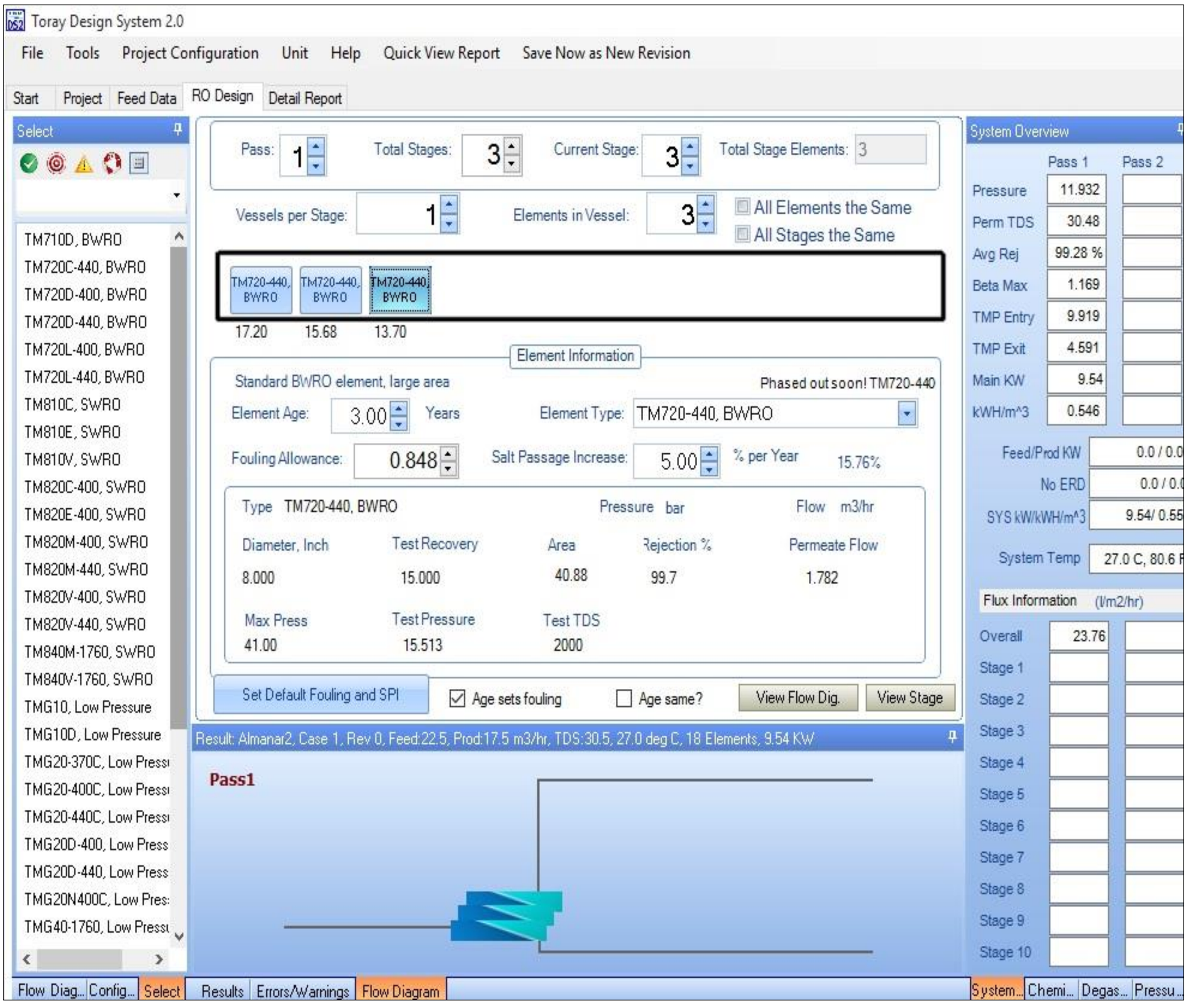


Figure (5.12): System design configuration in BWRO Al-Manar Plant.

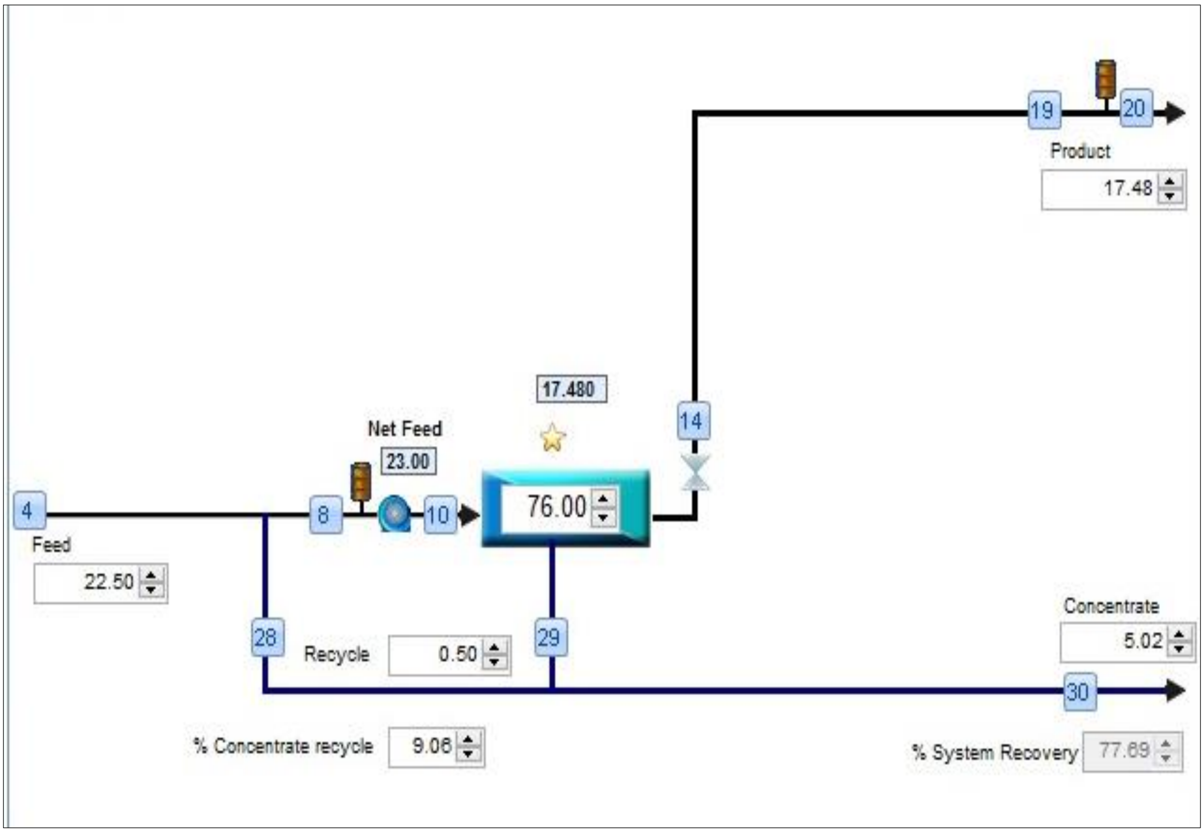


Figure (5.13): Schematic diagram of design configuration in BWRO Al-Manar Plant

The output of optimized Toray model in AlManar Plant

This output table shows the results by Toray of optimized model for BWRO in AlManar Plant as shown in Figure 5.14, where its explain feed flow, product flow, product TDS, concentrate TDS, and power consumption.

Toray Design System 2.0

File Tools Project Configuration Unit Help Quick View Report Save Now as New Revision

Start Project Feed Data RO Design Detail Report

'TORAY' Innovation by Chemistry

System Overview Report

Project	91:Almanar2
Case	1 2105 TDS AND RR%75
Revision	0 15% Recov, 1 Pass, RO Permeate, Feed: 6.7 m3/hr, TDS: 3888.9, Perm: 1.0, TDS: 22, Tot Elem: 1, 1st Elem: TM720-400
Feed Water Type	Brackish Well, Note: Auto Balance is ON
Warnings and Errors	Warnings:11, Errors:0. See Important Notes at end /E
Database Info :	Project Database : C:\Users\Mahmoud\Documents\TorayDS2\App_Data\DS2.sdf Membrane Database (V.20143) :.

		Overall	Pass 1
Raw water TDS	mg/l	2,106.1	2,275.1
Feed EC @25C / @27.00C	uS	3,468 / 3,624.2	3,730.6 / 3,898.5
Feed Pressure	bar	0.0	11.943
Temperature	deg C	27.00	
Total DP	bar	0.935	0.935
Brine Pressure	bar	11.007	11.007
Fouling Max	4.00 yrs		0.824
SP % Increase (Max)	4.00 yrs		46.41%
Recovery	%	77.69%	76.0%
Feed Flow	m3/hr	22.50	23.00
Recycle Flow	m3/hr	0.500	0.500
Product Flow	m3/hr	17.479	17.479
Average Flux	l/m2/hr	23.75	23.75
Concentrate Flow	m3/hr	5.021	5.021
Product TDS	mg/l	39.60	31.22
Concentrate TDS	mg/l	9,370	9,370
Primary HP Pump kW	kilowatt	9.546	9.546
Power Consumption	kWh/m^3	0.546	0.546

Figure (5.14): System design configuration in BWRO Al-Manar Plant

5.7. Relationships between the parameters in the design model in Al Manar plant BWDP

5.7.1. Recovery rate and Brine/Product Concentration Ratio

The relation between Recovery rate and Brine/Product Ratio is decreasing as shown in Figure 5.15 , where the modeling cases describe the effect of the recovery rate on the Brine/Product Ratio in AlManar plant modeling, leading to the optimal Brine/Product Ratio equal or more than 4 as range of (TM720-440) membrane, the optimal value of the recovery rate which adapt with the suitable Brine/Product Ratio is 76 % .

Where Brine/Product Concentration Ratio is design condition in Toray which it's limited in (4 ratio and more) .

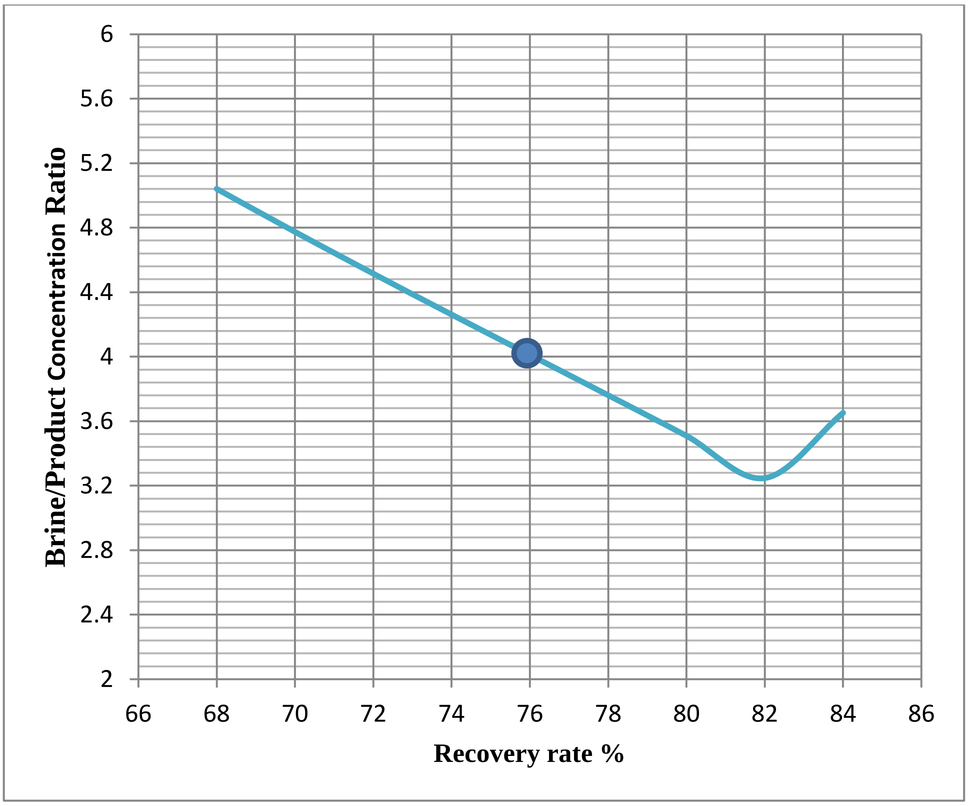


Figure (5.15): Relationship between recovery rate and Brine/Product Ratio(Al Manar Plant)

5.7.2. Recovery rate and Feed Pressure

The relation between recovery rate and and feed Pressure is increasing because of the increasing of Brine/Product Ratio and reaching to optimal ratio as shown in Figure 5.16, but it's clear that the certain feed pressure related in the optimized moldel in Al Manar plant is 11.947 bar.

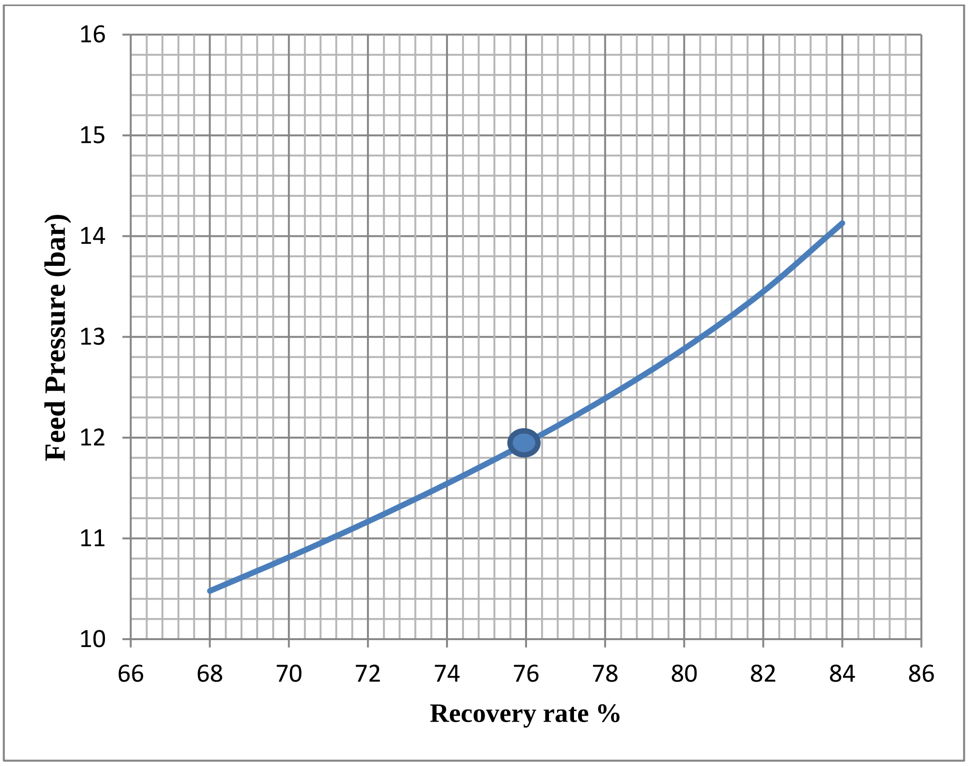


Figure (5.16): Relationship between recovery rate and Feed Pressure (Al Manar Plant)

5.7.3. Feed Pressure and power consumption

The relation between feed pressure and power consumption is increasing as shown in Figure 5.17, where the power consumption affect with the increasing of the feed pressure which related with the recovery rate.

It's found the optimal power consumption in Al Manar plant is 0.546 kWh/m^3 , where having the suitable rang of quantity and quality for the used membrane (TM720-440).

