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Effect of Water Wash on Aerosol Growth in Absorption Column

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PCCC4
4th Post Combustion Capture Conference
5th-8th September 2017
Brimingham, Alabama USA

Aerosol Science & CO_2 Capture

- Formation of aerosols can cause serious complications in industrial exhaust gas CO_2 capture processes.

- Aerosol based emissions in the order of grams per Nm^3 have been identified from PCCC plants*.

- Water-wash system is intended to control gas-phase emissions.

- Emissions related to mist and aerosols are not effectively removed in the water wash section and conventional demisting systems also have a limited effect on controlling these emissions**.

*Purvil Khakharia, Leonie Brachert, Jan Mertens, Christopher Anderlohr, Arjen Huizinga, Eva Sanchez Fernandez, Bernd Schallert K Schaber, Thijs J.H. Vlugt, Earl Goetheer *"Understanding aerosol based emissions in a Post Combustion CO_2 Capture process: Parameter testing and mechanisms"* International Journal of Greenhouse Gas Control 34, 63–7, **2015**.

**E.F. da Silva, H. Kolderup, E. Goetheer, K.W. Hjarbo, A. Huizinga, P. Khakharia, I. Tuinman, T. Mejdell, K. Zahlsen, K. Vernstad, A. Hyldbakk, T. Holten, H.M. Kvamsdal, P. van Os, A. Einbu, Emission studies from a CO2 capture pilot plant, Energy Procedia. 37 (2013) 778–783. doi:10.1016/j.egypro.2013.05.167.

Model Development

Model has already been described and discussed, some of the main points are*:

- Governing equations for growth of aerosol droplets.
- Particle internal variable profiles.
- Governing equations for the gas phase.
- How various entering droplets grow or shrink through an absorber.
- How their composition changes with respect to time.
- Effect of droplet number concentration on gas phase amine depletion.

* H. Majeed, H.K. Knuutila, M. Hillestad, H.F. Svendsen, Characterization and modelling of aerosol droplet in absorption columns, Int. J. Greenh. Gas Control. 58 (2017) 114–126. doi:10.1016/j.ijggc.2017.01.006.
* H. Majeed, H. Knuutila, M. Hillestad, H.F. Svendsen, Gas Phase Amine Depletion Created By Aerosol Formation and Growth, Int. J. Greenh. Gas Control. 64 (2017) 212-222. doi:http://dx.doi.org/10.1016/j.ijggc.2017.07.001.

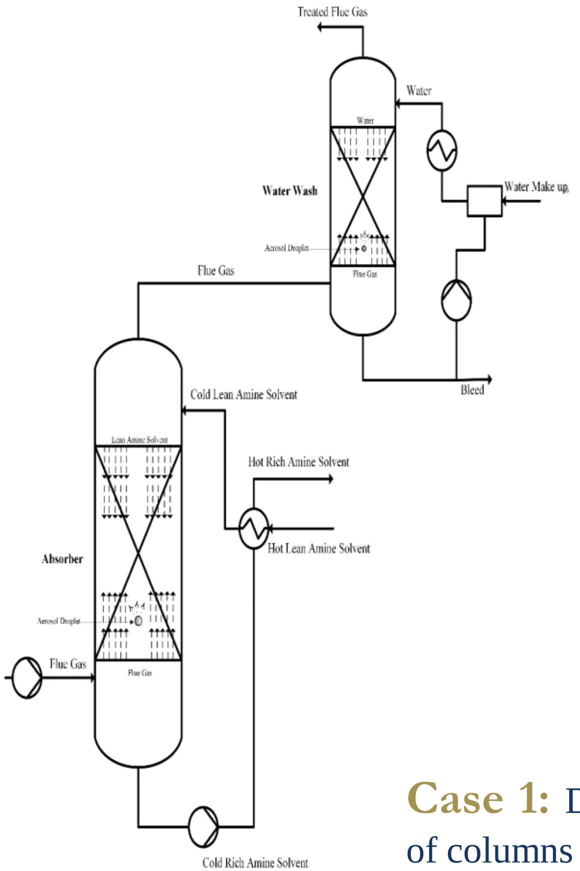
Water Wash Section

The current work is an extension of the already developed model focusing on the effect of the water wash section:

- Aerosol droplets travel with the gas phase from the absorber and into the water wash sections.
- Two separate water washes of 2m each are used.
- Wash water is recycled around each section.
- Resulting in particle internal variable, temperature and growth of aerosol droplet profiles in water wash section.
- Study effect of changes in selected operating and design variables

