Technical Letter

Low pressure CO_2 dissolvers

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Authors: M. Hernández, A. Díaz, P. Barrera and P. Hernández.

Summary

Fig.1: Experimental set up with transparent CO2 dissolver. Photo courtesy of Entemanser, S.A., Tenerife, Canary Islands.

Adding CO_2 to RO permeate before remineralisation is a frequent requisite for an adequate remineralisation. Using a low pressure CO_2 dissolver is an option to dissolve the required CO_2.

When placed in-line, pressure inside the dissolver is that of the permeate, i.e. 0.5 to 1.0 bar. If placed in a bypass, a booster pump is used to elevate pressure about 0.2 to 0.5 bar above permeate pressure.

The DrinTec low pressure CO_2 dissolver operates down flow and consists of a pressurised cylindrical tank with specially designed distribution plates at the upper and lower part of the tank. In between the plates, one or several CO_2 diffusers, depending on the dose, are placed to inject the CO_2 gas. Flow and turbulences inside the dissolver have been studied using a simulation program.

The distribution plates allow for a piston flow and improves CO_2 dissolution at the upper part of the dissolver. Superficial velocity inside the dissolver is 0.06 ± 0.5 m/s. Because of the low superficial velocity head loss of the dissolver is very small.

This superficial velocity has been selected to maximise diffusivity at the top of the dissolver but avoiding dragging micro CO_2 bubbles, < 100 µm in diameter, to the outlet of the dissolver. In any case, micro-bubbles have been seen to collapse in a few seconds.

Contact time between the dissolver plates has been defined between 20 and 25 seconds.

The CO_2 gas diffusers are made of PVC pipes of Ø32 mm with hole diameter and number depending on the required dose. CO_2 pressure at the inlet of the diffusers is normally set 0.2 bar above water pressure inside the dissolver.

DESIGN CRITERIA FOR DRINTEC LOW PRESSURE CO_2 DISSOLVER.

- CO_2 concentration in the dissolver < 600 ppm.
- Vsup: 0.065 ± 0.05 m/s.
- Contact time between plates: 20-25 seconds.
- Operating water pressure if dissolver placed in a bypass: 0.2 bar above permeate pressure.
- CO_2 injection pressure: 1.2 to 1.5 bar.
- Dissolution efficiency: 99.9%

Figure 2 shows the solubility of CO_2 in water for different temperatures at 1 atmosphere. It also shows the concentrations at which the DrinTec™ low pressure CO_2 dissolvers operate.

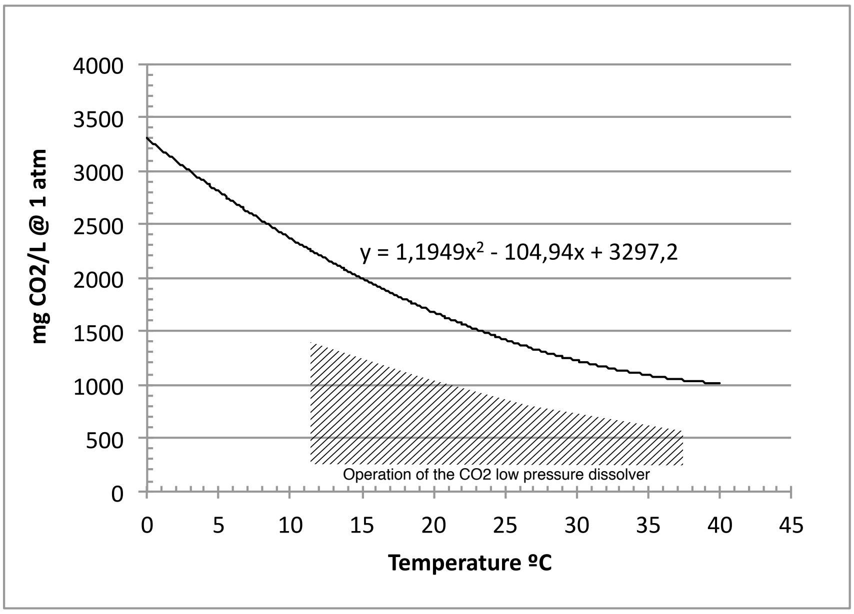

Fig.2: Solubility of CO_2 at different temperatures and operating conditions of the CO_2 dissolver.