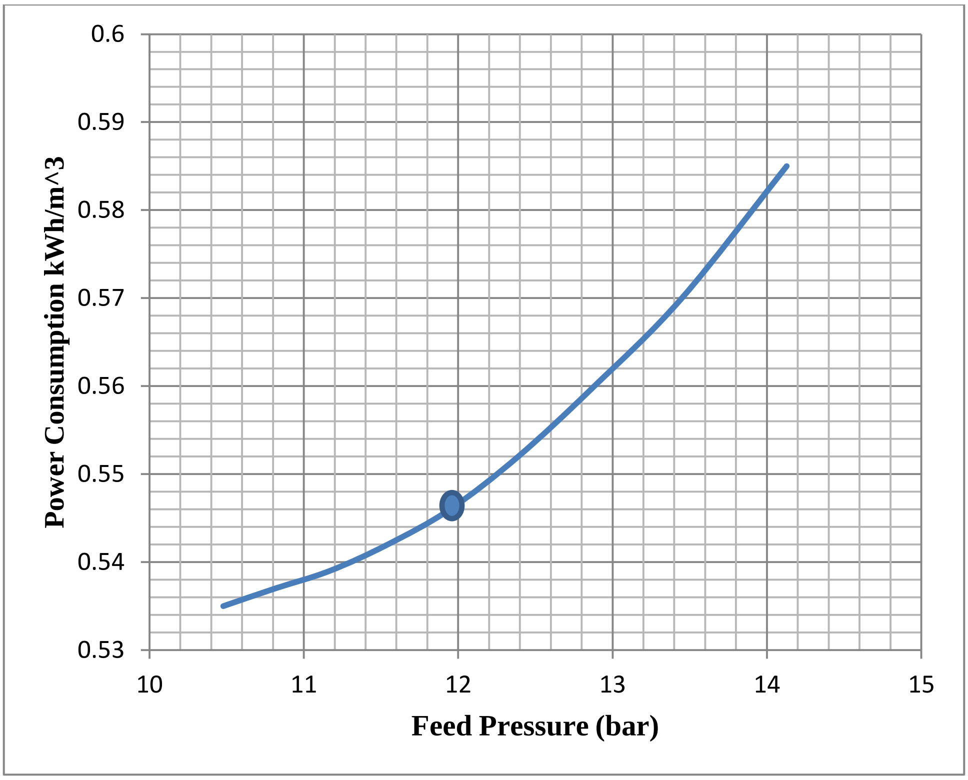


Figure (5.17):Relationship between recovery rate and Power Consumption (Al Manar Plant)

5.7.4. Recovery rate and Product Flow

The relation between recovery rate and product flow is increased as shown in Figure 5.18, which having the allowed percentage and range of recovery rate and pressure respectively, which is the optimal flow rate is 17.479 m^3/hr, and this flow rate is the optimal and suitable rate for the chosen design membrane in the best case.

The data source in these figures as result of design cases to reach the optimal case from the desirable objective function in the best design.

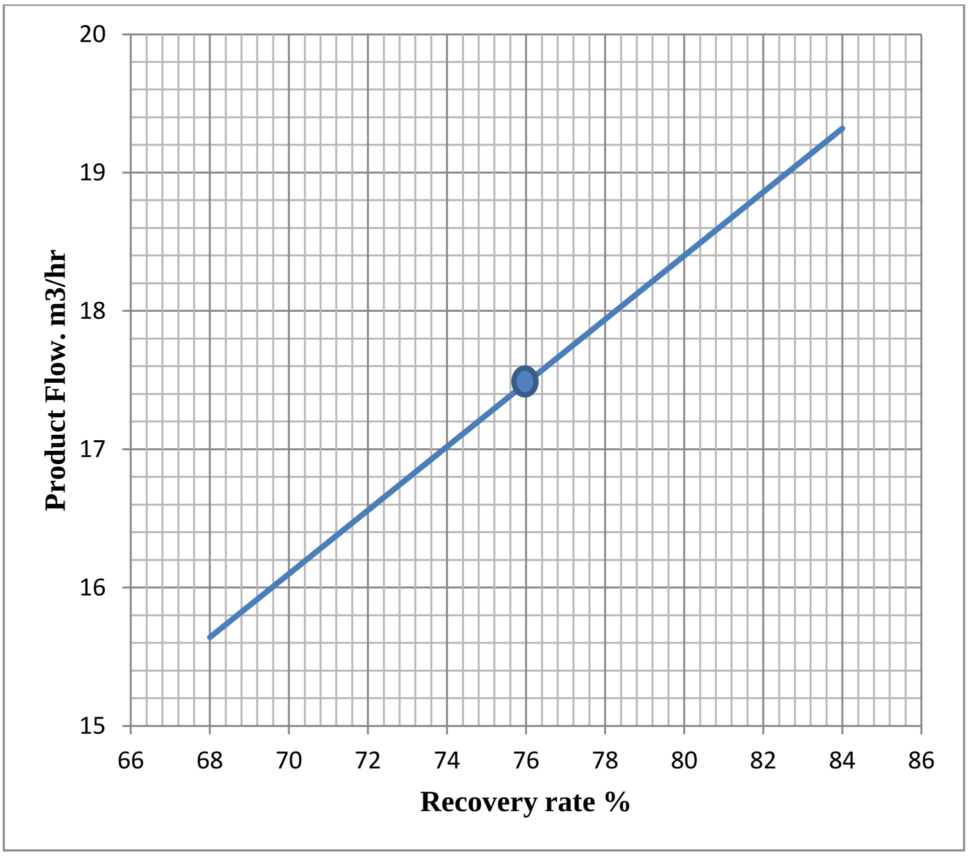


Figure (5.18): Relationship between recovery rate and Product Flow (Al Manar Plant)

5.8. Comparison between the actual and optimized model in Al-Manar plant

As shown in Table 5.6 and Figure 5.19, the system configuration in case tow consist of 18 membrane elements in 6 pressure vessels where each vessel consists of 3 elements , three pressure vessel in first stage, tow pressure vessel in the second stage and one pressure vessel in the third stage.

The membrane element type TM720-440 (Active area = 41.9m^2, flow rate 42.6 m^3/day), with flow factor 0.85. and appendix B shows more details.

The energy consumption of the system is 0.57 kWhr /m^3 as shown in Toray results in Figure 5.15 and the type of membrane (TM720-440), system configuration, and recovery rate leading to reduction energy consumption (0.57 kWhr/m3) and enhanced the permeate quality(40 ppm).

Table (5.6): Comparison between the actual and optimized model in Al-Manar plant

Design characteristics	**Real parameters**	**Optimized parameters**
Capacity of desalination plant	360 m^3/day	360 m^3/day
Feed water salinity	2105 ppm	2105 ppm
Permeate water salinity	116 ppm	40
Temperature	27^o	27^o
Recovery rate	68%	76%
PH	7.5	7.8
No of stages	3	3
No of elements / vessel	2	3
No of vessels	8	6
Total No of elements	16	18
Membrane element Model	Hydranautics ESPA2,CPA3	TM720-440

Power consumption	1.1 kWhr/m^3	0.55 kWhr/m^3
Membrane age	1 year	3 year

Then it have recycling 9.1% from the concentrate flow about 0.5 m^3/hr, leading to recovery ratio 77.7 % as by whole system that will be useful by decreasing the brine flow which draing to sewerage.

The core element (membrane) characteristics playing main role in life time cycle of system (where the age increased from 1 year to 3 years) and control fouling, flow rate, salt rejection as shown in Figure 5.14.

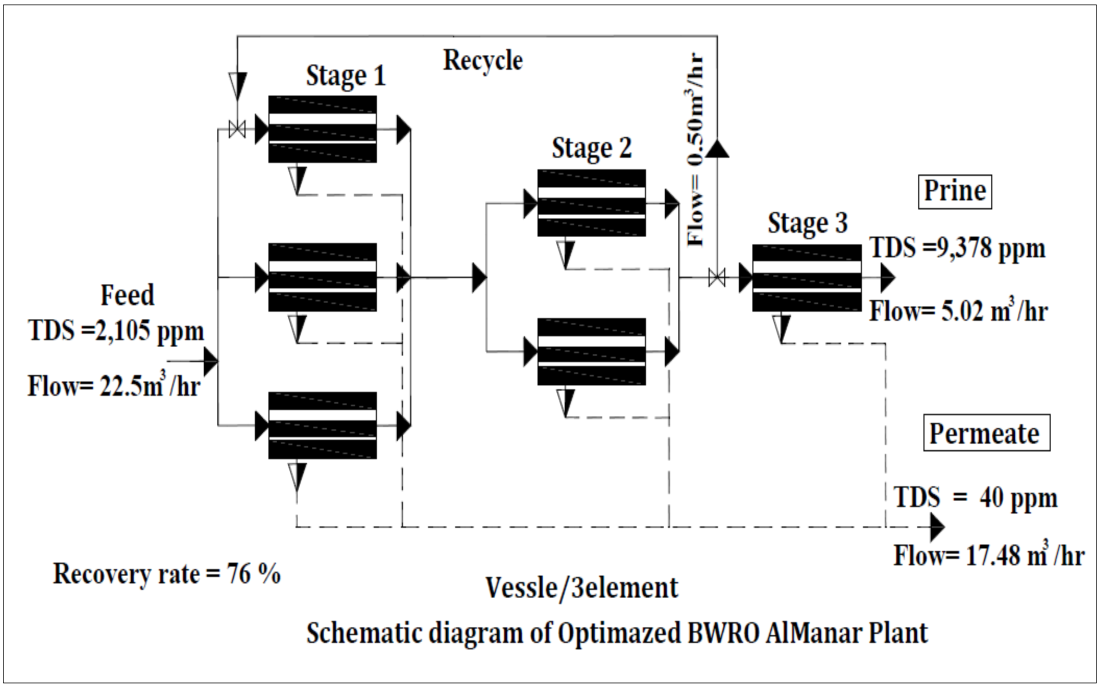


Figure (5.19): Schematic diagram of optimized design in AlManar plant

5.9. Cost analysis of unit cost in AlManar Plant

There are many factors which has an effect on water production cost of the desalination plant as shown in cost analysis in Table 5.7. These are as following:

1. Capital expense: which includes vessels and membranes, operating expense which includes pumping power and chemical operating at certain interest rate (4% - 7%) as percentage for small brackish water desalination plants and project life as assumption 15 year (Al Karapholi, et al., 2012) ,
2. labor.
3. Maintenance and parts.

4. Amortization expense which includes well water cost and licensing and rents
5. Membrane replacement .

The resulted unit cost in the analysis cost in Al Manar plant is 0.65 US$/$m^3$,these value has reduced by 37 % comparing with 1.04 US$/$m^3$ as unit cost in Table 3.4 in the existing plants in chapter three.

Net present value is used in formula by excel sheet and resulted unit cost in US$/$m^3$ in Cost analysis of Al Manar plant.

Table (5.7): Cost analysis per unit cost of the optimized case in in Al Manar plant

Plant Economic Variables	Al Manar plant				
Project Life (years)	15				
Interest rate (%)	5				
Power cost ($/kWh)	0.14				
Capital Expense					
	Total No	Per year	cost ($)	**Annual cost ($)**	**Total annual cost ($)**
Pressure vessels	6	1.2	1250	3500	
Total elements	18	6	1050	6300	
Pre-treatment (membrances)		12	450	5400	15200
Operating Expense					
	m3/year	Specific energy (kWh/m3)	Spacific energy cost ($/kWh)		
Pumping power	139840	0.55	0.14	10767.68	
Energy expense NPV ($)				$111,764.84	7,450.99
Chimichals Operating	m3/year	Rang (litre/m3)	Cost($/litre)		
	139840	0.02	4.2	11746.56	
Chimichals Operating NPV ($)				$121,925.28	8,128.35
	Man power	Month number	$/year		
Labor	1	12	500	6000	
Labor NPV ($)				$62,277.95	4,151.86
Miantinance and parts	1	12	850	10200	
Miantinance and parts NPV ($)				$105,872.51	7,058.17
Amortization Expense					
Class	Well feed water m3/year		cost ($)/m3		
Well water expence	184000		0.35	64400	
Well water expenceNPV ($)				$668,449.98	44,563.33
			$/year		
Licencing and returns			5500	5500	
Licencing and returns NPV ($)				$57,088.12	3,805.87
Membranes replacement	No of elemnt	Element /year	Replacement price ($/element)		
Class	18	6	150	900	
Membranes replacement NPV ($)				$9,341.69	622.78
			Total annual cost ($)		90,981
			Annual Product(m3)		139,840
			Unit Cost NPV ($/m3)		0.65

- **Costs percentages in Al Manar plant**

The major percentage cost as shown in Table 5.8 and Figure 5.20 is Amortization Expense 53.16 % which the costs of water well, licensing and returns, then the Operating Expense is 17.12 % and remaining percentage are distributed in the other costs.

Table (5.8): Costs percentages in in Al Manar plant.

class	Cost $/year	Percentage %
Capital Expense	15200	16.8

Operating Expense	15,579.34	17.12
Labor	4,151.86	4.56
Maintenance and parts	7,058.17	7.76
Amortization Expense	48,369.21	53.16
Membranes replacement	622.78	0.68
Total annual cost ($)	**90981.4**	**100**

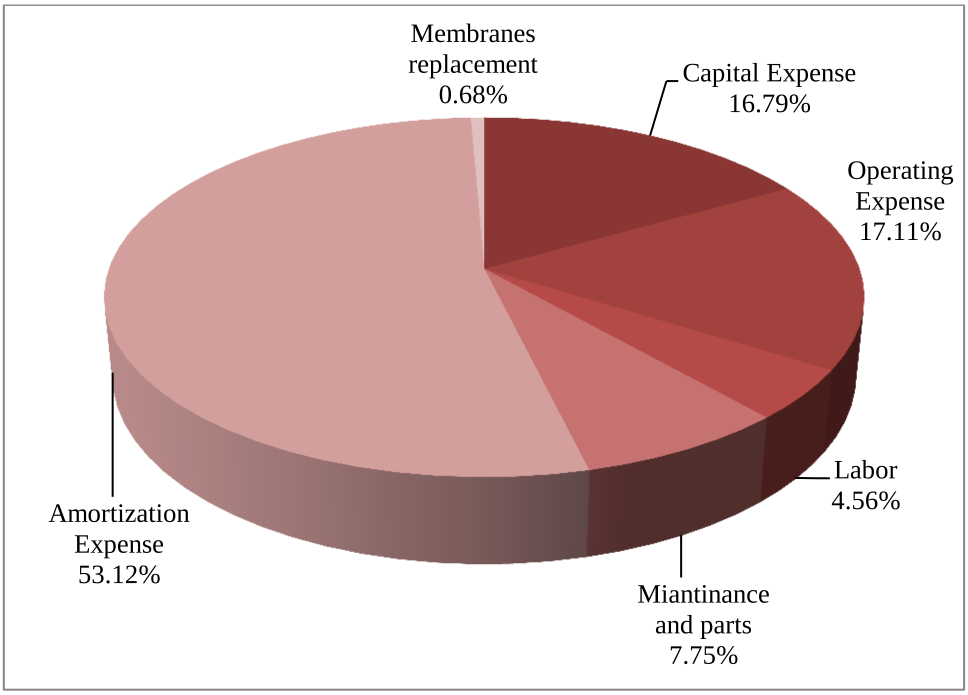


Figure (5.20): Costs percentages in Al Manar plant

Chapter 6

Conclusion and Recommendations

Chapter 6 : Conclusion and Recommendations

6.1. Conclusion

The main key factors that have potential effect on BWRO system optimization are membrane elements, operation parameters and design configuration. From this study the following concluding remarks can be outlined:

- Advanced and new membrane technology which commercially available is recommended to increases the membrane surface area and permeability to increase system performance, reducing energy, where results of case one (Yasin BWRO plant) and case two (Al Manar BWRO plant), the energy consumption reduced from 1.0 kWhr/m^3 to 0.56 Kwh/m^3 and reduced from 1.1 kWhr /m^3 to 0.55 kWhr /m^3 respectively.
- The optimization of operating parameters (pressure and conversion) and membrane type reduced desalted water cost by 42 % and 37 % in Yasin and Al Manar plant, respectively.
- The configuration of RO systems can influence the system's recovery rate significantly where optimization of these process configurations can yield efficiency improvements.
- Optimization of membrane elements and system configuration might reduce operating pressure. When the system uses lower operating pressure, less energy is consumed, resulting in reduced energy cost for the system.
- The cost of optimizing an RO system is influenced by many parameters that are specific to the application and operation of the system, such as feed water quality, membrane type, system configuration, and purity requirements. Therefore, to determine the costs and financial benefits of optimization options, the financial analysis must take into account.
- The optimization of pressure difference across the RO membrane will maximizes permeate volumetric flow rate and fulfill the permeate concentration constraint ,that will be an important environmental achievement (the permeate concentration to be less than the desired value).

