# Monitoring and Evaluation of the Performance of Reverse Osmosis Membrane Systems for the Treatment of the Central Danone Plant

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**Abstract**: The objective of the present work is to monitor and control the physicochemical quality of the osmosis water that feeds the dairy industry in our case the Danone plant (DP) "Factory of Salé", for good production and use without no risk. The drilling water treatment and purification technique applied in the Danone plant is reverse osmosis. The approach of this membrane technique at a pressure gradient, allows obtaining good quality water for use in the various activities of the plant. During a 30-day period, we tested the pH, conductivity, alkalinity, hydrometric title, total alkalinity, chlorides content and chlorine content on water drawn from the borehole, the 1µ filter output, the treated output A and the treated water. The results of the experimental analyzes generally comply with the standards imposed within the plant, with the exception of a few days where cleaning of the membranes is necessary.

**Keywords:** Membrane, Reverse osmosis, Treatment, Monitoring, Performance.

## 1. INTRODUTION

Water is an essential element for the development of industrial activity, agriculture and agriculture and energy production. The volumes of water used by the industrial sector are sector is the largest consumer of fresh water in the world [1-10]. Some industries, such as the Danone plant (DP), have their own raw water treatment plants in order to fulfill their functions. Reverse osmosis is currently one of the most widely used means of obtaining ultrapure water in industrial environments. The design of polyamide membranes started in the seventies [11-12]. Their deterioration and the appearance of a progressive blockage film, due on the one Hand to an intense use (6,500 hours per year) [13] and on the other hand to the limits of the pre-treatment efficiency, lead to an additional operating cost [14]. The Danone salt water plant is equipped with a reverse osmosis treatment plant. The reverse osmosis process is a membrane filtration technique generally used in the desalination of brackish water and sea water.The main objective of this technology is the removal of salts and organic substances substances present in water [15-18]. Wastewater treatment is the reduction of pollution that is present in the water. This contamination is the product of domestic and factory activities. The treatment of wastewater is to ensure its quality. In fact, the processed water, considering as "clean water", will be used during industrial activities or discharged in the natural environment.

The water supply to the Danone plant is provided through groundwater drilling within the plant. This water contains a high mineral salt content. The objective of our work is to follow the physico-chemical parameters of the water from its origin from the well until it is osmoses.

## 2. MATERIALS AND METHOD

### 1. Reverse Osmosis Plant of the Danone Plant, Salé Factory

#### *1.1. Presentation of the Reverse Osmosis Plant*

To meet the water needs of all departments at the Salé plant, the Danone plant has a reverse osmosis water treatment unit installed in 2010. The water supply is ensured through groundwater drilling within the plant. This pumped water requires specific treatment before being used for production, as it may be contaminated by natural or accidental pollution. The various stages of this treatment are as follows:

1. Chlorine disinfection at the well water basin.
2. The physical pre-treatment, whose objective is to eliminate all unacceptable substances,

