Optimal levels of remineralisation for desalinated waters

M. Hernández-Suárez, F.A. León

ABSTRACT

The purpose of remineralization is generally to produce water with a Langelier saturation index (LSI) very close to zero that remains stable in contact with the atmosphere. It is also important to accomplish this with the lowest possible consumption of CO₂ to minimize operating costs. This study considers the way to adequately remineralize desalinated water for a range of temperatures of between 14°C and 25°C. At most desalination plants, CO₂ needs to be added following reverse osmosis and prior to remineralization. The concentration of CO₂ in osmotized water required to reach the proposed levels of remineralization depends on the permeate alkalinity prior to remineralization. In this article, the dosage is shown that is required for each water according to the pH and alkalinity of the permeate prior to remineralization with calcite beds. In the case of using Ca(OH)₂, the dosage of CO₂ should be doubled. Underdosing of CO₂ produces water with low alkalinity. This implies a low buffering capacity and, therefore, a tendency to easily acidify through uptake of CO₂ from the atmosphere. This fact, coupled with the low calcium content, makes this type of water unstable, with a tendency to be corrosive. Overdosing of CO₂ implies higher alkalinity and hardness in remineralized water, as well as a CO₂ content that tends to decrease in contact with the atmosphere, causing the pH of the water to increase and thus giving rise to a slightly positive LSI. It is noted that the hardness of the remineralized water does not usually reach 100 mg CaCO₃ while the LSI is between 0.5 and 1.0, even at temperatures of 40°C. In many water distributions networks LSI values of between +0.1 to +0.5 are required to protect the facilities. This is achieved in the case of CaCO₃ post-treatment by slightly increasing the pH through the addition of NaOH (2–4 mg NaOH/L). In Ca(OH)₂ facilities this is done with a slight overdose of Ca(OH)₂. On some occasions, technical limitations in controlling the exact dose of Ca(OH)₂ may cause an increase in turbidity above 1 NTU.

Keywords: Remineralisation; Desalinated water; Temperature, CO₂; pH; Langelier saturation index

1. Introduction

Remineralisation is understood as the set of techniques that manage to increase the hardness and alkalinity of water to values that provide a saturation index, also called the Langelier saturation index (LSI), equal to or close to zero and in balance with the atmosphere. The CO₂ concentration of a water in equilibrium with the CO₂ in the atmosphere naturally defines the pH and the combination of carbonates and bicarbonates that corresponds to this pH. In open systems, when the CO₂ content of the water is higher than it should be in equilibrium with the air, the CO₂ escapes from the atmosphere and the pH increases. Conversely, if the CO₂ content is lower than it should be in equilibrium with the atmosphere, the water will absorb CO₂ from the atmosphere and the pH will decrease. The aim of remineralization is, on the one hand, to reach the carbon dioxide equilibrium point [1,2], where the pH,
dissolved calcium and alkalinity do not vary or vary very little in contact with the atmosphere, and, on the other, to do so as accurately as possible to minimise the consumption of energy and chemical products, especially CO₂.

The process of balancing CO₂ with the atmosphere depends on the temperature and partial pressure of CO₂ [3–6].

However, in the operating conditions of desalination plants only the water temperature can vary significantly. These differences are only seasonal and do not occur in short periods during the remineralization operation. In this article, the first task is to analyse the behaviour of different remineralized waters to check the concentration of CO₂ in equilibrium with the atmosphere and in the conditions of the Mediterranean coast. Next, the evolution of the saturation pH (pHsat), the equilibrium pH (pHeq) and the pH of the water at different levels of remineralization is analysed using a mathematical model. The objective is to identify the optimum level of remineralization that produces an LSI very close to zero and with a CO₂ content in equilibrium with that of the atmosphere. The relationship between the CO₂ content and the pH of the water is also evaluated based on the data obtained. Finally, data are presented on the evolution of the pH, bicarbonates, and LSI of the remineralized water and water in contact with the atmosphere, to corroborate the theoretical analysis of the first part of the article and help define the optimum levels of remineralization [1,7–8].

2. Material and methods

To analyse the behavior of the remineralized water in equilibrium with the atmosphere, samples were taken from different desalination plants after the remineralization treatment and in situ analyses were carried out of pH, electrical conductivity, temperature, bicarbonates, and carbonates. The sample was subsequently exposed to the atmosphere and gently stirred mechanically, taking samples for analysis every few days for up to 14 d.