- The membrane element quantity is not indicating reducing unit desalted water.

- The high cost in percentage of amortization expense in the results of two cases study leading to the increasing of the unit cost of product permeate water.

- TorayDS, Version 2.5 is a comprehensive RO membrane projection program that allows users to design an RO system using the company's membranes as using in two study cases. This software analyze and simulate the model and design configuration simpler and easier than mathematical calculation.

6.2. Recommendations

The optimal design is a very key factor in total operation cost of desalination plants Accordingly, the following recommendations should be considered:

- It is very important to establish the permeate water quality goals when starting the design of BWRO system.
- It is recommended to rearrange the configuration of existing costly BWRO plant and reconsider the individual installation of these plants.
- Using high performance membrane type preferred than low performance with lower cost.
- It is recommended to avoid the low salt groundwater to alleviate the aggressive extraction by other parties.
- Many existing local BWRO plant in Gaza strip avoid using antiscalant and other chemicals in polishing process to reduce the final cost, therefore, its strongly recommended to use the needed chemicals where it is necessary to protect public health.
- Using relative software might refine and simplify the objective functions in order to reach more improvements for process design.
- It is recommended that the governmental institutions such as, PWA and EQA have to review the plant design before given license such as feed water, recovery rate, stages and other parameters and conditions.
- PWA and EQA have to categorize and connect a group of plants in one well as a feed water source to reduce the unit cost of product permeate water, because of the high cost percentage of amortization expense in the results of two cases study.

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Appendix A

Table (A1): Parameters of permeate water in BWDP in Gaza North governorate (PWA, 2015).

#	Plant Name	Govrnte	pH	(Temp): oC	(Turb): NTU	(EC): µS/cm	(TDS): mg/L	(Cl2): mg/L	(Cl): mg/L	(F): mg/L	(SO4): mg/L	(HCO3); mg/L	(NO3): mg/L	(Ca): mg/L	(Mg): mg/L	(K): mg/L	(Na): mg/L	(TC): CFU /100 ml
1	YAFA	Gaza North	5.60	24	0.00	145	80	0.00	21.77	0.13	2.32	17.22	18.71	0.00	3.00	0.00	30	0
2	BALADNA	Gaza North	5.85	24	0.00	165	90	0.00	14.00	0.21	5.10	21.00	17.00	7.21	14.57	0.00	20	0
3	BESAN	Gaza North	6.84	22	0.10	280	140	0.00	28.14	0.35	6.83	54.88	5.74	0.00	5.00	0.60	40	70
4	SHAHID	Gaza North	5.65	24	0.20	200	110	0.00	33.00	0.17	1.02	20.17	16.00	0.00	14.38	0.00	38	100
5	ALBERKA	Gaza North	5.60	24	0.00	130	65	0.00	8.30	0.14	2.91	14.68	18.39	7.21	8.35	0.20	11	0
6	ALREDWAN	Gaza North	5.39	22	0.00	60	30	0.00	8.50	0.00	0.00	11.27	2.75	0.00	1.46	0.20	10	20
7	ALWEAAM	Gaza North	5.80	24	0.00	65	35	0.00	7.46	0.10	2.70	5.00	8.00	0.00	5.00	0.10	10	0
8	DAR ALSALAM ASSOCIATION	Gaza North	5.90	24	0.00	74	41	0.00	6.00	0.07	2.00	10.00	9.00	1.00	3.00	0.10	10	0
9	ALNNILE2	Gaza North	5.80	24	0.00	72	36	0.00	4.35	0.07	1.45	11.83	5.36	0.00	1.60	0.10	9	0
10	ALSABEEL	Gaza North	5.50	24	0.20	340	187	0.00	57.66	0.14	3.92	17.22	40.59	13.71	8.49	0.10	48	100
11	ALKARAMA	Gaza North	5.30	22	0.10	198	100	0.00	32.92	0.06	5.00	12.88	10.00	1.00	2.00	0.50	30	70
12	EHNEEF	Gaza North	6.20	22	0.20	265	135	0.00	45.00	0.07	2.82	32.93	15.07	8.02	2.42	1.00	36	0
13	KHAYRIEA	Gaza North	6.00	22	0.20	255	128	0.00	36.00	0.00	8.23	23.18	14.93	8.42	5.39	0.70	28	20
14	ALNEAMA	Gaza North	5.90	22	0.00	155	78	0.00	9.00	0.01	4.00	17.00	11.00	2.00	5.80	0.30	15	60
15	YASIN	Gaza North	5.40	25	0.00	150	83	0.00	33.75	0.13	8.72	5.00	18.00	1.52	1.26	0.00	35	100
16	ALWEFAG	Gaza North	4.70	25	0.00	65	32	0.00	7.00	0.17	0.00	7.26	9.50	0.68	0.56	0.00	10	0
17	SIGYA	Gaza North	6.00	22	0.00	153	77	0.00	8.00	0.12	4.20	16.00	10.00	2.00	6.51	1.00	14	60
18	YAFA	Gaza North	6.10	25	0.00	175	96	0.00	15.50	0.42	1.60	20.86	30.76	5.61	4.17	0.10	26	0
19	CHOMAR	Gaza North	5.97	22	0.00	115	60	0.00	7.00	0.05	3.77	11.40	12.90	0.00	2.53	0.60	14	100
20	ALRABEEA	Gaza North	5.00	25	0.00	50	25	0.00	4.30	0.36	0.50	5.64	6.45	0.00	1.09	0.00	7	0
21	ALFALAH	Gaza North	5.36	25	0.00	165	90	0.00	18.00	0.29	0.00	25.31	22.46	6.00	2.00	0.20	25	0
22	ALNILE1	Gaza North	5.70	24	0.00	160	88	0.00	25.00	0.25	6.00	10.00	15.00	8.00	18.00	0.10	22	100
23	SALSABEEL	Gaza North	6.20	26	0.10	190	105	0.00	30.17	0.00	8.43	26.32	10.60	1.12	2.23	0.20	40	100
24	SHOHADAA JABALIA SCHOOL	Gaza North	6.20	24	0.10	160	88	0.00	27.00	0.00	8.30	8.00	12.50	1.66	2.10	0.50	24	60
25	ASHABA ASSOCIATION	Gaza North	6.72	25	0.30	897	495	0.00	108.19	0.68	8.57	147.61	55.65	38.08	13.19	8.50	110	0
26	FIESAL BIN FAHED SCHOOL	Gaza North	6.40	26	0.20	360	198	0.00	90.00	0.21	6.62	20.11	28.15	28.06	7.76	1.30	40	0

Table (A2): Productivity of brackish water desalination plants in Gaza North governorate (PWA, 2015)

#	Plant Name	Type of the plant	Licensed	Governorate	Max plant production capacity (m3/hr)	Average working / Summer (hours/day)	Average working / Winter (hours/ day)	Average production: Summer (m3/day)	Average production / Winter (m3/day)
1	YAFA	Private	Yes	North	4.00	8	6	35.00	10.00
2	BALADNA	Private	No	North	13.00	10	6	10.00	4.00
3	BESAN	Private	Yes	North	7.00	8	6	50.00	30.00
4	SHAHID	Private	No	North	12.00	12	10	35.00	20.00
5	ALBERKA	NGO	Yes	North	10.00	8	5	80.00	50.00
6	ALREDWAN	Private	Yes	North	8.00	5	2	40.00	20.00
7	ALWEAAM	NGO	Yes	North	7.00	10	6	70.00	50.00
8	DAR ALSALAM ASSOCIATION	NGO	No	North	10.00	7	5	50.00	40.00
9	ALNNILE2	NGO	Yes	North	16.00	8	6	133.00	96.00
10	ALSABEEL	Private	No	North	1.50	8	6	12.00	10.00
11	ALKARAMA	Private	Yes	North	2.00	8	8	2.00	2.00
12	EHNEEF	Private	Yes	North	24.00	15	8	200.00	120.00
13	KHAYRIEA	NGO	Yes	North	22.00	3	2	60.00	40.00
14	ALNEAMA	Private	Yes	North	8.00	5	4	50.00	30.00
15	YASIN	Private	Yes	North	50.00	8	6	260.00	200.00
16	ALWEFAG	NGO	Yes	North	12.00	8	8	250.00	150.00
17	SIGYA	NGO	Yes	North	13.00	6	5	75.00	35.00
18	YAFA	Public	No	North	80.00	8	8	3.00	3.00
19	CHOMAR	Private	No	North	5.00	8	3	50.00	15.00
20	ALRABEEA	Private	Yes	North	11.00	20	20	220.00	220.00
21	ALFALAH	NGO	No	North	3.00	16	8	30.00	20.00
22	ALNILE1	NGO	Yes	North	12.00	8	6	80.00	56.00
23	SALSABEEL	Private	Yes	North	6.00	12	6	120.00	120.00
24	SHOHADAA JABALIA SCHOOL	Govermental	No	North	5.00	6	5	30.00	20.00
25	ASHABA ASSOCIATION	NGO	No	North	3.00	8	6	24.00	13.00
26	FIESAL BIN FAHED SCHOOL	Govermental	No	North	6.50	12	8	75.00	50.00

Table (A3): Parameters of permeate water in BWDP in Gaza City (PWA, 2015).

#	Plant Name	Govrnte	pH	(Temp): oC	(Turb): NTU	(EC): µS/cm	(TDS): mg/L	(Cl2): mg/L	(Cl): mg/L	(F): mg/L	(SO4): mg/L	(HCO3); mg/L	(NO3): mg/L	(Ca): mg/L	(Mg): mg/L	(K): mg/L	(Na): mg/L	(TC): CFU /100 ml
1	ALAQSA	Gaza	6.07	25	0.00	160	80	0.00	25.58	0.14	0.73	12.30	4.75	0.96	3.91	0.10	22	0
2	MACCA	Gaza	6.10	24	0.30	245	150	0.00	38.73	0.62	2.76	20.14	34.04	4.01	4.00	0.10	38	0
3	ALSHAHED1	Gaza	6.02	22	0.00	335	170	0.00	34.00	0.18	15.00	40.24	22.00	0.00	5.83	2.90	47	15
4	AABED	Gaza	5.83	26	0.00	96	53	0.00	17.00	0.05	0.00	7.63	15.64	0.88	0.63	0.20	18	100
5	ALMORGANA	Gaza	5.98	25	0.00	180	90	0.04	32.42	0.00	2.03	12.30	0.00	1.12	4.76	0.00	28	0
6	ALSABEEL	Gaza	5.60	24	0.00	140	77	0.00	29.84	0.55	1.00	6.15	12.00	1.40	4.00	0.20	22	0
7	ALMANAR	Gaza	5.88	25	0.00	130	75	0.00	18.92	0.76	1.16	10.01	22.11	1.60	4.49	0.00	23	16
8	ALKHIER	Gaza	6.10	24	0.00	170	94	0.00	25.00	0.38	4.94	12.00	22.00	3.21	7.00	0.00	25	0
9	ALSAHABA	Gaza	6.10	24	0.10	300	165	0.00	33.47	0.08	9.30	45.20	41.97	4.01	9.47	0.50	55	0
10	ALHARAMIEN	Gaza	5.71	24	0.00	145	75	0.00	15.35	0.55	4.07	10.27	19.58	2.81	6.51	0.10	18	0
11	TEBA	Gaza	5.50	22	0.00	190	95	0.00	32.00	0.00	4.40	10.30	18.00	0.00	0.83	0.60	34	30
12	ABU WATFA	Gaza	5.60	24	0.00	150	85	0.00	35.00	0.60	3.00	8.00	15.00	0.60	2.00	0.10	30	0
13	BER ZAMZAM	Gaza	5.74	25	0.00	160	80	0.00	35.74	0.00	2.74	14.07	0.00	0.66	2.33	0.30	32	0
14	ALSHATEA	Gaza	5.80	24	0.10	190	115	0.00	37.32	0.55	10.00	6.15	24.00	1.44	5.00	0.20	35	0
15	ALSABRA	Gaza	5.80	24	0.00	130	72	0.00	20.00	0.59	3.78	10.00	18.00	2.32	6.94	0.10	25	40
16	SAHA	Gaza	5.40	22	0.00	265	135	0.00	44.49	0.06	2.45	8.05	23.00	0.00	0.73	0.90	42	0
17	ALGEMA	Gaza	6.10	24	0.00	90	45	0.00	10.00	0.50	2.20	6.00	8.00	0.80	1.00	0.10	12	0
18	HASOUNA	Gaza	5.80	25	0.00	155	78	0.00	26.61	0.00	4.07	13.53	0.00	0.00	5.39	0.00	25	40
19	ISLAMIC CONGREGATION1	Gaza	5.50	24	0.10	180	102	0.00	25.40	0.41	2.03	13.28	36.12	3.61	8.06	0.20	30	100
20	ALSHAHID2	Gaza	5.50	26	0.30	250	138	0.00	50.86	0.25	3.78	13.53	18.38	2.20	0.68	0.60	48	0
21	ISLAMIC CONGREGATION2	Gaza	6.82	25	0.20	360	180	0.00	55.29	0.17	14.97	35.67	5.93	5.17	11.00	0.00	48	0
22	ALKAWTHAR-HAROUDA	Gaza	5.50	26	0.00	145	80	0.00	26.00	0.01	5.96	10.78	14.71	2.20	0.90	0.10	28	100
23	ALZAHRAA	Gaza	6.50	25	0.00	150	85	0.00	37.00	0.08	1.16	12.27	7.00	8.42	3.01	2.50	25	100
24	ALKAWTHAR-ERHEEM	Gaza	5.95	22	0.00	122	60	0.00	19.00	0.31	3.00	9.66	8.32	0.00	0.24	0.30	22	50
25	SAGYA-ALRAYAN	Gaza	5.80	24	0.00	65	35	0.00	9.27	0.41	0.00	6.00	7.00	0.00	4.00	0.00	10	0
26	ALFARDOS	Gaza	6.80	22	0.00	950	500	0.00	101.00	0.58	32.21	138.34	53.00	36.00	34.00	1.60	94	0
27	ALWEFAG	Gaza	5.40	26	0.00	160	88	0.00	20.26	0.58	0.00	7.87	32.01	0.00	0.83	1.60	30	100
28	ALRAHMA	Gaza	6.30	22	0.10	280	154	0.00	45.00	0.50	3.50	35.00	15.00	4.00	5.80	0.60	42	0
29	ALHANGOURI	Gaza	5.70	24	0.20	200	125	0.00	22.00	0.55	5.81	20.67	41.28	1.60	7.53	0.10	38	0
30	Fresh water	Gaza	5.40	24	0.00	65	35	0.00	11.00	0.62	0.00	4.82	5.56	0.00	2.03	0.10	10	0
31	ASOSI MOSQUE	Gaza	5.30	26	0.00	150	83	0.00	25.86	0.00	4.50	10.33	18.77	1.28	0.51	0.80	30	0
32	SAWAED	Gaza	6.32	25	0.00	155	78	0.00	27.42	0.00	4.36	19.44	0.00	0.00	7.14	0.00	25	100
33	ALFARABI SCHOOL	Gaza	5.80	26	0.20	220	120	0.00	20.00	0.21	5.81	22.39	36.05	3.61	6.21	1.40	32	0
34	ALRAHMA	Gaza	5.90	26	0.00	95	48	0.00	14.00	0.00	0.00	7.38	10.04	1.40	0.95	0.10	15	0
35	ALAQSA UNIVERSITY	Gaza	6.21	26	0.00	113	57	0.00	14.22	0.14	0.00	12.30	10.17	0.84	1.77	0.20	15	100
36	AHMED YASIN MOSQUE	Gaza	5.38	26	0.20	279	155	0.00	75.00	0.00	0.00	4.43	28.38	0.00	0.68	1.10	60	30
37	ALWEHDA MOSQUE	Gaza	5.52	26	0.00	68	34	0.00	9.00	0.10	0.00	5.90	12.12	0.00	0.36	0.30	12	100
38	Islamic University - library building	Gaza	6.11	26	0.20	295	163	0.00	70.00	0.00	0.00	15.25	29.49	3.33	1.09	2.70	60	0
39	Islamic University - laboratories building	Gaza	6.38	26	0.20	313	172	0.00	62.50	0.31	2.18	20.17	12.36	8.02	4.34	2.10	50	100
40	Aazhar University - Science building	Gaza	6.48	26	0.20	674	370	0.00	145.00	0.37	3.63	21.65	26.79	9.62	4.37	3.20	94	20
41	Aazhar University - Alkateba	Gaza	7.15	26	0.40	936	515	0.00	188.97	0.09	10.90	35.64	36.46	17.03	7.16	3.80	120	100
42	FAYROZ	Gaza	5.69	26	0.00	107	60	0.00	17.67	0.49	0.00	5.17	14.10	0.00	0.73	0.50	20	0
43	Aazhar University - Almoghraga building	Gaza	7.07	26	0.00	132	73	0.00	8.19	1.57	0.00	30.27	4.95	2.73	2.82	0.20	15	50
44	SADEG ALRAFIEI SCHOOL	Gaza	7.10	25	0.40	928	510	0.00	200.00	0.24	42.43	33.21	5.52	18.84	21.02	0.40	130	0
45	ADNAN AKGHOUL SCHOOL	Gaza	7.18	25	0.50	1180	649	0.00	165.00	1.30	90.74	115.00	22.75	22.44	31.80	1.20	155	0
46	ASAM BENT ABI BAKER SCHOOL	Gaza	7.18	25	0.50	1180	649	0.00	165.00	0.40	90.74	115.00	22.75	22.44	31.80	1.20	155	0
47	ALKARAMA SCHOOL	Gaza	7.18	25	0.50	1180	152	0.00	165.00	1.30	90.74	115.00	22.75	22.44	31.80	1.20	155	0
48	ALRAMLA	Gaza	5.40	26	0.10	370	205	0.00	52.83	0.17	6.10	19.93	54.30	1.36	1.50	3.80	70	0
49	ALMADINA COMPENY	Gaza	6.70	26	0.20	390	215	0.00	72.20	0.12	6.10	52.15	14.88	7.21	1.89	0.20	70	0
50	ALSHATEA1	Gaza	5.50	24	0.10	190	115	0.00	39.32	0.55	10.00	6.15	24.00	1.44	5.00	0.20	36	0
51	ALAMAL INISTITUTE FOR ORPHANS	Gaza	5.80	26	0.00	75	37	0.00	6.00	0.00	2.78	4.07	5.99	0.94	0.81	0.00	8	0