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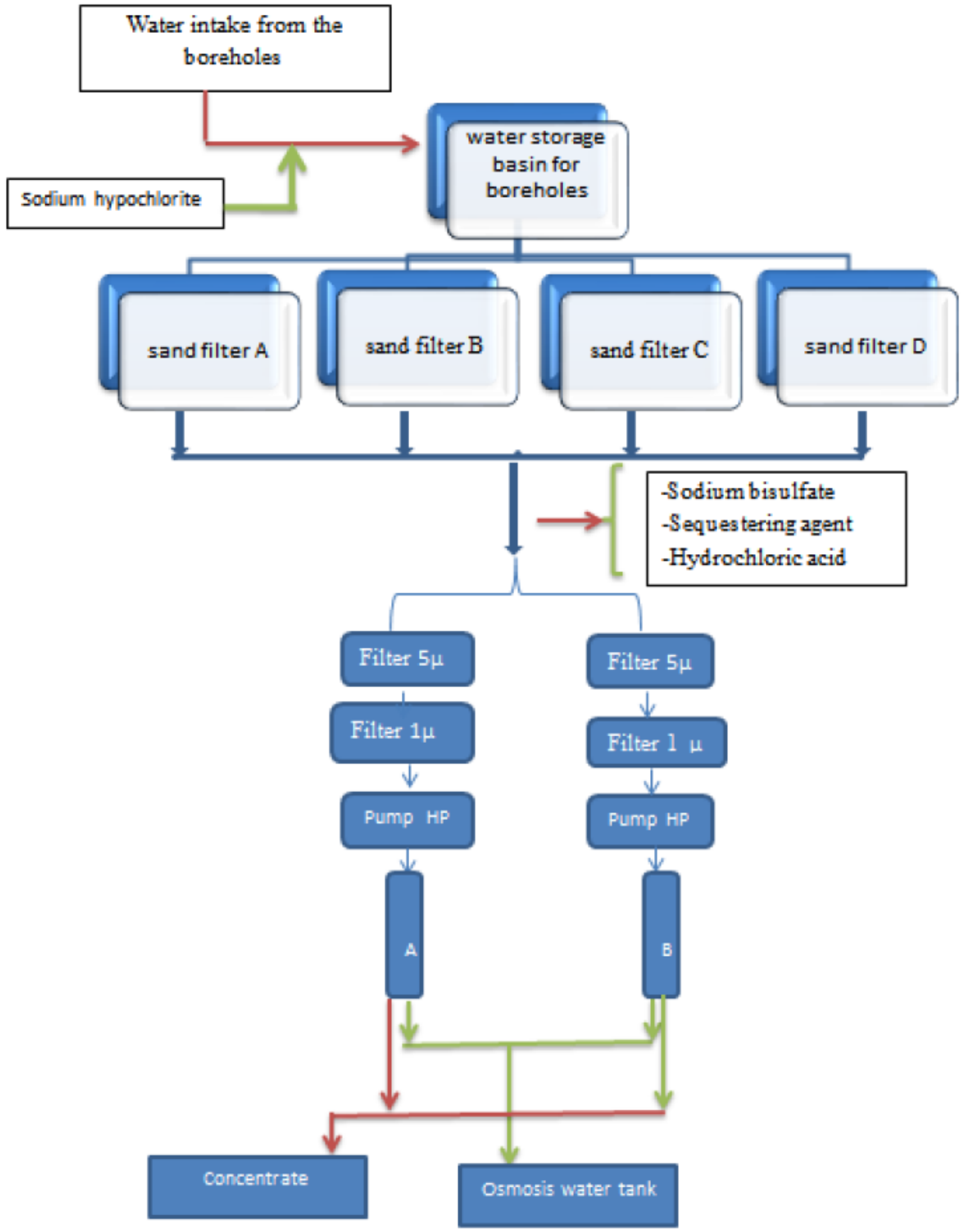


**Figure 1:** Reverse osmosis water treatment process.

suspended particles, colloids, etc. that may be in the feed water, is filtration through sand filters and then through cartridge filters by injecting chemicals such as bisulfite, sequestrant and hydrochloric acid.

At the exit of the two osmosis units, the concentrate is obtained which is discharged into the sewer system and the permeate to which a quantity of 0.5 to 0.8 ppm of sodium hypochlorite is added before being stored in a 200 $m^3$ tank and then fed to the different units [19].

### 1.2. Description of the Different Stages of Water Treatment in the Plant

#### a. Drilling Unit

The water pumped from the two wells (P1 and P2) passes through a well water tank injected with chlorine (bleach 12°). The role of the latter is to increase the kinetics of the chlorine reaction, to oxidize chemical compounds such as iron, and to limit all bacterial developments. The water will then be pumped to the sand filters by three horizontal centrifugal pumps centrifugal pumps (picture **1**). Two of them are in operation and a third one is a back-up. The pumping pressure is 4.1 $m^3$/h.

### *b. Filtration by Sand Filters*

#### Principle of Operation

The treatment plant has two sand filters for each line (picture **2**). These filters are used to remove suspended matter from the borehole water.

The sand filter consists of a tank filled with sand specially calibrated for the size and flow rate. The dirty water pushed by the filter pump enters the top of the filter the top of the filter and is then distributed over the surface of the sand by means of an upper upper diffuser. As it passes through the sand grains, the water is relieved of its impurities,

The water passes through the sand grains and is discharged through a set of strainers at the bottom of the filter, which retain the sand while allowing clean water to pass through. The pressure at the filter is indicated by a pressure gauge. It is 3.2 bar at the inlet of the sand filters and 3.1 bar at the outlet [20-24].

When the surface of the sand is dirty, the pressure gauge indicates an increase in pressure, which pressure, which requires cleaning.

