ETM 2

Report
Final year project

Instrumentation review
Perth Seawater Desalinization plant

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Summary

Perth Seawater Desalination Plant produces drinking water from seawater which means it needs to be very clean. The production of the water needs several treatments with dangerous chemicals, so it must be controlled and managed tightly; this is the reason why the plant is fitted with many analysers. But it appears that sometimes these analysers give wrong values, it can be traced back to the analyser and to the location or other external parameters.

The first step of this project was to understand the different phases of the treatment and the reasons the analysers were located there. During this stage each step of the process, each parameter and each analyser was described to provide a good understanding of the plant.

The second step was the identification of the weak analysers; a list was made and handed to the technicians and engineers. Thanks to this information the third step could start.

The third step was the experimentations. To identify the reasons of these dysfunctions several experiences had been realized. It allowed figuring out the issues and starting to find out solutions. The main problems were location, measured range, usury and external parameters like bubbles or sun.

The fourth step was to find out solutions to solve these problems. These solutions included change of location, change of device and arrange the sampling points by adding buffer pipes to remove bubbles.

The last step was monitoring and the recommendations of these changes. A turbidimeter has been ordered and needed to be implemented; the hydrocarbon has to be control in case of pollution. Furthermore the new implementations have to be tried after the restarting of the plant.


**Acknowledge**

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**Introduction**

Around 70% of earth is covered by water, an indispensable element for the life development of every organism and especially for human beings. The problem is only 2.6% of this water is fresh water and it is present only in glaciers, lakes and rivers. It seemed essential to find a solution to use the rest of this water. In this way several techniques have been developed from about 50 years ago, but the biggest evolution happened in the 60’s with the discovery of Reverse Osmosis. This technique uses the membrane technology to remove salt from seawater.

Perth Seawater Desalination Plant (PSDP) is the biggest in the south hemisphere and one of the biggest in the world to use the Reverse Osmosis technology with a production of 130,000 m$^3$ of drinking water per day. In the plant, water undergoes several treatments (physical and chemical) therefore it has to be monitored during the whole process. Different parameters are controlled according to their localisation in the process; they are used to measure out the chemicals, control the water quality and can lead to a shutdown of the plant in case of overdose. This is the reason why measurement devices need to be accurate.

Some analysers used to manage chemical dosage have shown erratic issues like temperature, hydrocarbon, pH, Dissolved oxygen ... These problems can arise from different sources including bad design, physical issues, sampling point location. The goal of this project is to identify these analysers, test them to know what their origins are and solve these problems by finding suitable solutions, in a technical and economical way.
I - General information about PSDP

This first part presents Degrémont Company and provides a good understanding of all the different treatments on water during all the process of Perth Seawater Desalination Plant (PSDP).

1 – Degrémont

Degrémont was founded in 1939 in Paris specializing in water treatment. After a few years in France Degrémont carried on its global expansion, especially in Egypt and Indonesia, by building and operating further plants. In 1954 Degrémont used for the first time an advanced sedimentation tank, the Pulsator.

1967 is the year of the gathering between Degrémont and the “Lyonnaise des eaux” group. 1975 is one of the most important year for Degrémont because they built their first reverse osmosis desalination plant (200 000 m³/d) in Riyadh, Saudi Arabia. 1985 represent the first use of Biofore®, a biological filtration. 3 years later the first membrane ultrafiltration facility has been built in France.

1997 is a new evolution for Degrémont because “Lyonnaise des eaux” merges with SUEZ to form SUEZ-Lyonnaise des eaux. In 2002 the world’s first hybrid desalination facility (Reverse Osmosis: 170,000 m³/day, Multi Stage Flash: 280,000 m³/day) in Fujairah, Saudi Arabia is built and is followed 2 years later by the world’s largest ultrafiltration facility (275,000 m³/day) in Moscow.

The largest Reverse Osmosis desalination facility in the southern hemisphere (143 000 m³/day) in Perth, Australia was commissioned in April 2006 and the first drops of water flowed through stakeholder taps in November 2006.

And finally the last major date is 2007 it is the building start-up of reverse osmosis desalination plant in Barcelona (200 000 m³/day).

Nowadays Degrémont is the world water treatment specialist. It is a subsidiary of SUEZ environment. Its teams design, build and commission facilities for drinking water production, desalination, wastewater treatment and sludge treatment for local authorities. They also directly operate facilities and provide all the services required for them to run smoothly – maintenance, spare parts, and upgrading work. It represents 10 000 facilities built worldwide, 4700 staff, 1 billion people served by Degrémont facilities and 978 billion in sales in 2007. [1]
2 – Description of the PSDP process

The main goal of this plant is to remove salt and other impurities from seawater thereby providing high quality water needed to sustain the well being of customers. Many operations are needed to achieve this (filtration, acidification ...). These treatments must be carried out in a clean fashion to avoid contamination and disturbance of the natural water cycle.

This part describes all the treatment steps, with using technologies and chemicals. Furthermore in appendix 1 and 2 a diagram explains the process and the different state changes undergo by water.

a – Intake

Perth Seawater Desalination Plant withdraws seawater from the seabed at 5 meters depth and 150 meters offshore in Cockburn sound and falls in the wet well (tank). The intake system is mainly located below sea level in order to use the gravity. At this point the seawater is charged in micro-organisms, molluscs... Every one or two weeks, sodium hypochlorite is injected into the wet well to eliminate the biological growth in the pipes. It goes through the screening (I.2.b), seawater pumps (I.2.c) and is neutralized by sodium metabisulfite just before the Dual Media filter (I.2.e), this operation is called shock chlorination.

b – Seawater screening

Seawater goes through a screening system: it is an onshore active screening with a 3 mm mesh. Large objects have already been removed at this stage. These objects are sent in the macerator where they are crushed and finish in the backwash effluent tank. Effluent water from the macerator will go in outfall tank.

c – Seawater pumps

After the screening, the seawater goes through the wet well where 6 centrifugal pumps (figure 1) divided in 2 independent banks (bank A: Pump 1, 2, 3 and bank B: pump 4, 5, and 6) send it to the chemical pre-treatment. The capacity of all these pumps together is 348 ML of water per day leading to a production of approximately 130 ML a day.
d – First chemical pre-treatment

The first pre-treatment is divided in 3 parts occurs just after the seawater pumps.