The LSI is calculated from the values of electrical conductivity or total dissolved solids, calcium, alkalinity, pH and temperature. In practice, the conductivity, pH and temperature are calculated. In most desalination plants, calcium is measured continuously, but it requires a specific temperature [1,9–12].

The LSI of the remineralized water can be calculated from the increase in electrical conductivity produced by the remineralization using the quotient:

\[
\Delta CE_{25} \over \Delta Alk = 2.976E-7 \times \left[ CE_{25(0)} \right]^2 - 0.0006 \times CE_{25(0)} + 1.84
\]  

(1)

The calcium value of the remineralized water is estimated as Ca²⁺(r) = Alk(r)/2.5. The pH used is the pH measured in situ, along with that corresponding to temperature [1,9–12].

Once all the parameters have been obtained, the LSI can be calculated. It allows to estimate the LSI in between +0.5 and −0.5. The LSI approaches the concept of saturation using pH as a main variable. The LSI can be interpreted as the pH change required to bring water to equilibrium. Water with an LSI of 1.0 is one pH unit above saturation [9–12].

The pHeq corresponds to the pH of the acid–base chemical equilibrium of reaction:

\[
CaCO_3(s) + CO_2(aq) + H_2O \rightarrow Ca^{2+}(aq) + 2HCO_3^-(aq)
\]  

(2)

\[
Ca(OH)_2 + 2CO_2 \rightarrow Ca^{2+} + 2HCO_3^-
\]  

(3)

It is evident from these reactions that the increase in electrical conductivity produced by remineralization is directly proportional to the increase in alkalinity, since only the calcium and bicarbonate content have increased.

In processes in which hydrochloric or sulfuric acid is added instead of CO₂, the proportions are different; however, these cases are not considered in this paper.

The pHeq is obtained from analysis of the acid–base chemistry and in accordance with the Henderson–Hasselbach formula [1,4]. Consequently, pHeq does not depend on whether the solution is saturated with calcite.

When the solution is saturated with calcite and is at the acid–base equilibrium pH, pHeq coincides with pHsat and the LSI is equal to zero. Figs. 3–5 illustrate the difference between pHeq and pHsat.

With respect to the indirect calculation of LSI based on electrical conductivity at 25°C (EC₂₅) and pH data prior to and following remineralization (depending on the permeate EC₂₅):

\[
\Delta EC_{25} = 1.55 - 1.75 \over \Delta Alk
\]  

(4)

where:

\[
\Delta Alk = Alk(r) - Alk(0)
\]  

(5)

and

\[
AEC25 = EC25(r) - EC25(0)
\]  

(6)

Consequently, and in view of the above, investigation of the relationship between the increase of AEC25 and ΔAlk is justified to be able to extrapolate the alkalinity values of remineralized water.

For instance, Alk(0) ranges from 0.5 to 2.8 mg CaCO₃/L for EC₂₅(0) values between 250 µS/cm and 700 µS/cm, respectively. The Ca(r) value of remineralized water can be calculated from the ratio Ca(r) = Alk(r)/2.5. The pH(r) and T(r) values will be those acquired in situ with the measuring equipment placed in line. Once all the parameters have been obtained, the LSI(r) calculation method should be the SM-2330 [11].

As in the case of desalinated water, a good relationship with the Tillmans formula (7) is confirmed:

\[
pH_{r} = 7 - \log \frac{3[CO_{2(r)}]}{0.61[Alk \text{ at } 17°C]}
\]  

(7)

This relationship corresponds practically to the formula presented by Tillmans and published in 1912 [1,3], where the concentrations of CO₂ and alkalinity are expressed in mg/L. Fig. 15 shows the clear relationship between both parameters.
The different remineralization techniques, equations, and methods are shown in Table 1. The most widely used of these 5 remineralization techniques are numbers 1 and 2. Further information on these methods can be found in the literature [9–12].

Total hardness is defined as the sum of concentrations of calcium and magnesium in accordance with the formula:

$$\text{mgCaCO}_3/L = 2.497[\text{Ca}^{2+}, \text{mg/L}] + 4.118[\text{Mg}^{2+}, \text{mg/L}]$$

(8)

When milligrams of CaCO$_3$ of hardness exceed the milligrams of CaCO$_3$ of alkalinity, the milligrams of CaCO$_3$ defined by alkalinity are understood to refer to carbonated hardness and the rest to non-carbonated hardness. The total hardness of desalinated and remineralized waters is greater than the alkalinity. It is understood that, in this case, the non-carbonated Ca and Mg is combined with chloride and sulphate anions [9–12].

