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Theme :

Computational Study of Data Using IMS-Design Software – Case of Brackish Water

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Dedication

I dedicate this work to my dear parents.

to my loving wife,

to my sister and her husband,

to my brothers and their wives,

and especially to my beloved daughter, Djana,

inexhaustible source of joy and motivation.

May this achievement be a tribute to your love, support and presence in my life.

May God protect you all and shower you with His blessings.

Thanks

Praise be to Almighty Allah, the Compassionate, the Merciful, who has enabled me to complete this work and take an important step in my academic career. May His peace and blessings be upon our Prophet Muhammad, and upon his family and companions.

I would like to express my deepest gratitude to ***Dr. Boudjema Boughrara*** *and* ***Dr. Walid Boudoun*** *whom supervised this work with great professionalism, exemplary scientific rigor and constant benevolence. their attentive supervision, sound advice and unfailing support were essential to the success of this dissertation. I would like to express my sincere thanks.*

My thanks also go to all my teachers, for the knowledge they passed on to me and for their support throughout my university career.

Last but not least, I would like to thank all the people who contributed, in one way or another, to the elaboration of this thesis. To each and every one of you, I say thank you from the bottom of my heart.

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Glossary of Abbreviations

RO	Reverse Osmosis
TDS	Total Dissolved Solids
SDI	Silt Density Index
pH	Potential of Hydrogen (acidity/basicity of water)
CE	Electrical Conductivity
TH	Total Hardness
TA / TAC	Alkalinity (Total Alkalinity / Complete Alkalimetric Title)
IMS-Design	Integrated Membrane System Design (simulation software developed by Hydranautics)
LD	Low Differential (Hydranautics membrane series with low pressure drop)
HP	High Performance or High Pressure
ESPA	Energy Saving Polyamide (series of Hydranautics RO membranes)
LMH	Liters per square Meter per Hour (unit of permeate flux)
kWh/m^3	Kilowatt-hours per cubic meter (specific energy consumption)
RAS	Sodium Adsorption Ratio
CIP	Clean-In-Place (membrane cleaning procedure)
CD	Capacitive Deionization
UF	Ultrafiltration
MF	Microfiltration
NF	Nanofiltration
MED	Multi-Effect Distillation
MSF	Multi-Stage Flash distillation
VC	Vapor Compression
π	Osmotic Pressure
Jw / Js	Water flux / Salt flux
CCPP	Calcium Carbonate Precipitation Potential
LSI	Langelier Saturation Index
SRSD	Scaling Risk and Saturation Degree
WHO	World Health Organization

GENERAL INTRODUCTION

General introduction

The scarcity of freshwater resources is one of the major challenges of the 21st century. Faced with a rising world population, growing urbanization and increasing industrial and agricultural activities, demand for drinking water is constantly increasing, while natural supplies are stabilizing or deteriorating under the impact of pollution and climate change. To this end, the desalination of brackish and marine waters is seen as an alternative solution to solving the water deficit especially in arid and semi-arid zones where the availability of freshwater is reduced. **[1 - 2].**

Brackish water, with a total dissolved solids (TDS) concentration of between 1,000 and 10,000 mg/L, represents an under-exploited but valuable resource. They are abundant in coastal aquifers, estuaries and certain continental areas, and their treatment can extend the potential for supplying drinking or industrial water. However, the variability of their chemical composition, the presence of scaling and organic ions, as well as the energy and economic stakes involved, require the judicious choice of high-performance, sustainable technologies.

Other desalination processes include membrane filtration based on reverse osmosis. This technique is currently enjoying great success due to its efficiency, adaptability and relatively low energy consumption. **[3].**

Although RO has been explored for over 50 years now, RO membranes have become increasingly specialized, varying in salinity and flow rate .Hydranautics, the world leader in membrane technology, offers a range of elements (ESPA2-LD, ESPA4-LD, ESPA2-LD MAX, ESPA4-LD HP) designed to optimize the compromise between flux, solute retention, energy consumption and robustness against clogging. **[4]**

The aim of this paper is to evaluate and compare, using IMS-Design simulation software, different configurations of Hydranautics reverse osmosis modules for the treatment of typical brackish water. Study parameters include feed pressure, specific energy, permeate quality (TDS, ions), concentrate composition, as well as clogging and saturation indices. The analysis will focus in particular on single-membrane and multi-membrane configurations (single and mixed), in order to identify the design offering the best technical, economic and environmental compromise.

This work is structured in four main parts:

1. Bibliographical chapter: State of the art on brackish water, desalination processes and membrane technology.
2. Practical chapter:

- ➢ Presentation of IMS-Design software, simulation methodology and description of scenarios.
- ➢ Results and discussion: Comparative analysis of the hydraulic, energetic and qualitative performance of permeates and concentrates.

3. Conclusion and outlook: Summary of findings, recommendations for optimization and future research avenues.

By laying the theoretical and methodological foundations, this introduction prepares the reader to approach the challenges and issues of membrane treatment of brackish water, with a view to efficiency and sustainability.

Chapter I: Brackish waters

I.1 Different types of salt water:

Salt water is distinguished primarily by its salinity, which is the concentration of dissolved salts in the water.

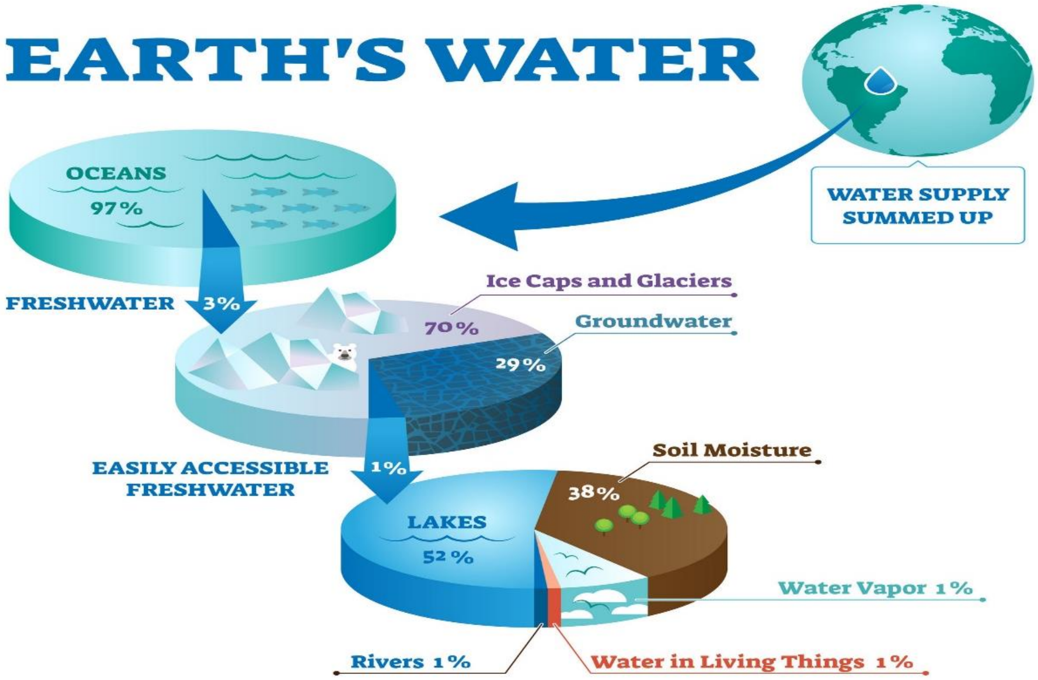


Figure I.1: The share of freshwater on earth **[5].**

I.1.1 Seawater

Seawater is a type of salt water that covers around 70% of the Earth's surface and constitutes the majority of the planet's water reserves. Here are some key characteristics of seawater **[6]**:

I.1.1.A Salinity

The average salinity of the oceans is around 35 g/L, although this can vary from region to region. For example, the Mediterranean Sea has a salinity of 36 to 39 g/L, while the Red Sea reaches around 40 g/L **[9]**.

I.1.1.B Chemical Compositions

Seawater is mainly composed of sodium ions (Na^+), chloride (Cl^-), magnesium (Mg^{2+}), sulfate (SO_4^{2-}), and calcium (Ca^{2+}). The main dissolved salts include sodium chloride (NaCl), magnesium chloride ($MgCl_2$), magnesium sulfate ($MgSO_4$), and calcium sulfate ($CaSO_4$).

I.1.1.C Physical properties

- The density of seawater varies between 1,020 and 1,029 kg/m³, depending on temperature and salinity.
- Seawater freezes at around -1.91°C for a salinity of 35 g/L.

I.1.1.D Radioactivity

- Seawater is naturally radioactive, mainly due to potassium-40.

I.1.1.E Ecological and economic importance

- Seawater plays an essential role in the global climate and is a major source of fish and mineral resources.

I.1.1.F Uses and Impact :

- *Desalination*: Seawater is often used for desalination to produce drinking water, particularly in regions where access to fresh water is limited.
- *Industry and energy*: Seawater is used in various industries, such as salt production, and can be a source of renewable energy via marine energies.
- *Marine ecosystems*: Seawater is home to a wide variety of marine ecosystems essential to biodiversity and the carbon cycle.

I.1.2 Closed salt water (salt lakes)

Closed salt waters, often referred to as salt lakes, are bodies of water of varying salinity that do not drain into the oceans **[7]**:

I.1.2.A Salinity

- The salinity of salt lakes can be very high, often higher than that of seawater, due to evaporation, which concentrates the salts.

For example, the Dead Sea has a salinity of around 270 g/L, much higher than the average for the oceans (around 35 g/L).

I.1.2.B Types of salt lakes

- **Endoreic lakes**: These lakes have no outlet and accumulate salts over time. Examples: Dead Sea, Lake Urmia.
- **Temporary lakes**: Some may be seasonal, forming after periods of heavy rainfall, but drying up quickly.

I.1.2.C Chemical composition

Salt lakes contain various dissolved salts, including sodium chloride (NaCl), magnesium sulfate ($MgSO_4$), and sodium carbonate (Na_2CO_3). The composition depends on the minerals present in the surrounding soil.

I.1.2.D Ecological and economic importance

- *Biodiversity*: Although their environment is hostile to many species, some organisms, such as halophiles (salt-tolerant micro-organisms), thrive in these extreme environments.
- *Mineral resources*: Salt lakes are often exploited for their minerals, particularly salt and lithium, making them important economic resources.
- *Environmental impact*: The high concentration of salts can have effects on surrounding ecosystems, notably by modifying the chemical composition of soils and affecting local flora and fauna.

I.1.3 Irrigation salt water

Saltwater irrigation is used to water crops in regions where access to fresh water is limited. Here are a few key aspects concerning these waters **[8]**:

I.1.3.A Salinity

- Salinity is measured by electrical conductivity (EC) or total dissolved solids (TDS). Water with an EC of over 1.5 dS/m is considered salty, and above 3 dS/m it is very salty.
- Waters with a salinity between 2 and 5 g/L are considered salty, and those above 5 g/L are very salty.

I.1.3.B Chemical composition

- Salt irrigation water contains mainly sodium (Na^+), chloride (Cl^-), sulfate (SO_4^{2-}), calcium (Ca^{2+}), and magnesium (Mg^{2+}) ions.
- The sodium absorption ratio (SAR) is important for assessing the risk of soil alkalinization, which can be problematic for certain crops.

I.1.3.C Risks and Concerns

- *Soil salinization*: The use of salt water can lead to an accumulation of salt in soils, reducing their fertility and affecting plant growth.
- *Impact on crops*: Plants vary in their tolerance to salinity. Some crops can be sensitive to even moderate levels of salt.

I.2 Brackish water: characteristics, challenges and treatment

I.2.1 Introduction

Brackish water is water with a salinity between that of freshwater and that of seawater. They generally contain between 1,000 and 10,000 mg/L of total dissolved solids (TDS), making them unfit for human consumption without prior treatment. These waters occur naturally in estuaries, lagoons, coastal aquifers and certain rivers subject to saline intrusion. They are an important water resource, particularly for arid and semi-arid regions where fresh water is scarce **[18].**

I.2.2 Characteristics and origin

Brackish water can be of natural or anthropogenic origin. It results from geological phenomena, such as the dissolution of minerals in aquifers, or seawater intrusions into groundwater. Human activity, notably excessive irrigation and groundwater extraction, can also increase the salinity of certain water resources.

Chemically speaking, brackish water contains major ions such as sodium (Na^+), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}) and sulfate (SO_4^{2-}). Their composition can vary according to origin and interactions with the surrounding soil and rocks **[14]**.

I.2.3 Issues related to brackish water exploitation

The use of brackish water presents several challenges, including:

- **Potability and public health**: Excessive salinity can cause kidney problems and electrolyte imbalances in humans.
- **Agriculture**: Irrigation with brackish water can cause salts to accumulate in the soil, reducing its fertility.
- **Industry**: Some industries, notably the textile and petrochemical sectors, use this water, but they often require prior treatment.

I.2.4 Environmental impact and sustainable solutions

The desalination of brackish water generates concentrated brine discharges that can affect aquatic ecosystems. Several strategies are in place to minimize this impact:

- **Optimized discharge management**: dilution before discharge into the environment.
- **Brine valorization**: Extraction of salts and minerals.
- **Use of renewable energies**: Reducing the carbon footprint of desalination plants.

I.2.5 Conclusion

Brackish water represents a valuable alternative resource in the face of increasing scarcity of fresh water. Thanks to technological advances, their treatment is becoming increasingly efficient and accessible. However, sustainable management is needed to limit environmental impacts and ensure responsible use of this resource.

I.3 Physical and chemical properties of water:

I.3.1 Temperature

For drinking water, the maximum acceptable temperature is 15°C, as it is accepted that water should be refreshing. In natural waters and above 15°C, there is a risk of accelerated growth of micro-organisms and algae, resulting in unpleasant tastes and odors, as well as increased color and turbidity.

I.3.2 pH

pH is a measure of the acidity of water, in other words the concentration of hydrogen ions (H+).

$$pH = -\log [H^+] \ldots\ldots\ldots I.1$$

The pH of natural water can vary from 4 to 10, depending on the acidic or basic nature of the soil **[5]**.

I.3.3 Electrical conductivity

Measuring electrical conductivity enables us to assess the overall mineralization of the water and monitor its evolution, but there is no process for modifying conductivity. On the other hand, in industrial water production or in the desalination of seawater or brackish water, ion removal is not achieved by ion exchange or membrane separation **[10]**.

I.3.4 Hardness (TH)

It indicates the overall calcium and magnesium salt content of the water. Algerian waters are semi-hard, around 30F° **[11]** in hardness in the north, and are considered hard (TH above 40 and 50F°) in the south of the country **[12]**.

I.3.5 Alkalinity

The alkalinity of a water corresponds to its capacity to react with H^+ ions, which is due to the presence of the alkaline constituents $HCO3^-$, $CO3\ 2^-$, OH^-. There are two types of alkalinity:

- Total alkalinity (or total alkalimetric titre) :

$$\mathbf{TAC = [OH^-] + [CO_3^{2-}] + [HCO_3^-] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ I.2}$$

- Composite alkalinity (or alkalimetric titre) :

$$\mathbf{TA = [OH^-] + (1/2)\ [CO3^{2\,-}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots I.3}$$

The TA is determined by neutralization with a strong acid ($H2SO4$) in the presence of a color indicator (phenophthalein, pink color after titration becomes colorless).

$pH < 8.3$ then $TA = 0$; $TAC = [HCO3^-]$.

$pH > 8.3$ then $TA \neq 0$

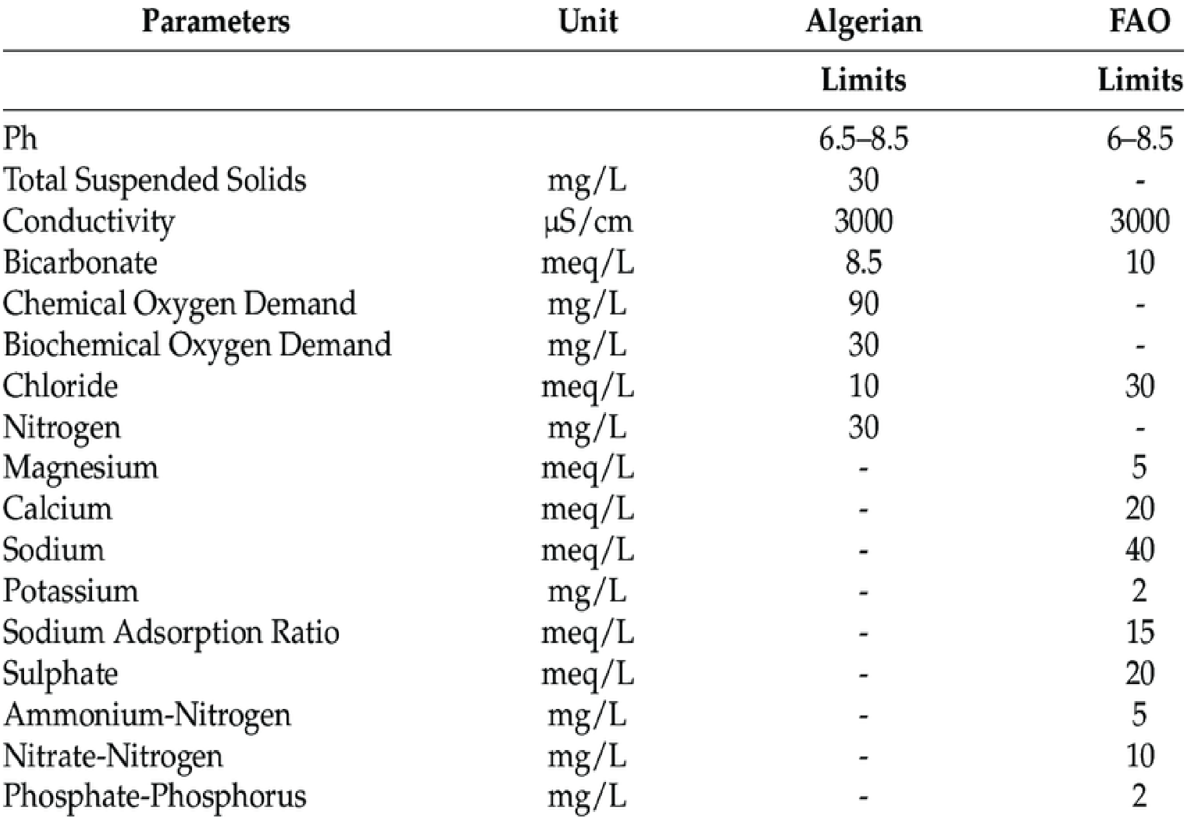
Like TA, TAC is determined by neutralizing all alkalinity with a strong acid in the presence of red-colored helianthin **[10]**.

I.3.6 Suspended solids

Suspended matter includes all mineral or organic matter that is insoluble in water. They include clays, sands, silts, small-scale organic and mineral matter, plankton and other micro-organisms in the water. The quantity of suspended solids varies according to season and water flow regime **[13]**.

I.3.7 Water potability standards (WHO)

Table 1: Algerian standards **[10].**



Parameters	Unit	Algerian	FAO
		Limits	Limits
Ph		6.5–8.5	6–8.5
Total Suspended Solids	mg/L	30	-
Conductivity	µS/cm	3000	3000
Bicarbonate	meq/L	8.5	10
Chemical Oxygen Demand	mg/L	90	-
Biochemical Oxygen Demand	mg/L	30	-
Chloride	meq/L	10	30
Nitrogen	mg/L	30	-
Magnesium	meq/L	-	5
Calcium	meq/L	-	20
Sodium	meq/L	-	40
Potassium	mg/L	-	2
Sodium Adsorption Ratio	meq/L	-	15
Sulphate	meq/L	-	20
Ammonium-Nitrogen	mg/L	-	5
Nitrate-Nitrogen	mg/L	-	10
Phosphate-Phosphorus	mg/L	-	2

Chapter II : Water desalination techniques

II.1 Introduction :

Current water desalination technologies fall into two categories, depending on the principle applied:

- Thermal processes involving phase change: freezing and distillation.
- Membrane-based processes: reverse osmosis and electrodialysis.

Among the above-mentioned processes, distillation and reverse osmosis are technologies with a proven track record in seawater desalination. In fact, these two processes are the most widely commercialized in the global desalination market. Other techniques have not experienced significant growth in the field, due to problems generally linked to energy consumption and/or the size of the investments they require.

Whatever the salt/water separation process, all desalination plants comprise 4 stages:

- seawater intake with pump and coarse filtration,
- pre-treatment with finer filtration, addition of biocides and anti-tartar products,
- the desalination process itself,
- post-treatment with remineralization of produced water.

Once these 4 steps have been completed, the seawater is ready for drinking or industrial use, and must contain less than 0.5 g of salts per liter **[15]**.

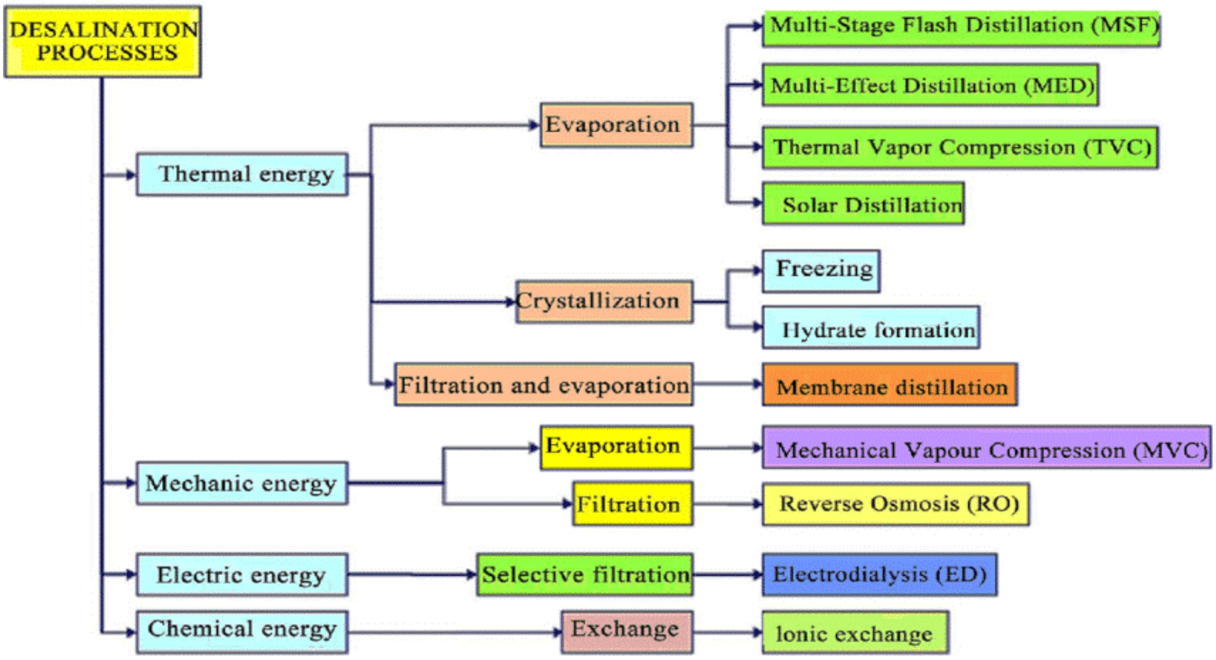


Figure II.1 : The various desalination processes **[15].**

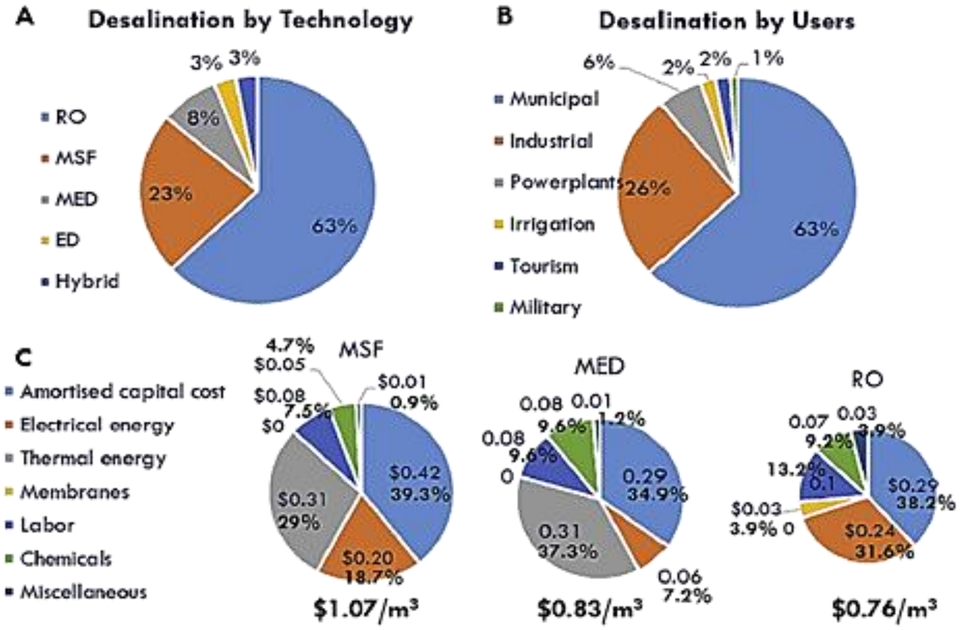


Figure II.2: Desalination industry by technology, users and cost components (Costs assume an electricity cost of \$0.05/kWh and an oil price of \$60/barrel) **[18]**

II.2 Thermal processes

Distillation is the oldest and most direct desalination process. The fundamental principle behind distillation processes is that the boiling temperature of water decreases with increasing pressure. The heat of condensation from steam produced in one stage can therefore be used to heat water in the next stage.

II.2.1 Multi Stage Flash (MSF):

In the MSF process, seawater is heated in a boiler. This is usually done by condensing the steam on a bundle of pipes carrying seawater through the boiler. This heated seawater then flows into another tank corresponding to another stage where the ambient pressure is lower, so that the water immediately begins to boil. The sudden introduction of heated water at each stage triggers expansion and instant evaporation ("flash").

In general, only a small fraction of this water is converted to steam, depending on the pressure maintained at the stage, since boiling will continue until the water returns to the boiling point.

Typically, an MSF plant comprises 15 to 25 floors. Figure II.3 shows a schematic diagram of an MSF plant **[15]**.

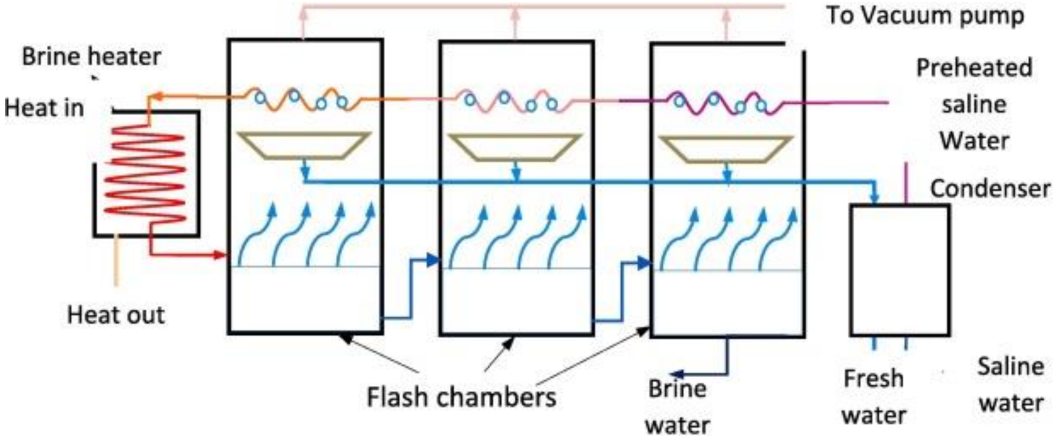


Figure II.3: Multi Stage Flash distillation **[32]**

The MED (Multi Effect Desalination) process is based on cascade distillation in several cells. The best example of how the MED process works is the "marine boiler", which has long been used on board ships.