- The first part is an addition of sulphuric acid (H₂SO₄) downstream seawater pumps to optimize raw water pH with a target at 6.8. This pH is calibrated to ensure a good coagulation in the Dual Media Filters (next step). The dosage of sulphuric acid is 116.6 L/h per bank at full capacity.

- The second part is addition of ferric sulphate (Fe₂(SO₄)₃) downstream seawater pumps to assist in the coagulation of suspended solids. The dosage of ferric sulphate is 57.6 L/h per bank at full capacity.

- The last part is addition of coagulant aid upstream Dual Media Filters to assist in flocculation phenomenon on the membranes. The dosage of coagulant aid is 5.6 L/h per bank at full capacity.

e – Dual Media Filters (DMF)

The plant is fitted up of 24 DMF (figure 2) able to treat 14 500 m³/h, 12 for each bank¹, with a surface area of 52 m² each. It consists of three layers of media: 10 mm of gravel, 300 mm of sand and 800 mm of anthracite (see figure 3). The gravel bed is used to protect the nozzles being clogged by the sand. The DMFs are gravity filters, water arrives from the overhead of the filters and goes through the medias. To manage the flow rate and backwash 12 DMF per bank are set up. Water leaving from DMF is called filtered water.

¹ Bank: is a line, the plant is separated in 2 banks, it allows to fine down the installation, for the maintenance and the different operations.
DMF backwashes are done regularly to maintain the filter in good condition and remove big particles retained by the Medias. Pressure drop is monitored by differential pressure transmitters on each bank. The evolution of pressure drop permits to the operator to check the fouling of the DMF and then organises a backwash. This operation takes place typically every 24 – 36 hours.

During the backwash air is sent from the bottom of the filters to remove impurities from Medias, after that water is injected from the bottom until it runs over. In this way all the flocculant (brine) goes through the backwash effluent tank (see wastewater treatment part). At the end of the backwash, water is evacuated by the bottom and the filter can take back its normal function.

**f - Second chemical pre-treatment**

The second chemical pre-treatment is used more as a cleaning treatment. Firstly to protect the reverse osmosis membranes against scale build-up, an antiscalant is injected. Secondly, after the shock chlorination the sodium hypochlorite needs to be removed because it damages the membranes, so for this reason a second treatment is done, sodium metabisulphite is injected into filtered seawater to allow the neutralization of the sodium hypochlorite.

**g – Cartridge filters (CF)**

To enhance filtered water quality, it goes through cartridge filters (figure 4). The water obtained then is called polished water. The filtration rate of the CF is 5 microns. Each bank is composed of 7 CF. 6 CF is enough to produce the required polished water flow but having 7 CF allows to one of them stopped for maintenance purpose. The main goal of these filters is protect reverse osmosis membranes against physical fouling by suspended solids.
**Figure 4 – Cartridge filters**

**h – Reverse osmosis first pass (RO 1st pass)**

Reverse osmosis is the finest level of filtration available. The RO membrane acts as a barrier to all dissolved salts and inorganic molecules, as well as organic molecules with a molecular weight greater than approximately 100. Water molecules, on the other hand, pass freely through the membrane creating a purified product stream. Rejection of dissolved salts is typically 95% to greater than 99%. The figure 5 shows the reverse osmosis filtration capacity.

![Image of reverse osmosis equipment]

**Figure 5 – RO filtration capacity**

<table>
<thead>
<tr>
<th>Ionic Range</th>
<th>Molecular Range</th>
<th>Macro Molecular Range</th>
<th>Micro Particle Range</th>
<th>Macro Particle Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micrometers</td>
<td>10^-3</td>
<td>10^3</td>
<td>10^1</td>
<td>10</td>
</tr>
<tr>
<td>Angstrom</td>
<td>10</td>
<td>10^2</td>
<td>10^1</td>
<td>10</td>
</tr>
<tr>
<td>Mol/Wt Range</td>
<td>100 200 1,000 10,000 20,000 100,000 500,000</td>
<td>10^5</td>
<td>10^4</td>
<td>10^3</td>
</tr>
</tbody>
</table>

- **Electron Microscopy**
- **Optical Microscopy**
- **Visible to Naked Eye**

- Latex Emulsions
- Sensitive
- Endotoxins (Pyrogen)
- Carbon Black
- Paint Pigment
- Yeast Cells
- Solute Salts (Ions)
- Virus
- Mycoplasma
- Blood Cells
- Colloids
- Red
- Sand
- Metal ions
- Proteins / Enzymes
- Human Hair

**Note:** 1 Angstrom Unit = 10^-10 Meters = 10^-4 Micrometers (Microns)
After several steps in the pre-treatment the “polished” water is sent to the reverse osmosis first pass. This step aims to remove a big part of salt from seawater; normally at the end of the first pass water have a TDS (Total Dissolved Solids) lower than 300 mg of salt/l.

**RO Process**

The water is pumped at 59 bars into 6 high pressure pumps (3 per bank) which supply 2 membrane racks each. The seawater flows through the feed channel spacer, next the “clean” water called permeate goes through the membrane and to the permeate collection material whereas the “dirty” water called brine (look at figure 5) continues through a feed channel spacer. A fibre layer (outer wrap) is added to protect the membranes against the fouling and shocks. Figure 6 explains the different layers of the membranes and figure 7 shows the travel of water.