Case Results

Case Outlines & Parameters



Schematic illustration of aerosol phenomena in absorber and water wash

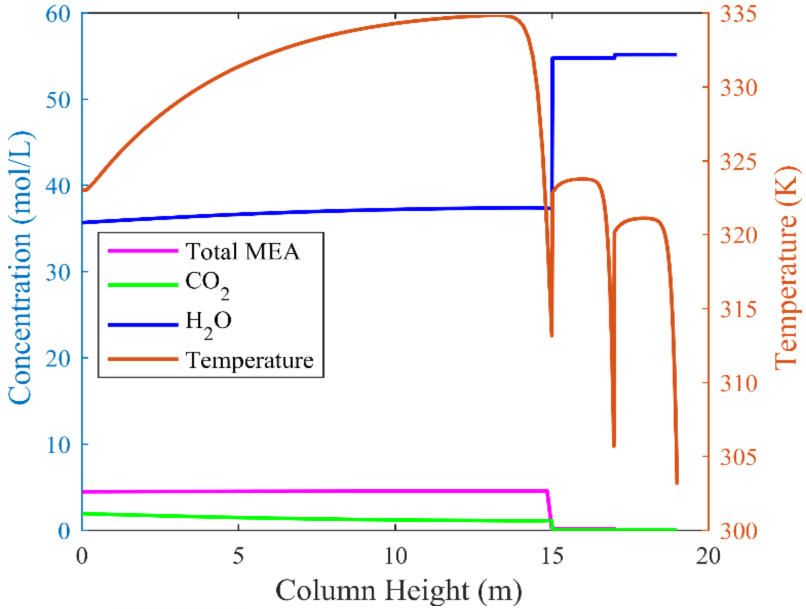


Fig. 1: Liquid phase composition and Temperature Profiles in Column from CO2SIM simulation

Case 1: Droplet, initial radius 0.15μ, containing 5M MEA travelling from bottom to top of columns (0-19 m) c_N= 1-10^7 drops/cm^3.

Case 2: Droplet, initial radius 0.15μ, containing 0.0001M MEA travelling from bottom to top of columns (0-19 m) c_N= 1-10^7 drops/cm^3.

Case 1: Droplet, initial radius 0.15µ, containing 5M MEA travelling from bottom to top of absorber and water wash columns (0-19 m), $c_N = 10^3$-10^7 drops/cm^3.

