Technical Letter

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Effect of partial treatment on CAPEX and OPEX of limestone contactor plants

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Introduction

It is common to find in tender documents the option of partial treatment in the remineralisation of R.O. permeate.

The partial treatment option, however, entails a chemical cost overrun that is not always evaluated in the tenders.

There are plants where the water temperature in winter requires high contact times (EBCT) to achieve a correct remineralisation. This means that the plant operators have no choice but to reduce the treatment percentage in order to increase the EBCT. This inevitably leads to an increase in CO_2 and NaOH doses.

On the other hand, during summer times when water is warmer, the beds need less EBCT and can, therefore, treat more water. This leads to a corresponding savings in chemicals consumption.

For that reason, it is advisable to design remineralisation plants with sufficient size so that they can be flexible. This means, treating less water in winter and more in summer in order to minimise chemical consumption.

The balance between minimising OPEX and CAPEX should therefore be analysed on a case-by-case basis considering 25-year operation, before selecting the optimum plant size.

This research letter summarises the difference between CAPEX and OPEX at different treatment percentages, using the data from a plant with 450.000 m^3/d total flow, as an example.

The work has been carried out using a simulation programme supported by the experience of the authors on the performance of limestone beds at different operating conditions as well as the required investment costs for different size plants.

Results

Partial treatment requires to add heavy doses of CO_2 to the treated water to generate water with sufficient level of alkalinity and hardness which can then be blended to obtain the target values.

It also requires higher doses of NaOH to bring the water to positive LSI after blending. Table 1 shows, as an example, the effect of a 40% treatment on CO_2 and NaOH consumption.

Figure 1 shows how reducing the percentage of treatment needs to be compensated with higher dose of CO_2 to the treated water, in order to reach the target values. In turn, the CO_2 content at the outlet of the beds becomes also higher. Consequently, the NaOH consumption to produce water with positive LSI is also higher at lower treatment rates. The percentage of CO_2 used decreases when reducing percentage treatment.

Table 1: Example the effect of a 40% treatment on CO_2 and NaOH consumption. Simulation work.

		Permeate	After 103.5 mg CO_2/L	After blending (40 % treated. + 60% permeate)	After 17.4 mg NaOH/L
Field Water Temperature	ºC	24.00	24.00	24.00	24.00
TDS (mg/L)	mg/L	76.50	228.80	137.40	147.40
pH		5.30	6.83	6.76	8.05
Alkalinity	mg/L as $CaCO_3$	0.28	152.60	61.20	83.00
Ca-Hardness	mg/L Ca^{2+}	0.11	152.40	61.00	61.00
Carbon Dioxide (CO_2)	mg/L as CO_2(aq)	5.20	42.00	20.00	1.40
LSI		-7.80	-0.55	-1.38	0.02