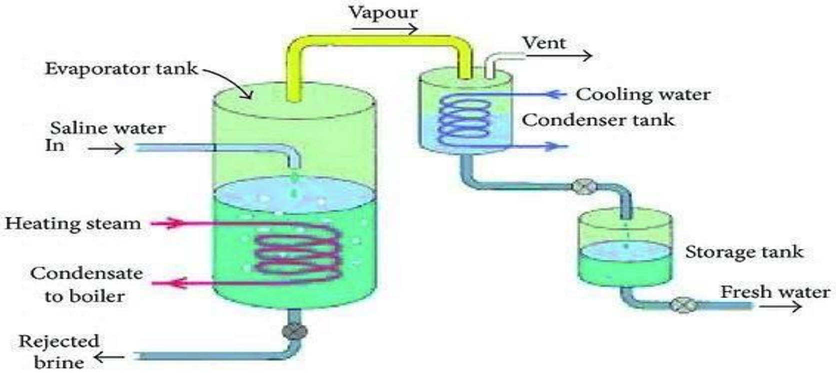


Figure II.4: Single-effect distillation principle **[33]**

A tubular bundle, fed by a heating fluid, is immersed in seawater at the bottom of a vacuum-tight enclosure. The heating fluid then evaporates the seawater. The resulting steam is condensed on a tube bundle in the upper part of the chamber, through which cold seawater circulates. The distilled and condensed water flows out of the bundle and is collected in a spout from which it is pumped for various uses.

A seawater top-up, greater than the production rate, is introduced into the chamber. Another pump evacuates a fraction of the brine so that the seawater's salinity remains at an acceptable concentration. Energy consumption in the marine boiler is around 590 kcal/kg. This is too high, and is only acceptable on boats where a large amount of heat from the various machines has to be evacuated **[16]**.

For an industrial MED process, the effects are multiplied (Figure II.5). Seawater is heated in the first effect, vaporizing a fraction of the seawater. Part of this steam is condensed by the tube bundle, where relatively cold seawater circulates. The other part of the steam is returned to the next effect, maintained at a lower pressure than the first.

Similarly, some of the brine heated in the first effect is also used to heat seawater in the second.

Steam from the first effect condenses in the second on the tube bundle, producing an almost equal amount of steam from the seawater, and so on. For each effect, the distilled water is sent to a collector **[18]**.

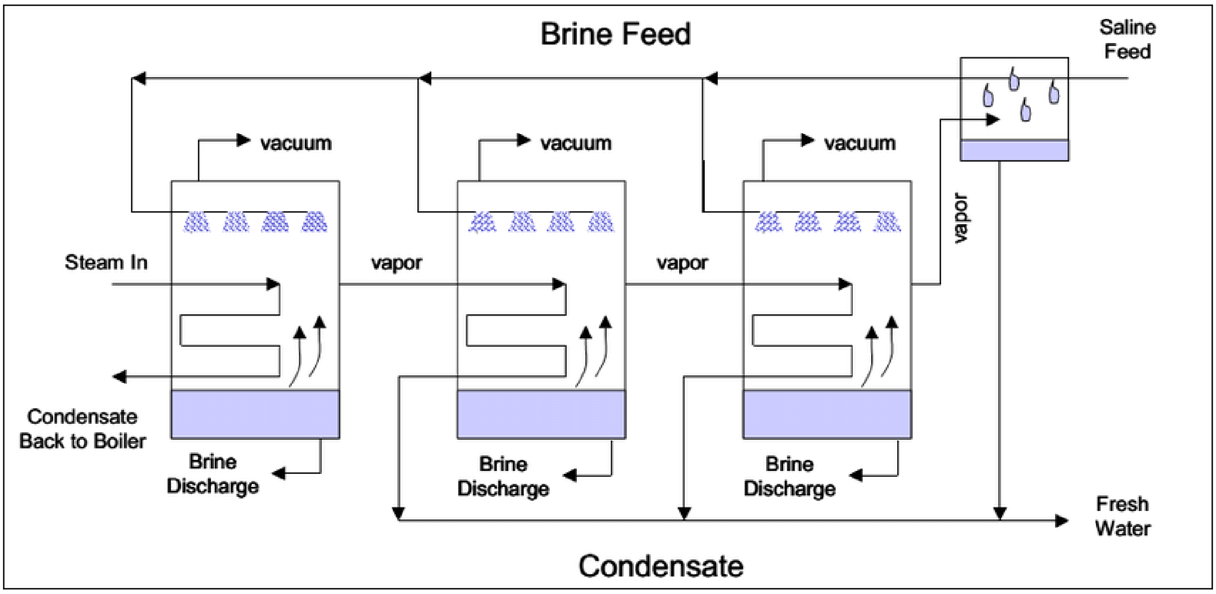


Figure II.5: Multiple-effect distillation

II.2.3 Mechanical Vapor compression (MVC)

The steam compression process involves evaporating seawater after preheating it in a heat exchanger that recovers heat from the brine.

The water vapor produced is compressed after being freed from entrained droplets by a separator. Having been pressurized, the steam then condenses at a higher temperature than that prevailing in the evaporator; thanks to the latent heat of condensation that is transferred, the evaporation and condensation cycle can then operate.

Condensed freshwater steam is extracted, along with concentrated brine containing salt (see figure II.6).

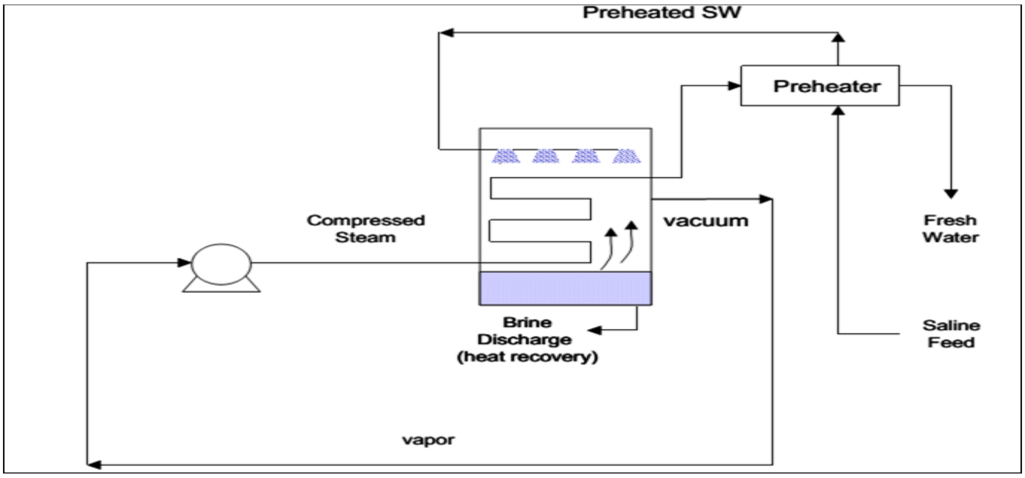


Figure II.6: Vapor compression distillation process **[35]**

If they multiply the number of effects as in the MED process, each at a higher temperature than the next, one kg of compressed steam produces **n** kg of distilled water, n being the number of effects (or cells).

II.2 Membrane processes :

II.2.1 Introduction :

Membrane filtration is a process for separating the components of a fluid. The role of the membrane is to act as a selective barrier, allowing certain elements to pass through and others to be retained, depending on the respective properties of these elements, under the effect of a driving force, which may be a potential, concentration or pressure gradient based on a pressure difference between the medium and the membrane, known as transmembrane pressure (TMP).

Figure II.7 illustrates the different areas of application for pressure-gradient membranes.

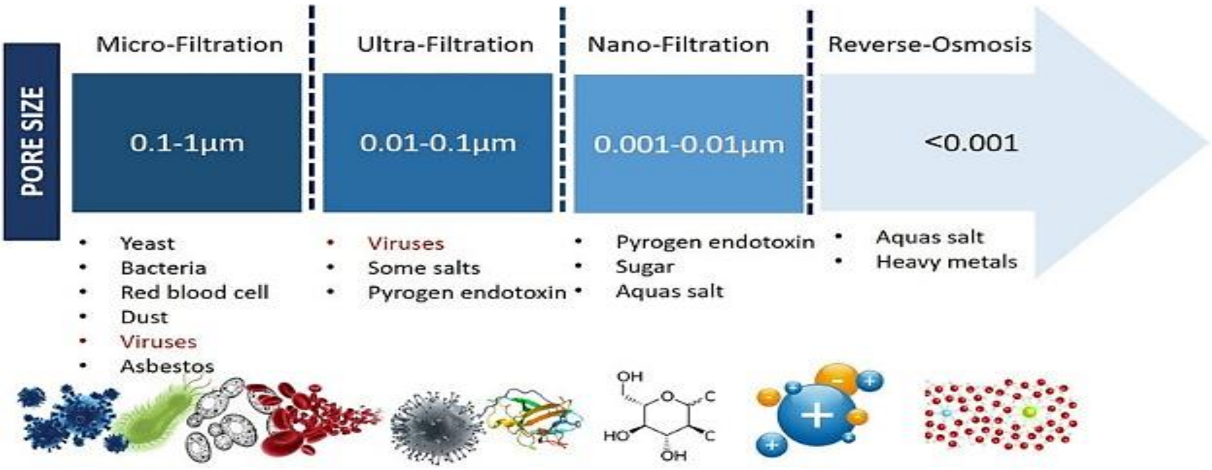


Figure II.7: Classification of barometric membrane processes according to separation size **[20].**

II.2.2 Reverse osmosis (RO):

Among membrane processes, only reverse osmosis is most utilizable for seawater desalination.

When a semi-permeable membrane is placed between two compartments filled with water of different dissolved salt concentrations, the water molecules tend to migrate from the less concentrated water to the more concentrated one, thereby reducing its salinity.

The phenomenon is called "direct osmosis". This migration stops when the difference between the levels of the two compartments has reached a value corresponding to the osmotic pressure **π**.

To reduce the concentration of dissolved salts in water, simply apply a pressure greater than the osmotic pressure to force the water molecules through the semi-permeable membrane. This is known as reverse osmosis (figure II.8).

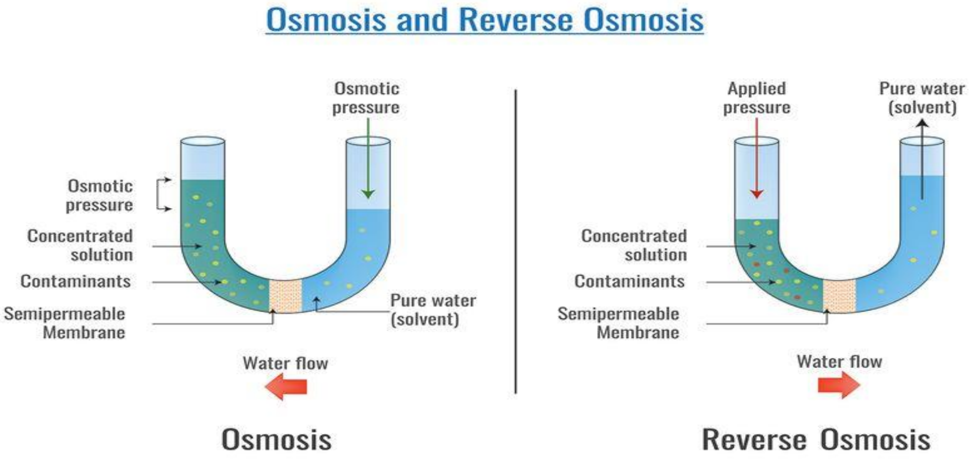


Figure II.8: principle of reverse osmosis **[21].**

An increase in pressure above the osmotic pressure will result in a flow of water in the opposite direction to the osmotic flow (see figure II.8), i.e. from the concentrated solution to the dilute solution: this is the phenomenon of reverse osmosis.

For sufficiently dilute solutions, the osmotic pressure π can be calculated according to Van't Hoff's law:

$$\pi = i \times C \times R \times T \quad \text{........II.1}$$

where :

- i: is the number of dissociated ions in the case of an electrolyte,
- C: is the salt concentration in mol.m^{-3}
- R : is the perfect gas constant R = 8.314 J.$mol^{(-1)} \cdot K^{-1}$
- T: is the absolute temperature of the solution in Kelvin.

- **Components of a reverse osmosis unit**

The components of a reverse osmosis unit are shown in figure II.9:

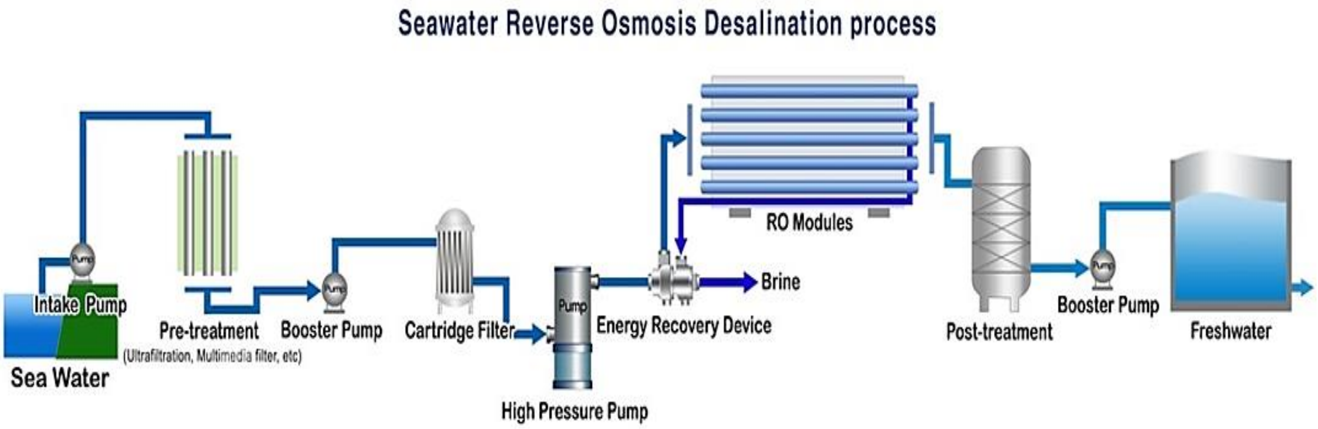


Figure II.9: Schematic diagram of a desalination plant based on the principle of reverse osmosis **[19].**

II.2.3 Electrodialysis

Electrodialysis involves the transfer of dissolved salt ions through membranes that do not allow the purified water to pass through; the movement of ions is caused by an electric field, where the negative electrode (cathode) attracts cations, while anions move towards the positive electrode (anode) (figure II.10).

The systems consist of compartmentalized stacks of alternating anionic and cationic membranes, with every other compartment containing concentrated brine and every other compartment containing purified permeate. The membranes used in electrodialysis are ion-exchange membranes in the form of sheets between 0.1 and 0.8 mm thick. In terms of properties, there are two types of membrane **[20]**:

- Cation exchange membranes are permeable only to cations, and their functional group is usually a sulfonic acid group (SO_3^-).
- Anion-exchange membranes are permeable only to anions, and their functional group is generally a quaternary ammonium group (NR_3^-).

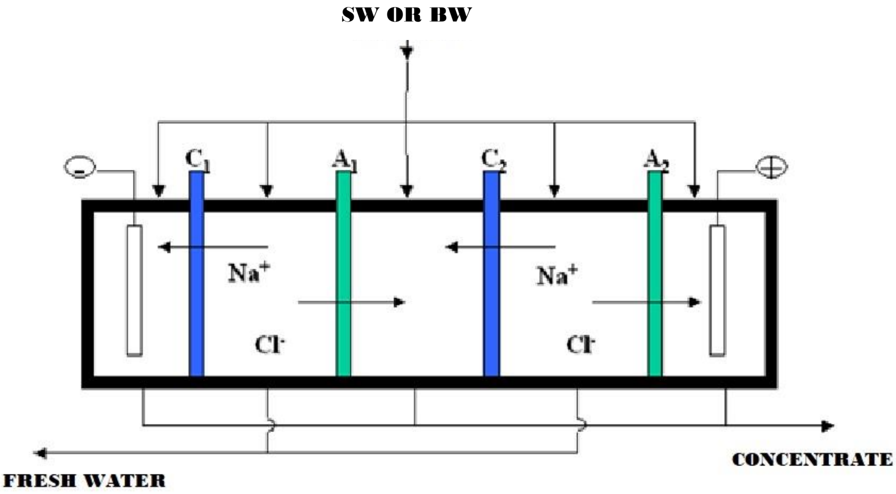


Figure II.10: Principle of desalination by electrodialysis **[21].**

II.2.4 Capacitive de-ionization

Porous carbon electrodes have significant potential for low-energy water desalination, thanks to a promising technology called capacitive de-ionization (DCM). In DCM, salt ions are removed from brackish water when an electrical voltage difference is applied between two porous electrodes, in which the ions are temporarily immobilized. These electrodes are made of porous carbons optimized for salt storage capacity and ion and electron transport.

Capacitive deionization (DCM) has emerged over the years as a robust, efficient and cost-effective technology for desalinating water with low to moderate salt content**.** The energy efficiency of DCM for water with a salt concentration of less than around 10 g/l is due to the fact that salt ions, which are the minority compound in the water, are removed from the mixture. Instead, other methods extract the majority water phase from the salt solution. In addition, the energy released during electrode regeneration (ion release, or electrode discharge) can be used to charge a neighboring cell operating in the ionic electro-sorption stage, and thus energy recovery is possible.

A DCM cycle consists of two stages, the first being an ionic electro-sorption, or charging, stage for purifying water, where ions are immobilized in pairs of porous carbon electrodes. In the next step, the ions are released, i.e. desorbed from the electrodes, and thus the electrodes are regenerated. The basic mechanism underlying capacitive de-ionization is shown schematically in figure II.11 **[26]**.

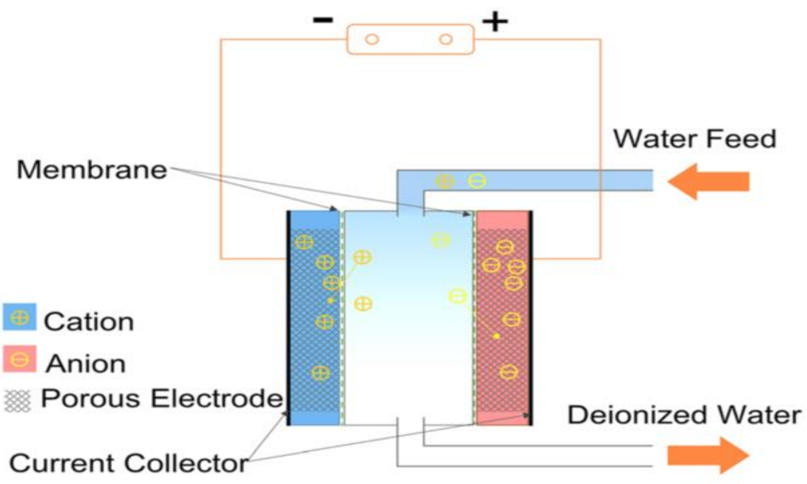


Figure II.11: DCM capacitive membrane de-ionization **[27].**

II.3 Comparative study of different technics:

There are various water desalination methods, but the choice of one technique over another depends on the type of water to be treated, local conditions, the total volume to be treated and, above all, the energy consumption of each technique. Table 2 shows a comparison based on the advantages and disadvantages of each technique.

Table 2: Comparison of different desalination techniques **[28]** :

Technical	**Benefits**	**Disadvantages**
Multi Effects (ME)	- High production capacity - Low investment costs. -High product purity (<30ppm). - Energy contribution independent of salinity. -Operator minimum qualification.	- Long construction period. - Low feed water conversion (30%-40%). - Requires large space with high equipment requirements.
Multi Stage Flash (MSF)	- Flexible feed water salinity. - High-purity production (<30ppm).	- Low conversion rate (30% -40%). - High operating costs.

Multi Stage Flash (MSF)	- High production capacity. - Low need for skilled operators. - Used for two purposes: water and electricity production. - High energy consumption.	- Many requirements during construction. - Limited potential for improvement after completion.
Steam compression (CV)	- High water quality (20ppm) - Short construction period. - Operational flexibility.	- High operating costs. - High energy consumption.
Reverse Osmosis (RO)	- Suitable for seawater and brackish water. - Flexibility in water quantity and quality. - Low energy consumption compared to MED and VC. - Flexibility of site location. - Flexibility in starting and stopping the desalination operation. - Simple technique.	- Low water quality (250-500ppm). - Requires feed water. - Relatively high investment and operating costs. - High-pressure requirements. - Long construction times for large-scale plants.
Electrodialysis	- Low operating and investment . - Flexible energy source.	- Recommended only for waters with relatively low salinity (< 3000 ppm)

Electrodialysis	- High conversion rate (80%). - Low energy consumption. - Small footprint - Low equipment requirements.	- Meticulous pre-treatment of feed water. - Low production capacity. - Purity affected by feed water quality.

PRACTICAL PART

Chapter III: Data simulation using IMS-design software

Simulation software are used in water demineralization plant design studies to develop different membrane configurations, with the aim of meeting customer requirements in terms of quality and quantity of water produced, while minimizing energy consumption.

Simulation tools play an essential role in the design and optimization of membrane-based water treatment systems. The **IMS-Design** software developed by **Hydranautics** is a powerful modeling tool for simulating the behavior of membrane modules under different operating conditions. It facilitates membrane selection, system performance evaluation and prediction of key parameters such as recovery rate, salt concentration, required pressure and clogging index.

This chapter is devoted to the use of IMS-Design software in our study. After a brief presentation of its main functionalities, simulation methodology adopted, the assumptions taken into account and the input data used. Finally, the simulation results obtained will be analyzed in order to validate the chosen configuration and guide the technical recommendations **[30]**.

III.1 Software presentation:

The Nitto Group is a world leader in the manufacture of numerous high-tech products, all using polymer synthesis technology. Founded in 1918, Nitto has always been at the forefront of new product development, integrating many cutting-edge technologies with its long-standing expertise in the synthesis of high-polymer materials.

Nitto consists of four major business divisions serving a wide range of markets, including optical media, semiconductors, flexible circuits, electrical insulation, packaging, insulation, automotive and healthcare. Nitto's global presence includes around 100 manufacturing and sales companies worldwide. At Nitto, the focus is on developing a leadership position in products and applications that create value for our customers in three strategic areas: the environment, electronics and energy **[29]**.

Nitto

HYDRANAUTICS

Nitto Group Company

Figure III.1: company logo **[29]**

Hydranautics is a world leader in membrane technology. They apply cutting-edge technology to manufacture the industry's most advanced and highest-performing membrane products.

Since their foundation in 1963, they have been committed to the highest standards of technological research, product excellence and customer satisfaction. They entered the field of reverse osmosis (RO) membranes in 1970, and today are one of the most respected and experienced companies in the industry. Nitto Denko Corporation, Japan, acquired Hydranautics in 1987, and they became part of the Nitto Global Membrane Division (GMD).

The Nitto Global Membrane Division comprises two production sites: Hydranautics, headquartered in Oceanside, California, USA, and a membrane manufacturing plant in the Shiga region of Japan. These two sites, together with a network of offices and warehouses around the world, ensure 24/7 technical and commercial support, with rapid response to customer requests. Their ongoing commitment to research and technology is reflected in the continuous development of specialized membrane products.

Hydranautics products are currently used on all seven continents. Product applications include drinking water, boiler feed water, industrial process water, wastewater treatment, surface water treatment, seawater desalination, residential water, electronics rinse water, agricultural irrigation and pharmaceuticals. Full customer service and support is available 24 hours a day, worldwide. **[29]**

III.2 IMSDesign

Integrated **M**embrane **S**ystem **Design** (**IMSDesign**) is a software package that calculates the throughput of a reverse osmosis (RO) plant. IMSDesign can be used to create a design for a water treatment plant using the reverse osmosis process. With IMSDesign, can create designs that can be implemented for plants that can be used for industries and cities. This application is designed to calculate the throughput of a reverse osmosis plant, and allows to move water data through a series of steps. Each step serves as an input to the next. Based on the results of all the steps, IMSDesign creates an analysis and design best suited to RO plants. To create the RO design, the following high-level steps are needed:

III.2.1 Analysis and backup:

This is the first step in calculating how the raw water sample is treated. Values can entered for the water analysis report and evaluate the analysis using techniques such as water balancing, measuring saturation levels and pH balance. When performing an analysis, Values needed to enter for the raw water ratio and analyze its ion combinations. In addition, IMSDesign let specify the ionic and chemical composition of feed water, permeate and reject water, and save your analysis.

III.2.2 Design

This is the second stage of the IMSDesign RO design system. In this high-level step, parameters such as permeate flow rate, recovery, membrane type, and number of stages can be specified. During the design process, it is also possible to define product flow and recovery, membrane type, membrane age, and the number of stages. Additional settings may include flow decrease rates, increased salt passage, sizing of a permeate desalting stage, application of permeate back pressure or an inter-stage booster, and concentrate flow recirculation

III.2.3 Calculation

This is the third step in the RO design process. During the calculation, the application calculates and displays the required power, chemical requirements and cost values. After creating the design, IMSDesign performs the calculation. The application calculates product quality and determines whether design limits have been exceeded.

III.2.4 Post-processing

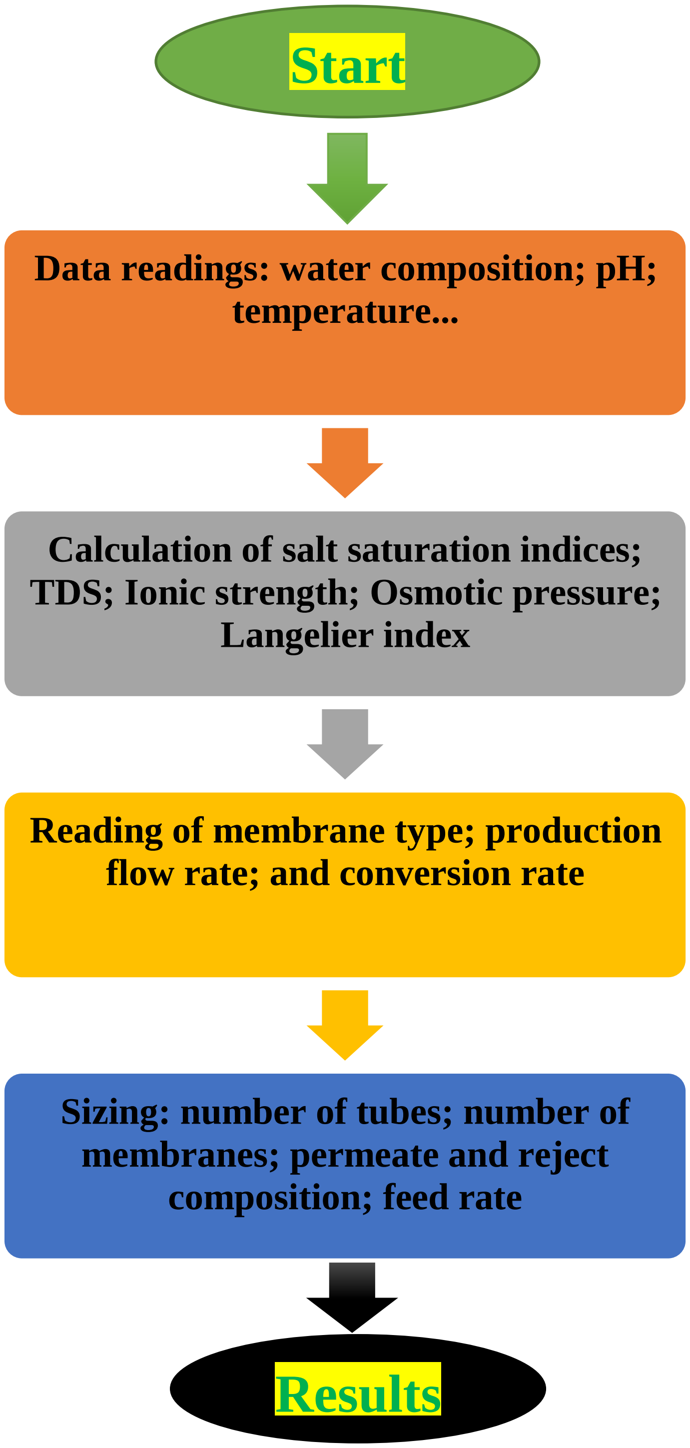
This is the fourth step in the RO design process. IMSDesign allows the addition of chemicals to the stream and the treatment of the permeate. During post-treatment, permeate treatment options can be defined along with the resulting changes in ionic concentrations and pH. Cost and energy calculations can also be analyzed.