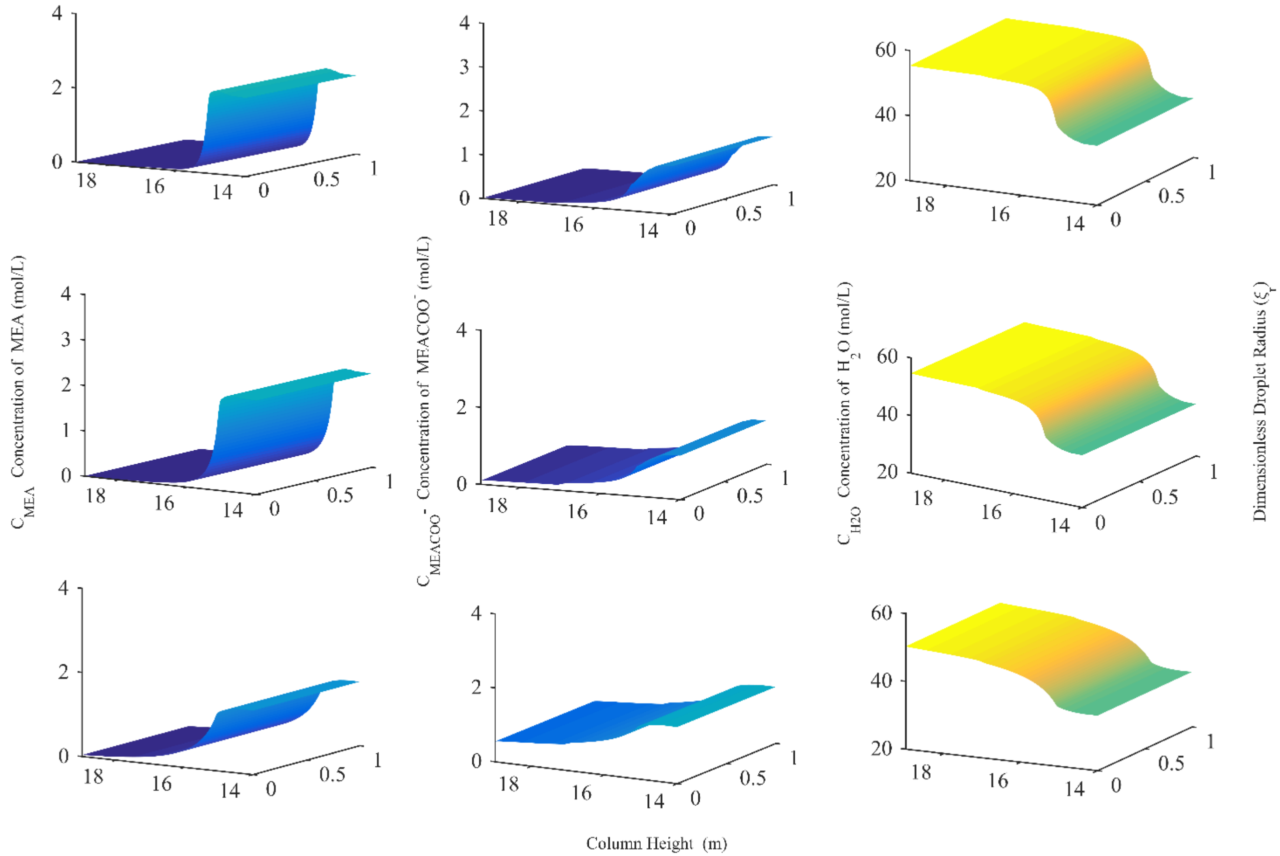


Figure 2: Case 1: Concentration profiles in water wash (a) MEA $c_N=10^3$, (b) Carbamate $c_N=10^3$, (c) Water $c_N=10^3$, (d) MEA $c_N=10^5$, (e) Carbamate $c_N=10^5$, (f) Water $c_N=10^5$, (g) MEA $c_N=10^7$, (h) Carbamate $c_N=10^7$, (i) Water $c_N=10^7$

Case 1: Droplet, initial radius 0.15μ, containing 5M MEA travelling from bottom to top of absorber and water wash columns (0-19 m), c_N= 1-10^7 drops/cm^3.

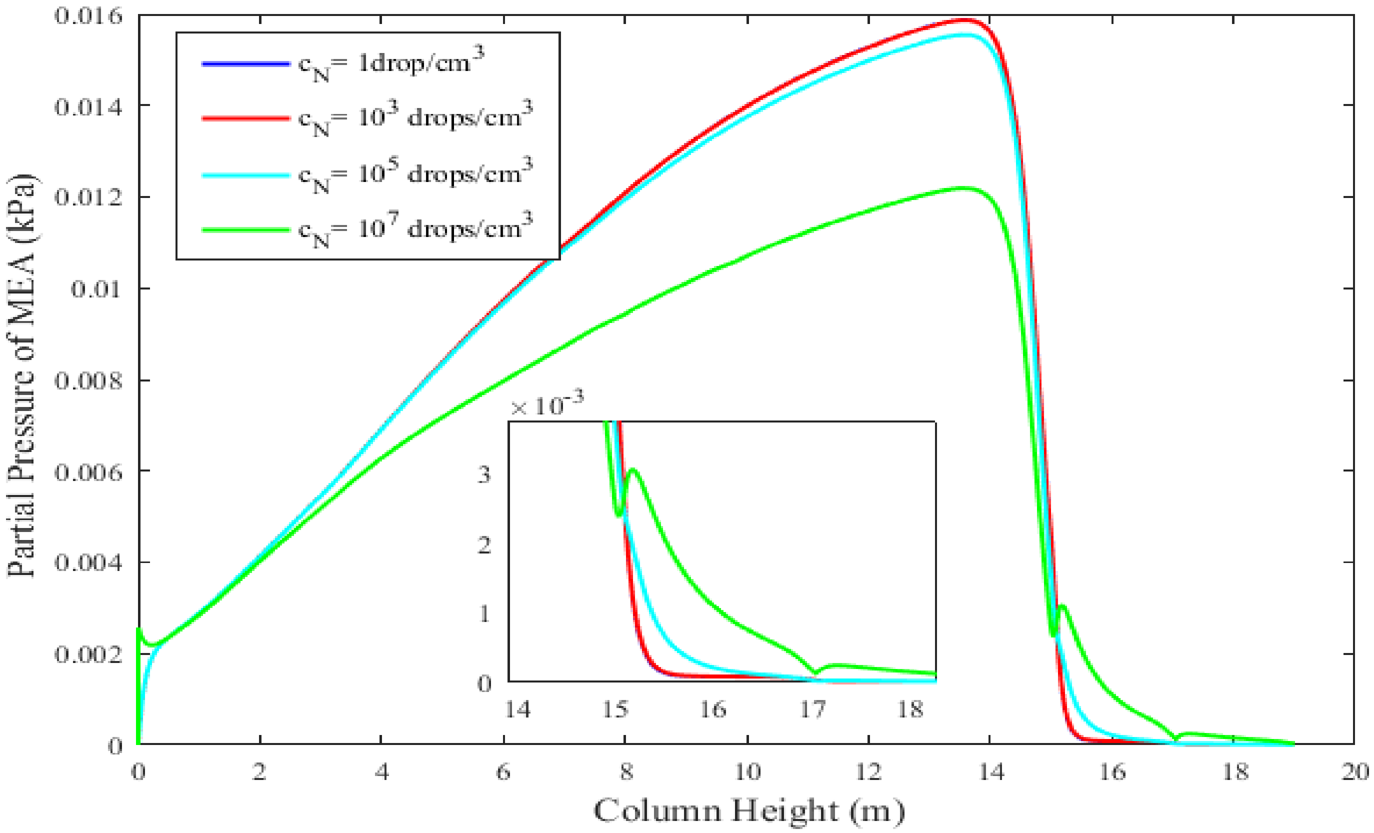


Figure 3: Case1: MEA partial pressure profiles in absorber and water wash

Case 1: Droplet, initial radius 0.15μ, containing 5M MEA travelling from bottom to top of absorber and water wash columns (0-19 m), c_N= 1-10^7 drops/cm^3.