Table (A4): Productivity of brackish water desalination plants in Gaza City (PWA, 2015)

#	Plant Name	Type of the plant	Licensed	Governorate	Max plant production capacity (m3/hr)	Average working/ Summer (hours/day)	Average working/ Winter (hours/ day)	Average production/ Summer (m3/day)	Average production / Winter (m3/day)
1	ALAQSA	Private	No	Gaza	13.00	8	4	100.00	50.00
2	MACCA	Private	Yes	Gaza	6.00	12	8	54.00	36.00
3	ALSHAHED1	Private	Yes	Gaza	15.00	15	12	200.00	70.00
4	AABED	Private	No	Gaza	8.00	10	7	50.00	30.00
5	ALMORGANA	Private	No	Gaza	4.00	12	8	48.00	30.00
6	ALSABEEL	Private	No	Gaza	3.00	16	14	30.00	25.00
7	ALMANAR	Private	Yes	Gaza	20.00	13	9	80.00	35.00
8	ALKHIER	Private	Yes	Gaza	30.00	9	8	270.00	240.00
9	ALSAHABA	Private	Yes	Gaza	4.00	10	8	30.00	24.00
10	ALHARAMIEN	Private	Yes	Gaza	13.00	10	6	60.00	48.00
11	TEBA	Private	Yes	Gaza	12.00	10	4	100.00	40.00
12	ABU WATFA	Private	No	Gaza	10.00	12	6	120.00	60.00
13	BER ZAMZAM	NGO	Yes	Gaza	15.00	10	8	150.00	100.00
14	ALSHATEA	Private	No	Gaza	8.00	12	7	96.00	47.00
15	ALSABRA	Private	Yes	Gaza	12.00	12	7	65.00	47.00
16	SAHA	Private	Yes	Gaza	12.00	14	7	140.00	70.00
17	ALGEMA	Private	Yes	Gaza	1.25	10	7	30.00	15.00
18	HASOUNA	Private	No	Gaza	10.00	12	9	100.00	80.00
19	ISLAMIC CONGREGATION1	NGO	Yes	Gaza	6.50	6	4	36.00	24.00
20	ALSHAHID2	Private	No	Gaza	12.00	12		120.00	
21	ISLAMIC CONGREGATION2	NGO	Yes	Gaza	6.50	6	4	35.00	24.00
22	ALKAWTHAR-HAROUDA	Private	No	Gaza	10.00	4	3	30.00	20.00
23	ALZAHRAA	Private	No	Gaza	10.00	12	8	18.00	8.00
24	ALKAWTHAR-ERHEEM	Private	Yes	Gaza	18.00	19	15	190.00	70.00
25	SAGYA-ALRAYAN	NGO	No	Gaza	6.00	9	7	54.00	42.00
26	ALFARDOS	Private	Yes	Gaza	6.50	8	5	45.00	30.00
27	ALWEFAG	Private	No	Gaza	11.00	18		160.00	
28	ALRAHMA	Private	Yes	Gaza	7.50	20	10	140.00	75.00
29	ALHANGOURI	Private	No	Gaza	10.00	17	10	170.00	80.00
30	Fresh water	Private	No	Gaza	12.00	12	6	120.00	60.00
31	ASOSI MOSQUE	Public	No	Gaza	2.20	6	5	13.00	10.00
32	SAWAED	NGO	Yes	Gaza	12.50	4	4	250.00	250.00
33	ALFARABI SCHOOL	Govermental	No	Gaza	6.50	12	8	75.00	50.00
34	ALRAHMA	NGO	No	Gaza	10.00	10	6	80.00	45.00
35	ALAQSA UNIVERSITY	Govermental	No	Gaza	1.00	10	7	10.00	7.00
36	AHMED YASIN MOSQUE	Public	No	Gaza	6.00	4	2	24.00	12.00
37	ALWEHDA MOSQUE	Public	No	Gaza	6.00	4	3	24.00	18.00
38	Islamic University - library building	Govermental	No	Gaza	2.00	8	6	16.00	12.00
39	Islamic University - laboratories building	Govermental	No	Gaza	1.00	8	6	8.00	6.00
40	Aazhar University - Science building	Govermental	No	Gaza	2.00	12	8	20.00	14.00
41	Aazhar University - Alkateba	Govermental	No	Gaza	2.00	12	8	20.00	14.00
42	FAYROZ	Public	No	Gaza	6.00	8	6	45.00	30.00
43	Aazhar University - Almoghraga building	Govermental	No	Gaza	2.00	10	6	18.00	10.00
44	SADEG ALRAFIEI SCHOOL	Govermental	No	Gaza	0.05	12	10	0.60	0.50
45	ADNAN AKGHOUL SCHOOL	Govermental	No	Gaza	0.05	12	10	0.60	0.50
46	ASAM BENT ABI BAKER SCHOOL	Govermental	No	Gaza	6.50	6	5	36.00	25.00
47	ALKARAMA SCHOOL	Govermental	No	Gaza	5.00	6	5	30.00	20.00
48	ALRAMLA	Govermental	No	Gaza	6.50	12	10	75.00	60.00
49	ALMADINA COMPENY	Private	Yes	Gaza	12.00	12	4	60.00	40.00
50	ALSHATEA1	Public	No	Gaza	2.00	8	6	16.00	12.00
51	ALAMAL INSTITUTE FOR ORPHANS	Private	No	Gaza	9.00	7	3	63.00	27.00

Table (A5): Parameters of permeate water in BWDP in Middle area governorate (PWA, 2015).

#	Plant Name	Govrnte	pH	(Temp): oC	(Turb): NTU	(EC): µS/cm	(TDS): mg/L	(Cl2): mg/L	(Cl): mg/L	(F): mg/L	(SO4): mg/L	(HCO3); mg/L	(NO3): mg/L	(Ca): mg/L	(Mg): mg/L	(K): mg/L	(Na): mg/L	(TC): CFU /100 ml
1	EBAD ELRAHMAN -SALSABEEL	Middle Area	5.59	25	0.20	350	175	0.00	45.00	0.30	14.69	19.51	35.00	0.00	2.72	0.70	52	100
2	ALFARDOS.NEW	Middle Area	5.50	25	0.00	116	65	0.00	12.08	0.00	0.00	14.76	19.36	1.32	1.67	0.10	20	0
3	ALHOR	Middle Area	4.40	25	0.00	145	80	0.00	25.00	0.35	2.91	10.33	10.15	0.48	2.65	0.20	25	0
4	ALJANOUB	Middle Area	6.15	25	0.10	225	115	0.00	34.00	0.00	5.00	16.00	13.00	0.00	0.49	0.50	32	30
5	ALHIDAYA	Middle Area	5.10	24	0.00	82	40	0.00	18.00	0.00	2.32	2.00	0.30	0.00	0.00	0.20	13	0
6	GHAYTH	Middle Area	5.50	24	0.00	95	48	0.00	15.92	0.00	1.16	7.38	10.21	0.00	0.39	0.20	17	10
7	ALMAGHAZI	Middle Area	6.60	25	0.10	220	120	0.00	27.16	1.51	0.00	36.90	17.77	8.90	3.27	0.40	28	0
8	ALRABEEA	Middle Area	5.70	24	0.20	250	138	0.00	39.17	0.00	4.50	35.00	15.00	7.90	9.30	0.40	40	0
9	ALFORGAN	Middle Area	5.45	25	0.10	290	160	0.00	46.25	0.14	2.62	9.84	39.48	1.20	2.06	0.40	50	100
10	TAG AL WAGAR	Middle Area	5.10	25	0.10	196	108	0.00	17.92	0.00	2.32	7.38	47.61	0.40	1.14	0.50	35	0
11	NABEA ALHOREIA	Middle Area	5.40	24	0.00	170	94	0.00	41.25	0.00	3.34	15.00	5.00	5.00	1.45	0.30	33	20
12	ALMOSADAR	Middle Area	6.29	25	0.00	148	81	0.00	27.75	0.46	0.87	15.56	12.80	1.72	1.24	0.10	28	0
13	ALBORIG PARK	Middle Area	5.30	25	0.00	170	95	0.00	25.67	0.00	0.73	8.98	31.79	0.64	2.38	1.00	34	0
14	ALBORIG MUNICIBALI	Middle Area	6.10	25	0.10	310	170	0.00	55.00	0.00	2.18	15.00	35.00	5.48	4.12	0.40	45	100
15	ALMAGHAZI PARK	Middle Area	5.56	24	0.00	72	36	0.00	8.83	0.29	8.72	6.00	0.00	2.81	1.24	0.10	10	0
16	AFAG JADEDA	Middle Area	5.40	24	0.00	175	96	0.00	32.17	0.39	1.89	6.89	20.40	0.80	1.82	0.20	33	0
17	ALNOR	Middle Area	5.80	24	0.00	130	72	0.00	12.00	0.00	1.45	25.00	11.00	2.00	1.57	0.50	22	0
18	DER ALBALAH	Middle Area	5.80	24	0.00	130	120	0.00	14.00	0.00	2.00	25.00	11.00	2.00	1.57	0.50	22	0
19	ALAQSA	Middle Area	6.20	24	0.20	1000	550	0.00	214.60	0.66	23.39	17.22	35.03	3.97	3.91	1.60	170	0
20	ABU NASER	Middle Area	6.30	24	0.30	260	142	0.00	47.50	0.24	2.91	15.74	17.23	1.40	1.14	0.40	47	15
21	ALFORAT	Middle Area	5.96	25	0.20	225	115	0.09	42.00	0.24	10.34	9.76	2.55	0.00	3.11	0.60	34	100
22	JUHER ALDEK	Middle Area	6.75	24	0.10	190	105	0.00	32.92	1.03	4.50	20.67	0.35	2.40	3.26	0.10	28	0
23	ISLAMIC ASSOCIATION	Middle Area	5.30	24	0.00	160	88	0.00	19.59	0.05	3.63	9.35	31.59	0.00	0.24	0.10	32	0
24	KHALED BIN ALWALEED SCHOOL	Middle Area	6.90	25	0.30	487	268	0.00	99.14	0.00	0.00	15.04	45.54	0.60	1.92	0.80	95	100
25	ALSALAH	Middle Area	5.76	25	0.00	125	68	0.00	17.00	0.32	0.00	10.58	8.72	0.00	1.24	0.00	19	100
26	ALMAGHAZI MOSQUE	Middle Area	5.60	24	0.00	140	75	0.00	15.00	0.71	0.00	9.84	28.00	0.84	0.00	0.40	25	0
27	FADAEL ALKHIER ASSOCIATION	Middle Area	5.68	25	0.20	498	275	0.00	65.00	0.09	0.00	35.00	60.00	1.20	1.99	0.20	75	20
28	ALSAHABA -ALDAAWA	Middle Area	5.98	25	0.00	155	85	0.00	35.33	0.00	0.00	5.92	5.54	2.00	0.83	0.20	24	100

Table (A6): Productivity of brackish water desalination plants in Middle area governorate (PWA, 2015).