III.3 Simulation software:

III.3.1 *IMSDesign* software:

IMS-Design is a sizing software package designed to meet the requirements of desalination professionals and experts. It offers enhanced program features, improved graphics and includes new functionalities, improving the user's ability to design and analyze membrane-based systems quickly and accurately, and to monitor the data and results obtained during reverse osmosis separation, with the aim of selecting the most efficient membrane and configuration according to the quality and quantity of demineralized water.

Intended for various activities, mainly water treatment, to supply the chemical industry (boiler), but also to supply drinking water to citizens. **[29]**



Flowchart: The software's operating mode

III.3.2 IMS-Design software operating parameters

➢ **Production flow rate:** the quantity of water produced per day **(m3/d)** in our test.

"Brackish water" 10000 m3/d.

- **Conversion rate:** The conversion rate is the ratio of the permeate flow rate to the feed flow rate. The conversion rate is highly variable, depending on the desired quality, the quality of the available resource and, in particular, the risk associated with precipitation of mineral salts on the membrane surface:

$$(\%) = \frac{Qp}{Qf} * 100 \text{ .... (III.1)}$$

Qf: Feed rate (m3/d)

Qp: Permeate flow rate (m3/d)

Y (%): Conversion rate (**60% in our "Brackish water 1" trial**)

- **Product water quality (TDS, pH....)**: analyses of permeate salinity (TDS) and pH.

- **Energy consumption:** calculates energy consumption in kilowatts per cubic meter **(kWh/m3).**

III.4 Use of software simulation for sizing and controlling the operation of different types of membrane under the following conditions: $Q_{permeate}$= 10,000 m^3/day, conversion rate = 60%.

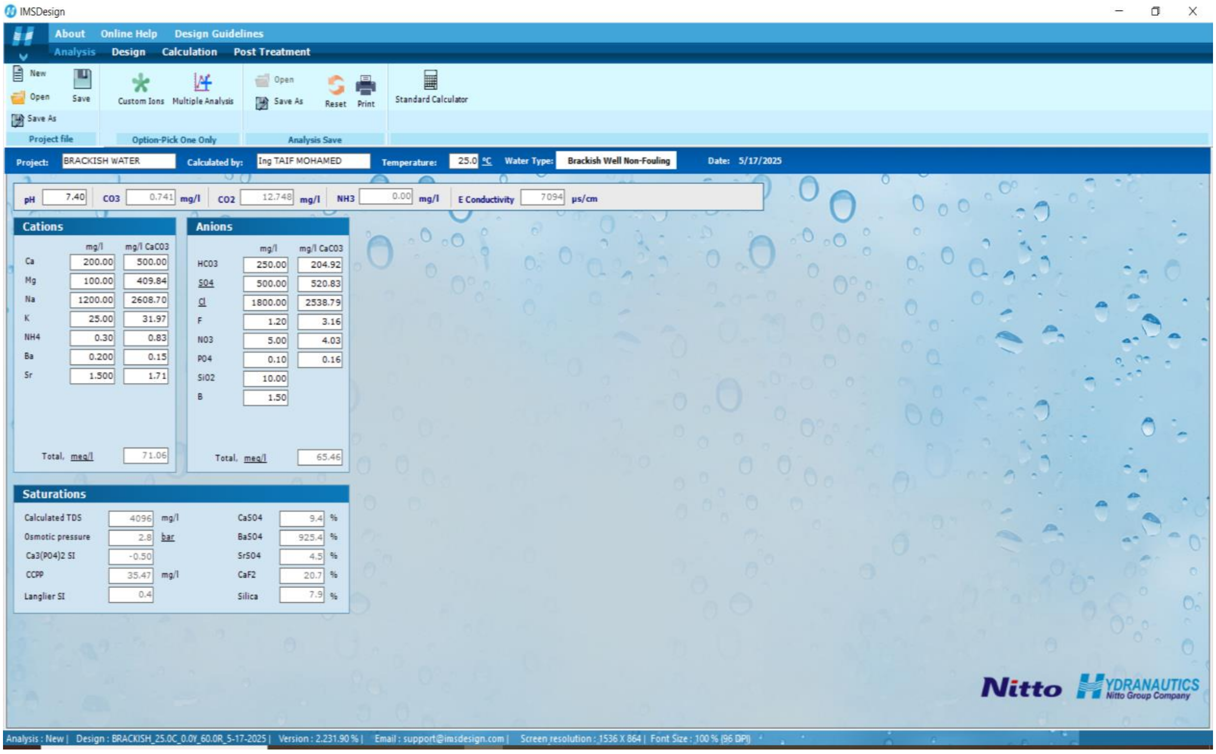
Step 1:

Analysis: This is the first stage in the process, where the raw water sample (seawater, brackish water, etc.) is processed and the water analysis report values are entered.

Table 3: Brackish water analysis ratio values

Ions	Concentration (mg/L or value)	Ions	Concentration (mg/L or value)
Calcium (Ca^{2+})	200	Nitrate (NO_3-)	5
Magnesium (Mg^{2+})	100	Phosphate (PO_4^3-)	0.1
Sodium (Na^+)	1200	Silica (SiO_2)	10

Potassium (K^+)	25	Boron (B)	1.5
Ammonium (NH_4^+)	0.3	Fluorine (F-)	1.2
Barium (Ba^{2+})	0.2	TDS	~ 4100
Strontium (Sr^{2+})	1.5	Temperature	25
Bicarbonate (HCO_3-)	250	Conversion rates	60%
Sulfate (SO_4^2-)	500	Feed rate	10000 m³/d
Chlorine (Cl-)	1800	pH	7.4



Project: BRACKISH WATER
Calculated by: Ing TAIF MOHAMED
Temperature: 25.0 °C
Water Type: Brackish Well Non-Fouling
Date: 5/17/2025

pH 7.40
CO3 0.741 mg/l
CO2 12.748 mg/l
NH3 0.00 mg/l
E Conductivity 7094 µs/cm

Cations

	mg/l	mg/l CaCO3
Ca	200.00	500.00
Mg	100.00	409.84
Na	1200.00	2608.70
K	25.00	31.97
NH4	0.30	0.83
Ba	0.200	0.15
Sr	1.500	1.71
Total, meq/l		71.06

Anions

	mg/l	mg/l CaCO3
HCO3	250.00	204.92
SO4	500.00	520.83
Cl	1800.00	2538.79
F	1.20	3.16
NO3	5.00	4.03
PO4	0.10	0.16
SiO2	10.00	
B	1.50	
Total, meq/l		65.46

Saturations

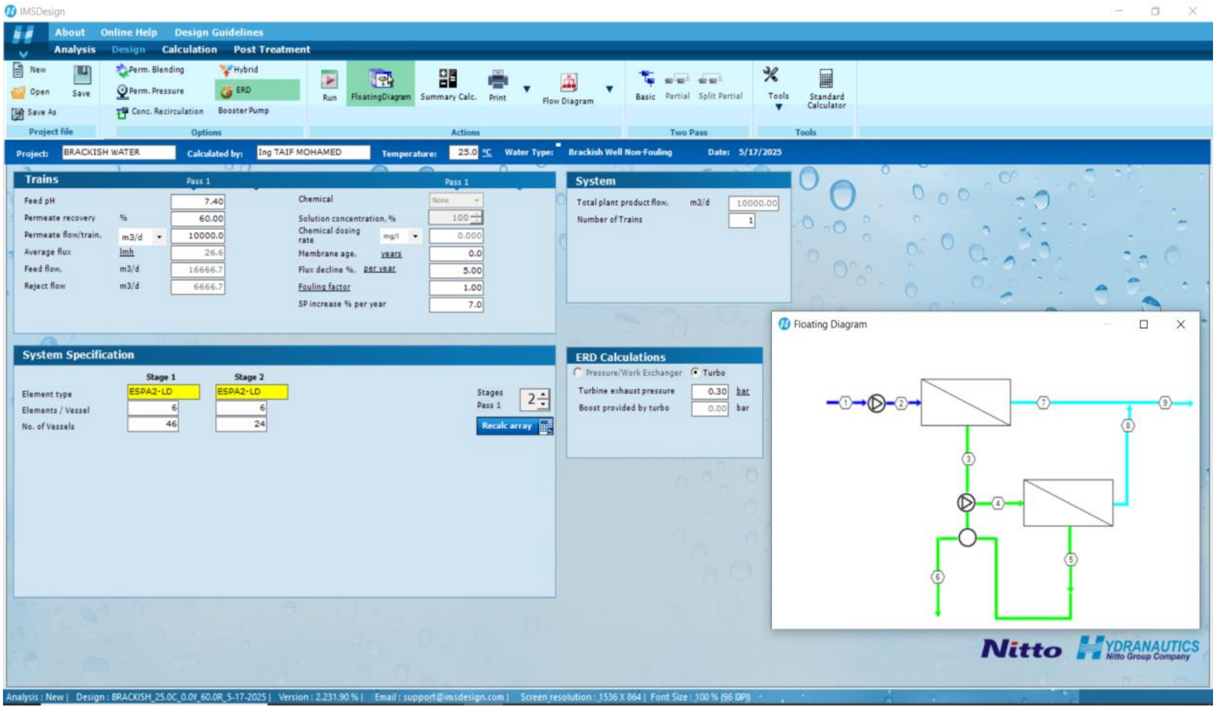
Calculated TDS	4096	mg/l	CaSO4	9.4	%
Osmotic pressure	2.8	bar	BaSO4	925.4	%
Ca3(PO4)2 SI	-0.50		SrSO4	4.5	%
CCPP	35.47	mg/l	CaF2	20.7	%
Langlier SI	0.4		Silica	7.9	%

Analysis : New | Design : BRACKISH_25.0C_0.0Y_60.0R_5-17-2025 | Version : 2.231.90 % | Email : support@imsdesign.com | Screen resolution : 1536 X 864 | Font Size : 100 % (96 DPI)

Figure III.2: Screenshot of the IMS-Design analysis stage

Step 2:

Sizing: This is the second stage of the system. In order to carry out this stage globally, it is possible to define certain parameters such as permeate flow rate, rejection rate, type of membrane used and number of stages.



Project: BRACKISH WATER Calculated by: Ing TAIF MOHAMED Temperature: 25.0 °C Water Type: Brackish Well Non-Fouling Date: 5/17/2025

Trains Pass 1

Feed pH 7.40
Permeate recovery % 60.00
Permeate flow/train. m3/d 10000.0
Average flux lmh 26.6
Feed flow. m3/d 16666.7
Reject flow m3/d 6666.7

Chemical None
Solution concentration, % 100
Chemical dosing rate mg/l 0.000
Membrane age, years 0.0
Flux decline %, per year 5.00
Fouling factor 1.00
SP increase % per year 7.0

System

Total plant product flow, m3/d 10000.00
Number of Trains 1

System Specification

	Stage 1	Stage 2
Element type	ESPA2-LD	ESPA2-LD
Elements / Vessel	6	6
No. of Vessels	46	24

Stages Pass 1 2

ERD Calculations

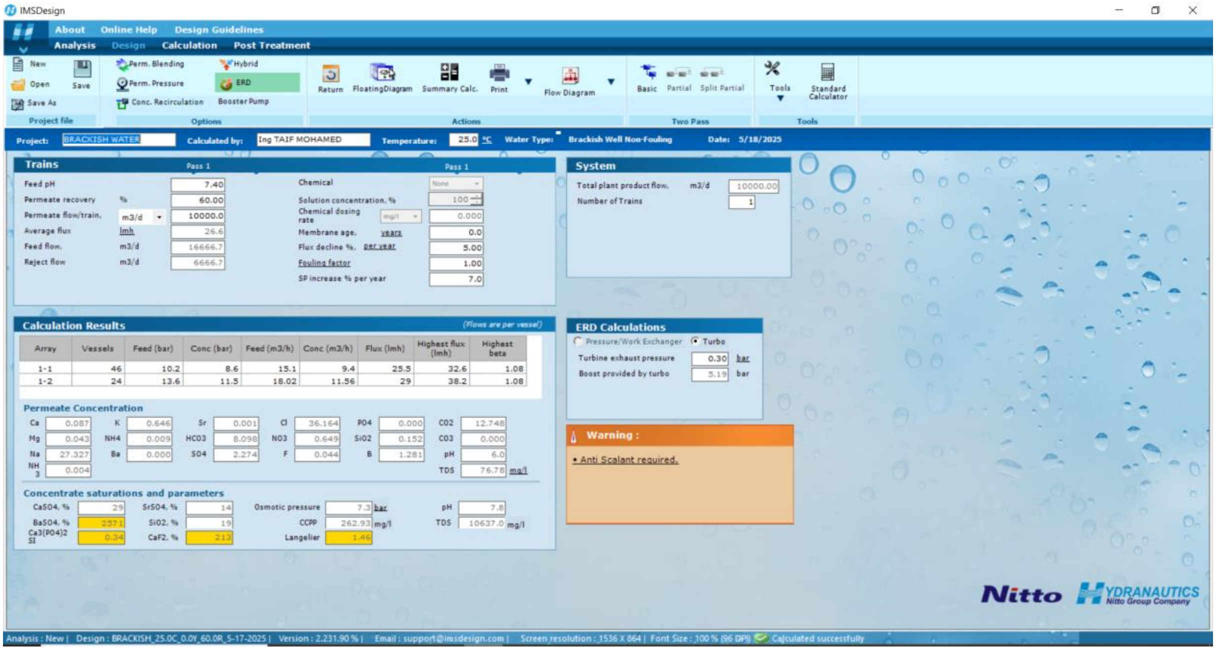
○ Pressure/Work Exchanger ● Turbo
Turbine exhaust pressure 0.30 bar
Boost provided by turbo 0.00 bar

Analysis : New | Design : BRACKISH_25.0C_0.0Y_60.0R_5-17-2025 | Version : 2.231.90 % | Email : support@imsdesign.com | Screen resolution : 1536 X 864 | Font Size : 100 % (96 DPI)

Figure III.3: Dimensioning screenshot before calculation

Step 3:

Calculation: This is the third step in the reverse osmosis (RO) design process. The application calculates and displays energy needs, chemical requirements, the associated cost, and the quality of the resulting product.



Project: BRACKISH WATER Calculated by: Ing TAIF MOHAMED Temperature: 25.0 °C Water Type: Brackish Well Non-Fouling Date: 5/18/2025

Trains Pass 1

Feed pH 7.40
Permeate recovery % 60.00
Permeate flow/train. m3/d 10000.0
Average flux lmh 26.6
Feed flow. m3/d 16666.7
Reject flow m3/d 6666.7

Chemical None
Solution concentration, % 100
Chemical dosing rate mg/l 0.000
Membrane age, years 0.0
Flux decline %, per year 5.00
Fouling factor 1.00
SP increase % per year 7.0

System

Total plant product flow, m3/d 10000.00
Number of Trains 1

Calculation Results (Flows are per vessel)

Array	Vessels	Feed (bar)	Conc (bar)	Feed (m3/h)	Conc (m3/h)	Flux (lmh)	Highest flux (lmh)	Highest beta
1-1	46	10.2	8.6	15.1	9.4	25.5	32.6	1.08
1-2	24	13.6	11.5	18.02	11.56	29	38.2	1.08

Permeate Concentration

Ca	0.087	K	0.646	Sr	0.001	Cl	36.164	PO4	0.000	CO2	12.748
Mg	0.043	NH4	0.009	HCO3	8.098	NO3	0.649	SiO2	0.152	CO3	0.000
Na	27.327	Ba	0.000	SO4	2.274	F	0.044	B	1.281	pH	6.0
NH3	0.004									TDS	76.78 mg/l

Concentrate saturations and parameters

CaSO4, %	29	SrSO4, %	14	Osmotic pressure	7.3 bar	pH	7.8
BaSO4, %	2571	SiO2, %	19	CCPP	262.93 mg/l	TDS	10637.0 mg/l
Ca3(PO4)2 SI	0.34	CaF2, %	213	Langelier	1.46		

ERD Calculations

○ Pressure/Work Exchanger ● Turbo
Turbine exhaust pressure 0.30 bar
Boost provided by turbo 5.19 bar

Warning :

- Anti Scalant required.

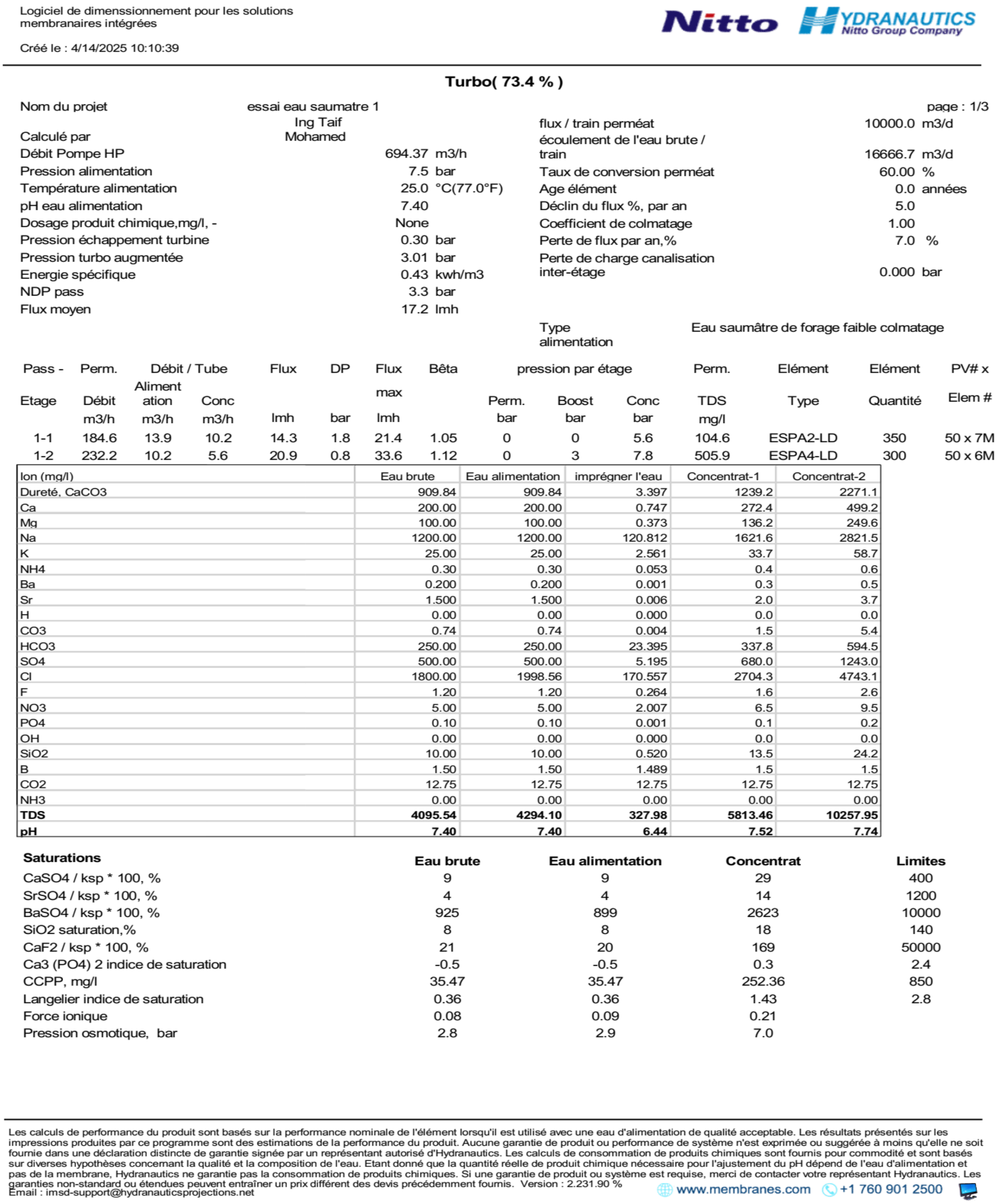
Analysis : New | Design : BRACKISH_25.0C_0.0Y_60.0R_5-17-2025 | Version : 2.231.90 % | Email : support@imsdesign.com | Screen resolution : 1536 X 864 | Font Size : 100 % (96 DPI) Calculated successfully

Figure III.4: Screenshot of sizing step after calculation

III.5 Results and discussion

III.5.1 Results:

- Membrane type **: ESPA2-LD + ESPA2-LD**



Logiciel de dimenssionnement pour les solutions membranaires intégrées

Créé le : 4/14/2025 10:10:39

Turbo(73.4 %)

page : 1/3

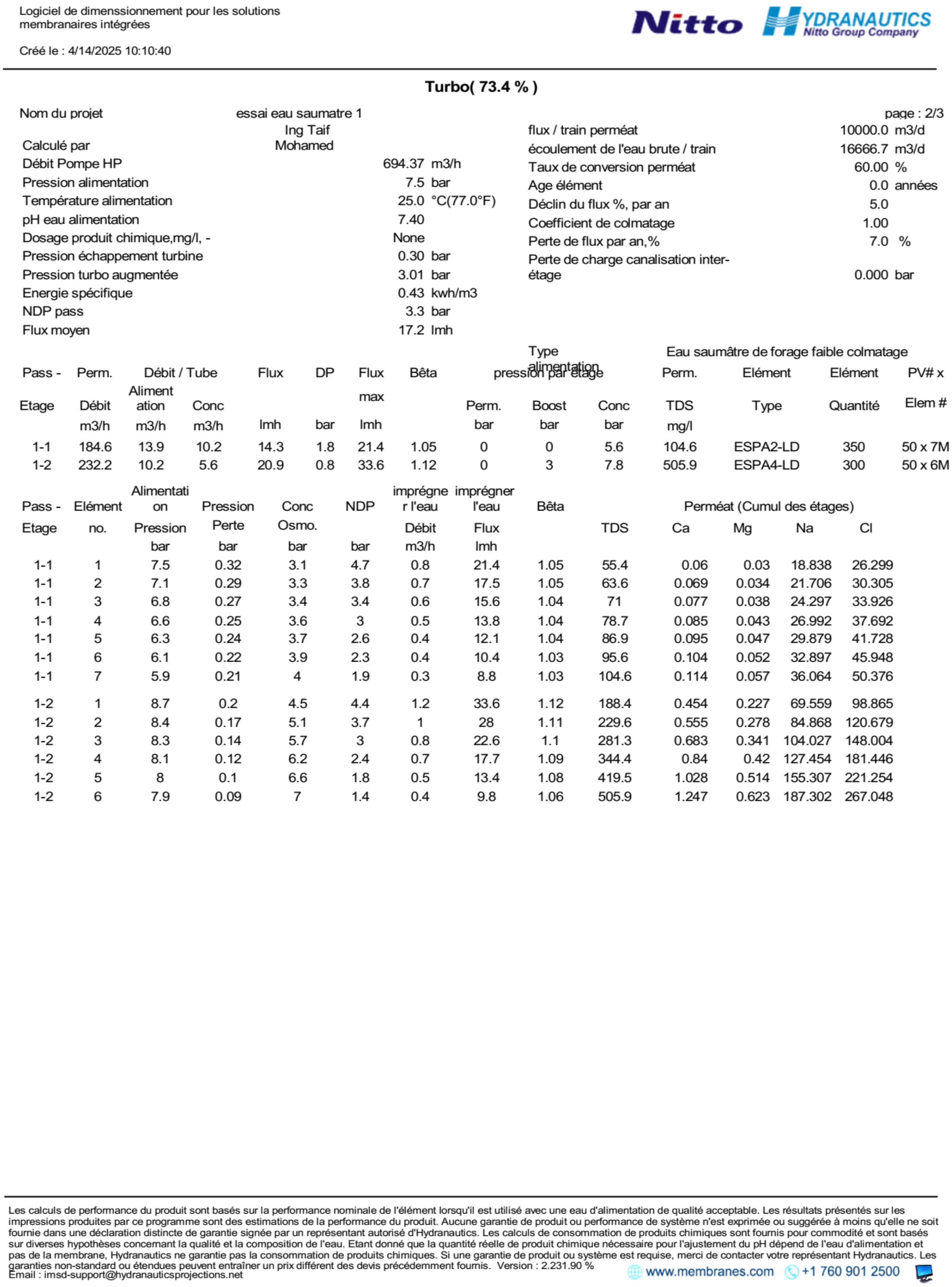
Nom du projet	essai eau saumatre 1
Calculé par	Ing Taif Mohamed
Débit Pompe HP	694.37 m3/h
Pression alimentation	7.5 bar
Température alimentation	25.0 °C(77.0°F)
pH eau alimentation	7.40
Dosage produit chimique,mg/l, -	None
Pression échappement turbine	0.30 bar
Pression turbo augmentée	3.01 bar
Energie spécifique	0.43 kwh/m3
NDP pass	3.3 bar
Flux moyen	17.2 lmh

flux / train perméat	10000.0 m3/d
écoulement de l'eau brute / train	16666.7 m3/d
Taux de conversion perméat	60.00 %
Age élément	0.0 années
Déclin du flux %, par an	5.0
Coefficient de colmatage	1.00
Perte de flux par an,%	7.0 %
Perte de charge canalisation inter-étage	0.000 bar
Type alimentation	Eau saumâtre de forage faible colmatage

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	184.6	13.9	10.2	14.3	1.8	21.4	1.05	0	0	5.6	104.6	ESPA2-LD	350	50 x 7M
1-2	232.2	10.2	5.6	20.9	0.8	33.6	1.12	0	3	7.8	505.9	ESPA4-LD	300	50 x 6M