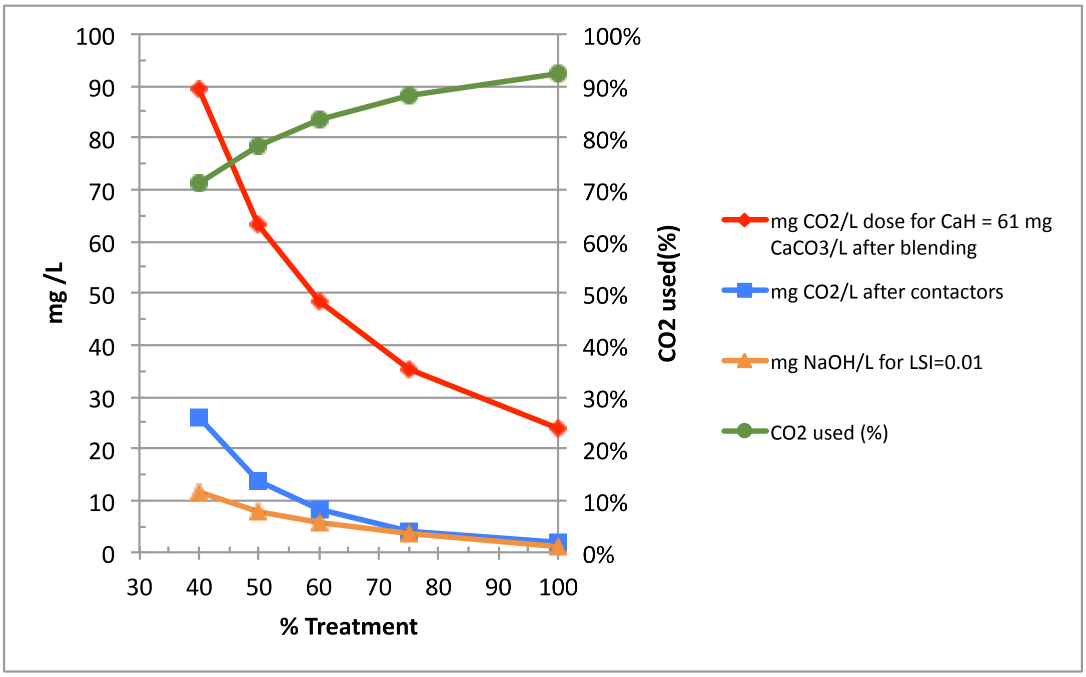
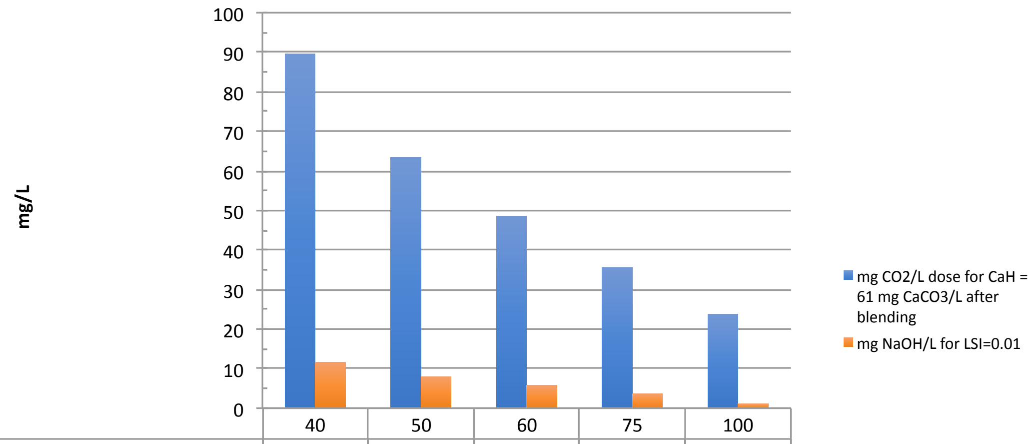


Figure 1: Dose of CO_2, concentration of CO_2 after contactors and dose of NaOH for positive LSI, for different percentage treatment.

Using the same data as those of Figure 1, Figure 2 shows that increase in CO_2 consumption with reducing treatment is not a linear relationship but an exponential one. So, it turnes out that the consumption of CO_2 for 50% treatment for producing water with 61 mg $CaCO_3$/L hardness after blending is not 2 x 23.8 mg CO_2/L but actually 63.4 mg CO_2/L which is 2.6 x 23.8 mg CO_2/L.



	40	50	60	75	100
mg CO2/L dose for CaH = 61 mg CaCO3/L after blending	89,5	63,4	48,6	35,5	23,8
mg NaOH/L for LSI=0.01	11,6	8	5,8	3,6	1,1
Assuming CO2 dose vs. % treatment is 1/1	59,6	47,7	39,7	31,8	23,8
mg CO2/L in excess	30,0	15,8	8,9	3,7	0,0

% Treatment

Figure 2: Consumption of CO_2 and NaOH for different percentage treatment.
Same data as those of Figure 1.

Figure 3 shows the simulation of CAPEX and OPEX for a 450.000 m^3/d desalination plant considering 3 different footprints: 510 m^2, 640 m^2 and 738 m^2. Bed height is maintained constant at 3.7 m for all cases (Fig. 3).

To considere varying environmental conditions, the year was divided into three periods according to water temperature: 17°C (3 months), 24°C (6 months) and 32°C (3 months). Saturation levels after treatment where selected according to water temperature based on DrinTec's research and field experience. Required EBCT and Vsup where achieved by varying percentage treatment between 40% and 100%, depending on plant size.

CO_2 and NaOH consumptions were obtained by simulation. For costs analysis, chemical prices were 100 €/t for calcite, 130 €/t for CO_2 and 135 €/t for 100% NaOH.

Larger plants are more efficient as they can treat more water in the summer when there is less EBCT requirement due to higher water temperature.

CAPEX for the different plant sizes was inferred from projects experience.