![Spiral-Wound Membrane Element](image)

At the end of the RO 1\textsuperscript{st} pass, one part of the water is evacuated in the permeate tank and the other part in the RO 2\textsuperscript{nd} pass.

The water effluent from the membranes (brine) is used by the Energy Recovery Device (see 2.i).
**i – Energy Recovery Device (ERD)**

Energy Recovery Device is a system which is used to decrease the energy consumption of the HP pumps, there is one ERD per rack. While one part of water from the pre-treatment is pumped by the HP pump the other part is directed in the ERD. Here water from the pre-treatment (2.4 bars) will be boosted by the brine (58 bars) to be rejected at a pressure of 57 bars. After water is boosted at 59 by the boost pump and is sent back in the RO first pass (Figure 8). This allows reusing brine potential energy and then decreasing the energy consumption of the HP pump.

![Figure 8 – ERD in the system](image)

**j – Reverse osmosis second pass (RO 2\textsuperscript{nd} pass)**

In the RO 2\textsuperscript{nd} pass water goes through 6 pumps (3 per bank) divided in two stages each, which used the same kind of membranes than RO first pass. Water goes through the 1\textsuperscript{st} stage membranes; the water which does not pass through the membranes (the brine 1) is re-injected in the 2\textsuperscript{nd} stage membranes. The water which does not go through the 2\textsuperscript{nd} stage (brine 2) is re-injected at the entrance of the RO 1\textsuperscript{st} pass. At the end the water which is passed through the membranes (permeate 1 and permeate 2) is evacuated in the permeate tank and will be mixed with the first pass permeate. Permeate 1 and 2 have salinity lower than 60 mg of salt/L. (Figure 9)
After the Reverse osmosis, the water from RO first pass and second pass goes through the permeate tank where they are mixed.

After this mixing the water will undergo four chemical treatments: chlorine, lime, carbon dioxide and Fluorosilicic acid.

- Chlorine is added to sanitize permeate water at approximately 0.7 to 0.8 mg/L
- Lime water addition to increase water alkalinity and pH as well as stabilize the water at approximately 42 mg of lime/L
- Fluorosilicic acid addition to prevent tooth decay. FSA is dosed to give a residual concentration of 0.85 mg/L.
- Carbon dioxide dosing for pH correction. Average consumption of $CO_2$ is approximately 30 mg/L, dictated by the lime addition and the combined permeate pH and FSA as well.

After these treatments the water goes through the drinking water tank, next to Thomson reservoir and then in the stakeholders tap.
I – Wastewater treatment

It is good to desalinate water but it creates some wastes, this is the reason why a wastewater treatment is needed. It is divided in two parts.

The first part is not a treatment. The brine from the membranes 1\textsuperscript{st} and 2\textsuperscript{nd} passes is used to supply the backwash tank. One part is used to wash the DMF and the other part is discharged in the outfall. The water from the outfall is discharged into the sea. (Appendix 3)

The second part which is the biggest is in charge to treat the brine from the Dual Media Filter (DMF) and the filtered objects from the screening. They are sent in backwash effluent tank and after in the thickener where they undergo a ferric chloride treatment to be disinfected. Polymers are injected in this mixing to agglomerate the mixture in the goal to accelerate the sedimentation.

After the sedimentation the sludge is sent in the centrifuge to be dewatered whereas the water is sent in the outfall. In this way solid sludge is obtained and is sent to a landfill. Water from the centrifuge goes in the backwash effluent tank.
II - Description of each parameters

Wherever possible, the PSDP has employed online analysis for the measurements of key operational and contractually guaranteed parameters. All online results are available for interrogation through the SCADA system by both Degrémont and Water Corporation. The main goal of these measurements is to protect the membranes and provides very high water quality. In case of overdose of the limit values the plant is in a first time alarmed and shutdown in a second time.

According to the Operational water quality monitoring plan 10 parameters have a major importance: pH, temperature, conductivity, turbidity, Oxidation Reduction Potential (ORP), Total Petrochemical Hydrocarbon (TPH), Dissolved Oxygen (DO), Chlorine, Silt Density Index (SDI) and fluoride.

The evolution of each parameter during the process and a map of the sampling point locations are shown in appendix 4 and 5.

1 – pH

The pH is influenced by the bicarbonate and the carbon dioxide:

\[ pH = f \left( \frac{\text{HCO}_3}{\text{CO}_2} \right) \]

During the process these two parameters are themselves influenced by the reverse osmosis which stops bicarbonate and then decreases the pH. Moreover the pH is used to adjust the flow rate of the sulphuric acid \( (\text{H}_2\text{SO}_4) \), the coagulant and the lime.

Device

Orbisint CPS 11D probe\(^2\) is the device used everywhere in the plant to measure the pH. It is fitted out of temperature probe to automatically correct the pH. Its accuracy is +/- 0.05 pH.

2 – Temperature

Controls of water temperature are completed during the process for many reasons.

- In the intake, water for contractual reasons has to be between 14 and 26°C.
- Before the reverse osmosis, if the water temperature in the membranes is too cold the pressure has to be increased.
- In the drinking water tank, the temperature of drinking water does not have to be higher than 28°C to avoid bacteria development
- In the brine the rejected water does not have a temperature higher than 2°C compare to intake water to avoid the warming of ocean water.

\(^2\) Probe: is the object used to make the measurement with the analyzers
Temperature is influenced by the weather but also by the friction in pipes, then it is important to limit the big pipes length and sun expositions.