Ion (mg/l)	Eau brute	Eau alimentation	imprégner l'eau	Concentrat-1	Concentrat-2
Dureté, CaCO3	909.84	909.84	3.397	1239.2	2271.1
Ca	200.00	200.00	0.747	272.4	499.2
Mg	100.00	100.00	0.373	136.2	249.6
Na	1200.00	1200.00	120.812	1621.6	2821.5
K	25.00	25.00	2.561	33.7	58.7
NH4	0.30	0.30	0.053	0.4	0.6
Ba	0.200	0.200	0.001	0.3	0.5
Sr	1.500	1.500	0.006	2.0	3.7
H	0.00	0.00	0.000	0.0	0.0
CO3	0.74	0.74	0.004	1.5	5.4
HCO3	250.00	250.00	23.395	337.8	594.5
SO4	500.00	500.00	5.195	680.0	1243.0
Cl	1800.00	1998.56	170.557	2704.3	4743.1
F	1.20	1.20	0.264	1.6	2.6
NO3	5.00	5.00	2.007	6.5	9.5
PO4	0.10	0.10	0.001	0.1	0.2
OH	0.00	0.00	0.000	0.0	0.0
SiO2	10.00	10.00	0.520	13.5	24.2
B	1.50	1.50	1.489	1.5	1.5
CO2	12.75	12.75	12.75	12.75	12.75
NH3	0.00	0.00	0.00	0.00	0.00
TDS	**4095.54**	**4294.10**	**327.98**	**5813.46**	**10257.95**
pH	**7.40**	**7.40**	**6.44**	**7.52**	**7.74**

Saturations	**Eau brute**	**Eau alimentation**	**Concentrat**	**Limites**
CaSO4 / ksp * 100, %	9	9	29	400
SrSO4 / ksp * 100, %	4	4	14	1200
BaSO4 / ksp * 100, %	925	899	2623	10000
SiO2 saturation,%	8	8	18	140
CaF2 / ksp * 100, %	21	20	169	50000
Ca3 (PO4) 2 indice de saturation	-0.5	-0.5	0.3	2.4
CCPP, mg/l	35.47	35.47	252.36	850
Langelier indice de saturation	0.36	0.36	1.43	2.8
Force ionique	0.08	0.09	0.21	
Pression osmotique, bar	2.8	2.9	7.0	



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 10:10:40

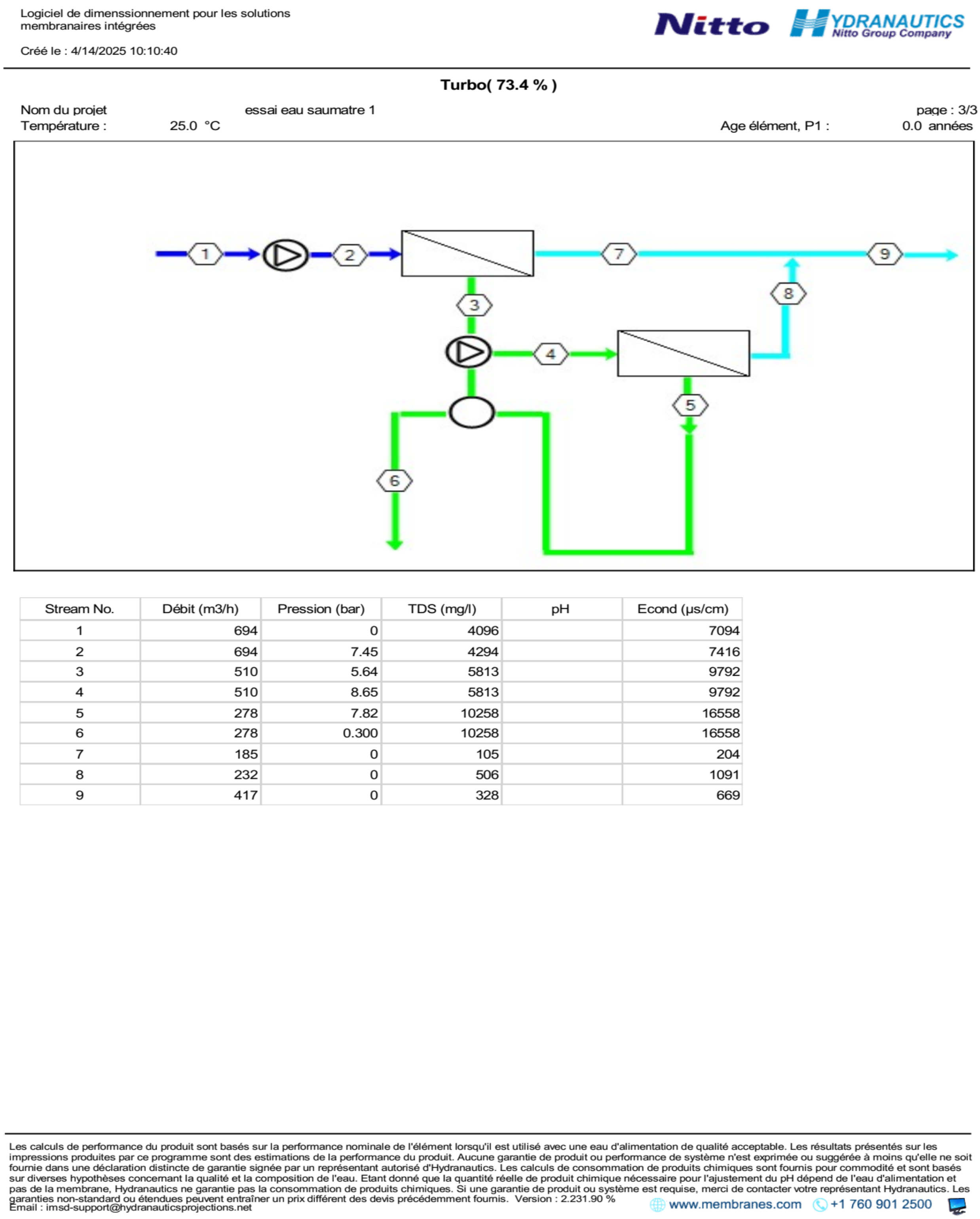
Turbo(73.4 %)

Nom du projet	essai eau saumatre 1		page : 2/3
Calculé par	Ing Taif Mohamed	flux / train perméat	10000.0 m3/d
Débit Pompe HP	694.37 m3/h	écoulement de l'eau brute / train	16666.7 m3/d
Pression alimentation	7.5 bar	Taux de conversion perméat	60.00 %
Température alimentation	25.0 °C(77.0°F)	Age élément	0.0 années
pH eau alimentation	7.40	Déclin du flux %, par an	5.0
Dosage produit chimique,mg/l, -	None	Coefficient de colmatage	1.00
Pression échappement turbine	0.30 bar	Perte de flux par an,%	7.0 %
Pression turbo augmentée	3.01 bar	Perte de charge canalisation inter-étage	0.000 bar
Energie spécifique	0.43 kwh/m3		
NDP pass	3.3 bar		
Flux moyen	17.2 lmh		

Type alimentation Eau saumâtre de forage faible colmatage

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	Boost bar	Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	184.6	13.9	10.2	14.3	1.8	21.4	1.05	0	0	5.6	104.6	ESPA2-LD	350	50 x 7M
1-2	232.2	10.2	5.6	20.9	0.8	33.6	1.12	0	3	7.8	505.9	ESPA4-LD	300	50 x 6M

Pass - Etage	Elément no.	Alimentation Pression bar	Pression Perte bar	Conc Osmo. bar	NDP bar	imprégner l'eau Débit m3/h	imprégner l'eau Flux lmh	Bêta	Perméat (Cumul des étages) TDS	Ca	Mg	Na	Cl
1-1	1	7.5	0.32	3.1	4.7	0.8	21.4	1.05	55.4	0.06	0.03	18.838	26.299
1-1	2	7.1	0.29	3.3	3.8	0.7	17.5	1.05	63.6	0.069	0.034	21.706	30.305
1-1	3	6.8	0.27	3.4	3.4	0.6	15.6	1.04	71	0.077	0.038	24.297	33.926
1-1	4	6.6	0.25	3.6	3	0.5	13.8	1.04	78.7	0.085	0.043	26.992	37.692
1-1	5	6.3	0.24	3.7	2.6	0.4	12.1	1.04	86.9	0.095	0.047	29.879	41.728
1-1	6	6.1	0.22	3.9	2.3	0.4	10.4	1.03	95.6	0.104	0.052	32.897	45.948
1-1	7	5.9	0.21	4	1.9	0.3	8.8	1.03	104.6	0.114	0.057	36.064	50.376
1-2	1	8.7	0.2	4.5	4.4	1.2	33.6	1.12	188.4	0.454	0.227	69.559	98.865
1-2	2	8.4	0.17	5.1	3.7	1	28	1.11	229.6	0.555	0.278	84.868	120.679
1-2	3	8.3	0.14	5.7	3	0.8	22.6	1.1	281.3	0.683	0.341	104.027	148.004
1-2	4	8.1	0.12	6.2	2.4	0.7	17.7	1.09	344.4	0.84	0.42	127.454	181.446
1-2	5	8	0.1	6.6	1.8	0.5	13.4	1.08	419.5	1.028	0.514	155.307	221.254
1-2	6	7.9	0.09	7	1.4	0.4	9.8	1.06	505.9	1.247	0.623	187.302	267.048



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 10:10:40

Nitto HYDRANAUTICS Nitto Group Company

Turbo(73.4 %)

Nom du projet essai eau saumatre 1 page : 3/3
Température : 25.0 °C Age élément, P1 : 0.0 années

Stream No.	Débit (m3/h)	Pression (bar)	TDS (mg/l)	pH	Econd (µs/cm)
1	694	0	4096		7094
2	694	7.45	4294		7416
3	510	5.64	5813		9792
4	510	8.65	5813		9792
5	278	7.82	10258		16558
6	278	0.300	10258		16558
7	185	0	105		204
8	232	0	506		1091
9	417	0	328		669

Les calculs de performance du produit sont basés sur la performance nominale de l'élément lorsqu'il est utilisé avec une eau d'alimentation de qualité acceptable. Les résultats présentés sur les impressions produites par ce programme sont des estimations de la performance du produit. Aucune garantie de produit ou performance de système n'est exprimée ou suggérée à moins qu'elle ne soit fournie dans une déclaration distincte de garantie signée par un représentant autorisé d'Hydranautics. Les calculs de consommation de produits chimiques sont fournis pour commodité et sont basés sur diverses hypothèses concernant la qualité et la composition de l'eau. Etant donné que la quantité réelle de produit chimique nécessaire pour l'ajustement du pH dépend de l'eau d'alimentation et pas de la membrane, Hydranautics ne garantie pas la consommation de produits chimiques. Si une garantie de produit ou système est requise, merci de contacter votre représentant Hydranautics. Les garanties non-standard ou étendues peuvent entraîner un prix différent des devis précédemment fournis. Version : 2.231.90 %
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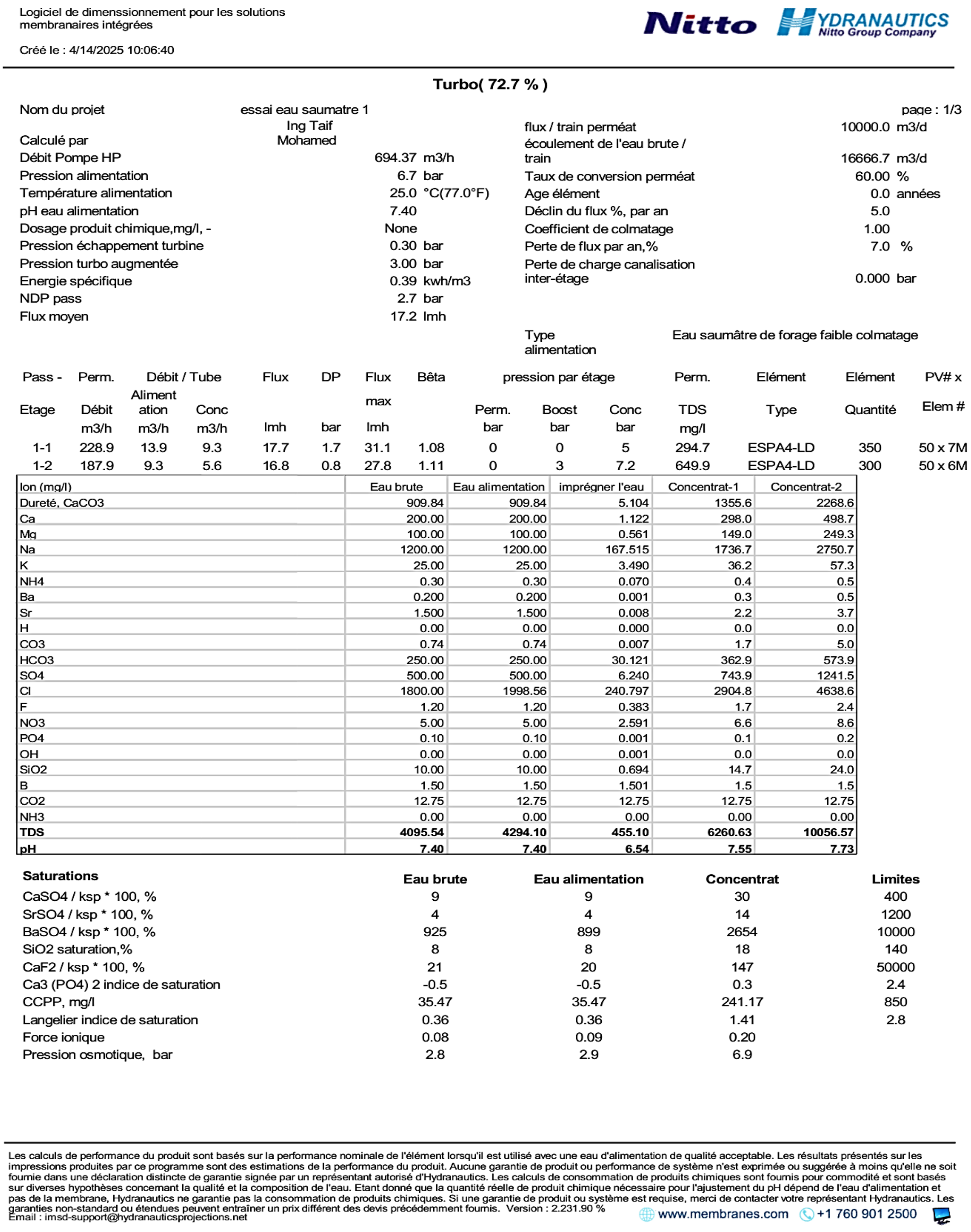
- Membrane type : **ESPA4-LD** + **ESPA4-LD**



Logiciel de dimenssionnement pour les solutions membranaires intégrées

Créé le : 4/14/2025 10:06:40

Turbo(72.7 %)

page : 1/3

Nom du projet	essai eau saumatre 1	
Calculé par	Ing Taif Mohamed	
Débit Pompe HP	694.37	m3/h
Pression alimentation	6.7	bar
Température alimentation	25.0	°C(77.0°F)
pH eau alimentation	7.40	
Dosage produit chimique,mg/l, -	None	
Pression échappement turbine	0.30	bar
Pression turbo augmentée	3.00	bar
Energie spécifique	0.39	kwh/m3
NDP pass	2.7	bar
Flux moyen	17.2	lmh

flux / train perméat	10000.0	m3/d
écoulement de l'eau brute / train	16666.7	m3/d
Taux de conversion perméat	60.00	%
Age élément	0.0	années
Déclin du flux %, par an	5.0	
Coefficient de colmatage	1.00	
Perte de flux par an,%	7.0	%
Perte de charge canalisation inter-étage	0.000	bar
Type alimentation	Eau saumâtre de forage faible colmatage	

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	228.9	13.9	9.3	17.7	1.7	31.1	1.08	0	0	5	294.7	ESPA4-LD	350	50 x 7M
1-2	187.9	9.3	5.6	16.8	0.8	27.8	1.11	0	3	7.2	649.9	ESPA4-LD	300	50 x 6M

Ion (mg/l)	Eau brute	Eau alimentation	imprégner l'eau	Concentrat-1	Concentrat-2
Dureté, CaCO3	909.84	909.84	5.104	1355.6	2268.6
Ca	200.00	200.00	1.122	298.0	498.7
Mg	100.00	100.00	0.561	149.0	249.3
Na	1200.00	1200.00	167.515	1736.7	2750.7
K	25.00	25.00	3.490	36.2	57.3
NH4	0.30	0.30	0.070	0.4	0.5
Ba	0.200	0.200	0.001	0.3	0.5
Sr	1.500	1.500	0.008	2.2	3.7
H	0.00	0.00	0.000	0.0	0.0
CO3	0.74	0.74	0.007	1.7	5.0
HCO3	250.00	250.00	30.121	362.9	573.9
SO4	500.00	500.00	6.240	743.9	1241.5
Cl	1800.00	1998.56	240.797	2904.8	4638.6
F	1.20	1.20	0.383	1.7	2.4
NO3	5.00	5.00	2.591	6.6	8.6
PO4	0.10	0.10	0.001	0.1	0.2
OH	0.00	0.00	0.001	0.0	0.0
SiO2	10.00	10.00	0.694	14.7	24.0
B	1.50	1.50	1.501	1.5	1.5
CO2	12.75	12.75	12.75	12.75	12.75
NH3	0.00	0.00	0.00	0.00	0.00
TDS	**4095.54**	**4294.10**	**455.10**	**6260.63**	**10056.57**
pH	**7.40**	**7.40**	**6.54**	**7.55**	**7.73**

Saturations	**Eau brute**	**Eau alimentation**	**Concentrat**	**Limites**
CaSO4 / ksp * 100, %	9	9	30	400
SrSO4 / ksp * 100, %	4	4	14	1200
BaSO4 / ksp * 100, %	925	899	2654	10000
SiO2 saturation,%	8	8	18	140
CaF2 / ksp * 100, %	21	20	147	50000
Ca3 (PO4) 2 indice de saturation	-0.5	-0.5	0.3	2.4
CCPP, mg/l	35.47	35.47	241.17	850
Langelier indice de saturation	0.36	0.36	1.41	2.8
Force ionique	0.08	0.09	0.20	
Pression osmotique, bar	2.8	2.9	6.9	

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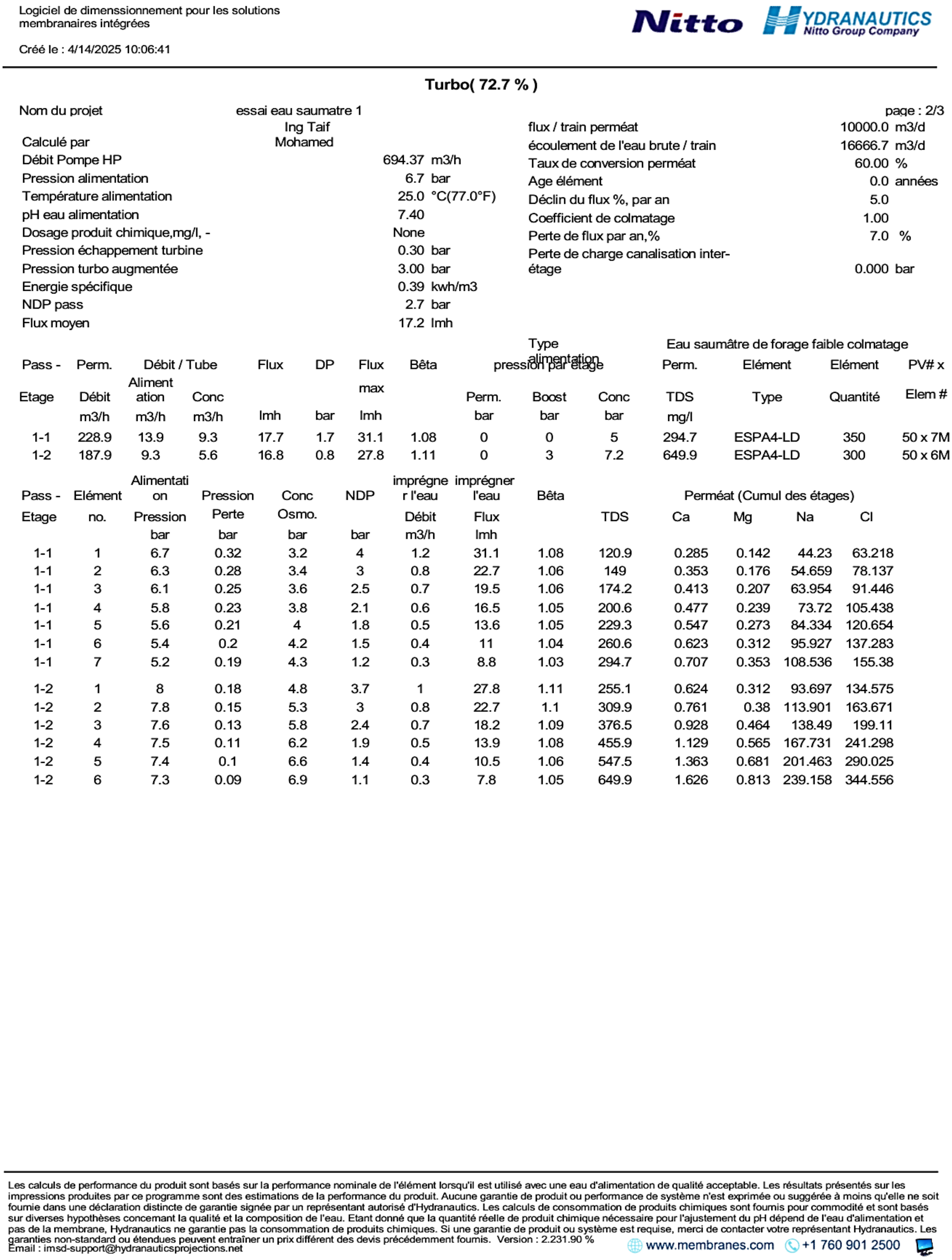


Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 10:06:41

Turbo(72.7 %)

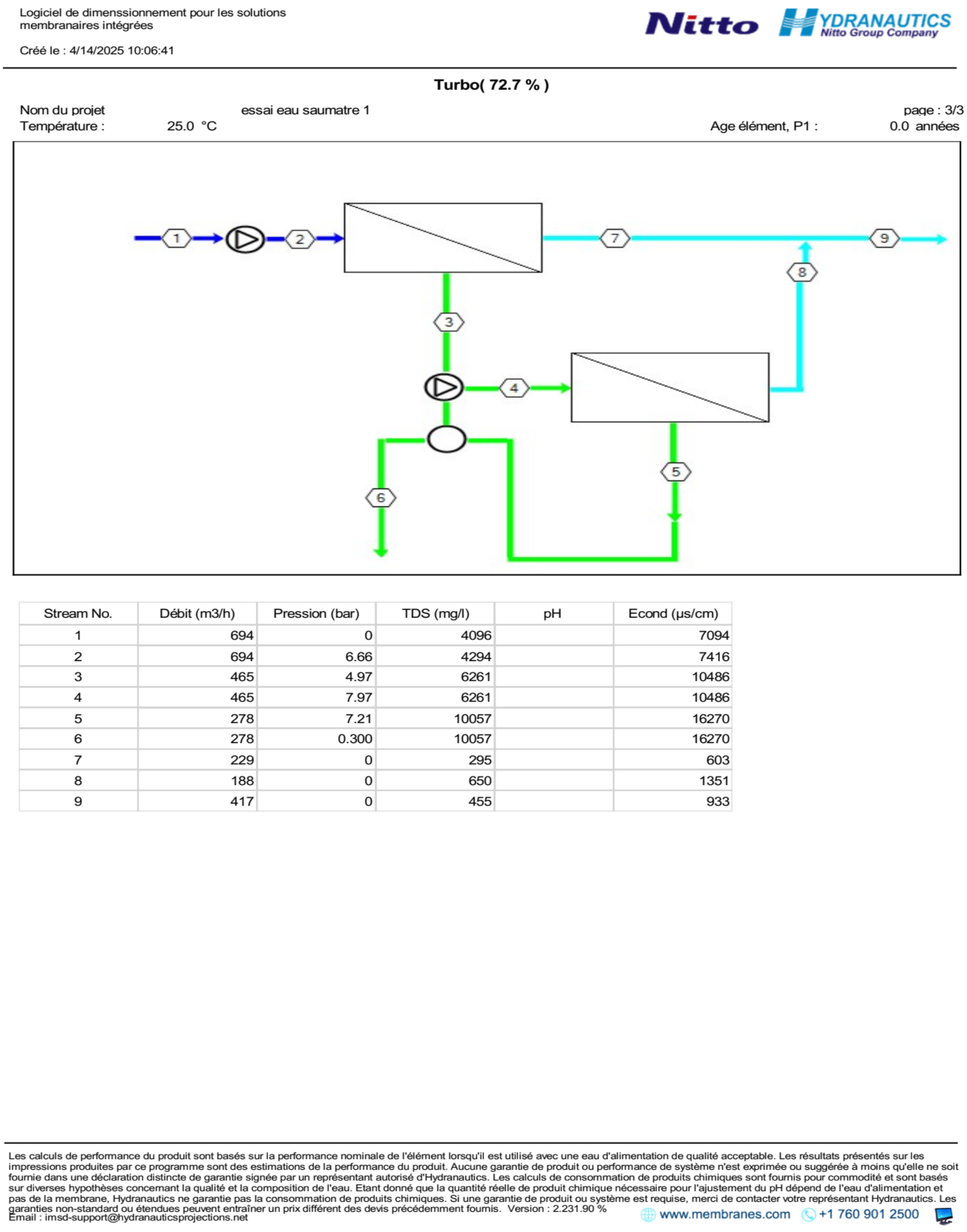
Nom du projet essai eau saumatre 1 page : 2/3

Calculé par	Ing Taif Mohamed	flux / train perméat	10000.0 m3/d
Débit Pompe HP	694.37 m3/h	écoulement de l'eau brute / train	16666.7 m3/d
Pression alimentation	6.7 bar	Taux de conversion perméat	60.00 %
Température alimentation	25.0 °C(77.0°F)	Age élément	0.0 années
pH eau alimentation	7.40	Déclin du flux %, par an	5.0
Dosage produit chimique,mg/l, -	None	Coefficient de colmatage	1.00
Pression échappement turbine	0.30 bar	Perte de flux par an,%	7.0 %
Pression turbo augmentée	3.00 bar	Perte de charge canalisation inter-étage	0.000 bar
Energie spécifique	0.39 kwh/m3		
NDP pass	2.7 bar		
Flux moyen	17.2 lmh		

Type alimentation Eau saumâtre de forage faible colmatage

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	228.9	13.9	9.3	17.7	1.7	31.1	1.08	0	0	5	294.7	ESPA4-LD	350	50 x 7M
1-2	187.9	9.3	5.6	16.8	0.8	27.8	1.11	0	3	7.2	649.9	ESPA4-LD	300	50 x 6M

Pass - Etage	Elément no.	Alimentation Pression bar	Pression Perte bar	Conc Osmo. bar	NDP bar	imprégner l'eau Débit m3/h	imprégner l'eau Flux lmh	Bêta	Perméat (Cumul des étages) TDS	Ca	Mg	Na	Cl
1-1	1	6.7	0.32	3.2	4	1.2	31.1	1.08	120.9	0.285	0.142	44.23	63.218
1-1	2	6.3	0.28	3.4	3	0.8	22.7	1.06	149	0.353	0.176	54.659	78.137
1-1	3	6.1	0.25	3.6	2.5	0.7	19.5	1.06	174.2	0.413	0.207	63.954	91.446
1-1	4	5.8	0.23	3.8	2.1	0.6	16.5	1.05	200.6	0.477	0.239	73.72	105.438
1-1	5	5.6	0.21	4	1.8	0.5	13.6	1.05	229.3	0.547	0.273	84.334	120.654
1-1	6	5.4	0.2	4.2	1.5	0.4	11	1.04	260.6	0.623	0.312	95.927	137.283
1-1	7	5.2	0.19	4.3	1.2	0.3	8.8	1.03	294.7	0.707	0.353	108.536	155.38
1-2	1	8	0.18	4.8	3.7	1	27.8	1.11	255.1	0.624	0.312	93.697	134.575
1-2	2	7.8	0.15	5.3	3	0.8	22.7	1.1	309.9	0.761	0.38	113.901	163.671
1-2	3	7.6	0.13	5.8	2.4	0.7	18.2	1.09	376.5	0.928	0.464	138.49	199.11
1-2	4	7.5	0.11	6.2	1.9	0.5	13.9	1.08	455.9	1.129	0.565	167.731	241.298
1-2	5	7.4	0.1	6.6	1.4	0.4	10.5	1.06	547.5	1.363	0.681	201.463	290.025
1-2	6	7.3	0.09	6.9	1.1	0.3	7.8	1.05	649.9	1.626	0.813	239.158	344.556