2.1. Simplified method for the calculation of pHsat

In respond to the demand for a numerical procedure for the calculation of pHsat, and in accordance with the work of Larson and Buswell [1] which follows Eq. (9), a simplified formula has been developed for the calculation of pHsat (13), which is becoming widespread because of its simplicity.

$$\text{Lal} = \left(\frac{[\text{Cl}^-]+[\text{SO}_4^{2-}]}{[\text{HCO}_3^-]+[\text{CO}_3^{2-}]}\right)$$

(9)

where the assessment criteria are as follows:

- Lal > 1.2  **High degree of corrosion**
- 0.8 < Lal < 1.2  **Significant degree of corrosion**
- Lal < 0.8  **No risk of corrosion**

$$\text{pHsat} = (9.3 + A + B) - \{C + D\}$$

(13)

where:

$$A = 1/10(\log(T\text{TDS}) - 1)$$

(14)

$$B = -13.2 \times \log\left(\frac{T(\text{°C}) + 273.2}{34.55}\right)$$

(15)

$$C = \log(\text{Ca}[\text{mg CaCO}_3/L]) - 0.4$$

(16)

$$D = \log \text{Alk}[\text{mg CaCO}_3/L]$$

(17)

This simplified method for the calculation of pHsat continues to be used frequently as an indicator of the tendency of water to dissolve or precipitate calcium carbonate. However, it is an empirical method that does not include a series of calculations of the thermodynamics of the process that should be considered in a complete analysis of the factors intervening in reaction [10].

2.2. SM2330 method for the calculation of pHsat

The standard SM2330 method [10] summarises the progress made to date in water chemistry and is the internationally accepted method for the calculation of pHsat.

The SM2330 method is a more accurate and precise model that includes thermodynamic concepts of reaction [10]. The SM2330 method implies correcting the original Langelier formula with the coefficient for the activity:

$$\text{pHsat} = pK_2 + pK_\text{sc} + p\text{Ca}^2 + p\text{Alk} + 5\text{pfm}$$

(18)

where $K_2$ = second constant of dissociation for carbonic acid of water temperature; $K_\text{sc}$ = product of solubility for calcite at water temperature; $\text{Ca}^2$ = calcium, in mols-g/L; Alk = alkalinity, in equivalents-g/L.

The following equations are proposed for calculation of each of the elements of the equation:

$$pK_2 = 107.8871 + 0.03252849T - 5.15179/T - 38.92561 \log 10T + 56.37139/T + 72.595log10T$$

(19)

for a temperature range of 273–373 K.

$$pK_\text{sc} = 171.9065 + 0.077993T - 2.839319/T - 71.595log10T$$

(20)

for a temperature range of 273–363 K.

$$\text{pfm} = A\left(\frac{p^{0.5}}{1 + p^{0.5}}\right) - 0.3I$$

(21)

valid for $I < 0.5$.

where:

$$I = 1.6 \times 10^{-5} \times \text{EC}_{25}$$

(22)

$$A = 1.82 \times 10^6 \left(E \times T\right) - 1.5$$

(23)

$$E = \left(\frac{60.954}{T + 116}\right) - 68.937$$

(24)

where $I$ = ionic strength; $\text{EC}_{25}$ = electrical conductivity, $\mu$mhos/cm or $\mu$S/cm; $T$ = temperature of water, $K$ (°C + 273.3); $E$ = dielectric constant.

LSI calculation method according to SM2330 [10].