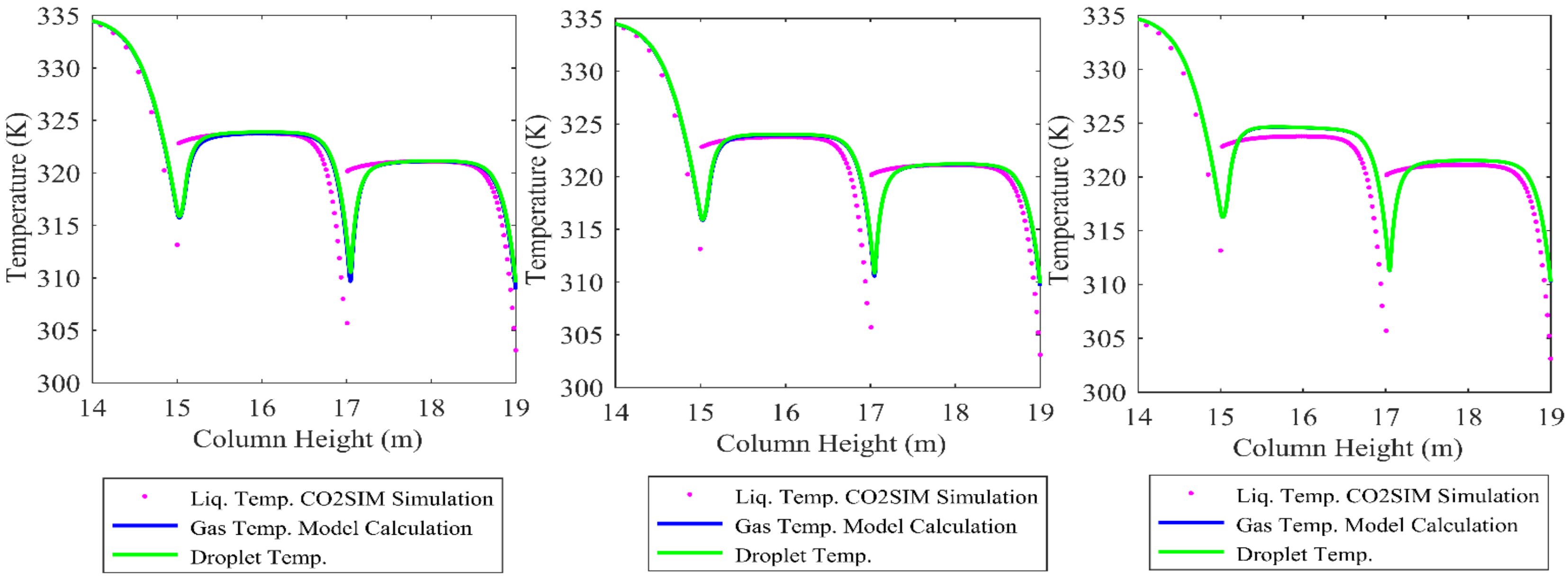


Figure 4: Case 1: Droplet temperature profiles in water wash; (a) $c_N=10^3$ (b) $c_N=10^5$ (c) $c_N=10^7$

Case 2: Droplet, initial radius 0.15μ, containing 0.0001M MEA travelling from bottom to top of absorber and water wash columns (0-19 m), $c_N = 10^3$-10^7 drops/cm^3.