Results

When the CO_2 dose is higher than its diffusion rate a large bubble of undissolved CO_2 forms at the upper part of the dissolver. This reaches equilibrium in size after approximately 1 to 1.5 hours.

Final size of the bubble depends on concentration of CO_2; flow rate to the dissolver and electrical conductivity, temperature and pressure of the permeate. Figures below summarised the results of the different experiments.

Figure 3 shows the evolution of bubble size inside the Ø400 transparent DrinTec™ dissolver shown on Figure 1 operating at 0,65 bar and at different CO_2 concentrations and for the same superficial velocity of 0.065 m/s. As can be seen bubble size increases with CO_2 concentration and equilibrates after about 1 to 1.5 hours.

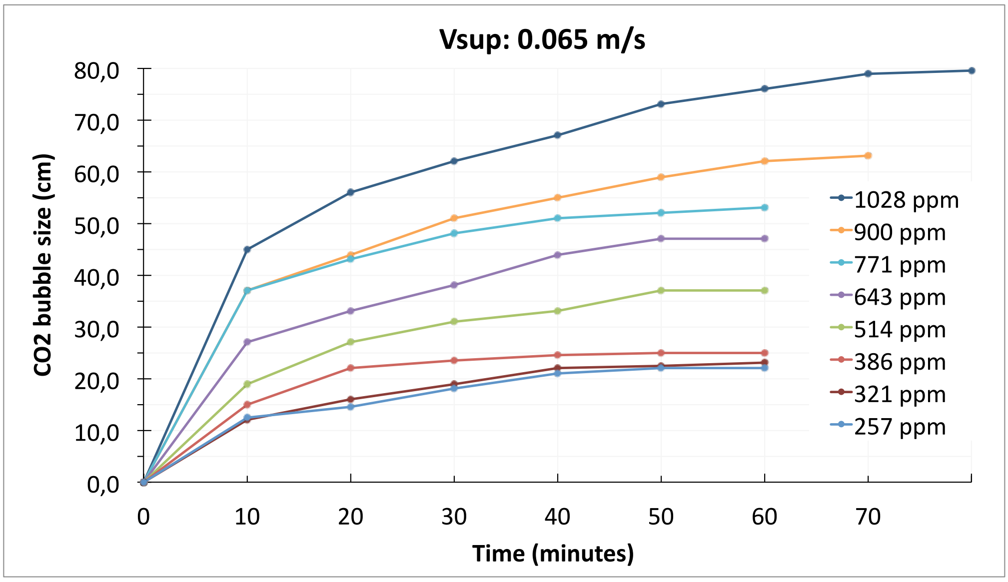

Fig.3: Bubble size with increasing CO_2 dose at 0.065 m/s. Permeate with EC of 398 µS/cm, Alk = 1.2 mg $CaCO_3$/L and T = 21ºC.

Figure 4 shows the effect of increasing permeate pressure from 1.15 to 1.4 bar on the evolution of bubble size for 300 mg CO_2/L concentration inside the dissolver and 0.065 m/s constant superficial velocity. CO_2 injection pressure was maintained at 0.2 higher than the permeate pressure.

As can be seen, increasing pressure reduces the bubble expansion velocity. However, after approximately 1 hour bubbles sizes tend to converge and the difference becomes insignificant and less than 2 cm.