3. Results and discussion

3.1. Balance with carbon dioxide in the atmosphere

The data in Figs. 1 and 2 show that remineralised water tends to balance with a CO$_2$ content of around 0.7 +0.1 mg of CO$_2$ per litre, for a temperature range between 14°C and 25°C [1]. It should be noted that the concentration of CO$_2$ in the atmosphere is equivalent to approximately 0.56 mg of CO$_2$ per litre [1,3]. A total of 9 water samples were taken in 5 different desalination plants: Plant 1 (one sample), Plant 2A (three samples), Plant 2B (two samples), Plant 3A (two samples) and Plant 3B (one sample).
Fig. 1 shows a series of plants where the output CO₂ is less than 0.7 mg of CO₂ per litre, which suggests that not enough CO₂ has been dosed and consumed during the remineralization process. Therefore, water tends to absorb CO₂ from the atmosphere until it is balanced with it. In Fig. 2 the phenomenon is the opposite, with the output CO₂ content higher than that of the atmosphere. Therefore, there is a loss of CO₂ from the water until it reaches equilibrium. Comparing the data in Figs. 1 and 2, the equilibrium pH, which corresponds to the pH of the acid–base chemical equilibrium of Eq. (2) explained in section 2, of the desalinated water is around 0.3 mg of CO₂ per litre instead of 0.7 mg of CO₂ per litre as in remineralized water. The equilibrium pH is obtained from analysis of the acid–base chemistry and in accordance with the Henderson–Hasselbach formula [1,4].

3.2. Mathematical simulation of remineralization

To better analyse this phenomenon of interaction between desalinated and remineralized water in equilibrium with the atmosphere, two mathematical simulations of the remineralization process have been carried out [1,4,5]. Firstly, desalinated water was used (200 mg TDS/L; pH 6.2; 0.5 mg Ca²⁺/L; 4.5 mg CaCO₃/L; 20°C) and the pH was increased with caustic soda to demonstrate that the lack of calcium is an unsurmountable factor that does not allow an LSI of zero to be achieved even if the pH is increased.

As can be seen in Fig. 3, at a CO₂ concentration of 0.7 mg/L, where the water would be in equilibrium with the atmosphere, the pH of the water reaches a value of around 7 and the LSI remains negative at around −4 to −3. The pHeq and the water pH cross at a pH of 12 [1,6,7].

The difference between pHeq and pHsat can be seen in Fig. 3. If the solution is saturated with calcite and it is at the acid–base equilibrium pH, pHeq coincides with pHsat and LSI is equal to zero.

Secondly, remineralized water was used with 300 mg TDS/L, 22 mg Ca²⁺/L, 60 mg CaCO₃/L of alkalinity, a temperature of 20°C and at pH seven, and the pH was increased with caustic soda to also see the evolution of the saturation pH balance and the LSI.

In Fig. 4 it can be seen, in this case, that the saturation pH, the equilibrium pH and the pH of the water cross at a value close to 8.2 where the LSI is zero, and it can also be seen that at this pH the CO₂ content is around 0.7 mg of CO₂ per litre. This would be the condition where, in theory, this water will remain stable with the atmosphere, also conserving the LSI equal or very close to zero.

In the following simulation, different quantities of CO₂ were dosed into a desalinated water and left in equilibrium with calcite until the saturation pH and therefore an LSI of zero were reached. Fig. 5 shows the evolution of pH, calcium, and CO₂ in water with different degrees of remineralization and in equilibrium with calcite [1,4–7].

In a situation of equilibrium (LSI equal to zero), the value of 0.7 mg of CO₂/L corresponds to an alkalinity of 64 mg of CaCO₃/L per litre and a pH of 8.24 and 24.7 mg of Ca²⁺/L. These values are, as expected, in line with those of Fig. 4.

The variation in the composition of the desalinated water from various desalination plants is illustrated in the results of Table 2.

3.3. Obtaining the pH in equilibrium with the CO₂

Fig. 6 illustrates the relationship between water pH and CO₂ content for remineralized water, based on the data collected.

Based on the regression in Fig. 6 obtained from the laboratory data and Eq. (7), it can be calculated that for a CO₂ content of 0.7 mg/L the pH of the remineralized water would be around 8.09.

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Table 1: Equations and methods for the remineralization of desalinated waters