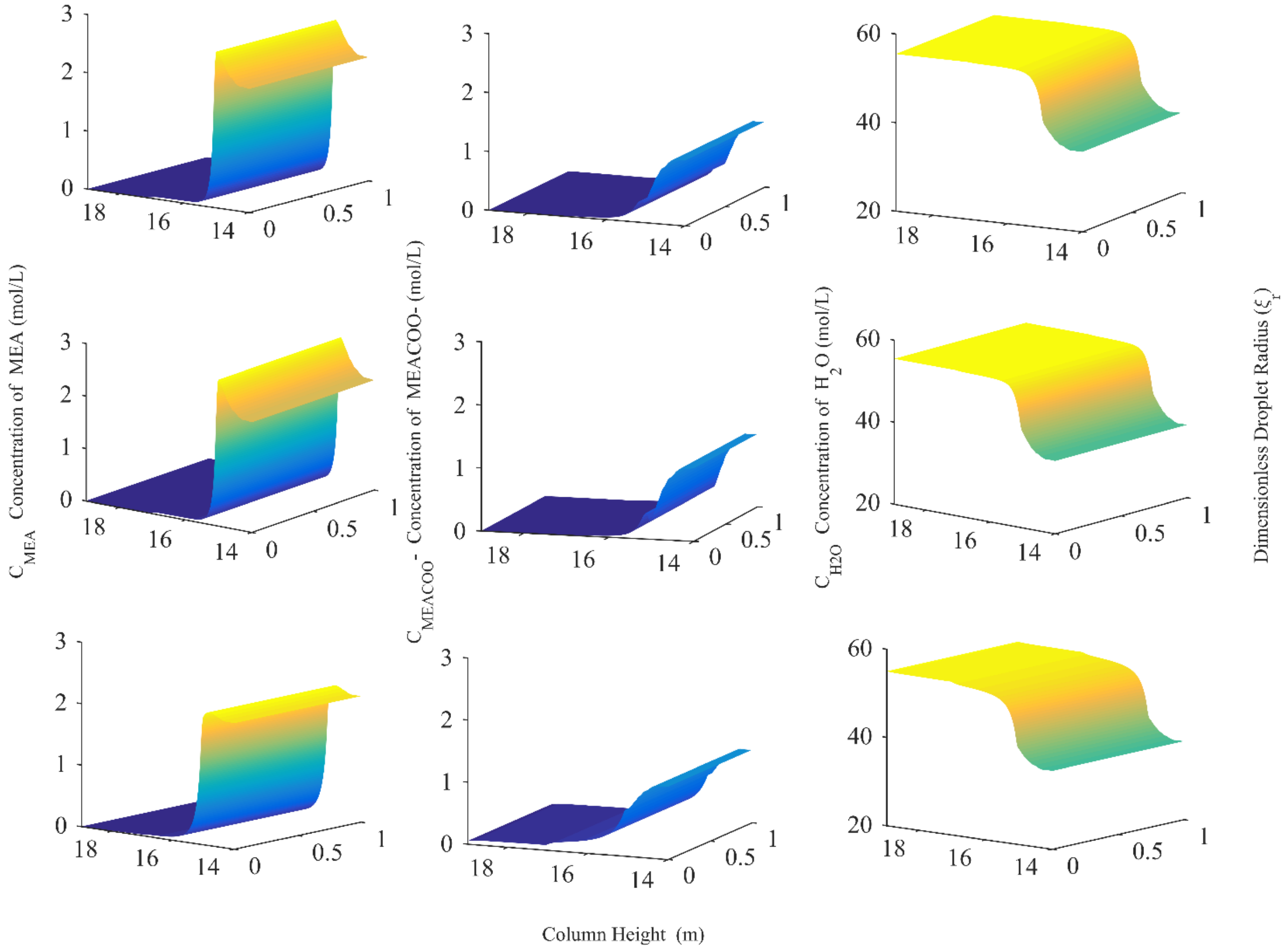


Figure 5: Case 2: Concentration profiles in water wash (a) MEA $c_N=10^3$, (b) Carbamate $c_N=10^3$, (c) Water $c_N=10^3$, (d) MEA $c_N=10^5$, (e) Carbamate $c_N=10^5$, (f) Water $c_N=10^5$, (g) MEA $c_N=10^7$, (h) Carbamate $c_N=10^7$, (i) Water $c_N=10^7$

Case 2: Droplet, initial radius 0.15μ, containing 0.0001M MEA travelling from bottom to top of absorber and water wash columns (0-19 m), c_N= 1-10^7 drops/cm^3.