-Cleaning the sand filters

The sand filters are cleaned automatically over time. The cleaning is done once a week with the feed water recirculated in countercurrent and takes 16 min5s according to the following procedure:

1. Partial emptying: 30 s
2. Air injection: 180 s
3. Backwash: 60 s
4. Backwash: 300 s
5. Rest: 60 s
6. Rinsing: 300 s
7. Pneumatic valve timing: 5 s

### *c. Cartridge Filtration*

At the outlet of the sand filters, the water injected with chemicals, then passes through PVC pipes to cartridge filters of 5 µm and 1 µm (photos 3 and 4). The inlet and outlet pressures of these filters are respectively 3 and 2.9 bar and 2.9 and 2.8 bar. The chemicals used are bisulfite, sequestrant and hydrochloric acid. Their corresponding characteristics are presented in Table **1**.

### *d. Membrane Filtration*

#### -Operating Principle

The reverse osmosis unit is made up of two stages which have respectively 5 and 4 modules with each 6 membranes in series (picture 5). Each module has one inlet and two outlets. One outlet for the treated water and another for the discharge. The discharge of the 1st stage feeds the 2nd stage modules [25]. The pressures of the membranes at the level of the 1st and 2nd stage are respectively 11 and 5 bar. The pressure at the RO outlet (rejection) is 4 bar. In addition, the flows rates of the feed water, concentrated water and permeate and permeate are 60, 15 and 45 $m^3$/h respectively. The properties of the membrane used are listed in Table **2**.

**Table 1: Chemical Characteristics**

| Products | Function | Density | Concentration | Dosage |
|---|---|---|---|---|
| Bleach 12° | Chlorination: Unit for disinfection | 1.05 | 38g/l | 7.5 ppm(as is) 3 ppm(in 100%) |
| Bisulfite (ROC 0136) | Powerful reducer: eliminates all traces of residual chlorine upstream of RO membranes | 1.37 | 40% | .5 ppm(as is) 3 ppm(in 100%) |
| sequestrant (ROC 0308) | Antitrate: Prevents the clogging of the membranes by decreasing the of precipitation of $CaCO_3$ in the feed. | 1.36 | _ | 0.5-0.8ppm |
| Hydrochloric acid | Acidification used for neutralization | 1.15 | 32% | 5 ppm(as is) |

**Table 2: Properties of the Membrane Used**

| | |
|---|---|
| **Active surface** | 39.9 $m^2$ |
| **Type** | Toray Membranes TM720-430 |
| **Flow rate** | 41.40 $m^3$/days |
| **Rejection rate** | 99.7 % |
| **Maximum pressure** | 4136.87 KPa |
| **External diameter** | 2.86 cm |
| **Maximum temperature** | 45 °C |

## 2. Characterization of the Water from the Reverse Osmosis Plant

The different physico-chemical parameters analyzed are pH, conductivity, TA, TAC TA, TAC, TH, chloride content, nitrate content and chlorine content. These analyses are carried out on water samples of various origins. These are borehole water, water from the borehole basin, water from the 1µ filter outlet, water from the A osmosis unit and osmosis water. For the

Picture 1: Centrifugal pumps of the well basin

Picture 2: Sand filters

Picture 3: Clean 5 µm filters

Picture 4: Clean 1 µm filters

Picture 5: RO membranes in the treatment plant

**Figure 2:** The Picture of treatment system.

determination of pH, conductivity, TA, TAC, TH and chloride content the tests were carried out in the physical-chemical laboratory of the Danone plant on the five danone on the five types of water mentioned above. The tests for nitrate content and chlorine content were carried out at the plant only on water leaving osmosis unit A and on osmosis water.

The chemical composition of water varies greatly from one region to another and for the same region from one season to another. These chemical variations depend on several parameters such as the solubility of salts constituting the earth's crust (CaCO3, CaSO4, MgCO3, NaCl), and the physical composition of rocks [26].

## 3. Inorganic Species

### *3.1. Major Constituents*

They are essentially ionic compounds, anions and cations, coming from the dissolution of rocks in the water which circulates in their contact. The main major elements found in water are mineral salts in the form of carbonates, bicarbonates, silicates, sulfates, chlorides and nitrates of sodium, calcium, magnesium, iron and potassium respectively [27-30].