<table>
<thead>
<tr>
<th>Remineralisation process</th>
<th>Process reaction</th>
<th>Consumption of chemical products per 1 unit increase in alkalinity</th>
<th>Increase in anion and cation content per mol/m³ of alkalinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Calcium carbonate + Carbon dioxide</td>
<td>CaCO₃ + CO₂ + H₂O ↔ Ca²⁺ + 2(HCO₃⁻)</td>
<td>50.1 mg CaCO₃ 100% 22 mg CO₂ 37.1 mg Ca(OH)₂ 100% 44 mg CO₂/L 35.1 mg MgOCaCO₃ 100% 33 mg CO₂ 100% 49 mg H₂SO₄ 100%</td>
<td>20 mg Ca²⁺ 20 mg Ca²⁺ 6.1 mg Mg²⁺ 10 mg Ca²⁺ 40.1 mg Ca²⁺ 48 mg SO₄²⁻</td>
</tr>
<tr>
<td>2 Calcium hydroxide + Carbon dioxide</td>
<td>Ca(OH)₂ + 2CO₂ ↔ Ca²⁺ + 2(HCO₃⁻)</td>
<td>37.1 mg Ca(OH)₂ 100% 44 mg CO₂/L 35.1 mg MgOCaCO₃ 100% 33 mg CO₂ 100% 49 mg H₂SO₄ 100%</td>
<td>20 mg Ca²⁺ 20 mg Ca²⁺ 6.1 mg Mg²⁺ 10 mg Ca²⁺ 40.1 mg Ca²⁺ 48 mg SO₄²⁻</td>
</tr>
<tr>
<td>3 Dolomite + Carbon dioxide</td>
<td>MgOCaCO₃ + 3CO₂ + 2H₂O ↔ Mg²⁺ Ca²⁺ + 4(HCO₃⁻)</td>
<td>35.1 mg MgOCaCO₃ 100% 33 mg CO₂ 100% 49 mg H₂SO₄ 100%</td>
<td>6.1 mg Mg²⁺ 10 mg Ca²⁺ 40.1 mg Ca²⁺ 48 mg SO₄²⁻</td>
</tr>
<tr>
<td>4 Calcium carbonate + Sulphuric acid</td>
<td>2CaCO₃ + H₂SO₄ ↔ Ca²⁺ + 2(HCO₃⁻) + Ca(SO₄)</td>
<td>100.1 mg CaCO₃ 100% 49 mg H₂SO₄ 100%</td>
<td>40.1 mg Ca²⁺ 48 mg SO₄²⁻</td>
</tr>
<tr>
<td>5 Calcium chloride + Sodium bicarbonate</td>
<td>CaCl₂ + 2NaHCO₃ ↔ Ca²⁺ + 2(HCO₃⁻) + 2NaCl</td>
<td>55.5 mg CaCl₂ (100%) 84 mg NaHCO₃ (100%)</td>
<td>23 mg Na⁺ 20 mg Ca²⁺ 35.5 mg Cl⁻</td>
</tr>
</tbody>
</table>
This is a value very close to the 8.24 obtained with the theoretical simulation procedure described in the previous subsection [1–3].

Fig. 15, at the end of section 3, also presents the results obtained and shows the clear relationship between both parameters. This relationship corresponds practically to the formula presented by Tillmans and published in 1912 [1,3], where the concentrations of CO₂ and alkalinity are expressed in mg/L.

3.4. Evolution of the pH and LSI of the remineralized water

In accordance with the field data, Figs. 7–12 show the evolution of the pH and LSI for remineralized water from the different desalination plants grouped using the same criteria as Figs. 1 and 2.

The data in Fig. 7 shows that the pH drops to equilibrium as the water balances with the CO₂ in the atmosphere.

The decrease in pH is more accentuated the lower the remineralization, for example lower CO₂ dosage (Plant 3A). Figs. 9 and 10 complement the data in Fig. 7 for bicarbonates and LSI respectively.

The data in Fig. 8, on the other hand, show that the pH rises when remineralization is excessive, as the water loses CO₂. The greater the overdose of CO₂, the greater the rise in pH after remineralization. Figs. 11 and 12 complement the data in Fig. 8 for bicarbonates and LSI respectively. The data in Fig. 11 also confirms that the equilibrium values of the remineralized water are around 73 ± 4 mg bicarbonate per litre (L) and the pH around 8.2. These data coincide with the data obtained by the simulation [1,4–7].

3.5. Relationship between alkalinity and CO₂ dosage

Fig. 13 illustrates the relationship between the alkalinity of a remineralized water and the required dosage of CO₂.
CO₂, assuming that there is no loss of CO₂ after the exit of the reverse osmosis frame and that the efficiency is 100 × 100. These data were obtained by mathematical simulation and for a water with total dissolved solids of 180 mg/L, 1.5 mg/L of calcium and 20°C [1,4–7].