Logiciel de dimenssionnement pour les solutions membranaires intégrées

Créé le : 4/14/2025 10:06:41

Nitto HYDRANAUTICS Nitto Group Company

Turbo(72.7 %)

Nom du projet essai eau saumatre 1 page : 3/3
Température : 25.0 °C Age élément, P1 : 0.0 années

Stream No.	Débit (m3/h)	Pression (bar)	TDS (mg/l)	pH	Econd (µs/cm)
1	694	0	4096		7094
2	694	6.66	4294		7416
3	465	4.97	6261		10486
4	465	7.97	6261		10486
5	278	7.21	10057		16270
6	278	0.300	10057		16270
7	229	0	295		603
8	188	0	650		1351
9	417	0	455		933

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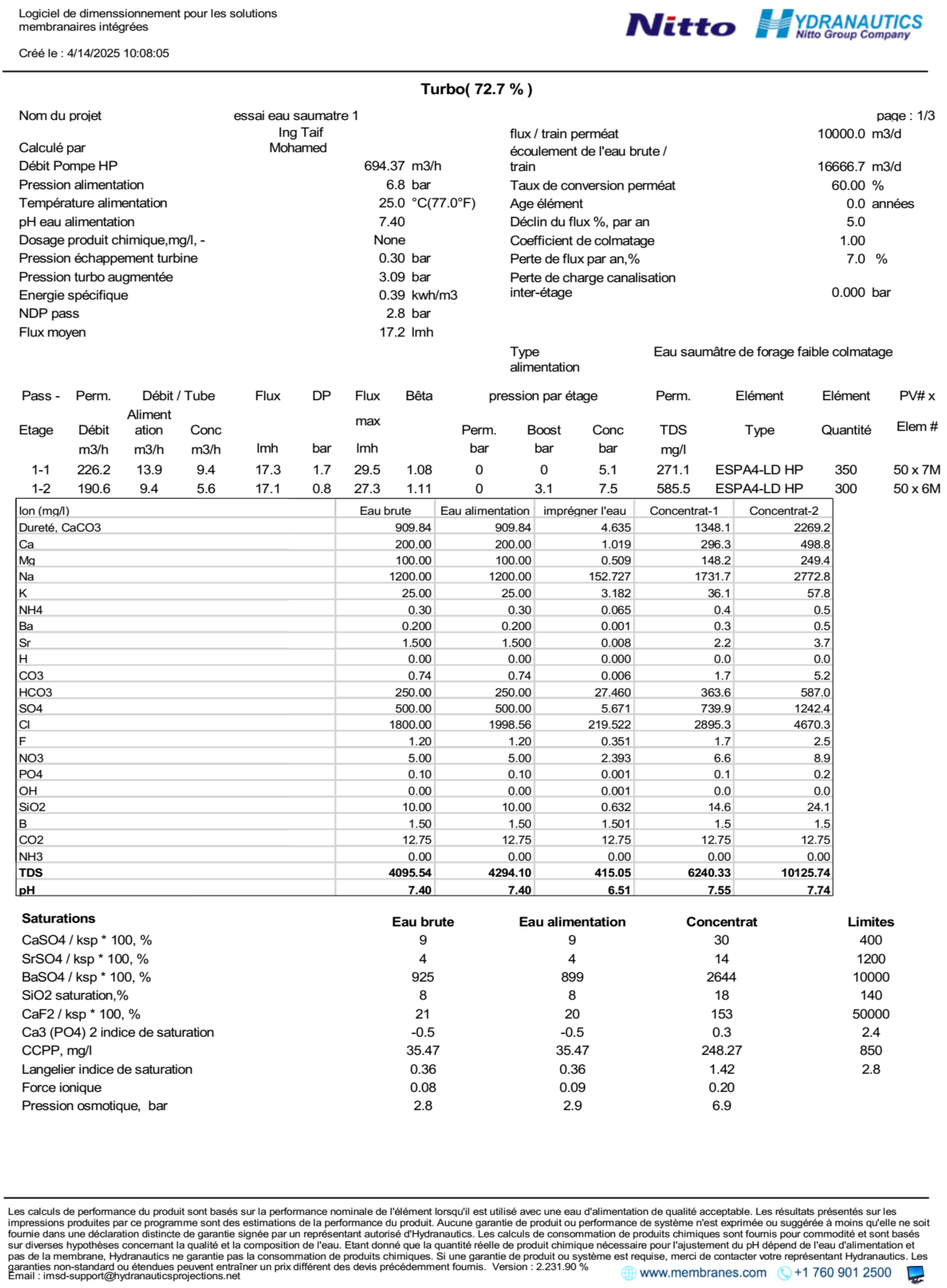
- Membrane type : **ESPA4-LD HP** + **ESPA4-LD HP**



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 10:08:05

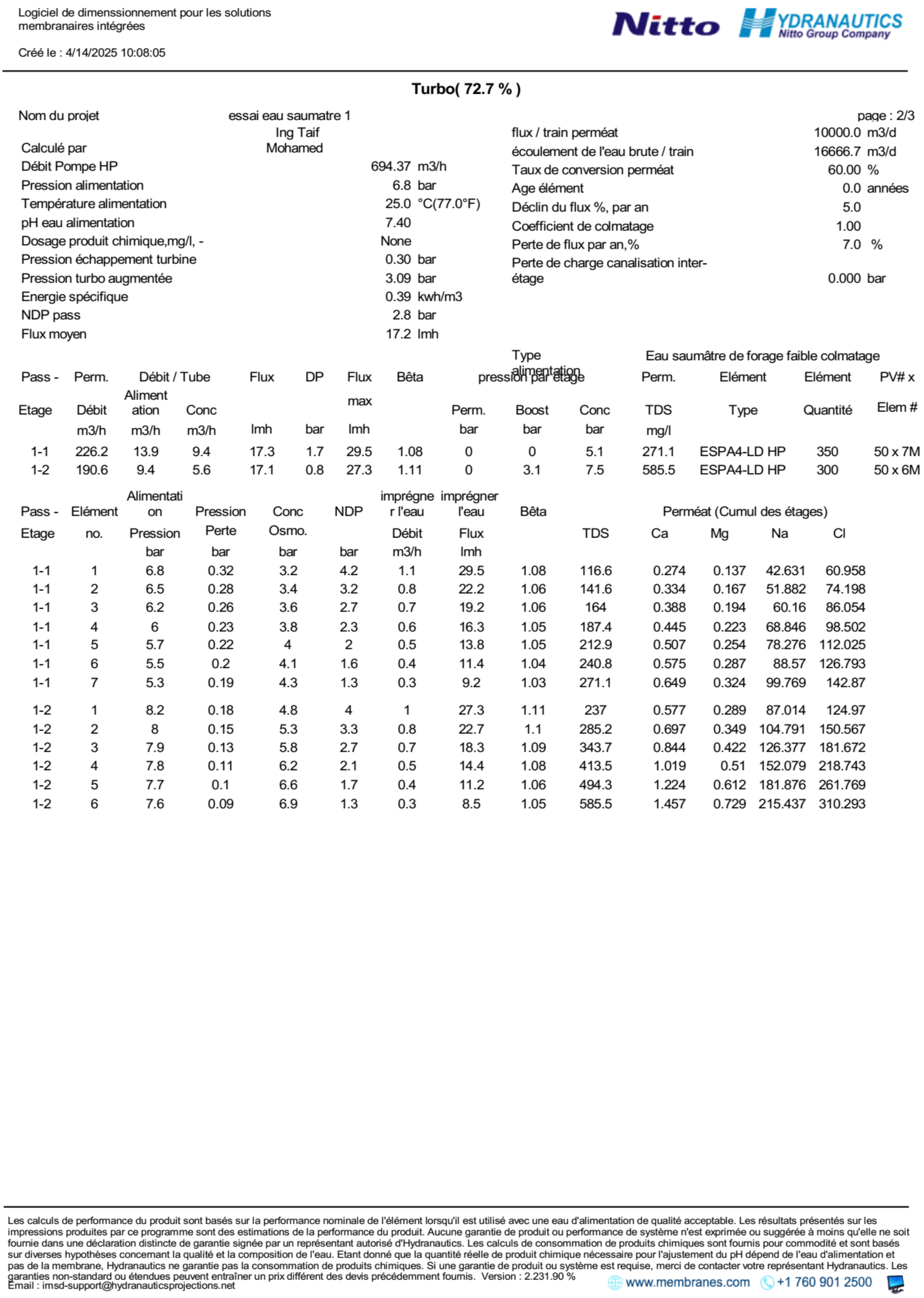
Turbo(72.7 %)

Nom du projet	essai eau saumatre 1		page : 1/3
Calculé par	Ing Taif Mohamed	flux / train perméat	10000.0 m3/d
Débit Pompe HP	694.37 m3/h	écoulement de l'eau brute / train	16666.7 m3/d
Pression alimentation	6.8 bar	Taux de conversion perméat	60.00 %
Température alimentation	25.0 °C(77.0°F)	Age élément	0.0 années
pH eau alimentation	7.40	Déclin du flux %, par an	5.0
Dosage produit chimique,mg/l, -	None	Coefficient de colmatage	1.00
Pression échappement turbine	0.30 bar	Perte de flux par an,%	7.0 %
Pression turbo augmentée	3.09 bar	Perte de charge canalisation inter-étage	0.000 bar
Energie spécifique	0.39 kwh/m3		
NDP pass	2.8 bar		
Flux moyen	17.2 lmh		
		Type alimentation	Eau saumâtre de forage faible colmatage

Pass -	Perm.	Débit / Tube		Flux	DP	Flux	Bêta	pression par étage			Perm.	Elément	Elément	PV# x
Etage	Débit m3/h	Alimentation m3/h	Conc m3/h	lmh	bar	max lmh		Perm. bar	Boost bar	Conc bar	TDS mg/l	Type	Quantité	Elem #
1-1	226.2	13.9	9.4	17.3	1.7	29.5	1.08	0	0	5.1	271.1	ESPA4-LD HP	350	50 x 7M
1-2	190.6	9.4	5.6	17.1	0.8	27.3	1.11	0	3.1	7.5	585.5	ESPA4-LD HP	300	50 x 6M

Ion (mg/l)	Eau brute	Eau alimentation	imprégner l'eau	Concentrat-1	Concentrat-2
Dureté, CaCO3	909.84	909.84	4.635	1348.1	2269.2
Ca	200.00	200.00	1.019	296.3	498.8
Mg	100.00	100.00	0.509	148.2	249.4
Na	1200.00	1200.00	152.727	1731.7	2772.8
K	25.00	25.00	3.182	36.1	57.8
NH4	0.30	0.30	0.065	0.4	0.5
Ba	0.200	0.200	0.001	0.3	0.5
Sr	1.500	1.500	0.008	2.2	3.7
H	0.00	0.00	0.000	0.0	0.0
CO3	0.74	0.74	0.006	1.7	5.2
HCO3	250.00	250.00	27.460	363.6	587.0
SO4	500.00	500.00	5.671	739.9	1242.4
Cl	1800.00	1998.56	219.522	2895.3	4670.3
F	1.20	1.20	0.351	1.7	2.5
NO3	5.00	5.00	2.393	6.6	8.9
PO4	0.10	0.10	0.001	0.1	0.2
OH	0.00	0.00	0.001	0.0	0.0
SiO2	10.00	10.00	0.632	14.6	24.1
B	1.50	1.50	1.501	1.5	1.5
CO2	12.75	12.75	12.75	12.75	12.75
NH3	0.00	0.00	0.00	0.00	0.00
TDS	**4095.54**	**4294.10**	**415.05**	**6240.33**	**10125.74**
pH	**7.40**	**7.40**	**6.51**	**7.55**	**7.74**

Saturations	**Eau brute**	**Eau alimentation**	**Concentrat**	**Limites**
CaSO4 / ksp * 100, %	9	9	30	400
SrSO4 / ksp * 100, %	4	4	14	1200
BaSO4 / ksp * 100, %	925	899	2644	10000
SiO2 saturation,%	8	8	18	140
CaF2 / ksp * 100, %	21	20	153	50000
Ca3 (PO4) 2 indice de saturation	-0.5	-0.5	0.3	2.4
CCPP, mg/l	35.47	35.47	248.27	850
Langelier indice de saturation	0.36	0.36	1.42	2.8
Force ionique	0.08	0.09	0.20	
Pression osmotique, bar	2.8	2.9	6.9	



Logiciel de dimenssionnement pour les solutions membranaires intégrées

Créé le : 4/14/2025 10:08:05

Turbo(72.7 %)

Nom du projet essai eau saumatre 1

page : 2/3

Calculé par	Ing Taif Mohamed	
Débit Pompe HP	694.37	m3/h
Pression alimentation	6.8	bar
Température alimentation	25.0	°C(77.0°F)
pH eau alimentation	7.40	
Dosage produit chimique,mg/l, -	None	
Pression échappement turbine	0.30	bar
Pression turbo augmentée	3.09	bar
Energie spécifique	0.39	kwh/m3
NDP pass	2.8	bar
Flux moyen	17.2	lmh

flux / train perméat	10000.0	m3/d
écoulement de l'eau brute / train	16666.7	m3/d
Taux de conversion perméat	60.00	%
Age élément	0.0	années
Déclin du flux %, par an	5.0	
Coefficient de colmatage	1.00	
Perte de flux par an,%	7.0	%
Perte de charge canalisation inter-étage	0.000	bar
Type alimentation	Eau saumâtre de forage faible colmatage	

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	226.2	13.9	9.4	17.3	1.7	29.5	1.08	0	0	5.1	271.1	ESPA4-LD HP	350	50 x 7M
1-2	190.6	9.4	5.6	17.1	0.8	27.3	1.11	0	3.1	7.5	585.5	ESPA4-LD HP	300	50 x 6M

Pass - Etage	Elément no.	Alimentation Pression bar	Pression Perte bar	Conc Osmo. bar	NDP bar	imprégner l'eau Débit m3/h	imprégner l'eau Flux lmh	Bêta	Perméat (Cumul des étages) TDS	Ca	Mg	Na	Cl
1-1	1	6.8	0.32	3.2	4.2	1.1	29.5	1.08	116.6	0.274	0.137	42.631	60.958
1-1	2	6.5	0.28	3.4	3.2	0.8	22.2	1.06	141.6	0.334	0.167	51.882	74.198
1-1	3	6.2	0.26	3.6	2.7	0.7	19.2	1.06	164	0.388	0.194	60.16	86.054
1-1	4	6	0.23	3.8	2.3	0.6	16.3	1.05	187.4	0.445	0.223	68.846	98.502
1-1	5	5.7	0.22	4	2	0.5	13.8	1.05	212.9	0.507	0.254	78.276	112.025
1-1	6	5.5	0.2	4.1	1.6	0.4	11.4	1.04	240.8	0.575	0.287	88.57	126.793
1-1	7	5.3	0.19	4.3	1.3	0.3	9.2	1.03	271.1	0.649	0.324	99.769	142.87
1-2	1	8.2	0.18	4.8	4	1	27.3	1.11	237	0.577	0.289	87.014	124.97
1-2	2	8	0.15	5.3	3.3	0.8	22.7	1.1	285.2	0.697	0.349	104.791	150.567
1-2	3	7.9	0.13	5.8	2.7	0.7	18.3	1.09	343.7	0.844	0.422	126.377	181.672
1-2	4	7.8	0.11	6.2	2.1	0.5	14.4	1.08	413.5	1.019	0.51	152.079	218.743
1-2	5	7.7	0.1	6.6	1.7	0.4	11.2	1.06	494.3	1.224	0.612	181.876	261.769
1-2	6	7.6	0.09	6.9	1.3	0.3	8.5	1.05	585.5	1.457	0.729	215.437	310.293

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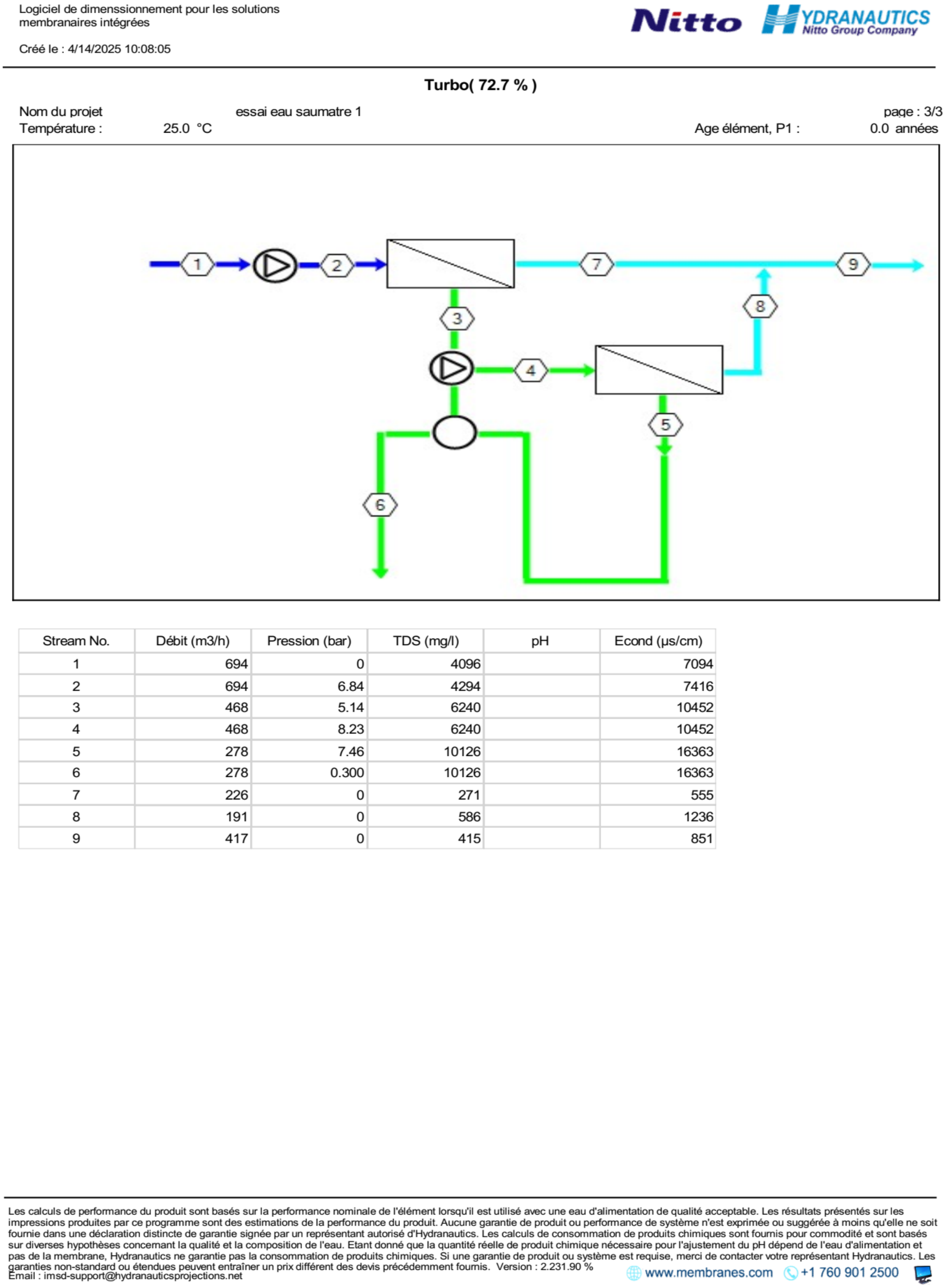


Logiciel de dimenssionnement pour les solutions
membranaires intégrées

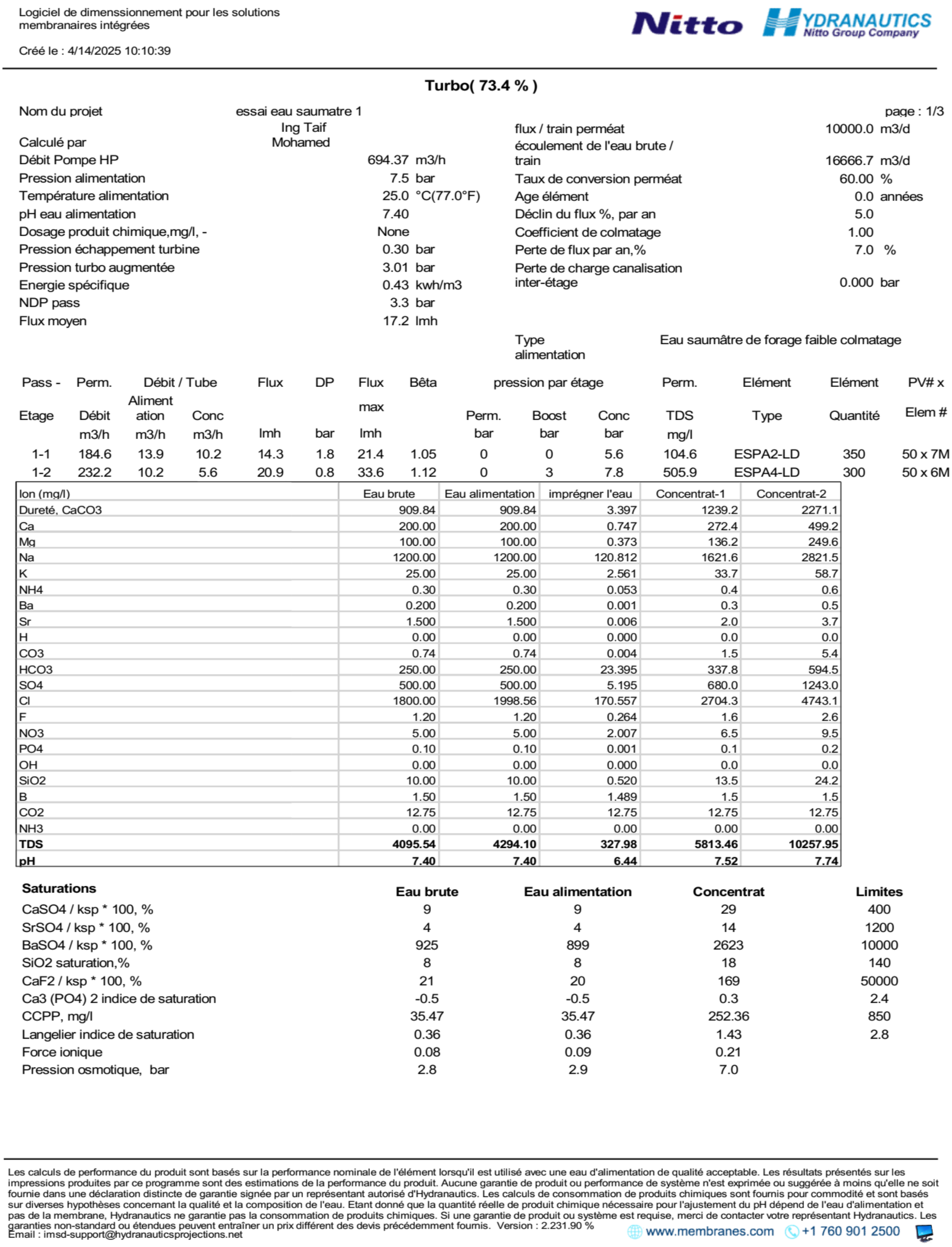
Créé le : 4/14/2025 10:08:05

Turbo(72.7 %)

Nom du projet essai eau saumatre 1 page : 3/3
Température : 25.0 °C Age élément, P1 : 0.0 années

Stream No.	Débit (m3/h)	Pression (bar)	TDS (mg/l)	pH	Econd (µs/cm)
1	694	0	4096		7094
2	694	6.84	4294		7416
3	468	5.14	6240		10452
4	468	8.23	6240		10452
5	278	7.46	10126		16363
6	278	0.300	10126		16363
7	226	0	271		555
8	191	0	586		1236
9	417	0	415		851

- Membrane type : **ESPA2-LD** + **ESPA4-LD**



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 10:10:39

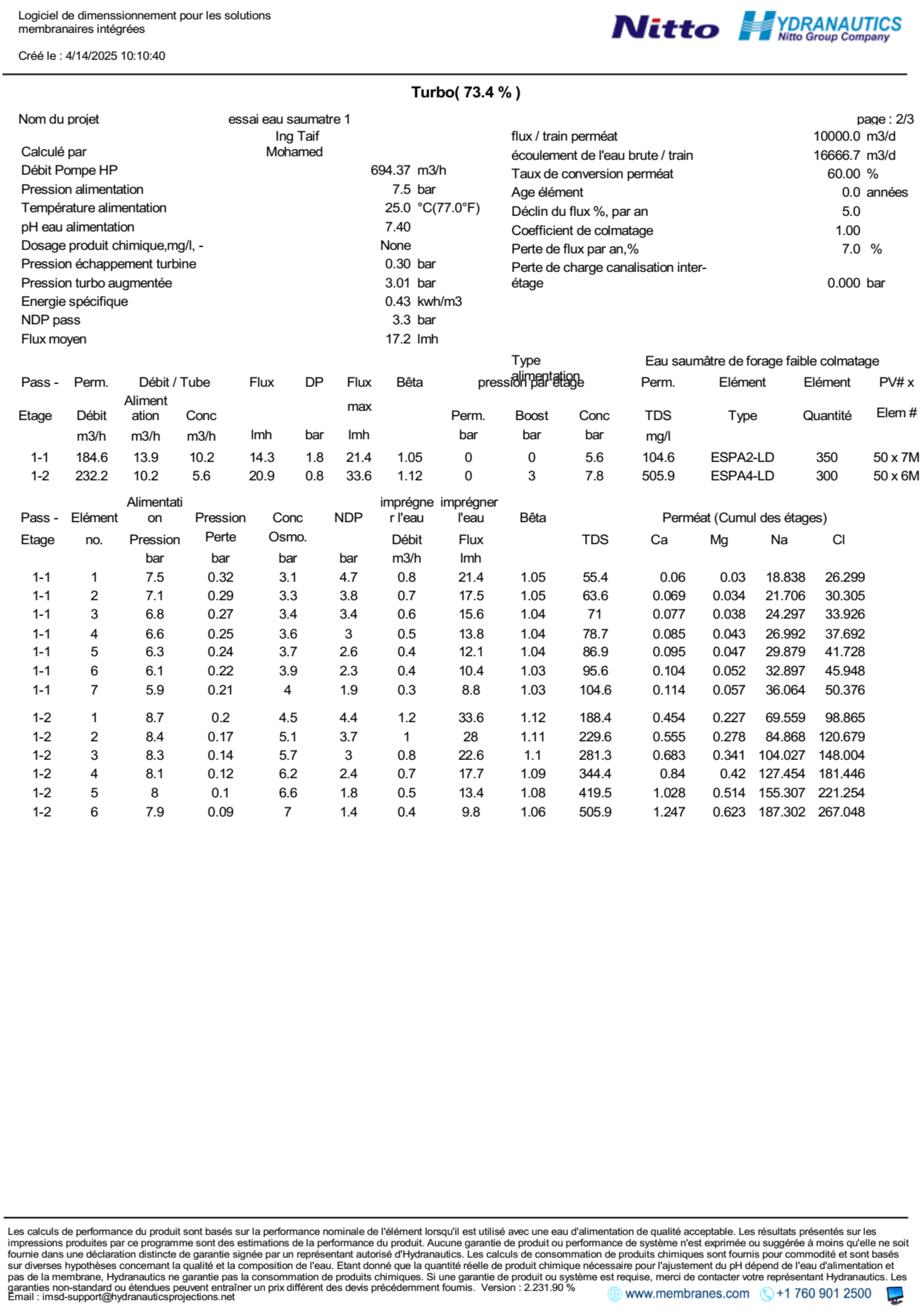
Turbo(73.4 %)