The metallic trace elements (ETM) are defined as the metallic elements present with a concentration of approximately one part per trillion ($10^{-3}$ mg.kg-1) by mass, or less. The main trace metals present in water are titanium, zinc are titanium, zinc, nickel, aluminum, chromium, cadmium, copper, iron manganese, lead and mercury [31].

These elements are composed mainly of nitrate (NO3-), ammonia (NH3), phosphorus in the form of phosphate ($PO_4^{3-}$) and silicon such as silica ($SiO_2$). Phosphorus in the form of phosphate ($PO_4^{3-}$) and silicon such as silica ($SiO_2$).

### *3.2. Organic Particulate Matter*

Most of the organic carbon in water is in the form of dissolved organic matter and mainly low molecular weight molecules of various origins. The concentration of these materials depends on the type of water and its depth. Surficial seawater has a higher concentration than water at depth. In addition, dissolved organic carbon is an important factor in the carbon cycle and the food chain. It has an influence on light penetration and gas exchange at the surface [32].

These are suspended and emulsified materials classified according to their size. In surface water, most of this material is of biological origin. The smallest particles, less than 1 µm up to a few tens of µm, consist of bacteria, other fine organic detritus, and inorganic particles particularly clay minerals and insoluble hydrated compounds such as $Fe(OH)_3$. The size range from a few tens to a few hundreds of µm includes large detritus, fecal agglomerates and products of biological aggregation (sand, sludge, oil, oils,...). Water also contains the dissolved gases having great importance in biological and chemical phenomena (corrosion) [8].

## 4. Water Quality Assessment Parameters

These parameters are generally carried out on the sampling site. They are immediately perceptible and concern the color, odor, taste and flavor of the water [33]. The color of water is due to dissolved substances and/or substances in suspension. These substances are most often of natural, vegetable or mineral origin. The color varies for natural waters from pale yellow to reddish brown according to the nature and the concentration of the coloring matter. The smell is the whole of the feelings perceived by the olfactory organ by sniffing certain volatile substances. Indeed, their presence in water is a sign of pollution or the presence of organic matter in decomposition like alcohols, sulfur dioxide and chlorine.

## 4. Water Treatment Process

### *4.1. General Information on Membrane Processes*

A membrane is a barrier a few hundred nanometers thick which, under the effect of a transfer force, allows or prevents the passage of certain components between two media it separates [17]. Selectivity corresponds to the total permeability rate of the different substances contained in a solution (Figure **3**).

The acting force can be a pressure gradient, as is the case for reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) and an electrical potential gradient for electrodialysis (ED). The criteria for selecting a process depend on the characteristics of the substances to be separated, those of the membrane (dimensions, shape, chemical nature,...) and the hydrodynamic working conditions [17].

### *4.2. Structure of the Membranes*

Symmetric (isotropic) membranes have a homogeneous structure throughout the thickness of the

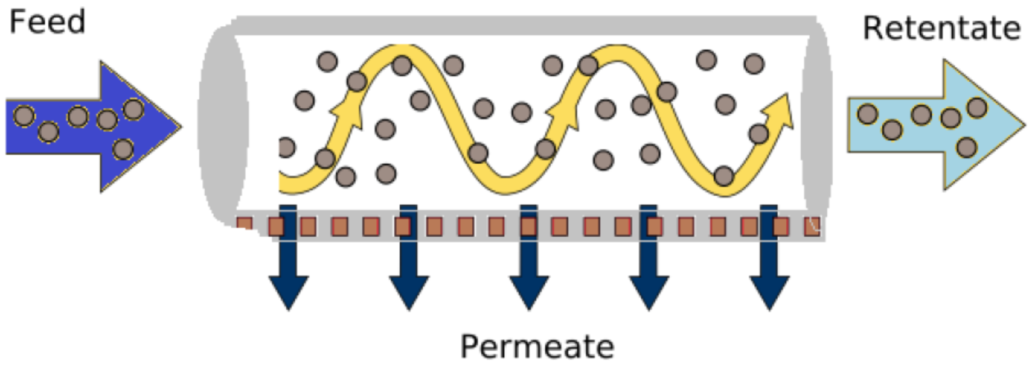


**Figure 3:** Explanatory diagram of the principle of membrane filtration (in tangential mode) [18].

membrane. Asymmetric (anistropic) membranes, on the other hand, have a heterogeneous structure, varying mainly from one layer to another. These layers are made of the same material with gradually varying porosities depending on the thickness or of different materials. The asymmetric membrane generally contains a resistant macroporous support layer and an active layer (retention property). Between the two, one or more intermediate layers are inserted [21].