#	Plant Name	Type of the plant	Licensed	Governorate	Max plant production capacity (m3/hr)	Average working / Summer (hours/day)	Average working / Winter (hours/ day)	Average production/ Summer (m3/day)	Average production / Winter (m3/day)
1	EBAD ELRAHMAN -SALSABEEL	Private	No	Middle Area	9.00	6	4	50.00	35.00
2	ALFARDOS.NEW	Private	Yes	Middle Area	9.00	14	6	66.00	33.00
3	ALHOR	Private	Yes	Middle Area	12.00	6	3	36.00	18.00
4	ALJANOUB	Private	No	Middle Area	9.00	16	10	120.00	60.00
5	ALHIDAYA	NGO	No	Middle Area	15.00	8	4	85.00	42.00
6	GHAYTH	NGO	Yes	Middle Area	10.00	8		20.00	
7	ALMAGHAZI	NGO	No	Middle Area	12.00	14	6	150.00	70.00
8	ALRABEEA	Private	Yes	Middle Area	7.00	12	6	85.00	42.00
9	ALFORGAN	Public	No	Middle Area	48.00	4	2	192.00	96.00
10	TAG AL WAGAR	Public	No	Middle Area	28.00	6	2	168.00	56.00
11	NABEA ALHOREIA	Private	Yes	Middle Area	15.00	8	3	90.00	60.00
12	ALMOSADAR	Public	No	Middle Area	2.00	16	16	32.00	32.00
13	ALBORIG PARK	Public	No	Middle Area	2.50	3	3	7.50	7.50
14	ALBORIG MUNICIBALI	Public	No	Middle Area	60.00	16	16	960.00	960.00
15	ALMAGHAZI PARK	Public	No	Middle Area	2.00	8	8	16.00	16.00
16	AFAG JADEDA	NGO	Yes	Middle Area	9.00	10	6	90.00	60.00
17	ALNOR	Private	No	Middle Area	10.00	10	6	100.00	60.00
18	DER ALBALAH	Public	No	Middle Area	45.00	6	6	270.00	270.00
19	ALAQSA	Public	No	Middle Area	8.50	6	6	50.00	50.00
20	ABU NASER	Public	No	Middle Area	8.50	6	6	50.00	50.00
21	ALFORAT	Private	Yes	Middle Area	14.00	8	4	112.00	56.00
22	JUHER ALDEK	Public	No	Middle Area	2.80	4	3	11.20	8.40
23	ISLAMIC ASSOCIATION	NGO	No	Middle Area	4.00	8	6	32.00	42.00
24	KHALED BIN ALWALEED SCHOOL	Govermental	No	Middle Area	5.00	6	5	30.00	25.00
25	ALSALAH	NGO	No	Middle Area	2.00	8	6	16.00	12.00
26	ALMAGHAZI MOSQUE	Public	No	Middle Area	1.00	12	10	12.00	10.00
27	FADAEL ALKHIER ASSOCIATION	NGO	No	Middle Area	2.00	12	10	24.00	20.00
28	ALSAHABA -ALDAAWA	NGO	No	Middle Area	6.00	10	7	40.00	30.00

Table (A7): Parameters of permeate water in BWDP in Khanyunis governorate (PWA, 2015).

#	Plant Name	Govrnte	pH	(Temp): oC	(Turb): NTU	(EC): µS/cm	(TDS): mg/L	(Cl2): mg/L	(Cl): mg/L	(F): mg/L	(SO4): mg/L	(HCO3); mg/L	(NO3): mg/L	(Ca): mg/L	(Mg): mg/L	(K): mg/L	(Na): mg/L	(TC): CFU /100 ml
1	ALALI	Khan Younes	5.82	25	0.10	260	130	0.13	32.92	0.06	7.15	15.45	30.00	0.00	2.33	0.40	38	0
2	ALMANASRA	Khan Younes	6.60	24	0.00	150	99	0.00	15.00	0.22	5.96	22.39	20.77	0.40	1.85	0.00	26	0
3	MAAN	Khan Younes	6.00	24	0.00	60	30	0.00	8.00	0.07	3.78	3.17	6.56	0.00	0.03	0.00	10	0
4	ABU RAMADAN	Khan Younes	7.30	25	0.00	94	52	0.00	7.50	0.09	1.74	10.78	17.70	0.00	0.34	0.10	15	100
5	ALALMAL	Khan Younes	5.60	25	0.00	110	60	0.00	13.33	0.00	1.31	8.05	14.31	0.00	0.63	0.20	16	100
6	YANABEEA ALAMAL	Khan Younes	5.70	24	0.00	135	75	0.00	16.67	0.00	3.05	8.61	28.88	0.00	1.12	0.10	25	0
7	WAFI	Khan Younes	6.05	25	0.00	185	95	0.00	25.80	0.15	4.54	16.10	17.85	0.00	0.34	0.30	30	0
8	ARAHMA ASSOCIATION	Khan Younes	7.70	25	0.00	100	55	0.00	7.42	0.09	4.68	5.25	9.56	0.41	0.47	0.40	12	100
9	ALGERIA	Khan Younes	5.39	22	0.00	150	78	0.00	20.00	0.08	3.78	8.54	22.50	1.00	2.00	0.20	23	0
10	ALSAADA	Khan Younes	6.10	24	0.10	260	143	0.00	33.34	0.00	5.96	23.13	36.74	0.00	2.38	0.40	51	100
11	AYA WELL	Khan Younes	6.20	24	0.00	177	97	0.36	21.00	0.00	3.05	15.57	18.62	2.00	4.00	0.20	23	0
12	ALSATER ALSHARGY	Khan Younes	6.20	24	0.20	420	230	0.00	77.00	0.36	15.00	40.00	42.00	3.77	2.19	0.20	75	0
13	ALAMAL AOBEEK	Khan Younes	6.00	26	0.00	158	87	0.00	30.00	0.85	0.00	8.15	12.00	3.86	2.79	0.30	25	0
14	SPORT CITY	Khan Younes	6.80	24	0.10	330	180	0.28	55.09	0.43	8.86	20.91	27.05	0.00	1.12	0.20	53	0
15	BANI SEHILA	Khan Younes	5.80	26	0.00	10	5	0.00	1.70	0.00	0.00	0.97	1.00	0.00	0.00	0.00	2	100
16	ALDAGHMA	Khan Younes	6.00	24	0.00	120	66	0.00	19.17	0.00	3.92	10.33	15.53	0.00	0.11	0.00	24	0
17	ALALAGA	Khan Younes	8.20	24	0.00	125	70	0.00	18.00	0.03	4.09	20.93	10.54	5.22	1.43	0.00	17	0
18	ALREDWAN	Khan Younes	6.16	26	0.10	203	112	0.00	38.93	1.02	0.00	10.58	19.45	1.32	0.66	0.00	40	0
19	ALSHAFEI	Khan Younes	6.60	24	0.00	176	97	0.00	22.92	0.05	2.83	16.32	19.75	2.18	4.37	0.40	25	0
20	ALAQSA UNIVERSITY-ALBALAD	Khan Younes	5.75	26	0.20	370	205	0.00	50.00	1.53	0.00	28.05	47.80	0.00	3.55	0.20	55	100
21	ALLAHAM	Khan Younes	6.53	26	0.00	171	94	0.00	17.24	1.12	0.00	18.70	24.03	1.20	2.38	2.40	25	20
22	ALAZIZA	Khan Younes	6.55	26	0.00	83	45	0.00	7.76	1.43	4.94	9.87	10.19	1.93	0.34	0.30	12	0
23	ALASTAL	Khan Younes	5.68	25	0.20	235	120	0.00	23.00	0.21	15.00	10.98	35.00	0.00	0.24	0.40	36	100
24	ALAQSA UNIVERSITY-THE SEA	Khan Younes	6.95	26	0.10	262	144	0.00	32.07	1.73	0.73	20.09	25.16	1.72	10.24	0.80	36	100
25	ALFARABI SCHOOL	Khan Younes	5.40	26	0.00	30	17	0.00	8.19	0.00	0.00	1.94	1.32	0.00	0.69	0.00	7	100
26	ALNOR	Khan Younes	5.98	26	0.10	327	180	0.00	63.36	0.77	1.60	10.33	20.82	0.00	0.63	0.50	58	0
27	ALHUDA	Khan Younes	6.30	26	0.10	199	110	0.00	35.00	0.36	3.63	17.22	9.93	0.00	1.31	0.20	33	100
28	ALSHARGIEA	Khan Younes	7.00	24	0.00	170	94	0.37	22.34	0.00	0.58	15.45	13.97	3.25	1.92	0.10	24	0
29	ALSHAHABA	Khan Younes	6.52	26	0.00	101	56	0.00	17.00	0.50	0.00	6.15	15.00	3.22	2.91	0.00	17	0
30	ALAMAL- CMWU	Khan Younes	6.30	26	0.20	394	217	0.00	46.55	0.49	0.00	22.14	54.02	2.12	13.45	1.00	55	100
31	ALHARETH MOSQUE	Khan Younes	6.18	26	0.00	72	40	0.00	12.93	0.88	0.00	6.89	4.91	0.00	0.36	0.00	14	100
32	ABU ESHAG	Khan Younes	5.80	26	0.00	107	58	0.00	18.53	0.62	0.00	7.38	8.54	0.00	0.39	0.10	17	0
33	ABU DAGA	Khan Younes	6.60	24	0.20	230	127	0.00	30.00	0.08	5.63	20.00	18.00	3.00	1.55	0.20	30	100
34	ALKHANSAA SCHOOL	Khan Younes	6.85	26	0.20	456	250	0.00	68.00	0.80	6.00	40.97	45.06	2.01	3.80	0.60	70	100
35	ALMASADER SCHOOL	Khan Younes	6.80	26	0.20	362	200	0.00	70.00	1.51	2.00	40.00	35.00	1.32	0.80	0.30	70	30

Table (A8): Productivity of brackish water desalination plants in Khanyunis governorate (PWA, 2015).

#	Plant Name	Type of the plant	Licensed	Governorate	Max plant production capacity (m3/hr)	Average working / Summer (hours/day)	Average working : Winter (hours/ day)	Average production / Summer (m3/day)	Average production / Winter (m3/day)
1	ALALI	Private	No	Khan Younes	12.00	12	4	50.00	20.00
2	ALMANASRA	NGO	No	Khan Younes	6.00	12	8	50.00	30.00
3	MAAN	Private	No	Khan Younes	6.00	12	7	96.00	40.00
4	ABU RAMADAN	Private	No	Khan Younes	6.00	12	12	60.00	30.00
5	ALALMAL	NGO	No	Khan Younes	18.00	12	7	85.00	50.00
6	YANABEEA ALAMAL	Private	Yes	Khan Younes	20.00	12	6	40.00	20.00
7	WAFI	Private	Yes	Khan Younes	8.00	12	7	90.00	60.00
8	ARAHMA ASSOCIATION	NGO	Yes	Khan Younes	20.00	16	12	30.00	15.00
9	ALGERIA	Private	No	Khan Younes	8.00	12	7	90.00	60.00
10	ALSAADA	Public	No	Khan Younes	60.00	8	4	200.00	100.00
11	AYA WELL	Public	No	Khan Younes	2.00	8	4	20.00	10.00
12	ALSATER ALSHARGY	Public	No	Khan Younes	2.00	8	4	20.00	10.00
13	ALAMAL AOBEEK	Public	No	Khan Younes	2.00	8	4	20.00	10.00
14	SPORT CITY	Public	No	Khan Younes	2.00	8	4	20.00	10.00
15	BANI SEHILA	Public	No	Khan Younes	2.00	5	4	20.00	10.00
16	ALDAGHMA	Private	No	Khan Younes	2.00	5	4	20.00	10.00
17	ALALAGA	NGO	No	Khan Younes	6.00	6	4	60.00	15.00
18	ALREDWAN	NGO	No	Khan Younes	18.00	6	4	30.00	15.00
19	ALSHAFEI	NGO	No	Khan Younes	7.00	12	12	50.00	20.00
20	ALAQSA UNIVERSITY-ALBALAD	Govermental	No	Khan Younes	3.00	7	7	7.00	7.00
21	ALLAHAM	Private	No	Khan Younes	13.00	3	3	8.00	4.00
22	ALAZIZA	Private	No	Khan Younes	5.00	3	2	17.00	11.00
23	ALASTAL	Private	No	Khan Younes	16.00	12	10	180.00	90.00
24	ALAQSA UNIVERSITY-THE SEA	Govermental	No	Khan Younes	3.00	7	7	7.00	7.00
25	ALFARABI SCHOOL	Private	No	Khan Younes	6.00	10	6	40.00	20.00
26	ALNOR	NGO	No	Khan Younes	6.00	4	4	6.00	3.00
27	ALHUDA	Private	No	Khan Younes					
28	ALSHARGIEA	Public	No	Khan Younes	60.00	8	4	200.00	100.00
29	ALSHAHABA	Private	No	Khan Younes	6.00	4	4	6.00	3.00
30	ALAMAL- CMWU	Public	No	Khan Younes	2.00	8	4	20.00	10.00
31	ALHARETH MOSQUE	Public	No	Khan Younes	6.00	4	4	6.00	3.00
32	ABU ESHAG	Private	No	Khan Younes	13.00	3	3	8.00	4.00
33	ABU DAGA	Private	No	Khan Younes	5.00	4	2	5.00	3.00
34	ALKHANSAA SCHOOL	Govermental	No	Khan Younes	5.00	6	5	30.00	25.00
35	ALMASADER SCHOOL	Govermental	No	Khan Younes	5.00	6	5	30.00	25.00

Table (A9): Parameters of permeate water in BWDP in Rafah governorate (PWA, 2015).

#	Plant Name	Govrnte	pH	(Temp): oC	(Turb): NTU	(EC): µS/cm	(TDS): mg/L	(Cl2): mg/L	(Cl): mg/L	(F): mg/L	(SO4): mg/L	(HCO3); mg/L	(NO3): mg/L	(Ca): mg/L	(Mg): mg/L	(K): mg/L	(Na): mg/L	(TC): CFU /100 ml
1	ALNILE REVIR	Rafah	6.03	22	0.20	425	215	0.00	76.00	0.33	8.56	17.07	36.50	0.00	1.65	0.40	75	0
2	EHJAZI	Rafah	5.30	22	0.20	410	205	0.00	47.16	0.68	8.00	25.76	55.00	2.00	3.00	0.90	60	100
3	ALSHOOT (ALSALAM)	Rafah	6.40	25	0.20	395	217	0.00	51.29	0.00	7.12	23.86	50.02	4.41	3.86	0.50	65	0
4	EBIN TAYMIA	Rafah	6.75	25	0.20	420	231	0.00	55.83	0.61	45.62	24.60	11.26	1.60	2.77	0.50	64	0
5	ALSALAH	Rafah	5.30	22	0.00	190	95	0.00	22.00	0.03	2.82	9.76	30.00	0.00	0.97	0.30	30	0
6	ALKHAIYRIA	Rafah	6.10	25	0.00	130	72	0.00	21.55	0.14	3.92	12.79	13.71	0.00	0.17	0.10	25	100
7	ALHUDA	Rafah	6.81	22	0.10	212	105	0.00	25.00	0.50	2.59	26.83	8.32	0.00	2.53	0.60	28	20
8	THE CHARITABLE SOCIETY	Rafah	6.10	25	0.10	320	176	0.00	48.28	0.15	7.85	20.91	41.44	3.69	4.54	0.40	49	100
9	ALSHAER	Rafah	5.95	22	0.10	280	140	0.00	44.49	0.22	6.16	12.23	29.76	0.00	1.21	0.20	50	30
10	ALFADELA	Rafah	5.80	25	0.00	100	55	0.00	13.79	0.06	4.65	7.63	13.28	1.40	0.44	0.90	17	100
11	ABU ZUHRI	Rafah	6.10	25	0.10	235	129	0.00	28.02	0.61	1.60	8.61	46.91	5.13	2.79	0.70	35	0
12	ALNAS	Rafah	5.60	25	0.10	205	115	0.00	29.31	0.00	3.78	12.76	38.50	3.01	1.31	0.30	38	100
13	BEERSHEBA	Rafah	6.60	25	0.00	90	50	0.00	11.00	0.57	0.00	9.84	12.00	0.00	1.80	0.10	14	100

Table (A10): Productivity of brackish water desalination plants in Rafah governorate (PWA, 2015).