Nom du projet	essai eau saumatre 1			page : 1/3	
Calculé par	Ing Taif Mohamed		flux / train perméat	10000.0	m3/d
Débit Pompe HP	694.37	m3/h	écoulement de l'eau brute / train	16666.7	m3/d
Pression alimentation	7.5	bar	Taux de conversion perméat	60.00	%
Température alimentation	25.0	°C(77.0°F)	Age élément	0.0	années
pH eau alimentation	7.40		Déclin du flux %, par an	5.0	
Dosage produit chimique,mg/l, -	None		Coefficient de colmatage	1.00	
Pression échappement turbine	0.30	bar	Perte de flux par an,%	7.0	%
Pression turbo augmentée	3.01	bar	Perte de charge canalisation inter-étage	0.000	bar
Energie spécifique	0.43	kwh/m3			
NDP pass	3.3	bar			
Flux moyen	17.2	lmh			
			Type alimentation	Eau saumâtre de forage faible colmatage	

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	184.6	13.9	10.2	14.3	1.8	21.4	1.05	0	0	5.6	104.6	ESPA2-LD	350	50 x 7M
1-2	232.2	10.2	5.6	20.9	0.8	33.6	1.12	0	3	7.8	505.9	ESPA4-LD	300	50 x 6M

Ion (mg/l)	Eau brute	Eau alimentation	imprégner l'eau	Concentrat-1	Concentrat-2
Dureté, CaCO3	909.84	909.84	3.397	1239.2	2271.1
Ca	200.00	200.00	0.747	272.4	499.2
Mg	100.00	100.00	0.373	136.2	249.6
Na	1200.00	1200.00	120.812	1621.6	2821.5
K	25.00	25.00	2.561	33.7	58.7
NH4	0.30	0.30	0.053	0.4	0.6
Ba	0.200	0.200	0.001	0.3	0.5
Sr	1.500	1.500	0.006	2.0	3.7
H	0.00	0.00	0.000	0.0	0.0
CO3	0.74	0.74	0.004	1.5	5.4
HCO3	250.00	250.00	23.395	337.8	594.5
SO4	500.00	500.00	5.195	680.0	1243.0
Cl	1800.00	1998.56	170.557	2704.3	4743.1
F	1.20	1.20	0.264	1.6	2.6
NO3	5.00	5.00	2.007	6.5	9.5
PO4	0.10	0.10	0.001	0.1	0.2
OH	0.00	0.00	0.000	0.0	0.0
SiO2	10.00	10.00	0.520	13.5	24.2
B	1.50	1.50	1.489	1.5	1.5
CO2	12.75	12.75	12.75	12.75	12.75
NH3	0.00	0.00	0.00	0.00	0.00
TDS	**4095.54**	**4294.10**	**327.98**	**5813.46**	**10257.95**
pH	**7.40**	**7.40**	**6.44**	**7.52**	**7.74**

Saturations	**Eau brute**	**Eau alimentation**	**Concentrat**	**Limites**
CaSO4 / ksp * 100, %	9	9	29	400
SrSO4 / ksp * 100, %	4	4	14	1200
BaSO4 / ksp * 100, %	925	899	2623	10000
SiO2 saturation,%	8	8	18	140
CaF2 / ksp * 100, %	21	20	169	50000
Ca3 (PO4) 2 indice de saturation	-0.5	-0.5	0.3	2.4
CCPP, mg/l	35.47	35.47	252.36	850
Langelier indice de saturation	0.36	0.36	1.43	2.8
Force ionique	0.08	0.09	0.21	
Pression osmotique, bar	2.8	2.9	7.0	



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 10:10:40

Turbo(73.4 %)

page : 2/3

Nom du projet	essai eau saumatre 1	
Calculé par	Ing Taif Mohamed	
Débit Pompe HP	694.37	m3/h
Pression alimentation	7.5	bar
Température alimentation	25.0	°C(77.0°F)
pH eau alimentation	7.40	
Dosage produit chimique,mg/l, -	None	
Pression échappement turbine	0.30	bar
Pression turbo augmentée	3.01	bar
Energie spécifique	0.43	kwh/m3
NDP pass	3.3	bar
Flux moyen	17.2	lmh

flux / train perméat	10000.0	m3/d
écoulement de l'eau brute / train	16666.7	m3/d
Taux de conversion perméat	60.00	%
Age élément	0.0	années
Déclin du flux %, par an	5.0	
Coefficient de colmatage	1.00	
Perte de flux par an,%	7.0	%
Perte de charge canalisation inter-étage	0.000	bar
Type alimentation	Eau saumâtre de forage faible colmatage	

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	184.6	13.9	10.2	14.3	1.8	21.4	1.05	0	0	5.6	104.6	ESPA2-LD	350	50 x 7M
1-2	232.2	10.2	5.6	20.9	0.8	33.6	1.12	0	3	7.8	505.9	ESPA4-LD	300	50 x 6M

Pass - Etage	Elément no.	Alimentation Pression bar	Pression Perte bar	Conc Osmo. bar	NDP bar	imprégner l'eau Débit m3/h	imprégner l'eau Flux lmh	Bêta	Perméat (Cumul des étages) TDS	Ca	Mg	Na	Cl
1-1	1	7.5	0.32	3.1	4.7	0.8	21.4	1.05	55.4	0.06	0.03	18.838	26.299
1-1	2	7.1	0.29	3.3	3.8	0.7	17.5	1.05	63.6	0.069	0.034	21.706	30.305
1-1	3	6.8	0.27	3.4	3.4	0.6	15.6	1.04	71	0.077	0.038	24.297	33.926
1-1	4	6.6	0.25	3.6	3	0.5	13.8	1.04	78.7	0.085	0.043	26.992	37.692
1-1	5	6.3	0.24	3.7	2.6	0.4	12.1	1.04	86.9	0.095	0.047	29.879	41.728
1-1	6	6.1	0.22	3.9	2.3	0.4	10.4	1.03	95.6	0.104	0.052	32.897	45.948
1-1	7	5.9	0.21	4	1.9	0.3	8.8	1.03	104.6	0.114	0.057	36.064	50.376
1-2	1	8.7	0.2	4.5	4.4	1.2	33.6	1.12	188.4	0.454	0.227	69.559	98.865
1-2	2	8.4	0.17	5.1	3.7	1	28	1.11	229.6	0.555	0.278	84.868	120.679
1-2	3	8.3	0.14	5.7	3	0.8	22.6	1.1	281.3	0.683	0.341	104.027	148.004
1-2	4	8.1	0.12	6.2	2.4	0.7	17.7	1.09	344.4	0.84	0.42	127.454	181.446
1-2	5	8	0.1	6.6	1.8	0.5	13.4	1.08	419.5	1.028	0.514	155.307	221.254
1-2	6	7.9	0.09	7	1.4	0.4	9.8	1.06	505.9	1.247	0.623	187.302	267.048

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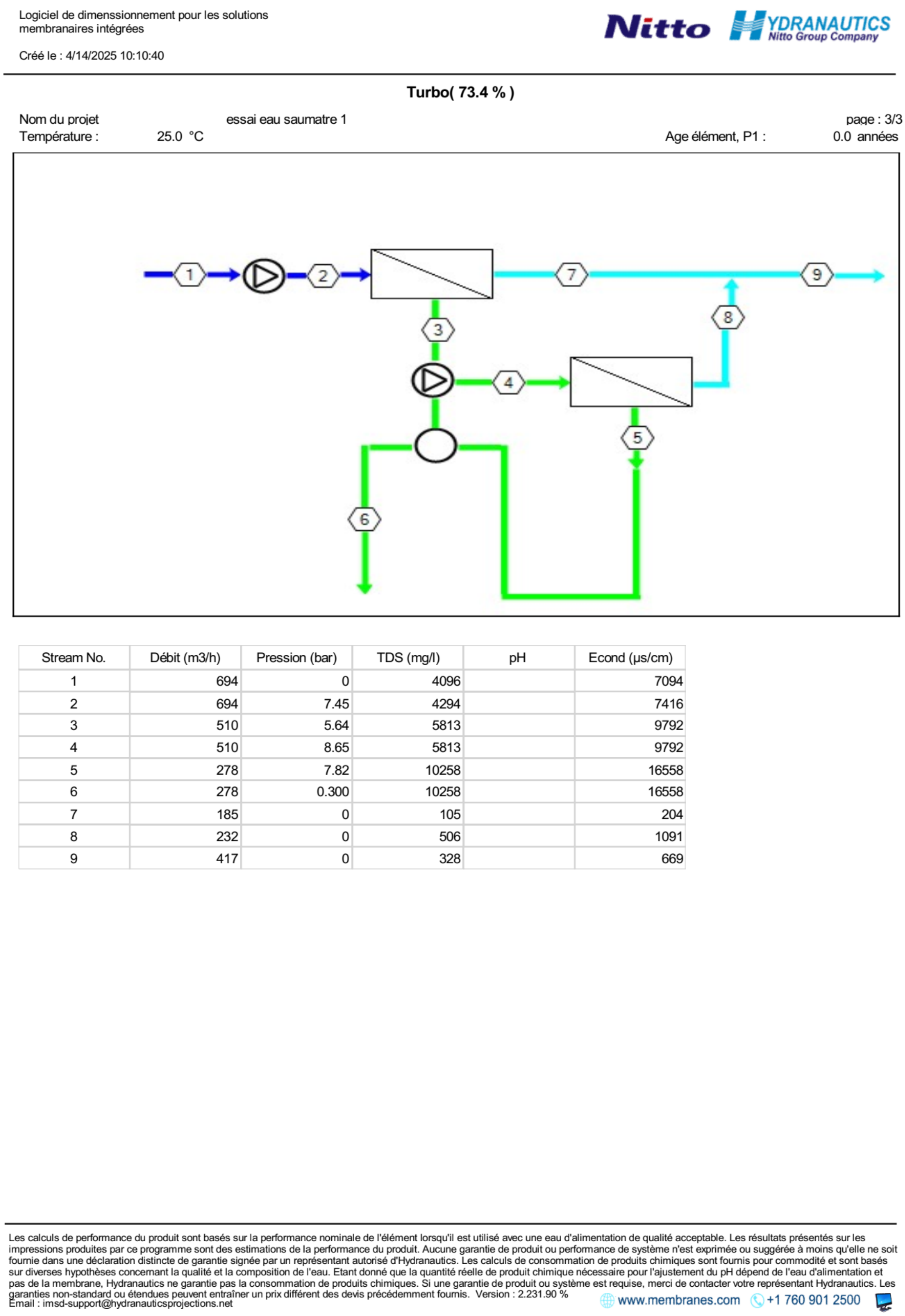


Logiciel de dimenssionnement pour les solutions
membranaires intégrées

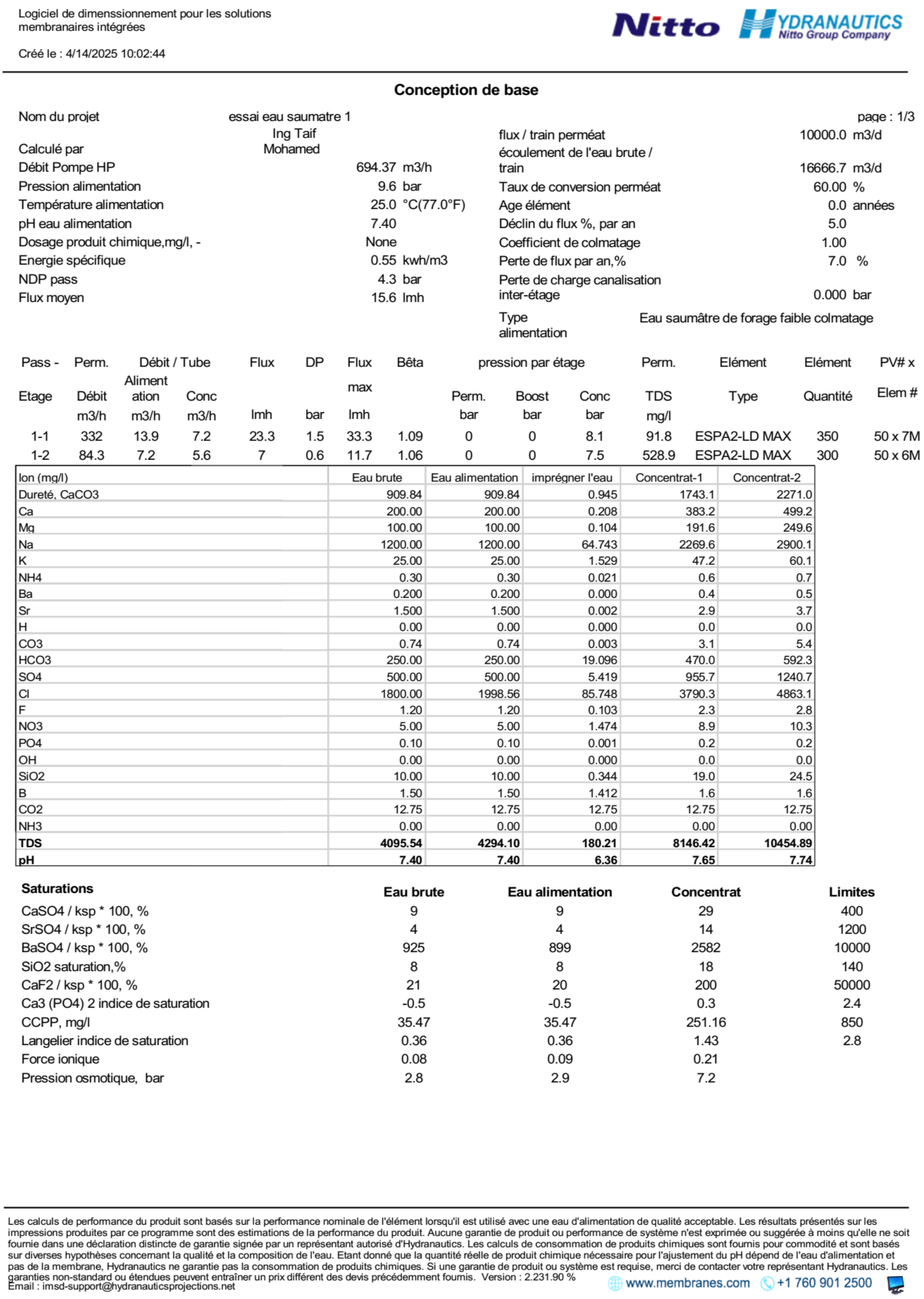
Créé le : 4/14/2025 10:10:40

Turbo(73.4 %)

Nom du projet essai eau saumatre 1 page : 3/3
Température : 25.0 °C Age élément, P1 : 0.0 années

Stream No.	Débit (m3/h)	Pression (bar)	TDS (mg/l)	pH	Econd (µs/cm)
1	694	0	4096		7094
2	694	7.45	4294		7416
3	510	5.64	5813		9792
4	510	8.65	5813		9792
5	278	7.82	10258		16558
6	278	0.300	10258		16558
7	185	0	105		204
8	232	0	506		1091
9	417	0	328		669

- Membrane type **: ESPA2-LD MAX + ESPA2-LD MAX**



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 10:02:44

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Conception de base

page : 1/3

Nom du projet	essai eau saumatre 1		
Calculé par	Ing Taif Mohamed	flux / train perméat	10000.0 m3/d
Débit Pompe HP	694.37 m3/h	écoulement de l'eau brute / train	16666.7 m3/d
Pression alimentation	9.6 bar	Taux de conversion perméat	60.00 %
Température alimentation	25.0 °C(77.0°F)	Age élément	0.0 années
pH eau alimentation	7.40	Déclin du flux %, par an	5.0
Dosage produit chimique,mg/l, -	None	Coefficient de colmatage	1.00
Energie spécifique	0.55 kwh/m3	Perte de flux par an,%	7.0 %
NDP pass	4.3 bar	Perte de charge canalisation inter-étage	0.000 bar
Flux moyen	15.6 lmh		
		Type alimentation	Eau saumâtre de forage faible colmatage

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	332	13.9	7.2	23.3	1.5	33.3	1.09	0	0	8.1	91.8	ESPA2-LD MAX	350	50 x 7M
1-2	84.3	7.2	5.6	7	0.6	11.7	1.06	0	0	7.5	528.9	ESPA2-LD MAX	300	50 x 6M

Ion (mg/l)	Eau brute	Eau alimentation	imprégner l'eau	Concentrat-1	Concentrat-2
Dureté, CaCO3	909.84	909.84	0.945	1743.1	2271.0
Ca	200.00	200.00	0.208	383.2	499.2
Mg	100.00	100.00	0.104	191.6	249.6
Na	1200.00	1200.00	64.743	2269.6	2900.1
K	25.00	25.00	1.529	47.2	60.1
NH4	0.30	0.30	0.021	0.6	0.7
Ba	0.200	0.200	0.000	0.4	0.5
Sr	1.500	1.500	0.002	2.9	3.7
H	0.00	0.00	0.000	0.0	0.0
CO3	0.74	0.74	0.003	3.1	5.4
HCO3	250.00	250.00	19.096	470.0	592.3
SO4	500.00	500.00	5.419	955.7	1240.7
Cl	1800.00	1998.56	85.748	3790.3	4863.1
F	1.20	1.20	0.103	2.3	2.8
NO3	5.00	5.00	1.474	8.9	10.3
PO4	0.10	0.10	0.001	0.2	0.2
OH	0.00	0.00	0.000	0.0	0.0
SiO2	10.00	10.00	0.344	19.0	24.5
B	1.50	1.50	1.412	1.6	1.6
CO2	12.75	12.75	12.75	12.75	12.75
NH3	0.00	0.00	0.00	0.00	0.00
TDS	**4095.54**	**4294.10**	**180.21**	**8146.42**	**10454.89**
pH	**7.40**	**7.40**	**6.36**	**7.65**	**7.74**

Saturations	**Eau brute**	**Eau alimentation**	**Concentrat**	**Limites**
CaSO4 / ksp * 100, %	9	9	29	400
SrSO4 / ksp * 100, %	4	4	14	1200
BaSO4 / ksp * 100, %	925	899	2582	10000
SiO2 saturation,%	8	8	18	140
CaF2 / ksp * 100, %	21	20	200	50000
Ca3 (PO4) 2 indice de saturation	-0.5	-0.5	0.3	2.4
CCPP, mg/l	35.47	35.47	251.16	850
Langelier indice de saturation	0.36	0.36	1.43	2.8
Force ionique	0.08	0.09	0.21	
Pression osmotique, bar	2.8	2.9	7.2	

Les calculs de performance du produit sont basés sur la performance nominale de l'élément lorsqu'il est utilisé avec une eau d'alimentation de qualité acceptable. Les résultats présentés sur les impressions produites par ce programme sont des estimations de la performance du produit. Aucune garantie de produit ou performance de système n'est exprimée ou suggérée à moins qu'elle ne soit fournie dans une déclaration distincte de garantie signée par un représentant autorisé d'Hydranautics. Les calculs de consommation de produits chimiques sont fournis pour commodité et sont basés sur diverses hypothèses concernant la qualité et la composition de l'eau. Etant donné que la quantité réelle de produit chimique nécessaire pour l'ajustement du pH dépend de l'eau d'alimentation et pas de la membrane, Hydranautics ne garantie pas la consommation de produits chimiques. Si une garantie de produit ou système est requise, merci de contacter votre représentant Hydranautics. Les garanties non-standard ou étendues peuvent entraîner un prix différent des devis précédemment fournis. Version : 2.231.90 %

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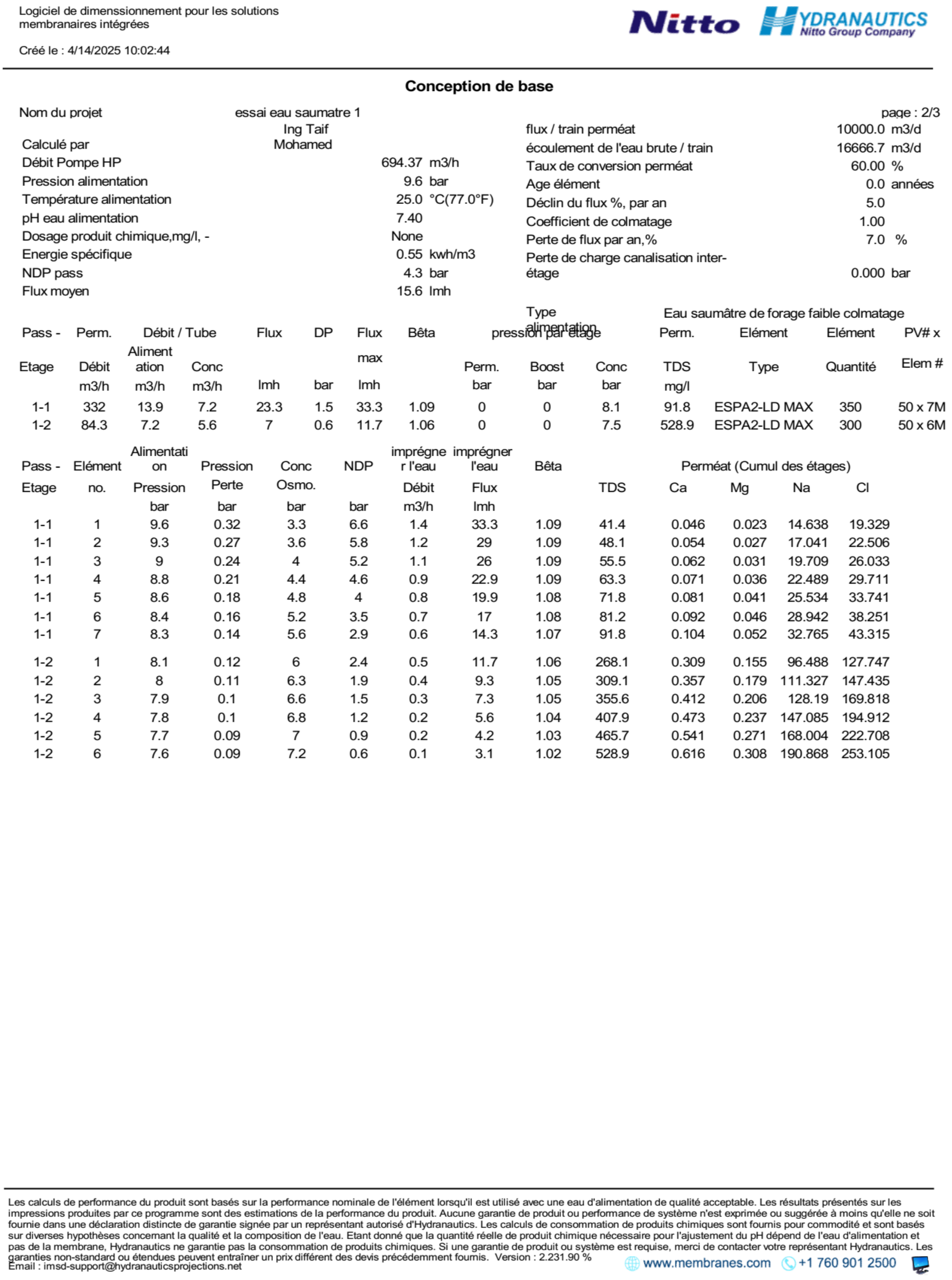

Logiciel de dimenssionnement pour les solutions membranaires intégrées

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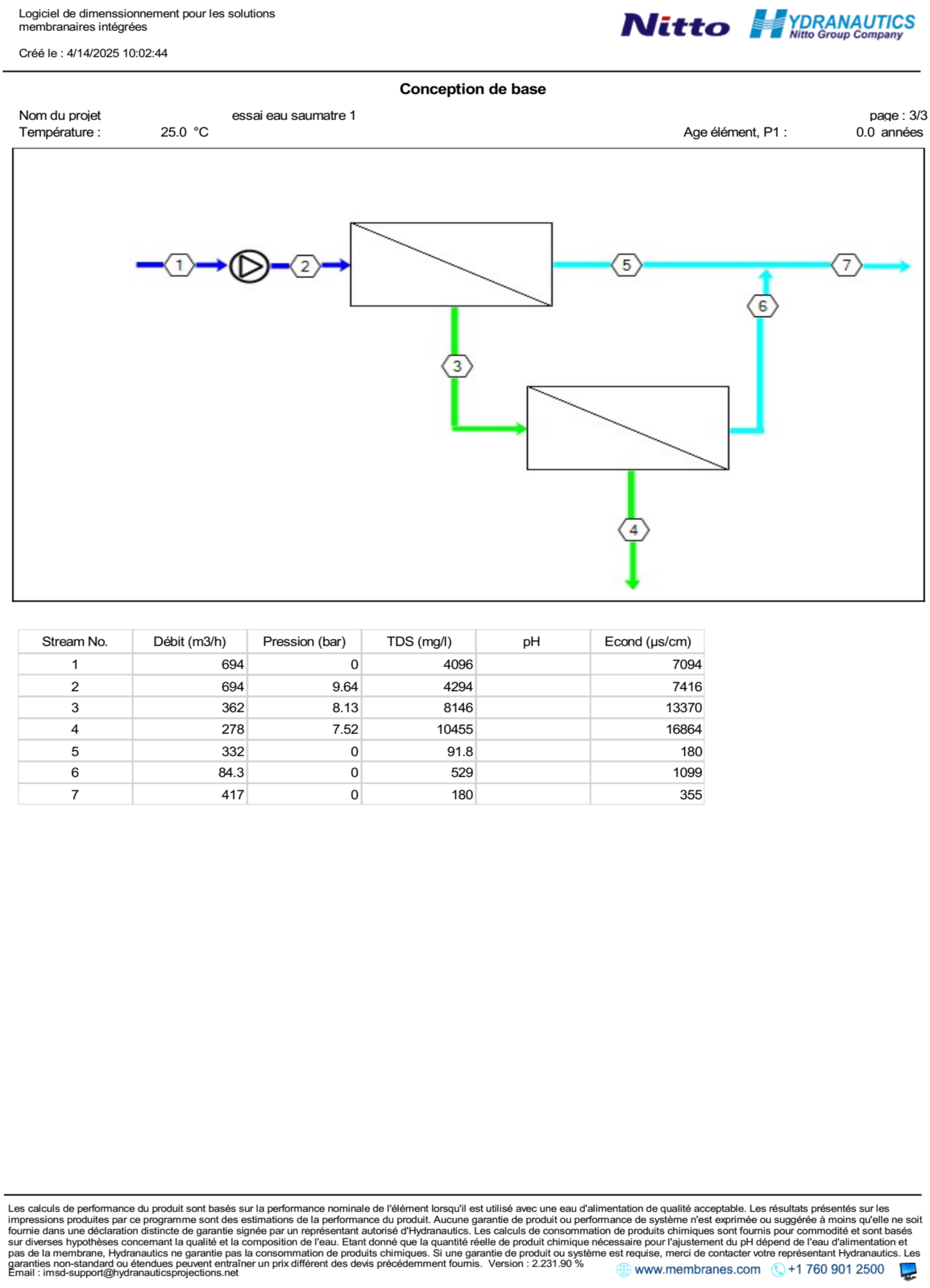
Conception de base