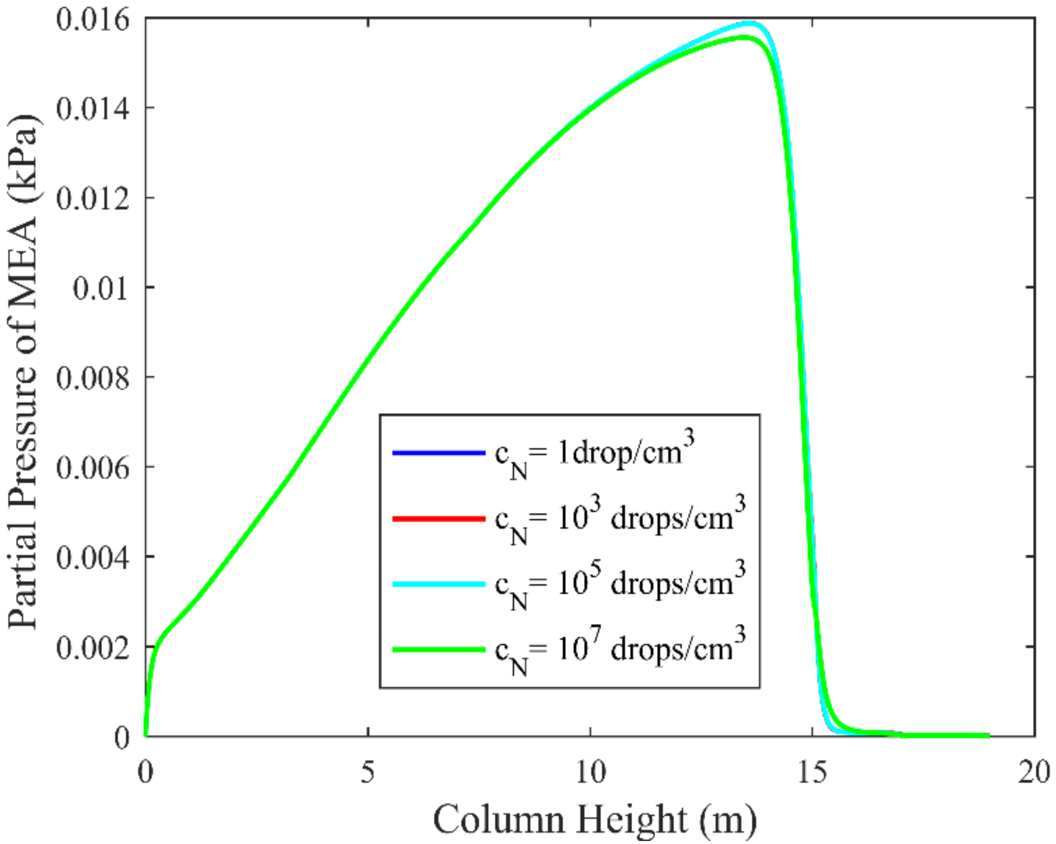


Figure 6: Case 2: Pressure profiles along column

Case 2: Droplet, initial radius 0.15μ, containing 0.0001M MEA travelling from bottom to top of absorber and water wash columns (0-19 m), c_N= 1-10^7 drops/cm^3.

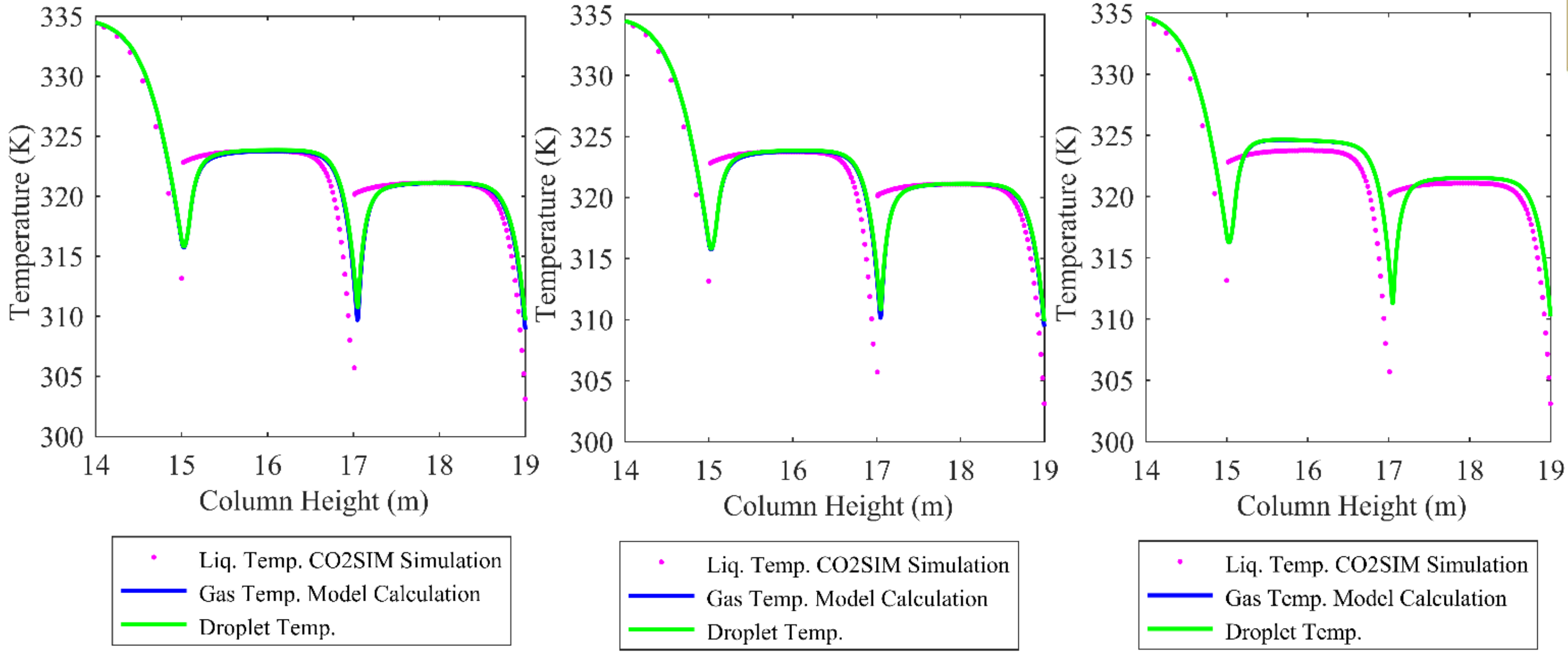


Figure 7: Case 2: Droplet temperature profiles in water wash; (a) $c_N=10^3$ (b) $c_N=10^5$ (c) $c_N=10^7$