#	Plant Name	Type of the plant	Licensed	Governorate	Max plant production capacity (m3/hr)	Average working /Summer (hours/day)	Average working / Winter (hours/ day)	Average production / Summer (m3/day)	Average production / Winter (m3/day)
1	ALNILE REVIR	Private	Yes	Rafah	14.00	14	10	200.00	140.00
2	EHJAZI	Private	Yes	Rafah	25.00	12	8	300.00	200.00
3	ALSHOOT (ALSALAM)	Public	No	Rafah	50.00	12	6	600.00	400.00
4	EBIN TAYMIA	Public	No	Rafah	50.00	12	6	600.00	400.00
5	ALSALAH	NGO	Yes	Rafah	5.00	14	8	70.00	40.00
6	ALKHAIYRIA	Private	No	Rafah		6	6	16.00	8.00
7	ALHUDA	NGO	No	Rafah	10.50	10	6	100.00	70.00
8	THE CHARITABLE SOCIETY	NGO	No	Rafah	7.50	10	6	75.00	45.00
9	ALSHAER	Private	No	Rafah	15.00	15	10	200.00	100.00
10	ALFADELA	NGO	Yes	Rafah	4.00	14	8	56.00	32.00
11	ABU ZUHRI	Private	No	Rafah	12.00	8	5	96.00	60.00
12	ALNAS	Private	No	Rafah	4.00	10	6	40.00	24.00
13	BEERSHEBA	Govermental	No	Rafah	6.00	6	4	36.00	24.00

Appendix B

'TORAY' Innovation by Chemistry

System Overview Report

Project	88:Yain plant -case study 1-Gaza north	
Case	1	Yasin in actual case
Revision	2	T=25.0 deg C, Recov=80.0%, FF(Elem1)=0.85, SPI(Elem1)=0.10, Brackish Well, Feed: 48.0 m3/hr, TDS: 1500.5, Perm: 38.4, TDS: 12, Tot Elem: 30, 1st Elem: TM720-370
Feed Water Type	Brackish Well, Note: Auto Balance is ON	
Warnings and Errors	Warnings:0, Errors:0. See Important Notes at end /E	
Database Info :	Project Database : C:\Users\Mahmoud\Documents\TorayDS2\App_Data\DS2.sdf Membrane Database (V.20143) :.	

		Overall	Pass 1
Raw water TDS	mg/l	1,502.6	1,765
Feed EC @25C / @25.00C	uS	2,521.1 / 2,521.1	2,933.8 / 2,933.8
Feed Pressure	bar	0.0	13.728
Temperature	deg C	25.00	
Total DP	bar	1.630	1.630
Brine Pressure	bar	12.098	12.098
Fouling Max	4.00 yrs		0.824
SP % Increase (Max)	4.00 yrs		46.41%
Recovery	%	86.41%	84.0%
Feed Flow	m3/hr	45.20	46.50
Recycle Flow	m3/hr	1.300	1.300
Product Flow	m3/hr	39.06	39.06
Average Flux	l/m2/hr	26.54	26.54
Concentrate Flow	m3/hr	6.141	6.141
Product TDS	mg/l	43.89	24.24
Concentrate TDS	mg/l	10,896	10,896
Primary HP Pump kW	kilowatt	22.18	22.18
Power Consumption	kWh/m^3	0.568	0.568

Ions		Feed	Net Feed	Conc	Product	RO Permeate
Ca	mg/l	146.0	171.7	1,066	1.310	1.310
Mg	mg/l	85.00	99.96	620.6	0.763	0.763
Na	mg/l	234.4	275.2	1,693	10.559	5.125
K	mg/l	3.100	3.632	22.15	0.105	0.105

Ba	mg/l	1.000	1.176	7.302	0.009	0.009
Sr	mg/l	1.000	1.176	7.302	0.009	0.009
NH4	mg/l	1.000	1.172	7.144	0.0338	0.0338
Fe	mg/l	1.000	1.178	7.359	0.0	0.0
HCO3	mg/l	165.0	193.2	1,173	17.948	3.746
CO3	mg/l	0.271	0.613	12.543	0.0091	0.0002
CO2	mg/l	12.821	12.926	16.563	2.933	13.182
Cl	mg/l	588.3	691.4	4,280	7.691	7.691
SO4	mg/l	170.0	200.0	1,245	1.007	1.007
NO3	mg/l	100.0	117.1	713.3	3.553	3.553
F	mg/l	2.000	2.343	14.282	0.0685	0.0685
Br	mg/l	1.000	1.175	7.270	0.014	0.014
PO4	mg/l	0.500	0.589	3.669	0.0016	0.0016
SiO2	mg/l	2.000	2.346	14.397	0.0505	0.0505
B(Boron)	mg/l	1.000	1.043	2.540	0.758	0.758
TDS	mg/l	1,503	1,765	10,896	43.89	24.24
Feed EC @25C / @25.00C	uS	2,521 / 2,521	2,934 / 2,934	16,217 / 16,217	77.3 / 77.3	49.5 / 49.9
pH	pH	7.260	7.320	7.925	7.000	5.476
Osmotic Press (DS1 / Pitzer)	bar	0.983 / 0.88	1.153 / 1.03	6.951 / 5.97	0.029 / 0.03	0.0176 / 0.03
LSI / SDSI		0.04 / 0.10	0.22 / 0.27	2.15 / 1.79	-2.93 / -3.01	-4.95 / -5.03
CaSO4 / SrSO4 %	%	4.5% / 2.0%	5.7% / 2.4%	60.0% / 18.0%	0.0% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	3100.2% / 1.6%	3838.0% / 1.9%	32276.2% / 10.3%		
Pitzer % Solubility	Calcite/Dolomite	57% / 140%	85% / 312%	5,899% / 1,483,346%		
Pitzer % Solubility	CaSO4/SrSO4	5% / 2%	6% / 2%	59% / 20%		

Stage/Bank Data	Pass1	Stage 1	Stage 2
Lead Element Type		TM720-440	TM720-440
Last Element Type		TM720-440	TM720-440
Total Elements	36	24	12
Total Vessels	6	4	2
Elements per Vessel		6	6
Feed Flow	m3/hr	46.50	17.050
Product Flow	m3/hr	29.45	9.609
Average Flux	l/m2/hr	30.02	19.587
Brine Flow	m3/hr	17.050	7.441
Recovery %	%	63.34 %	56.36 %

Feed Pressure	bar	13.728	12.766
dP Elements	bar	0.962	0.668
Boost Pressure	bar	0.0	0.0
Piping Loss	bar	0.0	0.0
Net (Boost - dP piping)	bar	0.0	0.0
Brine Pressure	bar	12.766	12.098
Permeate Pressure	bar	0.0	0.0
Feed TDS	mg/l	1,765	4,791
Perm TDS	mg/l	13.169	58.19
Lead Element	Pass1	Stage 1	Stage 2
Feed Flow	m3/hr	11.625	8.525
Product Flow	m3/hr	1.360	1.010
Product TDS	mg/l	7.216	30.05
Flux	l/m2/hr	33.28	24.71
Last Element	Pass1	Stage 1	Stage 2
Product Flow	m3/hr	1.064	0.563
Product TDS	mg/l	24.56	118.3
Brine/Product Ratio	ratio	4.007	6.607
Brine Flow	m3/hr	4.262	3.721
Net Driving Pressure	bar	9.552	5.056
Beta		1.183	1.109

Chemicals 100%. Disclaimer: These estimated dose rates are provided as a courtesy to Toray DS2 users and are not guaranteed.
Product: Sodium Hydroxide, 9.45 mg/l, 8.86 kg/day

Warnings
saturation.

Errors

Disclaimer :
The program is intended to be used by persons having technical skill, at their own discretion and risk. The projections, obtained with the program, are the expected system performance, based on the average, nominal element-performance and are not automatically guaranteed.
Toray shall not be liable for any error or miscalculation in the program.
The obtained results cannot be used to raise any claim for liability or warranty.
It is the users responsibility to make provisions against fouling, scaling and chemical attacks, to account for piping and valve pressure losses, feed pump suction pressure and permeate backpressure. For questions please contact us:

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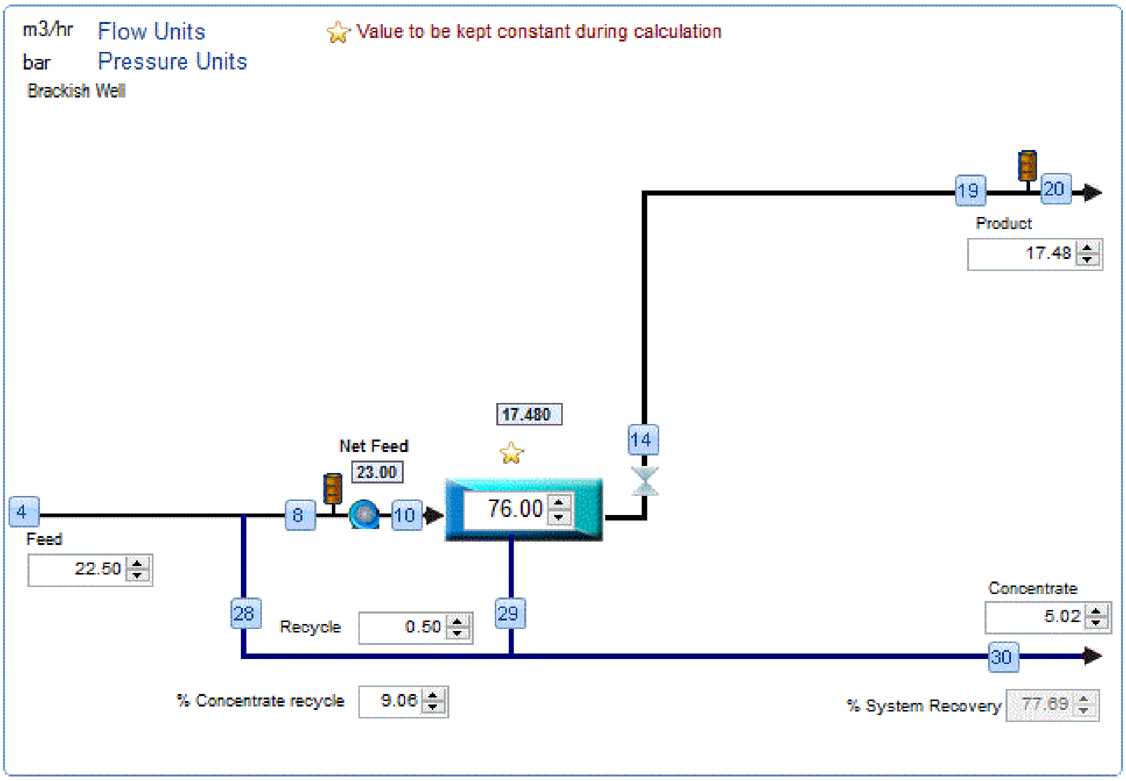
Date/Time :	16/10/12 4:50:37 PM
Project	88:Yain plant -case study 1-Gaza north
Case :	1:Yasin in actual case
Revision :	2:T=25.0 deg C, Recov=80.0%, FF(Elem1)=0.85, SPI(Elem1)=0.10, Brackish Well, Feed: 48.0 m3/hr, TDS: 1500.5, Perm: 38.4, TDS: 12, Tot Elem: 30, 1st Elem: TM720-370
User name :	DESKTOP-5OCOQI7\Mahmoud
Prepared for :	Islamic university
Notes :	
Membrane Database	
Version Number:	20143
ReleaseDate:	15/07/28
UpdateBy:	HirooT
Toray DS2 version :	2.0.3.114

Flow Diagram:



Stream Details					
Stream Number	Flow	Pressure	TDS	Est uS	pH
20. Final Product	39.06	0.0	43.89	77.3	7.000
4. Feed Net	45.20	0.0	1,502.57	2,521.1	7.260
28. Pass 1 Recycle	1.300	12.098	10,896.43	16,217.1	7.260
29. Pass 1 Conc	7.441	12.098	10,896.43	7.925	
10. Feed to Pass 1	46.50	13.728	1,764.97	2,933.8	7.320
19. Permeate with blend	39.06	0.0	24.24	49.5	5.476
30. Conc to brine	6.141	12.098	10,896.43	16,217.1	7.925

Element Details in Pass 1					
Pass 1 Stage 1	Element 1	Element 2	Element 3	Element 4	Element 5
Model	TM720-440	TM720-440	TM720-440	TM720-440	TM720-440
Area m^2 / dia inch	40.88 / 8	40.88 / 8	40.88 / 8	40.88 / 8	40.88 / 8
Age	4	4	4	4	4
SPI %/yr	10	10	10	10	10
SPI Applied	46.41	46.41	46.41	46.41	46.41
Fouling	0.824	0.824	0.824	0.824	0.824
Recovery %	11.701	12.805	14.143	15.766	17.714
Feed Flow(m3/hr)	11.625	10.265	8.950	7.684	6.473
Perm Flow(m3/hr)	1.360	1.314	1.266	1.212	1.147

Conc Flow(m3/hr)	10.265	8.950	7.684	6.473	5.326
Flux(l/m2/hr)	33.28	32.15	30.97	29.64	28.05
Beta	1.110	1.119	1.131	1.146	1.163
Feed Press(bar)	13.728	13.483	13.275	13.103	12.962
DP(bar)	0.245	0.208	0.173	0.140	0.111
Conc Press(bar)	13.483	13.275	13.103	12.962	12.851
Perm Press(bar)	0.0	0.0	0.0	0.0	0.0
Pi_Feed(bar)	1.153	1.304	1.492	1.734	2.053
Pi_Memb(bar)	1.360	1.561	1.819	2.160	2.626
Pi_Conc(bar)	1.304	1.492	1.734	2.053	2.486
Pi_Perm(bar)	0.0056	0.0066	0.008	0.01	0.0131
Net Press(bar)	12.252	11.826	11.379	10.884	10.297
Pass 1 Stage 1	Element 6				
Model	TM720-440				
Area m^2 / dia inch	40.88 / 8				
Age	4.000				
SPI %/yr	10.000				
SPI Applied	46.41				
Fouling	0.824				
Recovery %	19.973				
Feed Flow(m3/hr)	5.326				
Perm Flow(m3/hr)	1.064				
Conc Flow(m3/hr)	4.262				
Flux(l/m2/hr)	26.02				
Beta	1.183				
Feed Press(bar)	12.851				
DP(bar)	0.085				
Conc Press(bar)	12.766				
Perm Press(bar)	0.0				
Pi_Feed(bar)	2.486				
Pi_Memb(bar)	3.280				
Pi_Conc(bar)	3.093				
Pi_Perm(bar)	0.018				
Net Press(bar)	9.552				
Perm mg/l Pass 1 Stage 1	Element 1	Element 2	Element 3	Element 4	Element 5
Ca	0.359	0.436	0.545	0.701	0.939
Mg	0.209	0.254	0.317	0.408	0.547
Na	1.408	1.709	2.134	2.747	3.677
K	0.0289	0.0351	0.0438	0.0563	0.0753
Ba	0.0025	0.003	0.0037	0.0048	0.0064
Sr	0.0025	0.003	0.0037	0.0048	0.0064
NH4	0.0093	0.0113	0.0141	0.0182	0.0243
Fe	0.0	0.0	0.0	0.0	0.0