Nom du projet	essai eau saumatre 1			page : 2/3	
Calculé par	Ing Taif Mohamed		flux / train perméat	10000.0	m3/d
Débit Pompe HP	694.37	m3/h	écoulement de l'eau brute / train	16666.7	m3/d
Pression alimentation	9.6	bar	Taux de conversion perméat	60.00	%
Température alimentation	25.0	°C(77.0°F)	Age élément	0.0	années
pH eau alimentation	7.40		Déclin du flux %, par an	5.0	
Dosage produit chimique,mg/l, -	None		Coefficient de colmatage	1.00	
Energie spécifique	0.55	kwh/m3	Perte de flux par an,%	7.0	%
NDP pass	4.3	bar	Perte de charge canalisation inter-étage	0.000	bar
Flux moyen	15.6	lmh			

Type alimentation Eau saumâtre de forage faible colmatage

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	332	13.9	7.2	23.3	1.5	33.3	1.09	0	0	8.1	91.8	ESPA2-LD MAX	350	50 x 7M
1-2	84.3	7.2	5.6	7	0.6	11.7	1.06	0	0	7.5	528.9	ESPA2-LD MAX	300	50 x 6M

Pass - Etage	Elément no.	Alimentation Pression bar	Pression Perte bar	Conc Osmo. bar	NDP bar	imprégner l'eau Débit m3/h	imprégner l'eau Flux lmh	Bêta	Perméat (Cumul des étages) TDS	Ca	Mg	Na	Cl
1-1	1	9.6	0.32	3.3	6.6	1.4	33.3	1.09	41.4	0.046	0.023	14.638	19.329
1-1	2	9.3	0.27	3.6	5.8	1.2	29	1.09	48.1	0.054	0.027	17.041	22.506
1-1	3	9	0.24	4	5.2	1.1	26	1.09	55.5	0.062	0.031	19.709	26.033
1-1	4	8.8	0.21	4.4	4.6	0.9	22.9	1.09	63.3	0.071	0.036	22.489	29.711
1-1	5	8.6	0.18	4.8	4	0.8	19.9	1.08	71.8	0.081	0.041	25.534	33.741
1-1	6	8.4	0.16	5.2	3.5	0.7	17	1.08	81.2	0.092	0.046	28.942	38.251
1-1	7	8.3	0.14	5.6	2.9	0.6	14.3	1.07	91.8	0.104	0.052	32.765	43.315
1-2	1	8.1	0.12	6	2.4	0.5	11.7	1.06	268.1	0.309	0.155	96.488	127.747
1-2	2	8	0.11	6.3	1.9	0.4	9.3	1.05	309.1	0.357	0.179	111.327	147.435
1-2	3	7.9	0.1	6.6	1.5	0.3	7.3	1.05	355.6	0.412	0.206	128.19	169.818
1-2	4	7.8	0.1	6.8	1.2	0.2	5.6	1.04	407.9	0.473	0.237	147.085	194.912
1-2	5	7.7	0.09	7	0.9	0.2	4.2	1.03	465.7	0.541	0.271	168.004	222.708
1-2	6	7.6	0.09	7.2	0.6	0.1	3.1	1.02	528.9	0.616	0.308	190.868	253.105



Logiciel de dimenssionnement pour les solutions membranaires intégrées

Créé le : 4/14/2025 10:02:44

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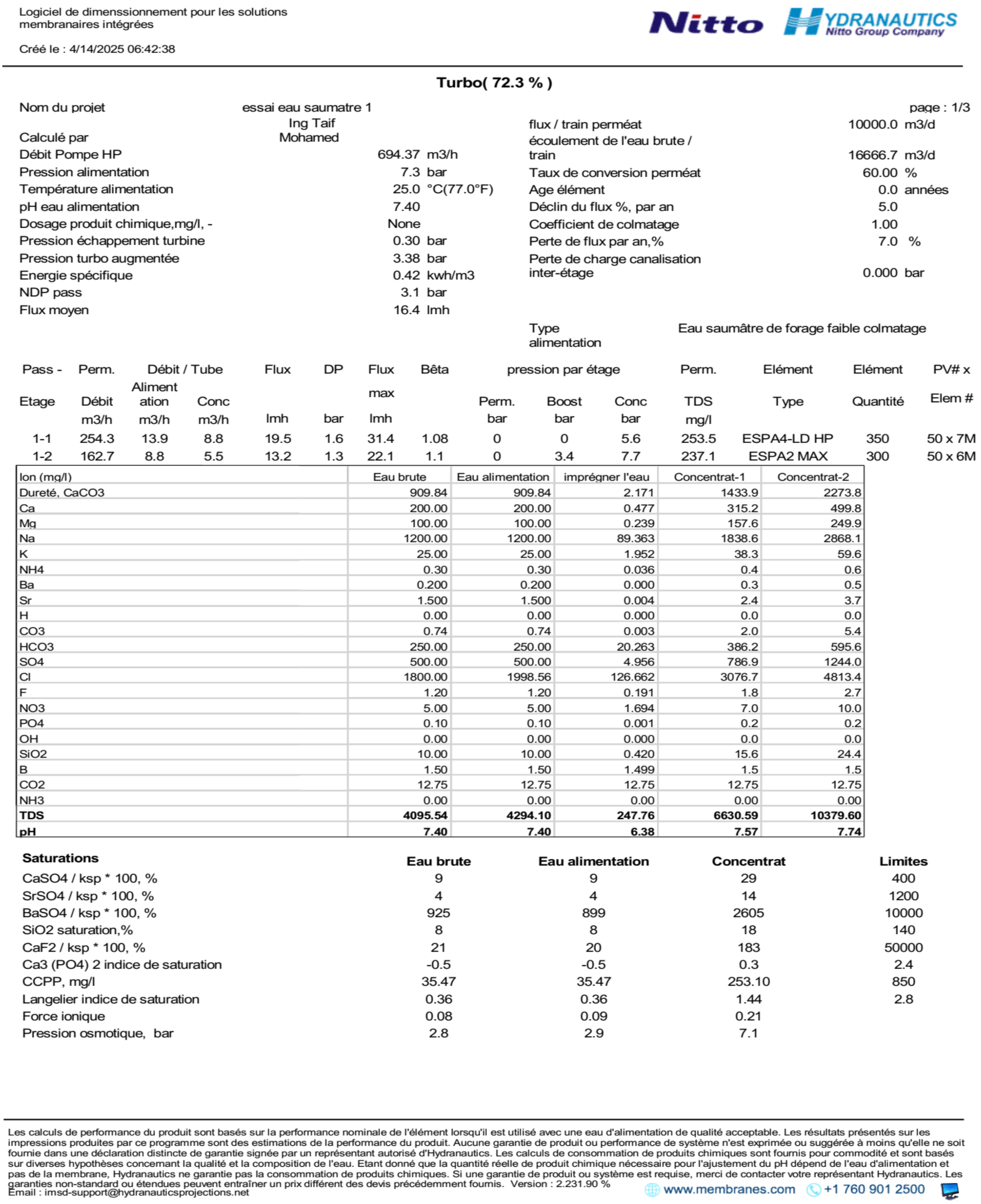
Conception de base

Nom du projet essai eau saumatre 1 page : 3/3
Température : 25.0 °C Age élément, P1 : 0.0 années

Stream No.	Débit (m3/h)	Pression (bar)	TDS (mg/l)	pH	Econd (µs/cm)
1	694	0	4096		7094
2	694	9.64	4294		7416
3	362	8.13	8146		13370
4	278	7.52	10455		16864
5	332	0	91.8		180
6	84.3	0	529		1099
7	417	0	180		355

- Membrane type **: ESPA4-LD HP + ESPA2- MAX**



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

Créé le : 4/14/2025 06:42:38

Turbo(72.3 %)

page : 1/3

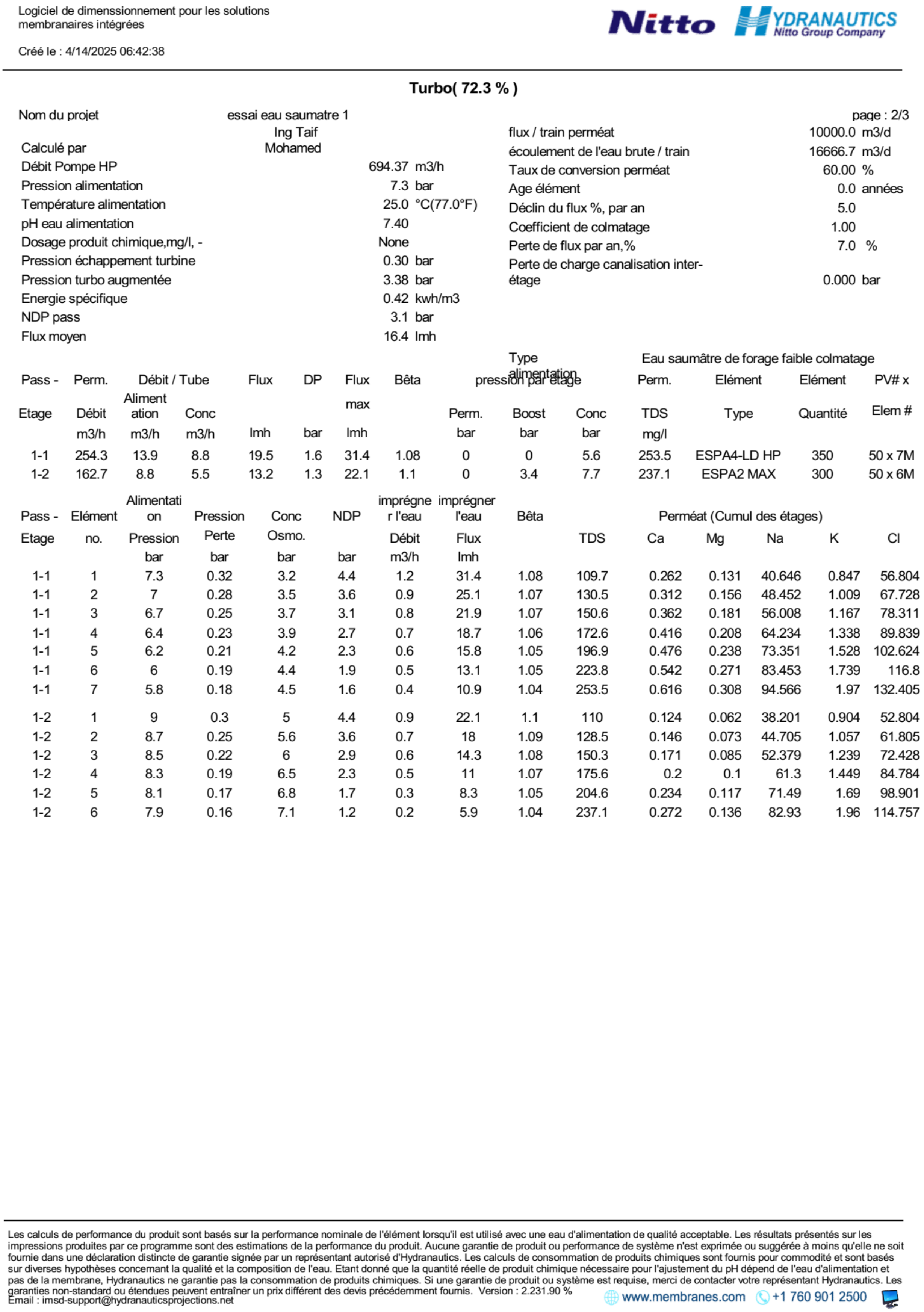
Nom du projet	essai eau saumatre 1 Ing Taif	
Calculé par	Mohamed	
Débit Pompe HP	694.37	m3/h
Pression alimentation	7.3	bar
Température alimentation	25.0	°C(77.0°F)
pH eau alimentation	7.40	
Dosage produit chimique,mg/l, -	None	
Pression échappement turbine	0.30	bar
Pression turbo augmentée	3.38	bar
Energie spécifique	0.42	kwh/m3
NDP pass	3.1	bar
Flux moyen	16.4	lmh

flux / train perméat	10000.0	m3/d
écoulement de l'eau brute / train	16666.7	m3/d
Taux de conversion perméat	60.00	%
Age élément	0.0	années
Déclin du flux %, par an	5.0	
Coefficient de colmatage	1.00	
Perte de flux par an,%	7.0	%
Perte de charge canalisation inter-étage	0.000	bar
Type alimentation	Eau saumâtre de forage faible colmatage	

Pass -	Perm.	Débit / Tube		Flux	DP	Flux	Bêta	pression par étage			Perm.	Elément	Elément	PV# x
Etage	Débit m3/h	Alimentation m3/h	Conc m3/h	lmh	bar	max lmh		Perm. bar	Boost bar	Conc bar	TDS mg/l	Type	Quantité	Elem #
1-1	254.3	13.9	8.8	19.5	1.6	31.4	1.08	0	0	5.6	253.5	ESPA4-LD HP	350	50 x 7M
1-2	162.7	8.8	5.5	13.2	1.3	22.1	1.1	0	3.4	7.7	237.1	ESPA2 MAX	300	50 x 6M

Ion (mg/l)	Eau brute	Eau alimentation	imprégner l'eau	Concentrat-1	Concentrat-2
Dureté, CaCO3	909.84	909.84	2.171	1433.9	2273.8
Ca	200.00	200.00	0.477	315.2	499.8
Mg	100.00	100.00	0.239	157.6	249.9
Na	1200.00	1200.00	89.363	1838.6	2868.1
K	25.00	25.00	1.952	38.3	59.6
NH4	0.30	0.30	0.036	0.4	0.6
Ba	0.200	0.200	0.000	0.3	0.5
Sr	1.500	1.500	0.004	2.4	3.7
H	0.00	0.00	0.000	0.0	0.0
CO3	0.74	0.74	0.003	2.0	5.4
HCO3	250.00	250.00	20.263	386.2	595.6
SO4	500.00	500.00	4.956	786.9	1244.0
Cl	1800.00	1998.56	126.662	3076.7	4813.4
F	1.20	1.20	0.191	1.8	2.7
NO3	5.00	5.00	1.694	7.0	10.0
PO4	0.10	0.10	0.001	0.2	0.2
OH	0.00	0.00	0.000	0.0	0.0
SiO2	10.00	10.00	0.420	15.6	24.4
B	1.50	1.50	1.499	1.5	1.5
CO2	12.75	12.75	12.75	12.75	12.75
NH3	0.00	0.00	0.00	0.00	0.00
TDS	**4095.54**	**4294.10**	**247.76**	**6630.59**	**10379.60**
pH	**7.40**	**7.40**	**6.38**	**7.57**	**7.74**

Saturations	**Eau brute**	**Eau alimentation**	**Concentrat**	**Limites**
CaSO4 / ksp * 100, %	9	9	29	400
SrSO4 / ksp * 100, %	4	4	14	1200
BaSO4 / ksp * 100, %	925	899	2605	10000
SiO2 saturation,%	8	8	18	140
CaF2 / ksp * 100, %	21	20	183	50000
Ca3 (PO4) 2 indice de saturation	-0.5	-0.5	0.3	2.4
CCPP, mg/l	35.47	35.47	253.10	850
Langelier indice de saturation	0.36	0.36	1.44	2.8
Force ionique	0.08	0.09	0.21	
Pression osmotique, bar	2.8	2.9	7.1	



Logiciel de dimenssionnement pour les solutions
membranaires intégrées

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Turbo(72.3 %)

page : 2/3

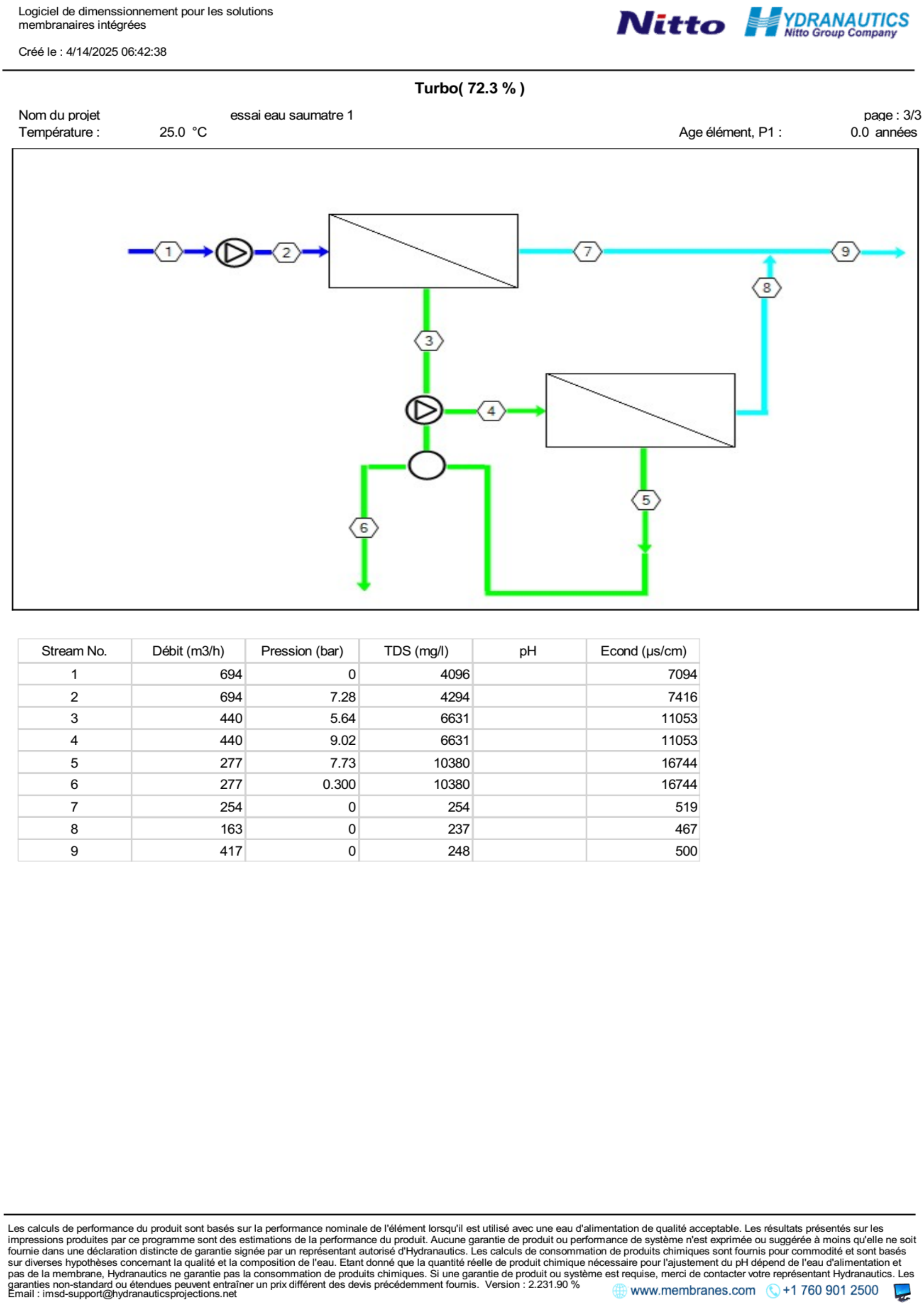
Nom du projet	essai eau saumatre 1	
Calculé par	Ing Taif Mohamed	
Débit Pompe HP	694.37	m3/h
Pression alimentation	7.3	bar
Température alimentation	25.0	°C(77.0°F)
pH eau alimentation	7.40	
Dosage produit chimique,mg/l, -	None	
Pression échappement turbine	0.30	bar
Pression turbo augmentée	3.38	bar
Energie spécifique	0.42	kwh/m3
NDP pass	3.1	bar
Flux moyen	16.4	lmh

flux / train perméat	10000.0	m3/d
écoulement de l'eau brute / train	16666.7	m3/d
Taux de conversion perméat	60.00	%
Age élément	0.0	années
Déclin du flux %, par an	5.0	
Coefficient de colmatage	1.00	
Perte de flux par an,%	7.0	%
Perte de charge canalisation inter-étage	0.000	bar

Type alimentation: Eau saumâtre de forage faible colmatage

Pass - Etage	Perm. Débit m3/h	Débit / Tube Alimentation m3/h	Débit / Tube Conc m3/h	Flux lmh	DP bar	Flux max lmh	Bêta	pression par étage Perm. bar	pression par étage Boost bar	pression par étage Conc bar	Perm. TDS mg/l	Elément Type	Elément Quantité	PV# x Elem #
1-1	254.3	13.9	8.8	19.5	1.6	31.4	1.08	0	0	5.6	253.5	ESPA4-LD HP	350	50 x 7M
1-2	162.7	8.8	5.5	13.2	1.3	22.1	1.1	0	3.4	7.7	237.1	ESPA2 MAX	300	50 x 6M

Pass - Etage	Elément no.	Alimentation Pression bar	Pression Perte bar	Conc Osmo. bar	NDP bar	imprégner l'eau Débit m3/h	imprégner l'eau Flux lmh	Bêta	Perméat (Cumul des étages) TDS	Ca	Mg	Na	K	Cl
1-1	1	7.3	0.32	3.2	4.4	1.2	31.4	1.08	109.7	0.262	0.131	40.646	0.847	56.804
1-1	2	7	0.28	3.5	3.6	0.9	25.1	1.07	130.5	0.312	0.156	48.452	1.009	67.728
1-1	3	6.7	0.25	3.7	3.1	0.8	21.9	1.07	150.6	0.362	0.181	56.008	1.167	78.311
1-1	4	6.4	0.23	3.9	2.7	0.7	18.7	1.06	172.6	0.416	0.208	64.234	1.338	89.839
1-1	5	6.2	0.21	4.2	2.3	0.6	15.8	1.05	196.9	0.476	0.238	73.351	1.528	102.624
1-1	6	6	0.19	4.4	1.9	0.5	13.1	1.05	223.8	0.542	0.271	83.453	1.739	116.8
1-1	7	5.8	0.18	4.5	1.6	0.4	10.9	1.04	253.5	0.616	0.308	94.566	1.97	132.405
1-2	1	9	0.3	5	4.4	0.9	22.1	1.1	110	0.124	0.062	38.201	0.904	52.804
1-2	2	8.7	0.25	5.6	3.6	0.7	18	1.09	128.5	0.146	0.073	44.705	1.057	61.805
1-2	3	8.5	0.22	6	2.9	0.6	14.3	1.08	150.3	0.171	0.085	52.379	1.239	72.428
1-2	4	8.3	0.19	6.5	2.3	0.5	11	1.07	175.6	0.2	0.1	61.3	1.449	84.784
1-2	5	8.1	0.17	6.8	1.7	0.3	8.3	1.05	204.6	0.234	0.117	71.49	1.69	98.901
1-2	6	7.9	0.16	7.1	1.2	0.2	5.9	1.04	237.1	0.272	0.136	82.93	1.96	114.757



Logiciel de dimenssionnement pour les solutions membranaires intégrées

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Turbo(72.3 %)

Nom du projet essai eau saumatre 1 page : 3/3

Température : 25.0 °C Age élément, P1 : 0.0 années

Stream No.	Débit (m3/h)	Pression (bar)	TDS (mg/l)	pH	Econd (µs/cm)
1	694	0	4096		7094
2	694	7.28	4294		7416
3	440	5.64	6631		11053
4	440	9.02	6631		11053
5	277	7.73	10380		16744
6	277	0.300	10380		16744
7	254	0	254		519
8	163	0	237		467
9	417	0	248		500

III.5.2 Discussion of the results

This study evaluated the performance of different configurations of Hydranautics reverse osmosis modules for the treatment of brackish water. Simulations were carried out with constant temperature (25°C), pH (7.4), feed rate **(10000 m^3/d = 694.37 m^3/h)** and conversion rate (**60%**). Elements tested included **ESPA2-LD**, **ESPA4-LD and HP**, **ESPA2-LD MAX**, as well as **ESPA4-LD HP**, alone or in combination.

1. Hydraulic and energy performance

The results show a clear variation in terms of **required feed pressure**, **specific energy** and **average flux** depending on the membranes used:

- The system based solely on **ESPA2-LD** requires the highest pressure (**10.2 bar**) and has the highest energy consumption (**0.59 kWh/m^3**). This system is therefore the least energy-efficient.
- The **ESPA2-LD MAX** configuration, optimized for more moderate flows (**15.6 lmh**), reduces supply pressure to 9.6 bar and slightly improves energy efficiency (0.55 kWh/m^3).
- The introduction of higher-efficiency membranes such as **ESPA4-LD** or **ESPA4-LD HP**, alone or in combination, enables a **significant reduction in pressure (up to 6.7 bar)** and **specific energy (down to 0.39 kWh/m^3)**.
- The **ESPA4-LD HP + ESPA2-LD MAX** mixed configuration combines the advantages of both models with a good compromise between flow, pressure (7.3 bar) and energy consumption (0.42 kWh/m^3).

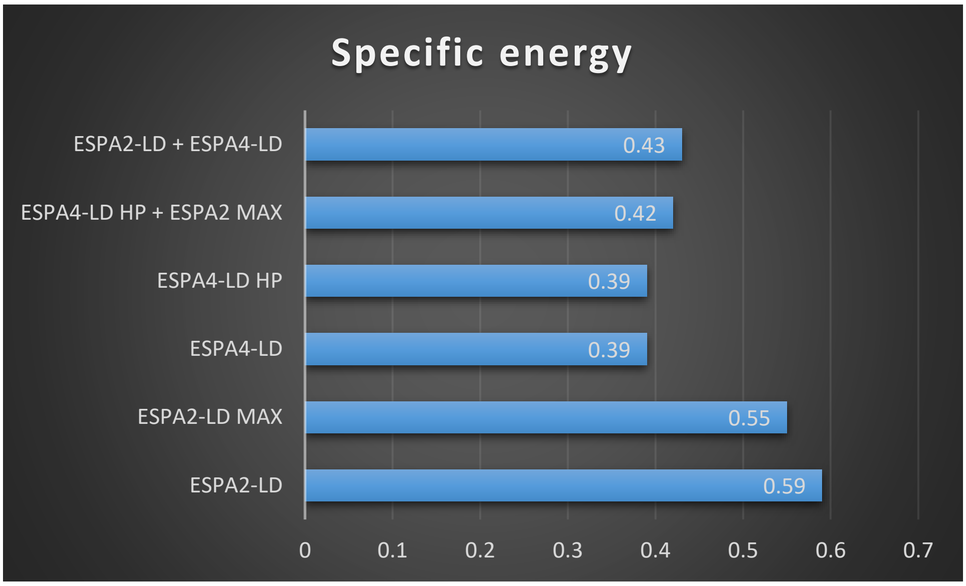

Figure III.5: Specific energy by membrane configuration

2. *Analysis of concentrate quality and scaling risk*

All simulated scenarios respect the saturation limits for the main encrusting salts:

- **The supersaturation** indices **of $CaSO_4$, $BaSO_4$, SiO_2** and the **Langelier and CCPP indices** remain **well below critical thresholds** in all configurations, indicating good chemical stability without the use of anti-scaling products.
- Saturation indices for **$Ca_{(3)}$ $(PO_{(4)})_{(2)}$** also remain low, even in final concentrate (≈ 0.3), reducing the risk of calco-carbonate or phosphate precipitation.