Device

TR10-AA-H1HD is the thermocouple used to measure the temperature throughout the plant. The measurement is done by the bottom of the probe then it has to be fully immersed to get an accurate value. This device has an accuracy of ±/− 0.06°C at 20°C then it is negligible.

3 – Conductivity

Since 1978, electrical conductivity (EC) is used to estimate the amount of Total Dissolved Solids (TDS) then roughly dissolved salt. It is known that 1 mS/cm = 1 ppm = 1 mg of salt per litre of seawater. This is the reason why EC is done in the PSDP.

The goal of the membranes is to stop the salt which is a mean to decrease the conductivity. Seawater enters at 55-60 mS/cm and goes out lower 100 µS/cm. The bad side of this is the high salt density of the flow back, but several studies have shown that the ocean regulates the salt density.

Devices

Two devices are used in the plant because there are two types of water: water before RO with a conductivity of 55-60 mS/cm and water after RO with a conductivity of 40-300 µS/cm. The two probes are fitted with an automatic temperature correction. The probes have to be regularly washed to avoid fouling.

4 – Turbidity

Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in the air. The measurement of turbidity is a key test of water quality. The turbidity is stated in Nephelometric Turbidity Unit (NTU).

Turbidity measurements are completed in many parts of the plant for many reasons:

• the one in the intake will be the reference
• after the DMF to know if they will filter the big particles
• after cartridge filters for the same reason of the previous one
• in drinking water to know if lime is well mixed
• in brine to control water turbidity discharged in the ocean
CUS 31 is the probe used throughout in the plant, it is situated in the chamber. It can be influenced by micro-organisms growing in the pipes and pulling up by high pressure in the pipe. These micro-organisms can pass in the chamber and then it disturbs the measurements. As for the conductimeter the probe needs to be regularly washed to avoid the fouling. This device has accuracy around 5% of the measures.

5 – Oxidation Reduction Potential (ORP)

Oxidation Reduction describes all chemical reactions in which atoms have their oxidation number changed. This can be either a simple redox process such as oxidation of carbon to yield carbon dioxide, or the reduction of carbon by hydrogen to yield methane (\( \text{CH}_4 \)), or it can be a complex process such as the oxidation of sugar in the human body through a series of very complex electron transfer processes. [3] In the case of PSDP this main component is the chlorine which in big quantity can destroy the membranes. This unit is mV.

ORP in seawater intake is used to adjust the flow rate of sodium hypochlorite. ORP has to be controlled before RO because chlorine can destroy the membranes this is the reason why there are 3 ORP measurements because of chlorine overdose the plant has to be shutdown. Chlorine is controlled in brine because it does not have to be rejected in the sea.

Orbisint CPS 12D is the probe used everywhere in the plant to measure the ORP. Such devices are influenced a lot by external parameters it means two censors have been calibrated in the same conditions, measured the same water at the same location and get a different value. So a margin of error can be accepted.

6 – Total Petrochemical Hydrocarbon (TPH)

Total petrochemical hydrocarbon (TPH) is a term used to denote a large family of several hundred chemical compounds that originally come from crude oil. Because there are so many different chemicals in crude oil and in other petroleum products, it is not practical to measure each one separately. However, it is useful to measure the total amount of TPH at a site. Its unit is \( \mu g \) of hydrocarbon per litre of seawater or in particles per billion (ppb). [4]

In PSDP, TPH is inevitably a very import parameter because the plant produces drinking water then intake water has to be clean and in case of pollution the captor should detect the pollution to shutdown the plant.
Device

The TD-4100 measures only fluorescent hydrocarbons in water. Fluorescence occurs when a molecule absorbs light energy of one specific wavelength and emits light energy of one longer wavelength. It means little or no interference from suspended solids. This device needs some calibration with benchmark liquid fourth a year and a replacement of the light twice per year.

7 – Dissolved Oxygen (DO)

Dissolved oxygen is the quantity of oxygen in water it is stated in particle per million (ppm) or mg of oxygen per litre of seawater. It is a big ecological parameter because it has a direct impact on the flora and fauna and has to be controlled very carefully.

The DO is controlled at seawater intake and at the brine discharge. In general the dissolved oxygen is higher in discharge than in entrance. But if the DO is too low in the brine discharge the plant has to be shutdown.

Device

The HACH LDO Dissolved oxygen sensor is coated with a luminescent material. Blue light from an LED is transmitted to the sensor surface. The blue light excites the luminescent material. As the material relaxes it emits red light. The time for the red light to be emitted is measured by a censor. Between the flashes of blue light, a red LED is flashed on the sensor and used as an internal reference. The time between red and blue light represent a dissolved oxygen rate. (Figure 10)

The red light emission time decreases if the dissolved oxygen increase then the presence of bubbles in the sampling can disturb the DO and then give wrong values.
8 – Chlorine

Chlorine is an important chemical for water purification, in disinfectants, and in bleach. In PSDP it is used under the form of sodium hypochlorite to kill bacteria and other microbes in drinking water supplies. But chlorine has to be eliminated from water after using because it is very harmful for the membranes this is the reason why sodium metabisulfite is used in neutralized sodium hypochlorite. Chlorine is injected in low quantities in the permeate water as well to purify water.

Chlorine measurements are checked at the entrance and at the end of the drinking water tank because between these two points there is what it is called “burnout” the chlorine will hang on to the air and then be removed from water. A difference between these two points can be observed because of the time which slips by between the entrance and outflow of water in the tank.

Device

CCA 250 is the measuring system used in the two cases. It is constituted of chlorine probe, a flow rate controller and a redox/pH probe. This is an amperometric measuring principle. The chlorine contained in the medium diffuses through the sensor membranes and is reduced to chlorine ions (Cl\(^-\)) on the gold cathode. On the silver anode, silver is oxidized to silver chloride. The electron release of the gold cathode and electron acceptance on the silver anode result in a current flow which is proportional to the chlorine dioxide concentration in the medium. This process takes place within a wide range pH (stability range of ClO\(_2\)) and temperature range (2 to 45 °C). The measure is formulated in ppm (mg/l) and is measure range is 0.01 to 5 mg of chlorine / l.