HCO3	1.317	1.494	1.740	2.126	2.735
Cl	2.108	2.558	3.195	4.114	5.510
SO4	0.275	0.334	0.417	0.537	0.720
NO3	0.980	1.188	1.484	1.909	2.554
F	0.0189	0.0229	0.0286	0.0368	0.0492
Br	0.0038	0.0047	0.0058	0.0075	0.01
B	0.475	0.521	0.576	0.645	0.733
SiO2	0.0177	0.0209	0.0251	0.031	0.0397
PO4	0.0004	0.0005	0.0007	0.0009	0.0011
CO3	1.08E-05	1.42E-05	1.92E-05	2.85E-05	4.69E-05
CO2	12.926	12.670	12.730	12.817	12.970
pH	5.238	5.300	5.363	5.445	5.548
TDS	7.216	8.594	10.534	13.348	17.628
Perm mg/l Pass 1 Stage 1	Element 6	Stage 1			
Ca	1.326	0.691			
Mg	0.772	0.402			
Na	5.190	2.707			
K	0.106	0.0555			
Ba	0.0091	0.0047			
Sr	0.0091	0.0047			
NH4	0.0343	0.0179			
Fe	0.0	0.0			
HCO3	3.723	2.123			
Cl	7.780	4.055			
SO4	1.017	0.530			
NO3	3.602	1.881			
F	0.0694	0.0363			
Br	0.0142	0.0074			
B	0.850	0.623			
SiO2	0.0532	0.0303			
PO4	0.0016	0.0008			
CO3	8.65E-05	3.23E-05			
CO2	13.093	12.860			
pH	5.675	5.393			
TDS	24.56	13.169			
Feed mg/l Pass 1 Stage 1	Element 1	Element 2	Element 3	Element 4	Element 5
Ca	171.7	194.4	222.9	259.5	308.0
Mg	99.96	113.2	129.8	151.1	179.3
Na	275.2	311.4	356.9	415.4	492.6
K	3.632	4.110	4.708	5.476	6.491
Ba	1.176	1.332	1.527	1.778	2.109
Sr	1.176	1.332	1.527	1.778	2.109

NH4	1.172	1.326	1.519	1.767	2.094
Fe	1.178	1.334	1.530	1.781	2.115
HCO3	193.2	219.3	251.1	292.0	345.9
Cl	691.4	782.7	897.3	1,044.61	1,239.35
SO4	200.0	226.5	259.7	302.4	358.9
NO3	117.1	132.5	151.8	176.6	209.3
F	2.343	2.651	3.037	3.533	4.187
Br	1.175	1.330	1.525	1.775	2.106
B	1.043	1.118	1.206	1.310	1.434
SiO2	2.346	2.655	3.042	3.539	4.195
PO4	0.589	0.666	0.764	0.890	1.056
CO3	0.613	0.425	0.567	0.779	1.110
CO2	12.926	12.670	12.730	12.817	12.970
pH	7.260	7.378	7.430	7.487	7.550
TDS	1,764.97	1,998.31	2,290.48	2,665.98	3,162.30
Feed mg/l Pass 1 Stage 1	Element 6	Stage 1			
Ca	374.1	171.7			
Mg	217.8	99.96			
Na	597.8	275.2			
K	7.872	3.632			
Ba	2.562	1.176			
Sr	2.562	1.176			
NH4	2.539	1.172			
Fe	2.570	1.178			
HCO3	419.4	193.2			
Cl	1,504.97	691.4			
SO4	436.0	200.0			
NO3	253.8	117.1			
F	5.078	2.343			
Br	2.557	1.175			
B	1.585	1.043			
SiO2	5.090	2.346			
PO4	1.284	0.589			
CO3	1.669	0.613			
CO2	13.093	12.926			
pH	7.622	7.260			
TDS	3,839.14	1,764.97			
Pass 1 Stage 2	Element 1	Element 2	Element 3	Element 4	Element 5
Model	TM720-440	TM720-440	TM720-440	TM720-440	TM720-440
Area m^2 / dia inch	40.88 / 8	40.88 / 8	40.88 / 8	40.88 / 8	40.88 / 8
Age	4	4	4	4	4
SPI %/yr	10	10	10	10	10
SPI Applied	46.41	46.41	46.41	46.41	46.41

Fouling	0.824	0.824	0.824	0.824	0.824
Recovery %	11.851	12.480	13.034	13.416	13.498
Feed Flow(m3/hr)	8.525	7.515	6.577	5.720	4.952
Perm Flow(m3/hr)	1.010	0.938	0.857	0.767	0.668
Conc Flow(m3/hr)	7.515	6.577	5.720	4.952	4.284
Flux(l/m2/hr)	24.71	22.94	20.97	18.771	16.352
Beta	1.107	1.111	1.115	1.116	1.115
Feed Press(bar)	12.766	12.602	12.462	12.345	12.247
DP(bar)	0.165	0.140	0.117	0.0978	0.0812
Conc Press(bar)	12.602	12.462	12.345	12.247	12.166
Perm Press(bar)	0.0	0.0	0.0	0.0	0.0
Pi_Feed(bar)	3.094	3.501	3.989	4.573	5.263
Pi_Memb(bar)	3.639	4.149	4.756	5.470	6.288
Pi_Conc(bar)	3.500	3.988	4.571	5.261	6.058
Pi_Perm(bar)	0.0218	0.0272	0.0345	0.045	0.0602
Net Press(bar)	9.073	8.418	7.693	6.886	6.000
Pass 1 Stage 2	Element 6				
Model	TM720-440				
Area m^2 / dia inch	40.88 / 8				
Age	4.000				
SPI %/yr	10.000				
SPI Applied	46.41				
Fouling	0.824				
Recovery %	13.146				
Feed Flow(m3/hr)	4.284				
Perm Flow(m3/hr)	0.563				
Conc Flow(m3/hr)	3.721				
Flux(l/m2/hr)	13.775				
Beta	1.109				
Feed Press(bar)	12.166				
DP(bar)	0.0676				
Conc Press(bar)	12.098				
Perm Press(bar)	0.0				
Pi_Feed(bar)	6.061				
Pi_Memb(bar)	7.189				
Pi_Conc(bar)	6.947				
Pi_Perm(bar)	0.0827				
Net Press(bar)	5.056				
Perm mg/l Pass 1 Stage 2	Element 1	Element 2	Element 3	Element 4	Element 5
Ca	1.632	2.057	2.650	3.498	4.740
Mg	0.950	1.198	1.543	2.037	2.761
Na	6.383	8.044	10.361	13.669	18.512
K	0.131	0.164	0.212	0.279	0.377
Ba	0.0112	0.0141	0.0182	0.024	0.0325

Sr	0.0112	0.0141	0.0182	0.024	0.0325
NH4	0.0421	0.053	0.0682	0.09	0.122
Fe	0.0	0.0	0.0	0.0	0.0
HCO3	4.553	5.670	7.260	9.478	12.810
Cl	9.576	12.072	15.556	20.54	27.83
SO4	1.253	1.580	2.037	2.691	3.649
NO3	4.427	5.576	7.178	9.464	12.807
F	0.0853	0.108	0.138	0.182	0.247
Br	0.0174	0.022	0.0283	0.0374	0.0507
B	0.918	1.012	1.123	1.254	1.405
SiO2	0.0624	0.0764	0.0954	0.122	0.161
PO4	0.002	0.0025	0.0032	0.0043	0.0058
CO3	0.0001	0.0002	0.0003	0.0005	0.0009
CO2	13.379	13.580	13.864	14.389	14.984
pH	5.753	5.840	5.938	6.035	6.148
TDS	30.05	37.66	48.29	63.39	85.54
Perm mg/l Pass 1 Stage 2	Element 6	Stage 2			
Ca	6.592	3.208			
Mg	3.839	1.869			
Na	25.73	12.536			
K	0.524	0.256			
Ba	0.0452	0.022			
Sr	0.0452	0.022			
NH4	0.169	0.0825			
Fe	0.0	0.0			
HCO3	17.627	8.722			
Cl	38.70	18.834			
SO4	5.078	2.468			
NO3	17.781	8.678			
F	0.343	0.167			
Br	0.0704	0.0343			
B	1.578	1.172			
SiO2	0.218	0.112			
PO4	0.0081	0.0039			
CO3	0.0017	0.0005			
CO2	15.786	14.171			
pH	6.260	5.931			
TDS	118.3	58.19			
Feed mg/l Pass 1 Stage 2	Element 1	Element 2	Element 3	Element 4	Element 5
Ca	467.1	529.7	604.9	695.1	802.3
Mg	271.9	308.4	352.2	404.7	467.1
Na	745.7	845.1	964.5	1,107.52	1,277.02

K	9.810	11.111	12.672	14.540	16.750
Ba	3.199	3.628	4.143	4.761	5.495
Sr	3.199	3.628	4.143	4.761	5.495
NH4	3.164	3.584	4.088	4.690	5.403
Fe	3.212	3.643	4.163	4.787	5.529
HCO3	522.2	591.1	673.7	772.3	888.8
Cl	1,878.64	2,129.92	2,431.92	2,794.08	3,223.85
SO4	544.6	617.6	705.5	810.9	936.1
NO3	316.2	358.1	408.4	468.5	539.7
F	6.328	7.167	8.174	9.378	10.803
Br	3.192	3.619	4.132	4.747	5.477
B	1.769	1.883	2.007	2.140	2.277
SiO2	6.347	7.192	8.206	9.422	10.863
PO4	1.604	1.819	2.078	2.389	2.758
CO3	2.633	3.399	4.431	5.758	7.527
CO2	13.379	13.580	13.864	14.389	14.984
pH	7.700	7.742	7.785	7.822	7.860
TDS	4,790.84	5,430.65	6,199.30	7,120.52	8,213.25
Feed mg/l Pass 1 Stage 2	Element 6	Stage 2			
Ca	926.8	467.1			
Mg	539.6	271.9			
Na	1,473.40	745.7			
K	19.304	9.810			
Ba	6.348	3.199			
Sr	6.348	3.199			
NH4	6.227	3.164			
Fe	6.391	3.212			
HCO3	1,023.36	522.2			
Cl	3,722.57	1,878.64			
SO4	1,081.65	544.6			
NO3	621.9	316.2			
F	12.450	6.328			
Br	6.323	3.192			
B	2.413	1.769			
SiO2	12.533	6.347			
PO4	3.188	1.604			
CO3	9.741	2.633			
CO2	15.786	13.379			
pH	7.892	7.700			
TDS	9,480.46	4,790.84			

'TORAY' Innovation by Chemistry

System Overview Report

Project	91:Almanar Plant	
Case	1	2105 TDS AND RR%75
Revision	0	15% Recov, 1 Pass, RO Permeate, Feed: 6.7 m3/hr, TDS: 3888.9, Perm: 1.0, TDS: 22, Tot Elem: 1, 1st Elem: TM720-400
Feed Water Type	Brackish Well, Note: Auto Balance is ON	
Warnings and Errors	Warnings:0, Errors:0. See Important Notes at end /E	
Database Info :	Project Database : C:\Users\Mahmoud\Documents\TorayDS2\App_Data\DS2.sdf Membrane Database (V.20143) :.	

		Overall	Pass 1
Raw water TDS	mg/l	2,107.2	2,276.2
Feed EC @25C / @27.00C	uS	3,469.9 / 3,626.2	3,732.6 / 3,900.6
Feed Pressure	bar	0.0	11.945
Temperature	deg C	27.00	
Total DP	bar	0.935	0.935
Brine Pressure	bar	11.009	11.009
Fouling Max	4.00 yrs		0.824
SP % Increase (Max)	4.00 yrs		46.41%
Recovery	%	77.69%	76.0%
Feed Flow	m3/hr	22.50	23.00
Recycle Flow	m3/hr	0.500	0.500
Product Flow	m3/hr	17.479	17.479
Average Flux	l/m2/hr	23.75	23.75
Concentrate Flow	m3/hr	5.021	5.021
Product TDS	mg/l	39.61	31.23
Concentrate TDS	mg/l	9,375	9,375
Primary HP Pump kW	kilowatt	9.548	9.548
Power Consumption	kWh/m^3	0.546	0.546

Ions		Feed	Net Feed	Conc	Product	RO Permeate
Ca	mg/l	71.00	76.34	316.5	0.495	0.495

Mg	mg/l	93.00	99.99	414.5	0.648	0.648
Na	mg/l	518.5	560.9	2,309	11.288	8.945
K	mg/l	5.000	5.368	21.94	0.133	0.133
Ba	mg/l	1.000	1.075	4.457	0.007	0.007
Sr	mg/l	1.000	1.075	4.457	0.007	0.007
NH4	mg/l	0.500	0.537	2.194	0.0133	0.0133
Fe	mg/l	1.000	1.076	4.481	0.0	0.0
HCO3	mg/l	246.0	270.7	1,093	10.612	4.627
CO3	mg/l	0.889	2.752	21.76	0.0563	0.0005
CO2	mg/l	9.229	3.668	7.997	0.169	4.527
Cl	mg/l	834.7	897.1	3,702	11.122	11.122
SO4	mg/l	200.0	215.1	892.4	1.128	1.128
NO3	mg/l	130.0	139.6	569.7	3.702	3.702
F	mg/l	1.000	1.074	4.384	0.0279	0.0279
Br	mg/l	1.000	1.075	4.431	0.0145	0.0145
PO4	mg/l	1.000	1.075	4.470	0.0032	0.0032
SiO2	mg/l	1.000	1.074	4.418	0.0182	0.0182
B(Boron)	mg/l	0.500	0.512	1.063	0.338	0.338
TDS	mg/l	2,107	2,276	9,375	39.61	31.23
Feed EC @25C / @27.00C	uS	3,470 / 3,626	3,733 / 3,901	14,376 / 15,009	72.8 / 76.2	60.6 / 63.5
pH	pH	7.560	8.000	8.213	8.000	6.107
Osmotic Press (DS1 / Pitzer)	bar	1.469 / 1.34	1.585 / 1.44	6.408 / 5.70	0.028 / 0.03	0.0231 / 0.02
LSI / SDSI		0.20 / 0.22	0.71 / 0.73	1.94 / 1.67	-2.55 / -2.65	-4.70 / -4.81
CaSO4 / SrSO4 %	%	2.3% / 2.0%	2.5% / 2.1%	15.9% / 11.1%	0.0% / 0.0%	0.0% / 0.0%
BaSO4 / SiO2 %	%	3138.3% / 0.8%	3432.8% / 0.7%	18065.6% / 2.6%		
Pitzer % Solubility	Calcite/Dolomite	80% / 643%	245% / 6,057%	3,441% / 1,193,543%		
Pitzer % Solubility	CaSO4/SrSO4	3% / 2%	3% / 2%	17% / 12%		

Stage/Bank Data	Pass1	Stage 1	Stage 2	Stage 3
Lead Element Type		TM720-440	TM720-440	TM720-440
Last Element Type		TM720-440	TM720-440	TM720-440
Total Elements	18	9	6	3
Total Vessels	6	3	2	1
Elements per Vessel		3	3	3
Feed Flow	m3/hr	23.00	12.766	7.425
Product Flow	m3/hr	10.234	5.342	1.904

Average Flux	l/m2/hr	27.82	21.78	15.524
Brine Flow	m3/hr	12.766	7.425	5.521
Recovery %	%	44.50 %	41.84 %	25.64 %
Feed Pressure	bar	11.945	11.624	11.366
dP Elements	bar	0.321	0.258	0.357
Boost Pressure	bar	0.0	0.0	0.0
Piping Loss	bar	0.0	0.0	0.0
Net (Boost - dP piping)	bar	0.0	0.0	0.0
Brine Pressure	bar	11.624	11.366	11.009
Permeate Pressure	bar	0.0	0.0	0.0
Feed TDS	mg/l	2,276	4,087	6,996
Perm TDS	mg/l	16.027	39.37	90.13
Lead Element	Pass1	Stage 1	Stage 2	Stage 3
Feed Flow	m3/hr	7.667	6.383	7.425
Product Flow	m3/hr	1.208	0.989	0.703
Product TDS	mg/l	11.576	28.35	85.25
Flux	l/m2/hr	29.54	24.19	17.197
Last Element	Pass1	Stage 1	Stage 2	Stage 3
Product Flow	m3/hr	1.061	0.785	0.560
Product TDS	mg/l	21.67	54.33	104.8
Brine/Product Ratio	ratio	4.011	4.727	9.862
Brine Flow	m3/hr	4.255	3.712	5.521
Net Driving Pressure	bar	8.719	6.456	4.603
Beta		1.170	1.141	1.072