Establishing a target pH of 8.2 and a CO₂ content after remineralization of 0.7 mg CO₂/L, under normal conditions the alkalinity of the permeate is usually around 1–2 mg of calcium carbonate per litre and so, depending on the pH of the permeate, the dose of CO₂ can be between 12 and 24 mg CO₂/L.

### 3.6. Effect of temperature on remineralization

Fig. 14 illustrates the relationship between the alkalinity of a water with different levels of remineralization and the LSI, at different temperatures and for an open system, that is, in equilibrium with the atmosphere.

The data were obtained by mathematical simulation and refer to a remineralization with CO₂ and calcite bed [1,5–7].

The hardness and alkalinity of desalinated water are obtained through reaction (3).

However, with an increase in the CO₂ content of the water the slope of the curve is gradually flattened, thus allowing for more accurate dosing. It should be remembered that the accuracy achieved with this system is around ±2 mg CaCO₃/L. In any case, the process is difficult to control.

A direct relation between the increase of alkalinity and the increase of the LSI is observed in Fig. 14.

The alkalinity obtained by adding more CO₂ implies an excess of CO₂ after remineralization. This excess CO₂ is lost at the exit of the plant as the water balances with the atmosphere. Thus, the LSI becomes positive.
In turn, a temperature increase further augments this effect, as the dissolved CO₂ decreases with increasing temperature. The effect of temperature changes on the LSI in the working ranges in desalination plants is in the order of +–0.1 LSI. It can also be observed in Fig. 14 that a water re-mineralized to 100 mg of calcium carbonate per litre of alkalinity and at 40°C does not exceed the LSI value equal to 0.7 once it is balanced with the atmosphere. 40 mg/L of calcium corresponds to this level of remineralization [13–15].

At this point it should be clarified that, as has been indicated by other authors, remineralized waters do not precipitate easily even if the LSI reaches values of 0.7 and the temperature 40°C provided that the pH does not exceed 8.4 after remineralization [1,2]. This is relatively easy to achieve with calcite beds, though it is not so easy with calcium hydroxide treatments.

4. Conclusions

According to this study, it is considered that remineralised water should have the conditions presented in Table 3 for a temperature range between 14°C and 25°C. There is an option to add more CO₂ to increase alkalinity and hardness, but then the remaining CO₂ will be excessive to be in balance with the atmosphere and will be lost in a few hours causing the pH to rise and thus obtain a positive LSI. The effect of temperature changes on the LSI in the operating ranges of desalination plants is in the order of +–0.1 LSI. In many water distributions networks, LSI values of between +0.1 and +0.5 are required to protect the facilities. This is achieved by slightly increasing the pH after calcite post-treatment with the addition of caustic soda (2–4 mg/L of caustic soda).
Fig. 13. Relationship between alkalinity and the dosage of CO₂ to achieve a remineralised water at pH 8.2 and 0.7 mg CO₂/L with a calcite contactor. Simulated data from desalinated water with 180 mg TDS/L, 1.5 mg Ca²⁺/L and 20°C.

Table 2
Average composition of desalinated waters from 6 desalination plants under normal operating conditions