9 – Silt Density Index

Suspended solids and colloidal materials in feed water are one of the biggest problems in reverse osmosis systems. Even though most systems have some pre-treatment including 5 μm pre-filters, these fine particles are responsible for fouling of reverse osmosis membranes.

In order to get some measure of the degree of this fouling problem, a concept called Silt Density Index is used. A 0.45 μm filter is placed before the reverse osmosis under pressure to avoid the membranes fouling; its filtration rate is calculated. It is given in percentage of membranes warping per minute.

For the reverse osmosis system a SDI lower than 5%/min is considered acceptable, this means for a SDI value lower than 5, the membranes should foul at a very low rate.
10 – Fluoride

The fluoride is a component added during the post-treatment, it is used to prevent tooth decay. This dose is imposed by the Australian government at 0.81 ppm but the aim of the company is between 0.8 and 0.9 ppm. This rate is controlled by a censor situated at the drinking water tank just after the injection of FSA.

Device

The dulcometer fluoride meter is a potentiometric measurement which uses an ion selective electrode (ISE) and a reference electrode to deliver a measurement signal in mV. The expertise of the newly developed fluoride ISE lies in the physical-chemical characteristics of the LaF$_3$ crystals (lanthanum fluoride) and the ion electrolytes which permit long-term stable and continuous measurement without additional use of special conditioning chemicals.

This device has been calibrated by a laboratory in February 2008 after a problem of accuracy. The problem came from the solution used to calibrate the analyser.
III – Identification and improvement of the weak points

After a description of the process and of each parameter, the main part of the project could start. A list of the online devices has been made and given to the technicians and to the engineers to identify the weak points according to their experiences. In parallel to that, the curves from HMI (device used to stock the online values) have been observed and crosschecked to identify the origin of certain problems. Furthermore in a few cases the suppliers have been contacted to know these advices concerning the analysers. The next step was to eradicate the issues, by testing the analysers and find solutions to solve the problems. 5 panels\(^3\) have been identified: intake panel (situated just after the seawater pumps), filtered panel, stabilized panel (panel situated just after the post-treatment), drinking panel (situated in the drinking water tank) and brine panel (situated in the outfall).

1 – Intake panel

On the intake panel, 3 main problems have been observed: Hydrocarbons, temperature and turbidity.

\(a – \text{Hydrocarbon} \quad \text{TD 4100 (Turner Designs)}\)

Observations

Hydrocarbon shows some difficulties to give out good values for the low level of hydrocarbon. The range of this device is 1 ppb to 1000 ppm but in reality for the values lower than 20 ppb it is very difficult to get a right value and this is true for every hydrocarbon device. In our case the limit value has been fixed at 30 ppb it means for the values higher the plant is shutdown. But unfortunately the online measurements (appendix 6) show that the hydrocarbon values are often higher than 30 ppb and moreover they appear in random time. These observations led to the suppression of the alarm; it means if there is hydrocarbon pollution nothing is going to happen.

According to the supplier the sodium hypochlorite added before the sampling does not have any reaction with the device. But these peaks being very high and very brief can be due to suspended particles.

But after observation of the trends from the last year it appears there was a pollution of 200 ppb in April 2008 during one hour and a half, this cannot arise from the instrument. To identify the reason of the pollution an alarm has been implemented allowing a technician to go and take a sample. The main problem is pollution like this can happen whenever but it is the only solution we have to get a sample.

\(^3\) Panels: the analysers are put together on panels simplify the controls and the maintenance.
Another issue is the buffer solution used to calibrate the device which is at 1000 ppm. The device has to be calibrated into the good range to get accurate measurements but currently the limit value is at 100 ppb, so it appears that the device is calibrated with the wrong buffer solution.

_Solutions_

A re-calibration is done every month and the light is changed twice a year so it is not due to a problem of device calibration or maintenance. The pikes last just 1 or 2 minutes then the solution will be to put a temporization on the alarm in this way the alarm will be activated only when the hydrocarbon is too high during a long period (the perturbations are around 20 – 30 ppb, the limit value for the alarm has been fixed at 50 ppb). The water spends 30 minutes to reach the membranes then the temporization can be fixed at 5 minutes.

But before doing this, water has to be controlled to see if it is really hydrocarbon pollution. In this way the alarm will be used to take a sample in a first time and if this sample is really polluted the alarm will be used to shutdown the plant.

In every case the buffer solution used to calibrate the device has to be changed because it is currently at 1000 ppm whereas the using range is between 1 to 100 ppb then a buffer solution at 100 ppb has to be used for the calibration.

---

**b – Temperature**  TR10-AA H1HD (E&H)

_Observations_

In appendix 7 it is observed that the intake temperature is lower than the temperature at the end of the cartridge filters during the night and higher during the day. This means the intake temperature is influenced by the external parameters.

These external parameters are: the sun which heats the sensor and the sampling pipe which is heated or cooled according to the weather because of its length (30m for bank B and 42m for bank A) which increases the exchange surface. Therefore friction inside the pipe can heat the water. According to the supplier the measurements are done with the bottom of the probe, but it can be influenced by thermal inertia, this explains that the probe is influenced by the sun.

_First test_

Water temperature has been measured at the beginning of the sampling pipe (just after the seawater pumps) and at the end (just after the online analyser) and has been compared to the online measurements. (See table 1 and appendix 8)
The results do not show any differences, but this can arise from the external temperature which is quite the same than water temperature then any variation can be observed.