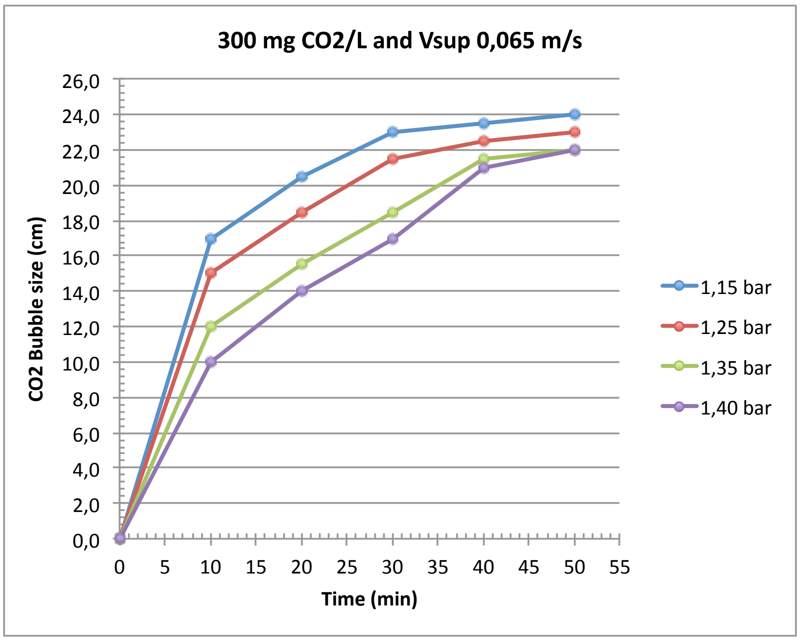

Fig.4: Bubble size for different permeate pressure for 300 mg CO_2/L at the same superficial velocity of 0,065 m/s. Water with EC of 198 µS/cm, Alk = 0.5 mg CaCO3/L and T = 21ºC.

Figure 5 summarises the effect of increasing superficial velocity on size of the bubble inside the dissolver. Increase in superficial velocity increases turbulence at the upper chamber of the dissolver which increases contact surface with the CO_2.

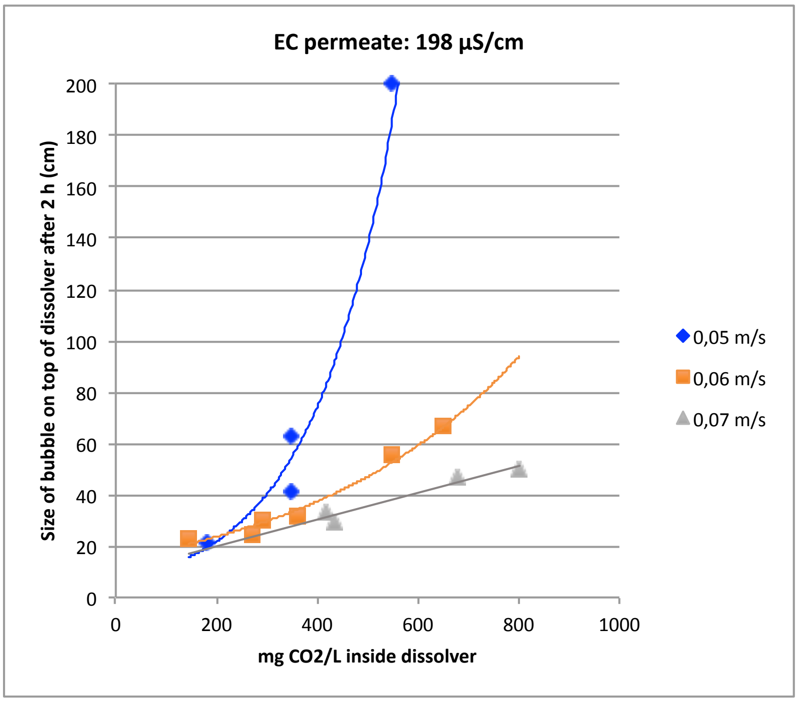

Fig.5: Bubble size and dissolver superficial velocity. Water with EC of 198 µS/cm, Alk = 0.5 mg $CaCO_3$/L and T = 21ºC.

Figure 6 shows the effect of permeate conductivity on final CO_2 bubble size. As can be seen bubbles expands more easily at lower EC values. It can be inferred that as EC is correlated to alkalinity an increase in alkalinity increases of amount of the CO_2 in solution. Figure 7 illustrates this aspect further.