<table>
<thead>
<tr>
<th>Plant 1</th>
<th>Plant 2A</th>
<th>Plant 2B</th>
<th>Plant 3A</th>
<th>Plant 3B</th>
<th>Plant 4</th>
<th>Average</th>
<th>STD</th>
<th>Seawater&lt;sup&gt;10,11,12&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>02/07/09</td>
<td>04/06/09</td>
<td>Average</td>
<td>04/06/09</td>
<td>y</td>
<td>26/06/09</td>
<td>12/6/09</td>
<td>October and November 2008</td>
</tr>
<tr>
<td>pH</td>
<td>6.60</td>
<td>5.52</td>
<td>5.22</td>
<td>5.35</td>
<td>5.29</td>
<td>5.92</td>
<td>5.65</td>
<td>0.48</td>
</tr>
<tr>
<td>CE&lt;sub&gt;µS/cm&lt;/sub&gt;</td>
<td>667</td>
<td>584</td>
<td>240</td>
<td>693</td>
<td>358</td>
<td>670</td>
<td>535.28</td>
<td>209.14</td>
</tr>
<tr>
<td>HCO₃⁻, mg/L</td>
<td>1.96</td>
<td>1.48</td>
<td>0.82</td>
<td>1.97</td>
<td>1.1</td>
<td>2.4</td>
<td>1.62</td>
<td>0.54</td>
</tr>
<tr>
<td>T°, °C</td>
<td>23.5</td>
<td>22.1</td>
<td>22.1</td>
<td>23.5</td>
<td>22.6</td>
<td>22.0</td>
<td>22.63</td>
<td>0.80</td>
</tr>
<tr>
<td>CO₂, mg/L</td>
<td>0.75</td>
<td>7.82</td>
<td>11.63</td>
<td>15.94</td>
<td>9.89</td>
<td>4.65</td>
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<tr>
<td>Ca²⁺, mg/L</td>
<td>1.20</td>
<td>1.54</td>
<td>1.90</td>
<td>1.18</td>
<td>0.95</td>
<td>1.80</td>
<td>1.43</td>
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<tr>
<td>Mg²⁺, mg/L</td>
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<td>1.77</td>
<td>2.90</td>
<td>2.39</td>
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<tr>
<td>Na⁺, mg/L</td>
<td>90.12</td>
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<td>72.79</td>
<td>32.04</td>
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<tr>
<td>K⁺, mg/L</td>
<td>3.85</td>
<td>1.46</td>
<td>5.30</td>
<td>3.62</td>
<td></td>
<td></td>
<td>3.56</td>
<td>1.59</td>
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<tr>
<td>Cl⁻, mg/L</td>
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<td>107.70</td>
<td></td>
<td></td>
<td>135.82</td>
<td>62.12</td>
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<tr>
<td>NO₃⁻, mg/L</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>&lt;0.7</td>
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<tr>
<td>SO₄²⁻, mg/L</td>
<td>4.28</td>
<td>4.65</td>
<td>5.34</td>
<td>8.80</td>
<td>5.77</td>
<td>2.07</td>
<td>2.650</td>
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<tr>
<td>RS&lt;sub&gt;µS&lt;/sub&gt;/CE&lt;sub&gt;µS&lt;/sub&gt;</td>
<td>274</td>
<td>97</td>
<td>340</td>
<td>172</td>
<td></td>
<td></td>
<td>220.65</td>
<td>107.56</td>
</tr>
<tr>
<td>STD&lt;sub&gt;µS&lt;/sub&gt;/CE&lt;sub&gt;µS&lt;/sub&gt;</td>
<td>0.47</td>
<td>0.41</td>
<td>0.49</td>
<td>0.48</td>
<td>0.46</td>
<td>0.04</td>
<td>0.46</td>
<td>0.04</td>
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<tr>
<td>Turbidity, NTU</td>
<td>0.20</td>
<td>0.30</td>
<td>0.21</td>
<td>0.18</td>
<td>0.18</td>
<td>0.21</td>
<td>0.05</td>
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</tr>
<tr>
<td>Langelier (SM2330)</td>
<td>−4.49</td>
<td>−5.55</td>
<td>−5.83</td>
<td>−5.70</td>
<td>−5.90</td>
<td>−5.26</td>
<td>−5.46</td>
<td>0.48</td>
</tr>
<tr>
<td>Larson-Skold</td>
<td>164</td>
<td>115</td>
<td>149</td>
<td>179</td>
<td>152</td>
<td>27</td>
<td>0.21</td>
<td>37</td>
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<tr>
<td>SAR</td>
<td>11.28</td>
<td>3.90</td>
<td>12.51</td>
<td>8.15</td>
<td>8.96</td>
<td>3.33</td>
<td>9.08</td>
<td>0.40</td>
</tr>
<tr>
<td>pHeq with CaCO₃</td>
<td>9.79</td>
<td>9.08</td>
<td>8.76</td>
<td>8.62</td>
<td>8.90</td>
<td>9.35</td>
<td>9.08</td>
<td>0.40</td>
</tr>
</tbody>
</table>

pH, CE, HCO₃⁻, CO₃²⁻ and temperature analyzed <i>in situ</i>. Other parameters analyzed in the laboratory are average values for each desalination plant.
In installations with calcium hydroxide, this is achieved by slightly overdosing with calcium hydroxide. On some occasions, technical limitations in the control of the exact dosage of calcium hydroxide can generate an increase of the turbidity above 1 NTU. This excess turbidity could result in the precipitation of calcium in the pipes and a consequent reduction of their internal diameter. Moreover, in the case of a second pass of reverse osmosis with this water the membrane supplier strongly requires a turbidity lower than 1 NTU.

References