Second test

After a first test is inconclusive, a second test has been completed. The idea of this test is to heat the top of the probe with a heat gun, control the online temperature and compare it to the outgoing water temperature just after the probe. (Appendix 9)

In this test it is observed the online temperature increases and the outgoing temperature stays the same (table 2). The second part of the test is to heat the chamber\(^5\) with the same method; in this case the water temperature increases a bit. This shows that if the pipes are heated (in the case of the external temperature is higher than the water temperature) the water temperature is heated as well. (Table 3)

<table>
<thead>
<tr>
<th>Heat gun temperature</th>
<th>Online temperature</th>
<th>Outgoing temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>19.65</td>
<td>19.5</td>
</tr>
<tr>
<td>50</td>
<td>23.7</td>
<td>19.5</td>
</tr>
</tbody>
</table>

**Table 2 – Heating of the probe**

<table>
<thead>
<tr>
<th>Heat gun temperature</th>
<th>Online temperature</th>
<th>Outgoing temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>19.65</td>
<td>19.77</td>
</tr>
<tr>
<td>50</td>
<td>19.6</td>
<td>19.8</td>
</tr>
</tbody>
</table>

**Table 3 – Heating of the chamber**

This test shows that the probe is influenced by the external temperature and furthermore the sampling pipe length appears clearly as an issue.

\(^4\) Offline intake is the measurement at the same point than the online intake but with a laboratory device.

\(^5\) Chamber is used to settle the probe in the circuit
**Solutions**

Two solutions can be conceivable: the first is to put an insulator on the probe and on the sampling pipe. This solution is more a “do it yourself” but it is the cheapest one and can be implemented easily.

The second solution will be changing the location of the analyser. The idea is to put the device closer to the seawater pipes protected from the sun (1 meter), to reduce the pipe length and sun exposure. But to implement these modifications several arrangements will be needed: the space near the new panel has to be lengthened and a fence has to be implemented to avoid the fall risks because it is situated just near the pump hole. (Appendix 10 and picture 11 and 12)

![Figure 11 – DO probe “Hach LDO”](image1)

![Figure 12 – DO probe “Hach LDO”](image2)

**c – Turbidity  CUS 31 (E&H)**

**Observations**

The turbidities higher than 1 or 2 are not normal and are linked to interferences which are influenced by micro-organisms growing up inside the sampling pipe (30m for blank B and 42m for blank A). They would be pulled up by water in the pipe and would disturb the measures. Furthermore the analyser range is very high (0-9999 NTU) compared to reality. (As for hydrocarbon III.1.a)

**Test**

As for the intake temperature, measurements have been checked at the beginning and at the end of the sampling pipe and have been compared to the online turbidity which is located on the intake panel (Table 4).

<table>
<thead>
<tr>
<th>Date</th>
<th>Online intake</th>
<th>Offline intake</th>
<th>Seawater pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>19/05</td>
<td>0.388</td>
<td>0.427</td>
<td>0.388</td>
</tr>
<tr>
<td>20/05</td>
<td>0.366</td>
<td>0.335</td>
<td>0.25</td>
</tr>
<tr>
<td>21/05</td>
<td>0.516</td>
<td>0.303</td>
<td>0.306</td>
</tr>
</tbody>
</table>

*Table 4 – Turbidity at different location*
The low turbidity measurements are really hard to realize because the analyser must be very accurate. On site the two available analysers are not really accurate, so it is difficult to make a good comparison. The table 4 shows that the turbidity is very hard to evaluate, sometimes higher in the online analyser, sometimes higher in the seawater pump.

**Solution**

For this problem two solutions are imaginable and can be mixed together: the first one is the relocation of the analyser, which can be put on the same panel than the temperature. This will permit to decrease the pipe length and then solve the problem of pipe fouling. (Appendix 10)

The second solution is to change the analyser, and choose a new one with a low range around 0.001 or 5 NTU (see III.2 filtered panel for the description of the new device).

2 – Filtered panel

**Observations**

Two measurements are taken on the filtered panel, ORP and turbidity. Their aim is to protect the membranes; ORP is used to protect the membranes against the chlorine and turbidity against the fouling. The ORP is a very simple simple, if there is chlorine in the water it reacts, the exact value is not needed. In the opposite the turbidimeter is a very sensitive analyser because the limit value of the turbidity is very low (0.5 NTU) and unfortunately its range is 0 – 9999 NTU.

The appendix 11 shows that both bank A and B which are normally the same water gives a different value with every time the same kind of offset. It appears that this offset is not really an offset according to the technicians it is due to the flow, the calibration and the accuracy of the device.

**Solution**

The solution will be to get a turbidimeter with a range around 0 – 5 NTU. By knowing that several suppliers have been contacted, and finally the Hach FT 660c laser turbidimeter has been chosen, its range is 0 – 5 NTU. It is associated with a controller to convert the signal and adapt it to our interface.

But this change has to be linked to a new calibration procedure: by using lower buffer solutions 0.01 to 5 NTU for instance.

3 – Stabilized panel

The stabilized panel is situated between permeate and drinking tanks. The problem is many bubbles are created in the permeate tank, flow through the pipe between the both tanks and go up in the buffer room. The sampling is taken in the buffer room then many bubbles enter in the sampling (appendix 13). These bubbles can influence the analysers present on this panel.

---

6 Offset is a value to compensate a gap between to value
According to the supplier and to the technicians the pH analyser can be disturbed by bubbles which come on the membrane and block it. Furthermore the chlorine is fitted with an automatic pH correction and could be influenced as well. After observation it appears that a few bubbles are inside the chlorine chamber.