The porous structure results from the interstices between the solid constituents of a membrane. It is presented by the spaces between the polymer chains for organic membranes and by the intergranular spaces for inorganic membranes. According to the size of the pores, we distinguish three categories: micropores with diameters inferior to 2 nm, mesopores with diameters between 2 and 50 nm and macropores with diameters superior to 50 nm. The porosity of a membrane is defined as the ratio between the volume of empty spaces on the total volume of the matrix [34].

### *4.3. Implementation of the Membranes*

Frontal mode filtration is based on the circulation of the solution perpendicular to the membrane. With this technology, all the retained solutes accumulate on the surface of the membrane, which leads to a drop in the permeation flux caused by the clogging of the membrane. The deposit formed (or cake) by the retained solutes constitutes a barrier to transfer. Figure **4** shows that the thickness of the cake increases continuously, making it impossible to continue the filtration process. Frontal mode filtration is the simplest and least expensive technology to implement, but it is the least suitable for some industrial processes that use solutions containing clogging solutes [22].

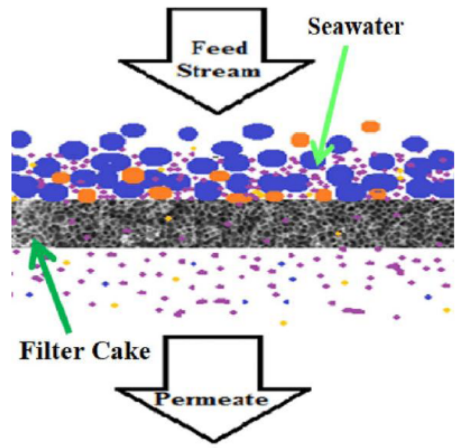


**Figure 4:** The filtration process.

Cross-flow filtration is a mode in which the fluid to be treated flows parallel to the membrane (Figure **4**). The advantage of this mode is that the clogging. The advantage of this mode is that clogging phenomena are reduced and continuous operation is possible. This mode of filtration is the most used in industrial membrane filtration plants [23-24].

This process uses membranes that are denser than those of nanofiltration and allow only the solvent to pass through. The solvent-solute separation is done by a solubilization-diffusion mechanism, the solvent adsorbs in the membrane phase and then diffuses through the material. The applied pressure must be higher than the osmotic pressure exerted upstream of the membrane by the filtered solution to observe a permeate flow through the membrane. Applied pressures range from 20 to 80 bar [34-35].

## 3. RESULTS AND DISCUSSION

The evaluation of the quality of the water sampled at the well water station (EF), the borehole water basin

(BEF), the 1µm filter outlet (ESF 1µm), the (ESO A) and the osmosis water (EO) was monitored for a period of 30 days from April 16 to May 16 for pH, conductivity, hardness (TH) alkalinity (TA, TAC), chloride content, nitrate content and chlorine content. The results of the measurements are shown in Figures **12** to **18**.

### ❖ pH

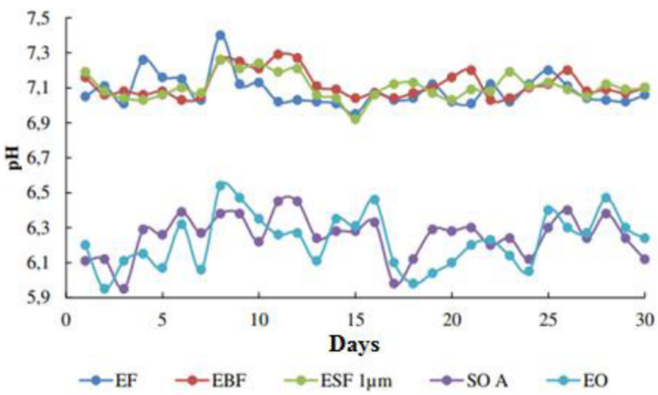


**Figure 5:** Evolution of the pH of different waters in the reverse osmosis plant

Examination of Figure **5** shows that during the entire analysis period, at the plant, the pH values of the borehole water, the borehole tank and the 1µm filter outlet vary from 6.95 to 7.29. For the osmosis outlet A and the osmosis water, the pH values are between 5.98 and 6.54. We found that all these values are within the norms.