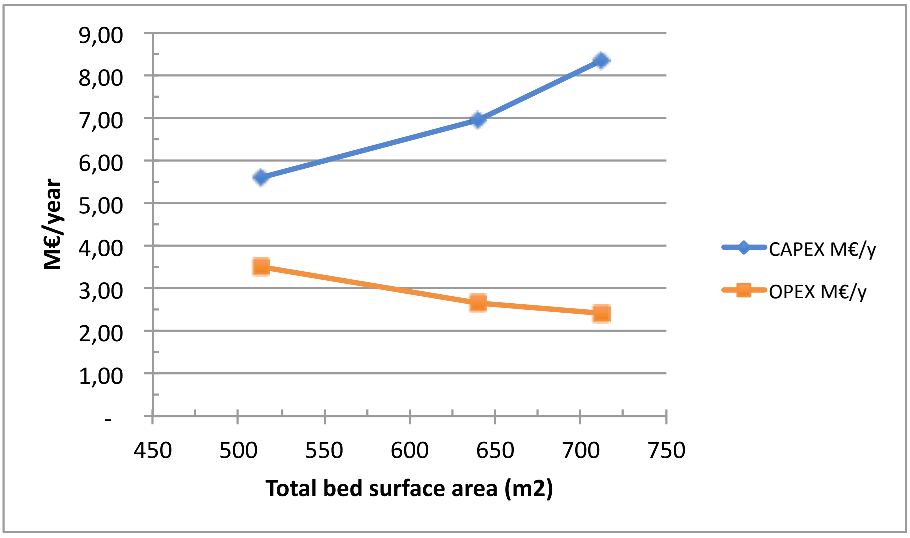


Figure 3: CAPEX and OPEX vs. plants bed surface area. Example for a 450.000 m^3/d plant. (See text for details)

Table 2: CAPEX and OPEX vs plant bed surface area. Example for a 450.000 m³/d plant. (See text for details). Same data as Figure 3.

Total bed surface area	512.8	640.0	712.0
CAPEX (M€)	5.58	6,96	8.37
OPEX (M€/y)	3.49	2.67	2.42
Average OPEX (€/m³ total flow)	0.0212	0.0163	0.0147

Conclusions

As shown on Table 2, the difference in OPEX between the plant with the smallest footprint (512.8 m²) and that with the largest footprint (712 m²) is 1.07 M€/year.

On the other hand, the difference in CAPEX between the 712 m² plant and the 512.8 m² plant is approximately 2.79 M€.

Other factors remaining similar, the 1.07 M€/y in OPEX against the 2.79 M€ in extra CAPEX can be recovered in about 2.6 years.

Figure 4 proposes a relationship between treatment percentage and operational expenses in euros per cubic meter of treated water. Although the figures may vary slightly depending on the operating conditions of the plant, especially water temperature, it gives an indication of the approximate values to be considered when remineralising with calcite contactors at different treatment rates.

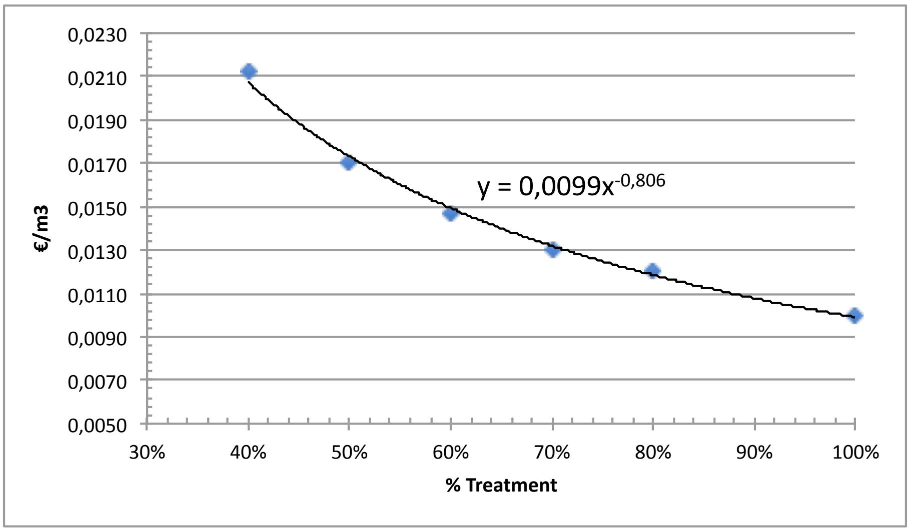


Figure 4: OPEX in €/m³ for total plant flow based on the example of a 450.000 m³/d plant considered in this study.

The results of this study lead to the final conclusion that balance between OPEX and CAPEX should be carefully considered before selecting the final design of the remineralisation plant, specially with the perspective of a 25-year operation.

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