Droplet Growth: Case 1 & 2

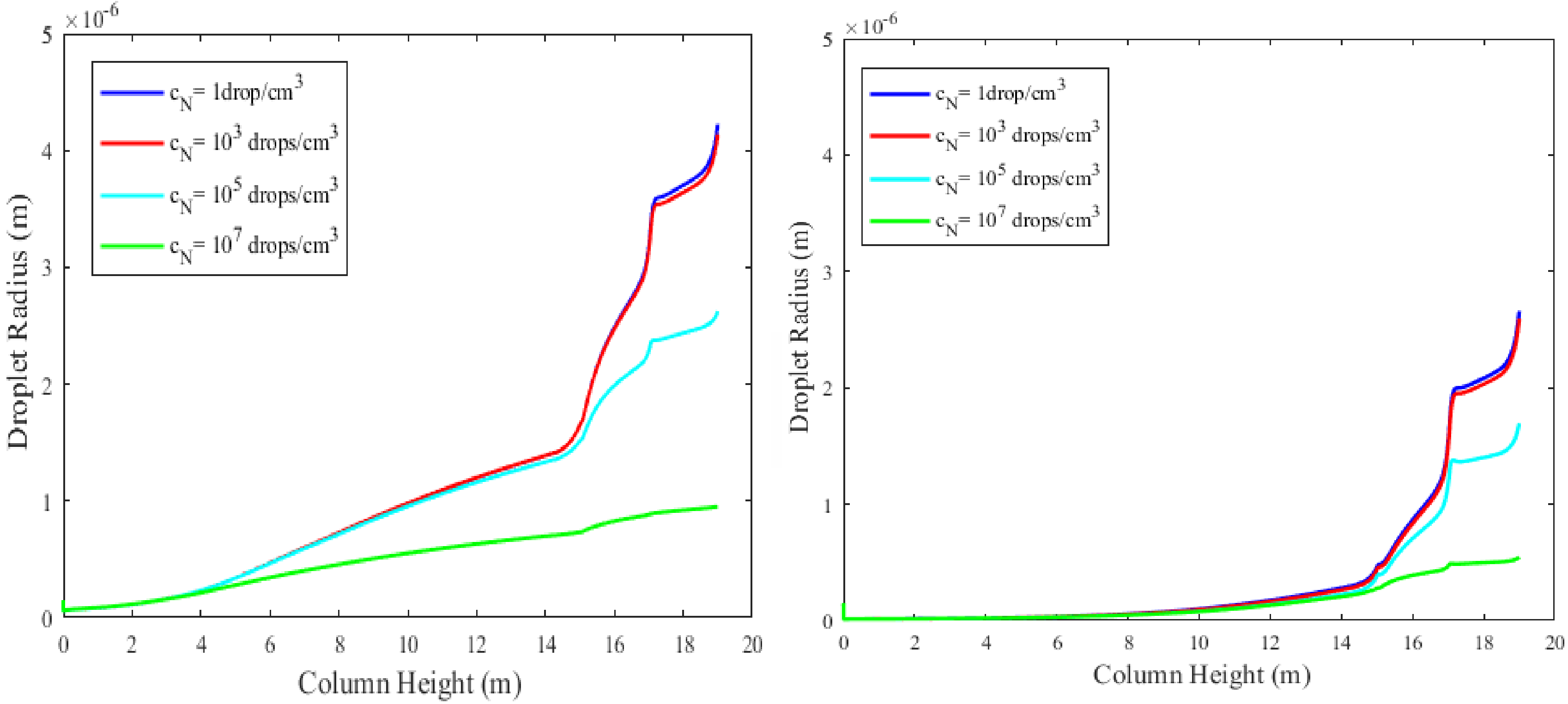


Figure 8: Growth of aerosol droplets with varying droplet number concentration, c_N (a) Case 1 (b) Case 2