### ❖ Conductivity

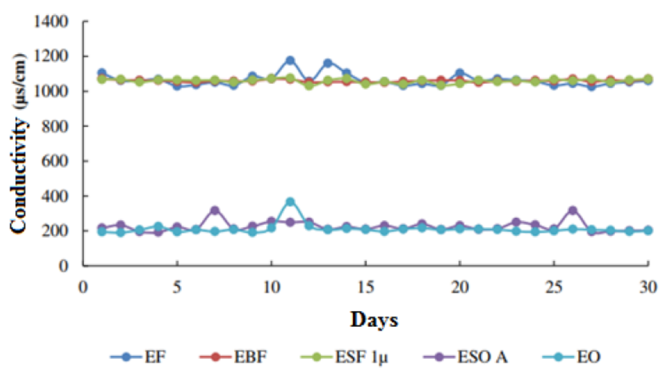


**Figure 6:** Evolution of the conductivity of the water in the reverse osmosis plant.

The results of the conductivity measurements shown in Figure **6**, show that for borehole water, borehole tank and 1µm filter outlet, the values are lower than 1200 µs/cm, *i.e*. acceptable values. For the water from the A osmosis outlet and the osmosis water, the values are around 230 µs/cm with the exception of those corresponding to the 7th and 26th day for (ESO A) which is 316 µS/cm and that of 366 µS/cm corresponding to the 11th day for (EO). For these three exceptions, a cleaning of the membranes is necessary.

### ❖ Hydrometric title

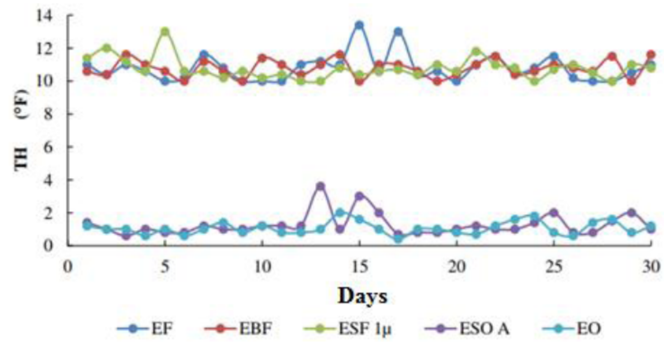


**Figure 7:** Evolution of the TH of the water from the reverse osmosis plant.

Figure **7** shows that for EF, EBF and ESF 1µm, all TH values are between 10 and 11.8°F. These three types of water analyzed are moderately hard. For the other two water types, ESO A and EO, the corresponding TH values are estimated to be between 0.4 and 2°F. These waters are then considered very soft. On the other hand, we noticed high TH values on the different plots. This could be due to the formation of deposits at the level of the pipes, which requires the change of the membrane filters.

### ❖ Full Alkalimetric Title

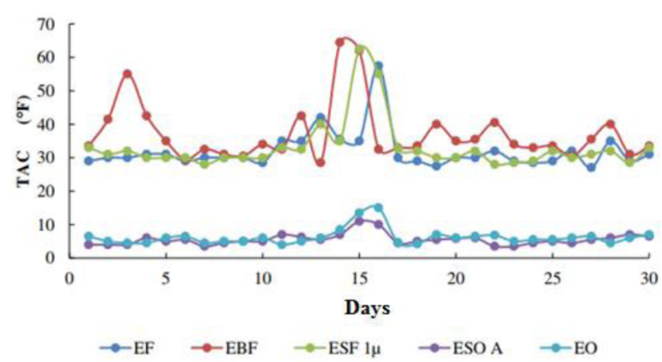


**Figure 8:** Evolution of the TAC of the water from the reverse osmosis plant.

Figure **8** shows that for EF, EBF and ESF 1µm, the TAC values respect the standards having values between 28 and 40°F except for some which are due to a strong increase in carbonate and bicarbonate ions. Some of them are due to a sharp increase in carbonate and bicarbonate ions. The content of these ions decreases with pretreatment and RO treatment. Figure **8** shows that for the EF, EBF and ESF 1µm, the TAC values meet the standards with values between 28 and 40°F, except for a few which are due to a strong increase in carbonate ions. Some of them are due to a sharp increase in carbonate and bicarbonate ions. The content of these ions decreases with pretreatment and treatment with RO.t