3. *Changes in salinity and pH*

Final concentrate salinity (TDS) varies between **~10,050 mg/L and ~10,500 mg/L**, consistent with a conversion rate of 60%. The **pH of** the permeate remains within an acceptable range (~6.25 to 6.5), confirming the efficiency of membrane passage without any noticeable effect on acid-base balance.

4. *Combination overview :*

Configuration	Pressure (bar)	Specific energy (kWh/m^3)	TDS Concentrate (mg/L)	Main comments
ESPA2-LD	10,2	0.59	10 518	High pressure and energy
ESPA2-LD MAX	9,6	0.55	10 454	Longer service life
ESPA4-LD	6,7	0.39	10 057	High energy efficiency
ESPA4-LD HP	6,8	0.39	10 126	Low-pressure performance
ESPA4-LD HP + ESPA2-LD MAX	7,3	0.42	10 380	Good overall compromise
ESPA2-LD + ESPA4-LD	7,5	0.43	10 257	Pressure/flow/energy balance

- **Comparison of configurations according to permeate qualities and salt discharges**

- **Permeate quality: salinity and ions:**

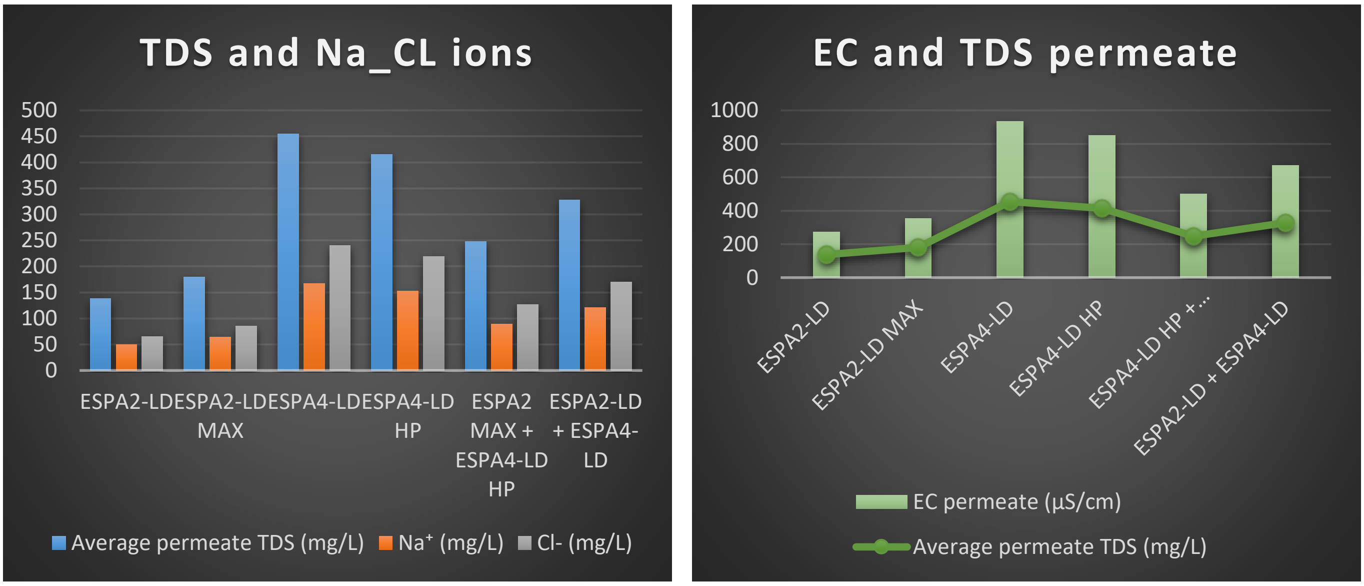

Figure III.6: Permeate quality (EC, TDS and Na^+ - Cl^- ions) according to membrane configuration

- **Analysis**:

- **The purest** permeate is produced by **ESPA2-LD**, followed by **ESPA2 - LD MAX**.
- The **100% ESPA4** configurations **(LD or HP)** produce a saltier permeate, which is expected as these membranes are optimized for flow, not maximum retention.
- The **ESPA4-LD HP + ESPA2 MAX** design achieves an **interesting balance** between **salt retention** and **hydraulic performance**.

- **Overall assessment of designs**

Table 4: Comparison criteria

Design	TDS permeate (mg/L)	Specific energy (kWh/m³)	Supply pressure (bar)	TDS concentrate (mg/L)	Comment
ESPA2-LD	**138**	0.59	10.2	10 518	Excellent for retention, but energy-hungry
ESPA2-LD MAX	180	0.55	9.6	10 454	Good compromise with less pressure
ESPA4-LD	455	0.39	6.7	10 056	Energy-saving, but saltier permeate
ESPA4-LD HP	415	**0.39**	**6.8**	10 126	Very good overall performance
ESPA4-LD HP + ESPA2 LD MAX	248	0.42	7.3	10 379	Good compromise between retention and energy
ESPA2-LD + ESPA4-LD	328	0.43	7.5	10 257	Average on all counts

Comparative analysis of the six configurations shows that the design **combining ESPA4-LD HP elements in the first pass and ESPA2-LD MAX in the second pass** offers the **best overall performance**. It features an excellent **compromise** between **permeate quality (TDS ≈ 248 mg/L)**, **moderate energy consumption (0.42 kWh/m³**), and **reasonable operating pressure (7.3 bar)**. What's more, scaling salt saturation indices remain well below critical thresholds, guaranteeing long-lasting system operation without intensive antiscalant treatment.

This design is therefore recommended for use in industrial-scale brackish water desalination plants.

Choosing the best design

✅ Recommendation: ESPA4-LD HP + ESPA2-LD MAX

This combination offers **the best balance** between the following criteria:

- **Good permeate quality** (TDS ≈ 248 mg/L)
- **Moderate pressure** (7.3 bar)
- **Low energy consumption** (0.42 kWh/m³)
- **Concentrate discharge controlled** (TDS ≈ 10,380 mg/L)
- **Low risk of scaling**, depending on observed saturation levels

This **reduces operating costs** while guaranteeing **high-quality water** for drinking water treatment or sensitive industrial uses.

- **Discussion of the risk of fouling in the ESPA4-LD HP + ESPA2-LD MAX system**

Fouling is one of the major challenges in the operation of reverse osmosis membranes, as it can lead to reduced flow, increased differential pressure, higher energy consumption and shorter element life. The system combining ESPA4-LD HP in the first pass and ESPA2-LD MAX in the second pass offers several advantages that significantly reduce this risk.

➢ **Controlled average flow**

The system's average flux is **16.4 lmh**, which remains below the critical threshold (20-25 lmh) for brackish water applications.

This flow rate limits the deposition of colloidal and biological particles, thus reducing conditions favorable to organic clogging or biofouling.

➢ **Moderate concentration profile**

TDS levels in the final concentrate (~10,380 mg/L) remain compatible with membrane performance limits, with no excess osmotic salinity to promote salt precipitation.

The progressive two-pass design distributes hydraulic and chemical stress over two types of membrane, reducing localized build-up of clogging substances.

- **Stable nominal clogging index**

The fouling factor used in the projection is 1.00, indicating a design for low fouling water, in line with the nature of the brackish water used.

Estimated flux loss is 7% per year, which is acceptable and manageable via periodic chemical cleaning (CIP).

- **No critical saturation zones**

Saturation indices for mineral components such as $CaSO_4$ (29%), $BaSO_4$ (2605%), SiO_2 (18%) and the Langelier index (1.44) are well below the critical thresholds recommended by Hydranautics.

This means that the system is chemically stable and not very prone to scaling, a form of mineral fouling.

- **Choice of anti-clogging membranes**

The ESPA4-LD HP model is specifically designed to limit hydraulic clogging, with an optimized internal structure and advanced surface properties (smooth surface, balanced load).

ESPA2-LD MAX in the second pass ensures additional retention at low flux, minimizing concentration polarization, an important factor in the appearance of biofouling.

Conclusion

The ESPA4-LD HP + ESPA2-LD MAX design represents a robust and durable configuration, with a very low risk of clogging thanks to an optimum balance between flow, pressure, salt retention and chemical stability. This configuration is therefore highly recommended for high-flow industrial plants requiring controlled maintenance and extended membrane longevity.

Conclusion :

Faced with the ever-increasing scarcity of freshwater resources, the exploitation of brackish water is a strategic solution to drinking and industrial water needs, particularly in arid and semi-arid zones. Reverse osmosis desalination has become a mature, high-performance and progressively energy-optimized technique.

In this thesis, a comparative study was carried out on different membrane configurations from the Hydranautics range (**ESPA2-LD, ESPA4-LD, ESPA2-LD MAX, ESPA4-LD HP**), using simulations performed with IMS-Design software. This approach enabled us to quantify the influence of each configuration on key parameters such as feed pressure, specific energy consumption, permeate quality, as well as clogging and scaling risks.

Of all the configurations tested, the **ESPA4-LD HP + ESPA2-LD MAX** combination showed the best overall performance, offering a good balance between hydraulic performance, energy efficiency, permeate quality and chemical stability. This design is particularly well suited to industrial desalination plants, where reliability, membrane durability and control of operating costs are essential criteria.

Perspectives :

In order to extend this study and respond to future challenges linked to sustainable water management, several avenues of research may be considered:

1. **Complete economic optimization:** Integrate a detailed economic analysis taking into account investment, operating, maintenance and membrane replacement costs, for an overall assessment of the cost per cubic meter of water produced.
2. **Experimental validation:** Complement the simulation results with real-life tests, to confirm the predictive performance of the IMS-Design software and observe the long-term behavior of the membranes.
3. **Evaluation of renewable energy scenarios:** Investigate the possibility of powering the desalination plant with renewable energies (solar, wind) to further reduce the environmental impact of the process.
4. **Waste treatment**: Explore technologies for reclaiming or treating discharged concentrated brine, in order to limit its ecological impact and, possibly, recover certain high value-added salts.

5. **Membrane aging study:** Analyze the effect of aging on membrane performance over time, including parameters such as biofouling, chemical fouling and permeability evolution.

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Annexe

ESPA2-LD MAX

Specified Performance*

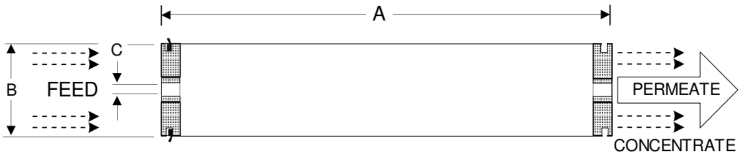
Permeate Flow:	12,000 gpd (45.4 m^3/d)
Salt Rejection:	99.6% (99.5% minimum)
Test Conditions:	1500 ppm NaCl solution 150 psig (1.03 MPa) Applied Pressure 77 °F (25 °C) Operating Temperature 15% Permeate Recovery 6.5 - 7.0 pH Range

*The Specified Performance is based on data taken after a minimum of 10 minutes of operation. Actual testing of elements may be done at conditions which vary from these exact values; in which case, the performance is normalized back to these standard conditions. Permeate flow for individual elements may vary ±15 percent from the value specified.

General Product Description**

Configuration:	Low Fouling Spiral Wound
Membrane Polymer:	Composite Polyamide
Membrane Active Area**:	440 ft^2 (40.9 m^2)
Feed Spacer:	34 mil (0.86 mm)

Packaging: All membrane elements are supplied with a brine seal, interconnector, and O-rings. Elements are enclosed in a sealed polyethylene bag containing less than 1.0% sodium meta-bisulfite solution, and then packaged in a cardboard box.



Element Details**

A, inches (mm)	B, inches (mm)	C, inches (mm)
40.0 (1016)	7.89 (200)	1.125 (28.6)

**Values listed are indicative, not specified. For more detailed specifications, see our Technical Service Bulletin documents or contact Hydranautics Technical Department.

Product Use and Restrictions^

Maximum Applied Pressure:	600 psig (4.14 MPa)
Maximum Chlorine Concentration:	< 0.1 ppm
Maximum Operating Temperature:	113 °F (45 °C)
pH Range, Continuous (Cleaning):	2-10.6 (1-12)
Maximum Feedwater Turbidity:	1.0 NTU
Maximum Feedwater SDI (15 mins):	5.0
Maximum Feed Flow:	85 gpm (19.3 m^3/h)
Minimum Brine Flow:	12 gpm (2.7 m^3/h)
Maximum Pressure Drop for Each Element:	15 psi (0.10 MPa)

^ The limitations shown here are for general use. For specified projects, operation at more conservative values may ensure the best performance and longest life of the membrane. See Hydranautics Technical Bulletins for more details.

9/14/2022

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Web: www.membranes.com Email: hy-info@nitto.com

ESPA2-LD-4040

Specified Performance*

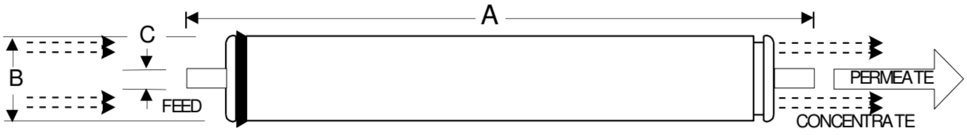
Permeate Flow:	2,000 gpd (7.57 m^3/d)
Salt Rejection:	99.6% (99.4% minimum)
Test Conditions:	1500 ppm NaCl solution 150 psig (1.03 MPa) Applied Pressure 77 °F (25 °C) Operating Temperature 15% Permeate Recovery 6.5 - 7.0 pH Range

*The Specified Performance is based on data taken after a minimum of 10 minutes of operation. Actual testing of elements may be done at conditions which vary from these exact values; in which case, the performance is normalized back to these standard conditions. Permeate flow for individual elements may vary + or -20 percent from the value specified.

General Product Description**

Configuration:	Low Fouling Spiral Wound
Membrane Polymer:	Composite Polyamide
Membrane Active Area**:	80 ft^2 (7.43 m^2)
Feed Spacer:	34 mil (0.86 mm)

Packaging: All membrane elements are supplied with a brine seal, interconnector, and O-rings. Elements are enclosed in a sealed polyethylene bag containing less than 1.0% sodium meta-bisulfite solution, and then packaged in a cardboard box.



Element Details**

A, inches (mm)	B, inches (mm)	C, inches (mm)
40.0 (1016)	3.95 (100.3)	0.75 (19.1)

Core tube extension = 1.05" (26.7 mm)

**Values listed are indicative, not specified. For more detailed specifications, see our Technical Service Bulletin documents or contact Hydranautics Technical Department.

Product Use and Restrictions^

Maximum Applied Pressure:	600 psig (4.14 MPa)
Maximum Chlorine Concentration:	< 0.1 ppm
Maximum Operating Temperature:	113 °F (45 °C)
pH Range, Continuous (Cleaning):	2-10.6 (1-12)
Maximum Feedwater Turbidity:	1.0 NTU
Maximum Feedwater SDI (15 mins):	5.0
Maximum Feed Flow:	16 gpm (3.6 m^3/h)
Minimum Brine Flow:	3 gpm (0.7 m^3/h)
Maximum Pressure Drop for Each Element:	15 psi (0.10 MPa)

^ The limitations shown here are for general use. For specified projects, operation at more conservative values may ensure the best performance and longest life of the membrane. See Hydranautics Technical Bulletins for more details.

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HYDRANAUTICS

ESPA4-LD

Specified Performance*

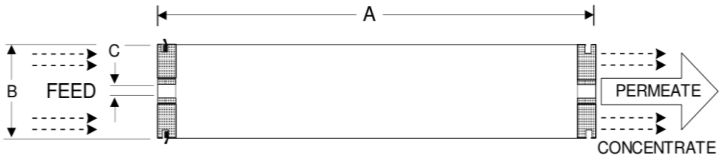
Permeate Flow:	12,000 gpd (45.4 m^3/d)
Salt Rejection:	99.2% (99.0% minimum)
Test Conditions:	500 ppm NaCl solution 100 psig (0.7 MPa) Applied Pressure 77 °F (25 °C) Operating Temperature 15% Permeate Recovery 6.5 - 7.0 pH Range

*The Specified Performance is based on data taken after a minimum of 10 minutes of operation. Actual testing of elements may be done at conditions which vary from these exact values; in which case, the performance is normalized back to these standard conditions. Permeate flow for individual elements may vary ±15 percent from the value specified.

General Product Description**

Configuration:	Low Fouling Spiral Wound
Membrane Polymer:	Composite Polyamide
Membrane Active Area**:	400 ft^2 (37.2 m^2)
Feed Spacer:	34 mil (0.86 mm)

Packaging: All membrane elements are supplied with a brine seal, interconnector, and O-rings. Elements are enclosed in a sealed polyethylene bag containing less than 1.0% sodium meta-bisulfite solution, and then packaged in a cardboard box.



Element Details**

A, inches (mm)	B, inches (mm)	C, inches (mm)
40.0 (1016)	7.89 (200)	1.125 (28.6)

**Values listed are indicative, not specified. For more detailed specifications, see our Technical Service Bulletin documents or contact Hydranautics Technical Department.

Product Use and Restrictions^

Maximum Applied Pressure:	600 psig (4.14 MPa)
Maximum Chlorine Concentration:	< 0.1 ppm
Maximum Operating Temperature:	113 °F (45 °C)
pH Range, Continuous (Cleaning):	2-10 (1-12)
Maximum Feedwater Turbidity:	1.0 NTU
Maximum Feedwater SDI (15 mins):	5.0
Maximum Feed Flow:	85 gpm (19.3 m^3/h)
Minimum Brine Flow:	12 gpm (2.7 m^3/h)
Maximum Pressure Drop for Each Element:	15 psi (0.10 MPa)

^ The limitations shown here are for general use. For specified projects, operation at more conservative values may ensure the best performance and longest life of the membrane. See Hydranautics Technical Bulletins for more details.

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ESPA4-LD HP

Hydranautics membrane elements are favorite elements for maple sap concentration, balancing high sucrose rejection with high flux. This composite polyamide membrane provides better than 99% sucrose rejection, making it ideal for removing water from maple sap before further concentration in the evaporator step. It is provided in 8040 sizes with 34 mil feed spacer and high-pressure construction.

Specified Performance*

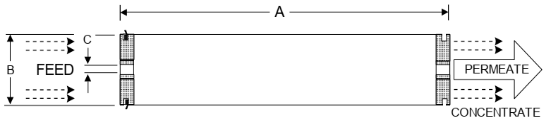
Permeate Flow (Nominal):	11,000 gpd (41.6 m^3/h)
Salt Rejection:	99.2% (99.0% minimum)
Test Conditions:	500 ppm NaCl Solution 100 psig (0.69 MPa) Applied Pressure 77 °F (25 °C) Operating Temperature 15% Permeate Recovery 6.5 - 7.0 Feed pH

* The Specified Performance is based on data taken after a minimum of 10 minutes of operation. Actual testing of elements may be done at conditions which vary from these exact values; in which case, the performance is normalized back to these standard conditions. Permeate flow for individual elements may vary ±15 percent from the value specified.

General Product Description**

Configuration:	Spiral Wound with FRP wrapping (high pressure construction)
Membrane Polymer:	Composite Polyamide
Membrane Active Area**:	400 ft^2 (37.2 m^2)
Feed Spacer:	34 mil (0.86 mm)

Packaging: All membrane elements are supplied with a brine seal, interconnector, and O-rings. Elements are enclosed in a sealed polyethylene bag containing less than 1.0% sodium meta-bisulfite solution, and then packaged in a cardboard box.



Element Details**

A, inches (mm)	B, inches (mm)	C, inches (mm)
40.0 (1016)	7.89 (200)	1.125 (28.6)

**Values listed are indicative, not specified. For more detailed specifications, see our Technical Service Bulletin documents or contact Hydranautics Technical Department.

Product Use and Restrictions^

Maximum Applied Pressure:	1200 psig (8.27 MPa)
Maximum Chlorine Concentration:	< 0.1 ppm
Maximum Operating Temperature:	113 °F (45 °C)
pH Range, Continuous (Cleaning):	2-10 (1-12)
Maximum Feedwater Turbidity:	1.0 NTU
Maximum Feedwater SDI (15 mins):	5.0
Maximum Feed Flow:	85 gpm (19.3 m^3/h)
Minimum Brine Flow:	12 gpm (2.7 m^3/h)
Maximum Pressure Drop for Each Element:	15 psi (0.10 MPa)

^ The limitations shown here are for general use. For specific projects, operating at more conservative values may ensure the best performance and longest life of the membrane. See Hydranautics Technical Bulletins for more detail on operation limits, cleaning pH, and cleaning temperatures.

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ESPA2 MAX

Specified Performance*

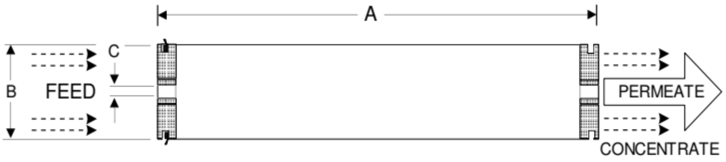
Permeate Flow:	12,000 gpd (45.4 m^3/d)
Salt Rejection:	99.6% (99.5% minimum)
Test Conditions:	1500 ppm NaCl solution 150 psig (1.03 MPa) Applied Pressure 77 °F (25 °C) Operating Temperature 15% Permeate Recovery 6.5 - 7.0 pH Range

*The Specified Performance is based on data taken after a minimum of 10 minutes of operation. Actual testing of elements may be done at conditions which vary from these exact values; in which case, the performance is normalized back to these standard conditions. Permeate flow for individual elements may vary ±15 percent from the value specified.

General Product Description**

Configuration:	Spiral Wound
Membrane Polymer:	Composite Polyamide
Membrane Active Area**:	440 ft^2 (40.9 m^2)

Packaging: All membrane elements are supplied with a brine seal, interconnector, and O-rings. Elements are enclosed in a sealed polyethylene bag containing less than 1.0% sodium meta-bisulfite solution, and then packaged in a cardboard box.



Element Details**

A, inches (mm)	B, inches (mm)	C, inches (mm)
40.0 (1016)	7.89 (200)	1.125 (28.6)

**Values listed are indicative, not specified. For more detailed specifications, see our Technical Service Bulletin documents or contact Hydranautics Technical Department.

Product Use and Restrictions^

Maximum Applied Pressure:	600 psig (4.14 MPa)
Maximum Chlorine Concentration:	< 0.1 ppm
Maximum Operating Temperature:	113 °F (45 °C)
pH Range, Continuous (Cleaning):	2-10.6 (1-12)
Maximum Feedwater Turbidity:	1.0 NTU
Maximum Feedwater SDI (15 mins):	5.0
Maximum Feed Flow:	75 gpm (17.0 m^3/h)
Minimum Brine Flow:	12 gpm (2.7 m^3/h)
Maximum Pressure Drop for Each Element:	15 psi (0.10 MPa)

^ The limitations shown here are for general use. For specified projects, operation at more conservative values may ensure the best performance and longest life of the membrane. See Hydranautics Technical Bulletins for more details.

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الملخص:

مع استمرار ارتفاع الطلب على مياه الشرب في الوقت الذي تتناقص فيه إمدادات المياه العذبة بسبب التلوث وتغير المناخ، يُنظر إلى تحلية المياه المالحة ومياه البحر كحل محتمل، خاصة في المناطق القاحلة. يمكن أن تكون المياه قليلة الملوحة، التي تحتوي على مستوى معتدل من المواد الصلبة الذائبة، مورداً قيماً في المناطق الساحلية وبعض المناطق القارية. إن اختيار تكنولوجيا تحلية المياه أمر بالغ الأهمية بسبب تباين التركيب الكيميائي للمياه ومتطلبات الطاقة. يعتبر الترشيح الغشائي بالتناضح العكسي (RO) تقنية فعالة وقابلة للتكيف مع استهلاك منخفض نسبياً للطاقة. تقدم شركةHydranautics ، وهي شركة رائدة في مجال تكنولوجيا الأغشية، مجموعة من أغشية التناضح العكسي بمواصفات مختلفة لتحقيق الأداء الأمثل. تهدف هذه المذكرة إلى تقييم ومقارنة التكوينات المختلفة لوحدات التناضح العكسي Hydranautics RO باستخدام برنامج محاكاة IMS-Design. سيركز التحليل على معايير مثل الضغط واستهلاك الطاقة وجودة المياه والانسداد لتحديد أفضل تصميم من حيث الاعتبارات التقنية والاقتصادية والبيئية. تنقسم هذه المذكرة إلى أربعة أجزاء رئيسية: مراجعة للأدبيات، وفصل عملي يصف منهجية المحاكاة، وقسم النتائج والمناقشة، وخاتمة مع توصيات للتحسين والبحث المستقبلي. تمهد هذه المقدمة الطريق لأهمية المعالجة الغشائية للمياه قليلة الملوحة من حيث الكفاءة والاستدامة.

Summary:

As the demand for drinking water continues to rise while freshwater supplies are diminishing due to pollution and climate change, desalination of brackish and seawater is seen as a potential solution, especially in arid areas. Brackish water, which has a moderate level of dissolved solids, can be a valuable resource in coastal areas and certain continental regions. The choice of desalination technology is crucial due to the variability of the water's chemical composition and energy requirements. Reverse osmosis (RO) membrane filtration is an efficient and adaptable technique with relatively low energy consumption. Hydranautics, a leading membrane technology company, offers a range of RO membranes with different specifications for optimal performance. This paper aims to evaluate and compare different configurations of Hydranautics RO modules using IMS-Design simulation software. The analysis will focus on parameters such as pressure, energy consumption, water quality, and clogging to identify the best design in terms of technical, economic, and environmental considerations. The paper is divided into four main parts: a literature review, a practical chapter describing the simulation methodology, a result and discussion section, and a conclusion with recommendations for optimization and future research. This introduction sets the stage for the importance of membrane treatment of brackish water in terms of efficiency and sustainability.

Résumé :

La demande en eau potable ne cessant d'augmenter alors que les réserves d'eau douce diminuent en raison de la pollution et du changement climatique, le dessalement de l'eau saumâtre et de l'eau de mer est considéré comme une solution potentielle, en particulier dans les zones arides. L'eau saumâtre, qui présente un niveau modéré de solides dissous, peut être une ressource précieuse dans les zones côtières et certaines régions continentales. Le choix de la technologie de dessalement est crucial en raison de la variabilité de la composition chimique de l'eau et des besoins énergétiques. La filtration membranaire par osmose inverse (OI) est une technique efficace et adaptable qui consomme relativement peu d'énergie. Hydranautics, l'un des principaux fabricants de membranes, propose une gamme de membranes d'osmose inverse avec différentes spécifications pour des performances optimales. Cet article vise à évaluer et à comparer différentes configurations de modules d'OI Hydranautics à l'aide du logiciel de simulation IMS-Design. L'analyse se concentrera sur des paramètres tels que la pression, la consommation d'énergie, la qualité de l'eau et le colmatage afin d'identifier la meilleure conception en termes de considérations techniques, économiques et environnementales. Le document est divisé en quatre parties principales : une revue de la littérature, un chapitre pratique décrivant la méthodologie de simulation, une section de résultats et de discussion, et une conclusion avec des recommandations pour l'optimisation et la recherche future. Cette introduction met en évidence l'importance du traitement membranaire de l'eau saumâtre en termes d'efficacité et de durabilité.