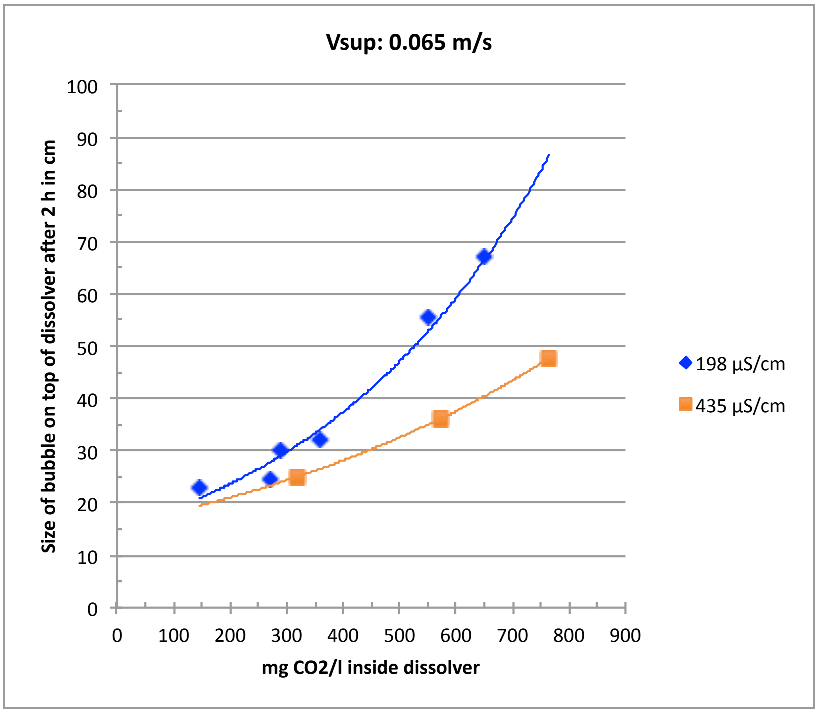

Fig.6: Bubble size on the upper part of the dissolver for different concentration of CO_2 inside the dissolver and different EC and at constant Vsup = 0.065 m/s.

Figure 7 shows the titration curves for the same permeate with increasing alkalinity simulated with the program Water!Pro (http://schotteng.com). As can be expected, increasing alkalinity increases the amount of CO_2 required to reach the same pH.

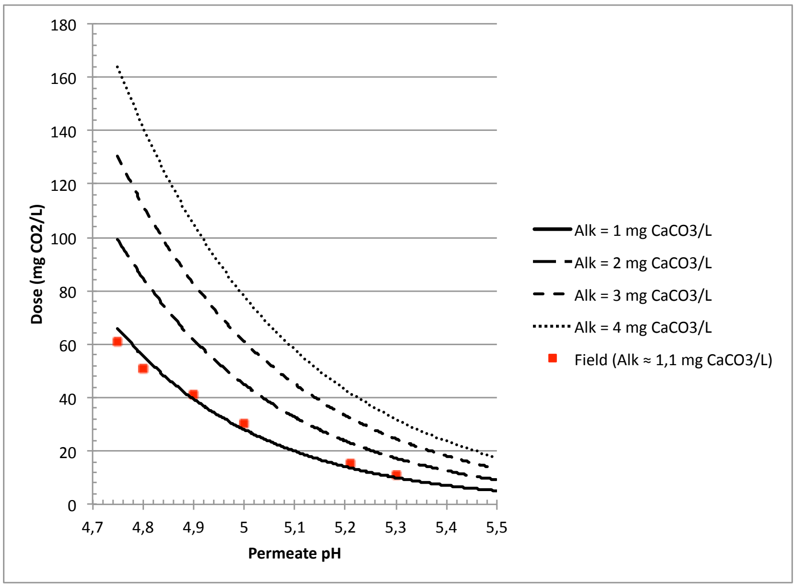

Fig.7: Theoretical and field titration with CO_2 of the same permeate with increasing alkalinity. Permeate with 212 mg TDS/L, pH 5.98 and at 21ºC.

Figure 8 shows a comparative results of the titration with CO2 of a permeate compared with the figures obtained by simulation with Water!Pro (http://schotteng.com). As can be seen, the program simulates very close the field data.