**Solution**

The solution is to implement a buffer tank but for this the flow rates have to be managed, because the size of the buffer tank is directly linked to the flow rate. By knowing the minimum flow rate for the chlorine is 0.03 m$^3$/h and for the pHmeter is 0.02 m$^3$/h, then it means a total flow rate of 0.05 m$^3$/h. It is not that much so the chlorine analyser can be included in the circuit.

But if we want to take the security margin we can take a total flow rate (Q) of 0.1 m$^3$/h. By knowing the ascension velocity (v) of bubble is between 2 and 18 cm/s (for bubbles around 0.2 – 2 mm) the pipe section (S) can be found:

\[
S = \frac{Q}{v} = \frac{0.1}{72} = 13 \text{ cm}^2
\]

So the minimum pipe section is 13 cm$^2$ (diameter of 4 cm). After the velocity of the bubble ingoing in the pipe has to be calculated:

\[
v = \frac{Q}{S} = \frac{0.1}{0.0314} = 318 \text{ m/h} = 8.83 \text{ cm/s}
\]

Avec $S =$ section of the ingoing pipe

Then if the ascension velocity of bubbles is 2 cm/s and diameter of the pipe 2 cm, it means the bubbles will need 1 second to reach the top of the pipe. According to the calculation in one second the bubbles will have covered 8.83 cm then the minimum pipe length is 8.83 cm and if we take a margin it can reach a size of 20 cm.

Basically the idea is to use a pipe of 13 cm$^2$ and 20 cm of length inclined at 45 degrees in this way the bubbles will come up more easily. (Appendix 12) This buffer pipe has to be easily removable, to facilitate the maintenance and the cleaning.

Another solution is to put protection on the sampling point, in this way the bubbles could not enter on the sampling pipe. (Appendix 14)
4 – Drinking panel

On the drinking panel, 4 analysers have been identified as being a problem: temperature, turbidity, pH and chlorine.

a – Temperature  TR10- AA H1HD (E&H)

**Observations**

As for the intake panel, the temperature probe is sometimes exposed to the sun. A solution was to close the door but unfortunately it is not enough because sometimes people leave the door open.

**Solutions**

In this case the only solution is to put an insulator on the probe to protect it against the sunray.

b – Turbidity, pH and chlorine

**Observations**

Turbidity and pH are analysers that can clearly be influenced by bubbles in a different way. In a lower level the chlorine can be influenced because of its automatic pH correction which has the same principle as the other pH meter. Bubbles block the pH analyser membranes and then disturb its measurements. In spite of its degassing room the turbidity can be influenced by bubbles if there are too many.

**Solution**

The solution will be to divide the panel in two parts: the analysers not influenced by the bubbles (conductivity, temperature and fluoride) and the ones influenced by bubbles (pH, turbidity and chlorine). For the second ones the same buffer pipe than for the stabilized panel can be implemented. The same flow rate (0.1 m$^3$/h) can be considered and then the pipe size will stay the same as well. (See part III.2 Stabilized panel)

For the chlorine, an analyser is proposed by “Wallace and Tiernan”. The Depolox 5+ is fitted up by an automatic pH correction which is immersed in a buffer solution, in this way the chlorine measurement is not influenced anymore by the pH variation.
5 – Brine

The brine panel is influenced mainly by bubbles and almost every device appears influenced by them.

*Observations*

In spite of the degassing room the bubbles come through the turbidimeter and disturb the analyser, they pass through the light ray of the censor and are considered as little particles.

As for the stabilized and drinking panels the pH meter is influenced by these bubbles which block the membranes and then disturb the measurements.

Even if the device does not show any curious measures, according to the Dissolved oxygen analyser supplier the air bubbles influence a lot of the device. So we can consider that the device has a problem.

*Solutions*

To solve this problem two solutions are imaginable: the first one is the implementation of a buffer tube before the analysers. But to do that the sampling flow rate which is currently at 1 l/s has to be decreased. Otherwise the tank will be very huge and it will generate a lot of problems like algae, fouling ... and furthermore the time spent by the water in the tank will be too long so the value obtained by the analysers will be too late.

With a flow rate of 0.1 l/s the size of the tank will be 50 cm$^2$ (diameter of 8 cm) and a length of 40 cm inclined at 45 degrees. (The dimensioning has been done with the same method than for the stabilized). The buffer tube has to be on the top of the analysers to let the bubbles up. Furthermore a U is used for each analyser to let the instruments in the water in case of shutdown. (See appendix 15 and 16) The less influenced by bubbles will be put in first to allow the bubbles to be evacuated.

The second solution will be to modify the sampling point. It is located in the mixing area because it is at this point where there is a good mixing, but this involves a lot of bubbles.

There is another place where the sampling can be done. After the outfall water continues until a well before being rejected in the sea. But this will involve a change of the whole panel.
5 – Other panels

The high conductivities and the turbidity present accuracy problems on a different panel for these analysers it is more the calibration or the device directly which are in cause.

a – Conductivity

Observation

High conductivities on the intake and polished panels (conductivity around 50 and 60 mS/cm) are not really accurate. When online and offline values are compared, a difference of +/- 1 mS/cm is observed. This problem is more a calibration issue; the conductimeter used to calibrate the online one is calibrated with a solution at 1278 µS/cm which is very low compare to high conductivities around 50 and 60 mS/cm.

Solution

The solution is quiet simple; the conductimeter used for the calibration has to be calibrated with a higher solution around the measured value (50 – 60 ms/cm). For that a calibration device has been implemented it gives a different value of conductivity.

b – Turbidity

Observation

As it has been said before, the turbidity is an issue on the intake, filtered and brine because of its high range, but it is a problem for every turbidity devices on site. The reason is the same for all, the turbidity in the plant is very low (between 0.05 and 2 NTU) whereas the analyser ranges is 0 - 9999 NTU.