Chemicals 100%. Disclaimer: These estimated dose rates are provided as a courtesy to Toray DS2 users and are not guaranteed.
Feed Final: Sodium Hydroxide, 6.00 mg/l, 3.31 kg/day Product: Sodium Hydroxide, 4.07 mg/l, 1.71 kg/day

Warnings

Errors

Disclaimer :
The program is intended to be used by persons having technical skill, at their own discretion and risk. The projections, obtained with the program, are the expected system performance, based on the average, nominal element-performance and are not automatically guaranteed. Toray shall not be liable for any error or miscalculation in the program.
The obtained results cannot be used to raise any claim for liability or warranty.
It is the users responsibility to make provisions against fouling, scaling and chemical attacks, to account for piping and valve pressure losses, feed pump suction pressure and permeate backpressure. For questions please contact us:

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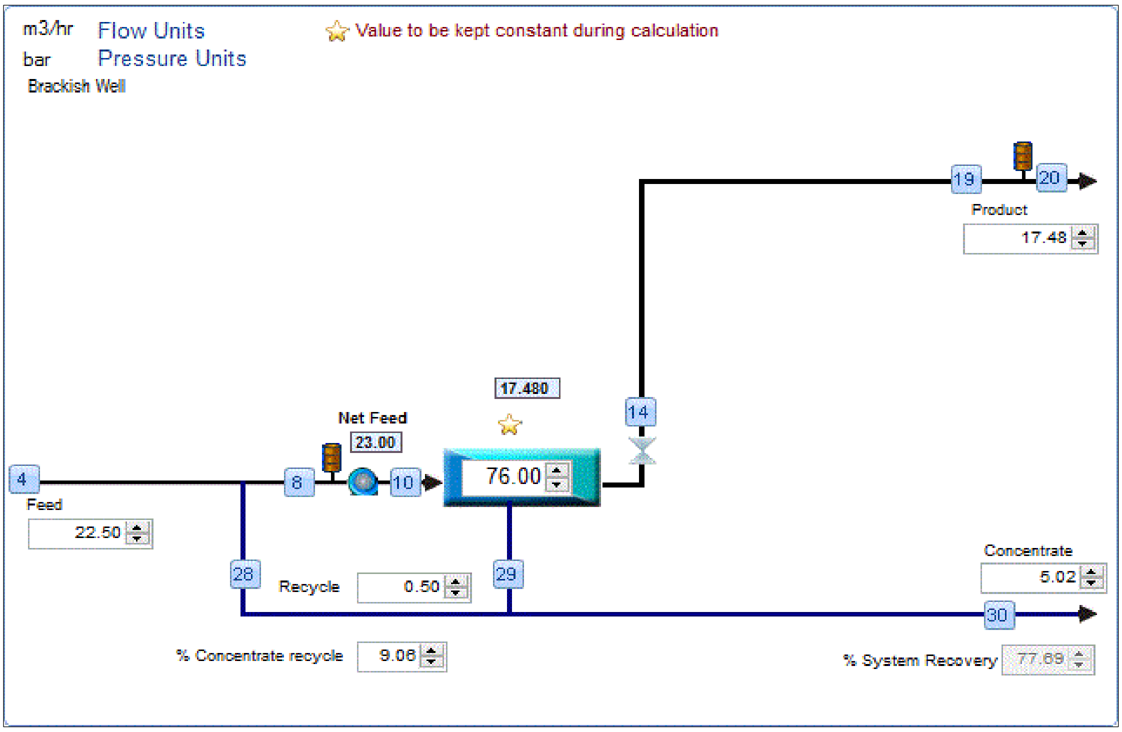
Date/Time :	16/10/12 4:40:08 PM
Project	91:Almanar2
Case :	1:2105 TDS AND RR%75
Revision :	0:15% Recov, 1 Pass, RO Permeate, Feed: 6.7 m3/hr, TDS: 3888.9, Perm: 1.0, TDS: 22, Tot Elem: 1, 1st Elem: TM720-400
User name :	TDS2 USER
Prepared for :	
Notes :	
Membrane Database	
Version Number:	20143
Release Date:	15/07/28
Update By:	HirooT
Toray DS2 version :	2.0.3.114

Flow Diagram:



Stream Details					
Stream Number	Flow	Pressure	TDS	Est uS	pH
20. Final Product	17.479	0.0	39.61	72.8	8.000
4. Feed Net	22.50	0.0	2,107.16	3,469.9	7.560
28. Pass 1 Recycle	0.500	11.009	9,375.10	14,376.4	7.560
29. Pass 1 Conc	5.521	11.009	9,375.10	8.213	
10. Feed to Pass 1	23.00	11.945	2,276.24	3,732.6	8.000
19. Permeate with blend	17.479	0.0	31.23	60.6	6.107
30. Conc to brine	5.021	11.009	9,375.10	14,376.4	8.213

Pass 1 Stage 1	Element 1	Element 2	Element 3	
Model	TM720-440	TM720-440	TM720-440	
Area m^2 / dia inch	40.88 / 8	40.88 / 8	40.88 / 8	
Age	3	3	3	
SPI %/yr	5	5	5	
SPI Applied	15.763	15.763	15.763	
Fouling	0.848	0.848	0.848	
Recovery %	15.751	17.694	19.955	
Feed Flow(m3/hr)	7.667	6.459	5.316	
Perm Flow(m3/hr)	1.208	1.143	1.061	
Conc Flow(m3/hr)	6.459	5.316	4.255	
Flux(l/m2/hr)	29.54	27.96	25.95	
Beta	1.135	1.151	1.170	
Feed Press(bar)	11.945	11.811	11.705	
DP(bar)	0.134	0.106	0.0811	
Conc Press(bar)	11.811	11.705	11.624	
Perm Press(bar)	0.0	0.0	0.0	
Pi_Feed(bar)	1.585	1.876	2.272	
Pi_Memb(bar)	1.957	2.376	2.964	
Pi_Conc(bar)	1.876	2.272	2.826	
Pi_Perm(bar)	0.0087	0.0116	0.0161	
Net Press(bar)	9.931	9.395	8.719	
Perm mg/l Pass 1 Stage 1	Element 1	Element 2	Element 3	Stage 1
Ca	0.180	0.242	0.341	0.251
Mg	0.236	0.318	0.447	0.329
Na	3.262	4.390	6.173	4.545
K	0.0488	0.0657	0.0923	0.068
Ba	0.0025	0.0034	0.0048	0.0035
Sr	0.0025	0.0034	0.0048	0.0035
NH4	0.0049	0.0066	0.0092	0.0068
Fe	0.0	0.0	0.0	0.0

HCO3	1.774	2.345	3.251	2.425
Cl	4.049	5.450	7.666	5.643
SO4	0.409	0.551	0.776	0.571
NO3	1.354	1.821	2.559	1.885
F	0.0102	0.0137	0.0193	0.0142
Br	0.0053	0.0071	0.01	0.0074
B	0.228	0.261	0.306	0.263
SiO2	0.0078	0.01	0.0134	0.0103
PO4	0.0011	0.0015	0.0022	0.0016
CO3	7.16E-05	0.0001	0.0002	0.0001
CO2	3.668	3.696	4.042	3.794
pH	5.908	6.025	6.128	6.006
TDS	11.576	15.489	21.67	16.027
Feed mg/l Pass 1 Stage 1	Element 1	Element 2	Element 3	Stage 1
Ca	76.34	90.57	110.0	76.34
Mg	99.99	118.6	144.1	99.99
Na	560.9	665.2	807.2	560.9
K	5.368	6.363	7.717	5.368
Ba	1.075	1.276	1.549	1.075
Sr	1.075	1.276	1.549	1.075
NH4	0.537	0.636	0.772	0.537
Fe	1.076	1.277	1.551	1.076
HCO3	270.7	320.9	388.4	270.7
Cl	897.1	1,064.01	1,291.58	897.1
SO4	215.1	255.2	309.9	215.1
NO3	139.6	165.4	200.6	139.6
F	1.074	1.272	1.543	1.074
Br	1.075	1.274	1.547	1.075
B	0.512	0.565	0.631	0.512
SiO2	1.074	1.274	1.545	1.074
PO4	1.075	1.276	1.550	1.075
CO3	2.752	3.264	4.506	2.752
CO2	3.668	3.696	4.042	3.668
pH	8.000	8.063	8.100	8.000
TDS	2,276.24	2,699.64	3,276.22	2,276.24
Pass 1 Stage 2	Element 1	Element 2	Element 3	
Model	TM720-440	TM720-440	TM720-440	
Area m^2 / dia inch	40.88 / 8	40.88 / 8	40.88 / 8	
Age	3	3	3	
SPI %/yr	5	5	5	
SPI Applied	15.763	15.763	15.763	
Fouling	0.848	0.848	0.848	
Recovery %	15.495	16.618	17.462	
Feed Flow(m3/hr)	6.383	5.394	4.498	

Perm Flow(m3/hr)	0.989	0.896	0.785	
Conc Flow(m3/hr)	5.394	4.498	3.712	
Flux(l/m2/hr)	24.19	21.93	19.211	
Beta	1.129	1.137	1.141	
Feed Press(bar)	11.624	11.518	11.433	
DP(bar)	0.106	0.0848	0.0667	
Conc Press(bar)	11.518	11.433	11.366	
Perm Press(bar)	0.0	0.0	0.0	
Pi_Feed(bar)	2.826	3.333	3.982	
Pi_Memb(bar)	3.465	4.140	4.989	
Pi_Conc(bar)	3.333	3.982	4.802	
Pi_Perm(bar)	0.021	0.0283	0.0399	
Net Press(bar)	8.130	7.368	6.456	
Perm mg/l Pass 1 Stage 2	Element 1	Element 2	Element 3	Stage 2
Ca	0.448	0.609	0.864	0.625
Mg	0.587	0.799	1.133	0.818
Na	8.101	11.019	15.622	11.292
K	0.121	0.164	0.233	0.169
Ba	0.0063	0.0086	0.0122	0.0088
Sr	0.0063	0.0086	0.0122	0.0088
NH4	0.0121	0.0164	0.0233	0.0169
Fe	0.0	0.0	0.0	0.0
HCO3	4.219	5.662	7.994	5.813
Cl	10.066	13.698	19.430	14.038
SO4	1.020	1.388	1.971	1.423
NO3	3.356	4.562	6.463	4.674
F	0.0253	0.0344	0.0487	0.0352
Br	0.0131	0.0178	0.0253	0.0183
B	0.345	0.398	0.465	0.398
SiO2	0.0168	0.0221	0.0303	0.0225
PO4	0.0029	0.0039	0.0055	0.004
CO3	0.0003	0.0005	0.001	0.0006
CO2	4.580	5.054	5.706	5.070
pH	6.185	6.268	6.365	6.260
TDS	28.35	38.41	54.33	39.37
Feed mg/l Pass 1 Stage 2	Element 1	Element 2	Element 3	Stage 2
Ca	137.3	162.4	194.7	137.3
Mg	179.9	212.8	255.0	179.9
Na	1,006.90	1,190.05	1,425.03	1,006.90
K	9.617	11.359	13.589	9.617
Ba	1.934	2.288	2.742	1.934

Sr	1.934	2.288	2.742	1.934
NH4	0.962	1.136	1.359	0.962
Fe	1.938	2.293	2.750	1.938
HCO3	483.0	569.4	680.0	483.0
Cl	1,611.65	1,905.32	2,282.32	1,611.65
SO4	387.0	457.8	548.7	387.0
NO3	249.9	295.1	353.0	249.9
F	1.923	2.271	2.716	1.923
Br	1.930	2.282	2.733	1.930
B	0.712	0.779	0.855	0.712
SiO2	1.927	2.278	2.727	1.927
PO4	1.936	2.291	2.747	1.936
CO3	6.376	8.264	10.778	6.376
CO2	4.580	5.054	5.706	4.580
pH	8.133	8.155	8.173	8.133
TDS	4,086.84	4,830.40	5,784.55	4,086.84
Pass 1 Stage 3	Element 1	Element 2	Element 3	
Model	TM720-440	TM720-440	TM720-440	
Area m^2 / dia inch	40.88 / 8	40.88 / 8	40.88 / 8	
Age	4	3	3	
SPI %/yr	10	5	5	
SPI Applied	46.41	15.763	15.763	
Fouling	0.824	0.848	0.848	
Recovery %	9.469	9.538	9.207	
Feed Flow(m3/hr)	7.425	6.722	6.080	
Perm Flow(m3/hr)	0.703	0.641	0.560	
Conc Flow(m3/hr)	6.722	6.080	5.521	
Flux(l/m2/hr)	17.197	15.682	13.694	
Beta	1.076	1.076	1.072	
Feed Press(bar)	11.366	11.232	11.114	
DP(bar)	0.134	0.118	0.104	
Conc Press(bar)	11.232	11.114	11.009	
Perm Press(bar)	0.0	0.0	0.0	
Pi_Feed(bar)	4.803	5.291	5.834	
Pi_Memb(bar)	5.420	5.972	6.548	
Pi_Conc(bar)	5.290	5.833	6.407	
Pi_Perm(bar)	0.0624	0.0605	0.0765	
Net Press(bar)	5.952	5.271	4.603	
Perm mg/l Pass 1 Stage 3	Element 1	Element 2	Element 3	Stage 3
Ca	1.362	1.321	1.678	1.441
Mg	1.785	1.731	2.199	1.889
Na	24.60	23.85	30.28	26.01

K	0.366	0.355	0.450	0.387
Ba	0.0192	0.0186	0.0236	0.0203
Sr	0.0192	0.0186	0.0236	0.0203
NH4	0.0366	0.0355	0.045	0.0387
Fe	0.0	0.0	0.0	0.0
HCO3	12.436	12.083	15.240	13.141
Cl	30.61	29.69	37.71	32.39
SO4	3.108	3.016	3.833	3.290
NO3	10.168	9.849	12.498	10.746
F	0.0767	0.0743	0.0942	0.081
Br	0.0399	0.0386	0.0491	0.0422
B	0.563	0.552	0.608	0.573
SiO2	0.0464	0.0443	0.0555	0.0484
PO4	0.0087	0.0084	0.0107	0.0092
CO3	0.0021	0.0019	0.0028	0.0022
CO2	6.494	6.966	7.477	6.942
pH	6.498	6.455	6.523	6.490
TDS	85.25	82.68	104.8	90.13
Feed mg/l Pass 1 Stage 3	Element 1	Element 2	Element 3	Stage 3
Ca	235.7	260.2	287.5	235.7
Mg	308.7	340.8	376.6	308.7
Na	1,723.20	1,900.86	2,098.76	1,723.20
K	16.415	18.094	19.964	16.415
Ba	3.319	3.665	4.049	3.319
Sr	3.319	3.665	4.049	3.319
NH4	1.642	1.809	1.996	1.642
Fe	3.332	3.681	4.069	3.332
HCO3	820.0	903.1	995.6	820.0
Cl	2,761.04	3,046.63	3,364.71	2,761.04
SO4	664.4	733.5	810.6	664.4
NO3	426.4	469.9	518.4	426.4
F	3.281	3.616	3.989	3.281
Br	3.306	3.647	4.028	3.306
B	0.937	0.976	1.021	0.937
SiO2	3.298	3.638	4.017	3.298
PO4	3.326	3.673	4.060	3.326
CO3	14.255	16.421	18.946	14.255
CO2	6.494	6.966	7.477	6.494
pH	8.190	8.198	8.205	8.190
TDS	6,995.77	7,717.94	8,522.25	6,995.77