### ❖ Chlorides

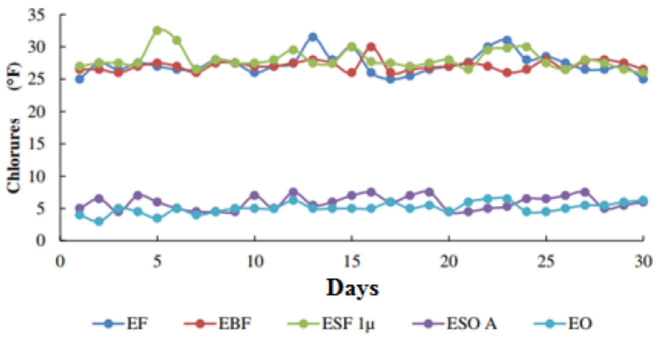


**Figure 9:** Evolution of chlorides in the water of the reverse osmosis plant.

The results in Figure **9** indicate that the chloride content of the borehole water, the borehole basin and 1µm filter outlet, the chloride content does not exceed 30 mg/L. The chloride content decreases in the water leaving the A and RO plants. The water becomes less corrosive.

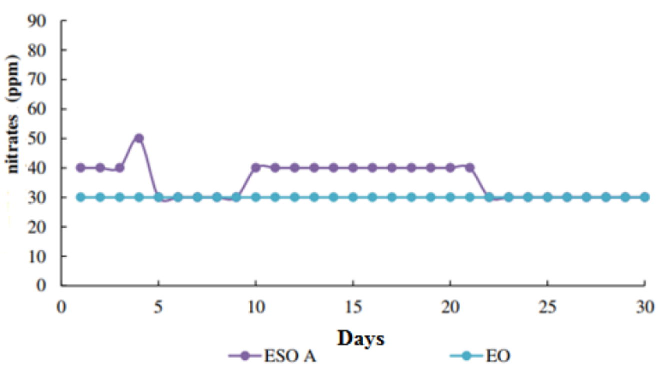


**Figure 10:** Evolution of the nitrate content of SOA and EO water.

The nitrate content determined for the osmosis outlet water A varies from 30 to 50 ppm. The value based on the recommendations of the World Health Organization (WHO) is 50 ppm. For RO water, the nitrate value is always fixed at 30 ppm, which is an acceptable value and complies with the standards.

### ❖ Chlorine content

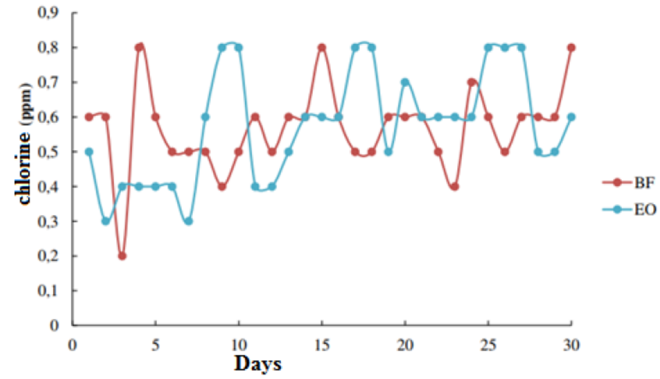


**Figure 11:** Evolution of the chlorine content of the well and osmosis pond water.

## CONCLUSION

During the period under review, chlorine levels ranged from 0.4 to 0.8 mg/L for both types of of water. Some values are lower than 0.4 mg/l indicating the problem of clogging of the bleach injection valve at the dosing pump. The operation of the feed water station at the Danone plant goes through several steps several steps after having water respecting the standards of the physicochemical parameters. The follow-up of the quality control of the physico-chemical parameters of the treated water at the level of the station shows that:

-The average value of pH is 6.24.

-The average value of conductivity is 205 µS/cm.

-The alkalinity has an average value of 5.64 °F.

-The hydrometric title has an average value of 1 °F. This value indicates that the water obtained is very soft.

-The average value of nitrate content is 30 ppm. The value based on recommendations of the World Health Organization (WHO) is 50 ppm.

-The chlorine content varies from 0.4 ppm to 0.8 ppm.

When the TAC and TH values sometimes exceed the standards, the membrane filters must be changed membrane filters should be changed, because if they exceed their life expectancy, they can cause.

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