The second thing is the calibration is done with two buffer solutions of 5 and 100 NTU, which is out of the measured range.

Solution

Two solutions are possible, the first one is to change the buffer solutions and use ones around 0.1 and 5 NTU. The second solution is to change all the turbidimeters and take one with a very low range, like the filter Trak 660 from Hach which has a range between 0 and 5 NTU.
c – pH

Observation

An offset of 0.2 is put on all the pHmeters on site; this can result from the analyser usuries. According to the supplier the probes need to be changed every 12 to 24 months. It appears that the probes are implemented from 2 years, so it can be explained easily.

Solution

The supplier proposes to replace the Orbisint CPS 11D (old probe) by the Ceragel CPS 71D. The advantage of these probes is that they are made with ceramic diaphragm which allows to get a quicker response.

Some probes have been change on drinking water, permeate and acidified water but an offset is still added on (table 5).

<table>
<thead>
<tr>
<th>Probe offset</th>
<th>Acidified</th>
<th>Permeate</th>
<th>Drinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS 11D (old)</td>
<td>0.55</td>
<td>0.46</td>
<td>0.45</td>
</tr>
<tr>
<td>CPS 71D (new)</td>
<td>0.14</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Table 5 – pH comparisons

The table 5 shows clearly that the new probe is more accurate than the old one. Furthermore this offset is just about 0.03 pH which is due to the margin of error of the device. (Margin of error at 0.05 pH).

But the most important thing which can be observed is that offset is higher for the water with a high conductivity (acidified water). The conductivity can be a factor because the pH is measured according to a difference of potential and the conductivity can influence it.
Conclusion and discussions

The instrumentation is a very tough area because all the parameters can be influenced by others and it needs to find a compromise. Furthermore each instrument has its own accuracy and is influenced by different parameters according to its location or to the measured solution.

Measurements have been made in different ways according to the measured parameters but the major part was a comparison between laboratory and online analysis. The major problem came from the accuracy of the laboratory analysers which were unfortunately not sufficient enough to get a correct value especially for the turbidity. For the dissolved oxygen it was impossible to know if the value was good or bad because the measurement can only be taken in the black room of the analyser which is stuck on the panel.

Another issue was the way in which the samples were taken, for instance the turbidity is a very sensitive parameter, so if the bottle used to make the sample is a bit dirty or if the bottle is moved, some bubbles can be created and then perturb the measures.

The other measurements were not influenced by external parameters
Recommendations

The Hach Filter Trak 660 sc used to measure the turbidity has been ordered and will be tried. If the trials are good it could be implemented throughout on the plant.

The pHmeters are currently changing one at a time as an old one goes a new one is replaced and it appears that the offset is not used anymore for the ones used after the RO (with low conductivity). But after the RO where the conductivity is high, an offset is still added, so investigations have to be done to know if the conductivity influences the pH measurements.

The hydrocarbon calibration has to be made with a new buffer solution at 100 ppb to increase its accuracy and thus get the right value. It has to be controlled in case of pollution to see if it is really a pollution problem and not just interference in the analyser. If this control shows hydrocarbon pollution the alarm level should be modified.

The new device used to calibrate the conductimeter has to be tried and its accuracy has to be verified.

The modifications on the stabilized sampling, drinking water panel and brine panel need to be made during the next shutdown in October. The test has to be realized after the modification to see if there are still bubbles inside the pipes.
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Appendix 2 - Different states of water during the process
Appendix 3 - Tanks discharge

Brine

Backwash Tank

Backwash Dual Media Filters

Backwash Effluent tank

Thickener

Centrifuge

Landfill

Outfall

Sea

Clean brine

Dirty brine

Clean brine

Liquid sludge

Solid sludge
### Appendix 4 - Evolution of each parameter during the process

<table>
<thead>
<tr>
<th>Steps</th>
<th>By-steps</th>
<th>Sampling</th>
<th>pH</th>
<th>Temp</th>
<th>Cond</th>
<th>Turb</th>
<th>ORP</th>
<th>TPH</th>
<th>DO</th>
<th>Chlorine</th>
<th>SDI</th>
<th>Fluoride</th>
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<td>Antiscalant</td>
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<tr>
<td></td>
<td>Sodium metabisulfite</td>
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**Steps**

- **Screening**
  - Seawater intake
  - Sodium hypochlorite
  - Screen penstock
  - Band screen

- **Pre-treatment**
  - Seawater pumps
    - Seawater intake
    - Sulphuric acid
    - Ferric sulphate
    - Dosed seawater
    - Coagulant
    - Dual filters
    - Antiscalant
    - Sodium metabisulfite
    - Filtered seawater
    - Cartridge filters
    - Cartridge filters discharge

- **RO**
  - RO feed water
  - HP pumps
  - RO first pass
  - 1st pass permeate (per racks)
  - 1st pass permeate (per bank)

**Sampling**

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**Pump**

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Appendix 7 - Temperature comparison between intake and polished water
Appendix 8 - Temperature sampling for the first test

Seawater pump

End of the sampling panel

Online analyzer

Other analyzer
Appendix 9 - Temperature test 2
Appendix 10 - Intake panel relocation
Appendix 11 - Turbidity in filtered panel

Turbidity filtered bank A
Turbidity filtered bank B
Appendix 12 - Buffer pipe for stabilized water
Appendix 13 - Stabilized sampling

Bubbles go up

Sampling

Water from permeate tank
Appendix 14 - Stabilized sampling solution

Currently

Bubbles go up
Sampling
Buffer room

Water from permeate tank

With the protection

Bubbles go up
Sampling
Buffer room

Protection
Appendix 15 - Current brine Sampling
Appendix 16 - New brine panel

Buffer pipe

Ingoing water

Analysers no influenced by bubbles

Analysers influenced by bubbles