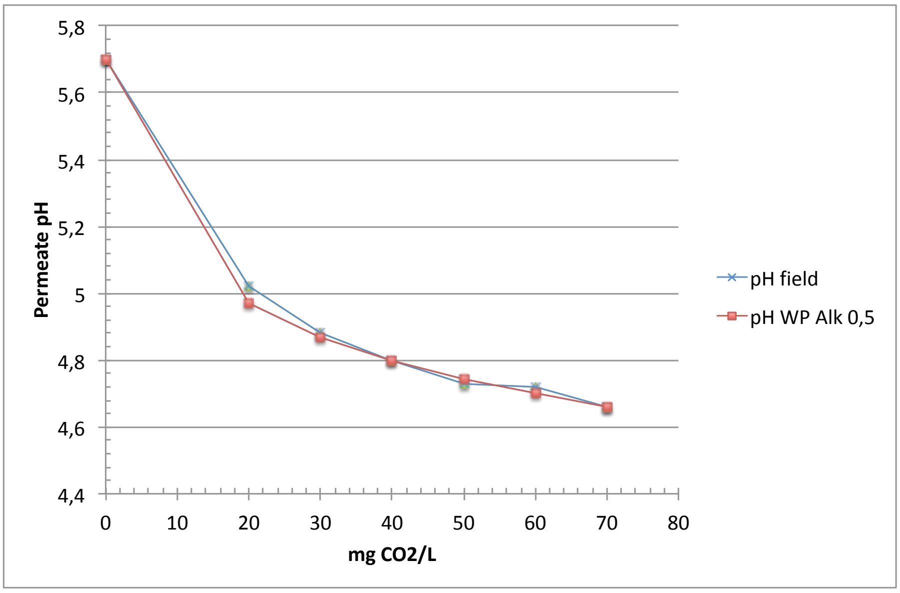

Fig.8: Titration RO permeate with CO_2. Permeate with 215 TDS/cm; pH 5,9; Alk: 0,5 mg $CaCO_3$/L and 21ºC.

Figure 9 shows also a comparative results of the titration with CO2 of a permeate compared with the figures obtained by simulation with Water!Pro (http://schotteng.com) for a wider range. Considering the field data where collected at different days the program simulates well the field data.

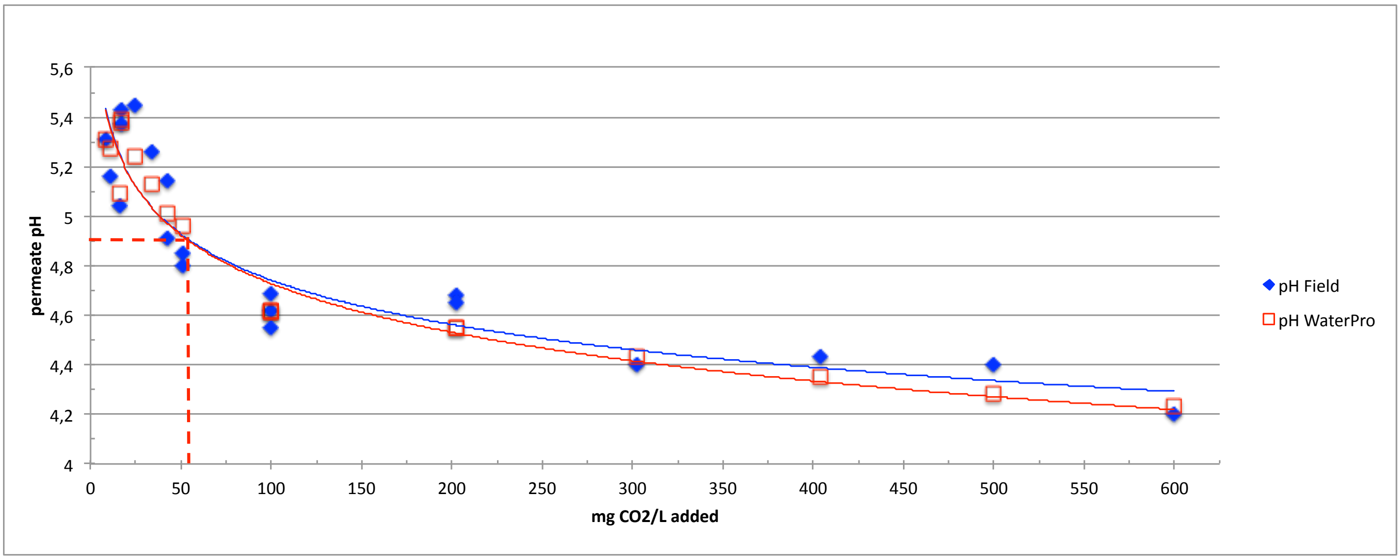

Fig.9: Titration of RO permeate with CO_2. Permeate with 215 mg TDS/L, pH 5.9 ± 0.06, Alk: 1.2 ± 1 mg $CaCO_3$/L and 21ºC.

Acknowledgment: This research has been possible thanks to the technical support of the Municipality of Adeje and Entemanser, S.A. of Tenerife, Canary Islands. Special thanks also to Francisco García plant manager of La Caleta desalination plant for his continuous support.

Fig. 10: Two CO_2 dissolvers measuring 1.4 m in diameter and 5 m in height at the inlet of a DrinTec™ remineralisation plant. Photo courtesy of Acciona Agua.

Fig. 11: CO_2 dissolver in bypass configuration at the inlet of a remineralisation plant with DrinTec contactors. Photo courtesy of Tagua, S.L., Canary Islands.