Emissions: Case 1 & 2

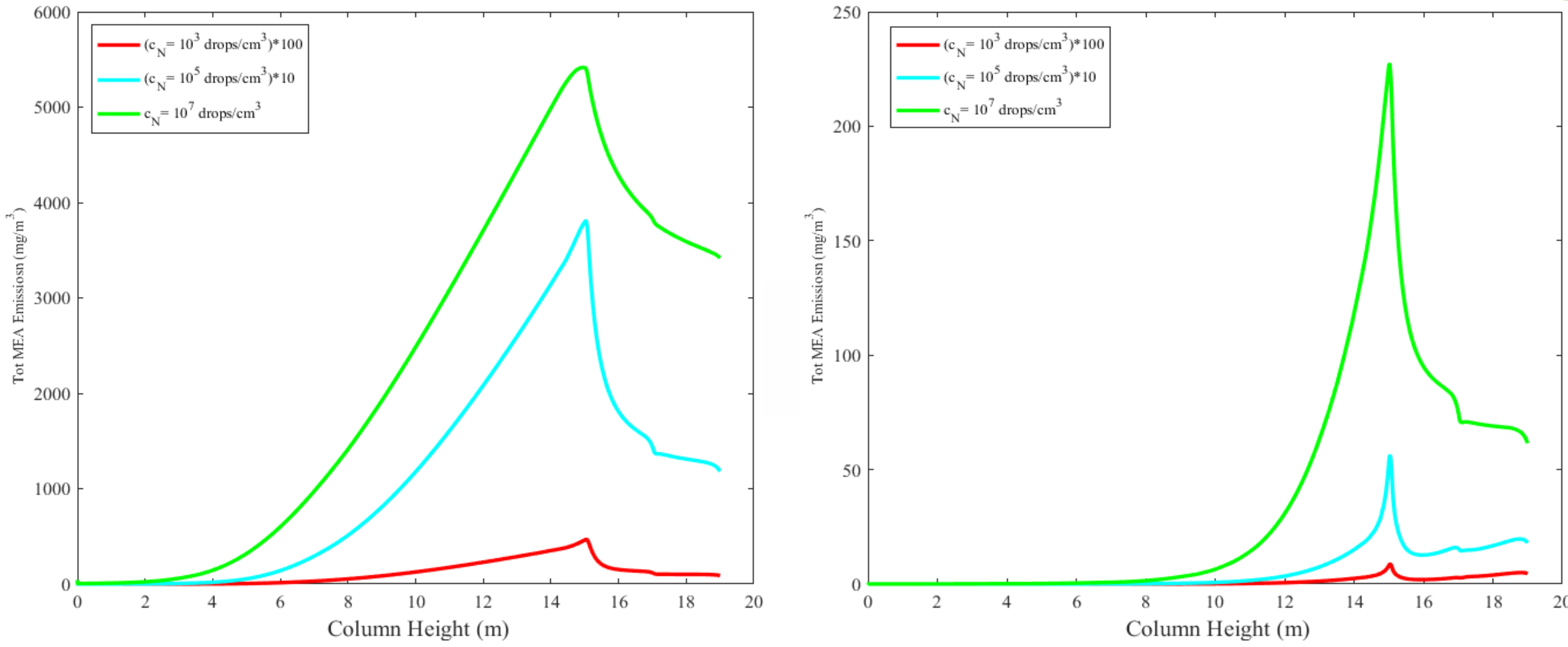


Figure 9: Total amine emissions through out the column (a) Case 1 (b) Case 2

Effect of parameter changes

Case 2 is base case: effect of varying operating and design parameters

Case 3	Case 2: Varying Parameter: Lean solution temperature increased from 40 ^{0}C to 60 ^{0}C
Case 4	Case 2: Varying Parameter: Temperature of first water wash increased from 30 ^{0}C to 40 ^{0}C
Case 5	Case 2: Varying Parameter: Temperature of second water wash increased from 30 ^{0}C to 40 ^{0}C
Case 6	Case 2: Varying Parameter: Water wash height increased from 2m to 2.5m each
Case 7	Case 2: Varying Parameter: Wash water flow rate in both washes doubled from base case

Cases	Final Growth (10^3-10^7 droplets/cm^3)	Total Amine emissions (10^3-10^7 droplets/cm^3)
Case 2 (Base Case)	2.7-0.55 µ	0.05-62 mg/Nm^3
Case 3	3.2-0.58 µ	0.15-66 mg/Nm^3
Case 4	2.56-0.53 µ	0.06-65 mg/Nm^3
Case 5	2.4-0.5 µ	0.1-70 mg/Nm^3
Case 6	2.85-0.55 µ	0.06-61 mg/Nm^3
Case 7	3-0.55 µ	0.03-56 mg/Nm^3

Conclusions & Future Work

- In order to minimize aerosol emissions from absorption based CO_2 capture plants a deep understanding of the mechanisms relating to droplet formation and growth is necessary.
- Water wash systems are mainly intended to control gaseous emissions from absorption columns, but results indicate that water wash systems can be an effective method also for reducing mist-born emissions through desorption of amine from aerosol droplets.
- Initial droplet number concentration plays a crucial role in final droplet growth by affecting the gas phase amine partial pressure.
- Droplet sizes are increased by a factor of 2-8 from absorber section outlet to wash section outlet. Largest increase for low droplet number concentrations.
- Droplet growth is very sensitive to gas phase amine depletion.
- Varying operating conditions influence final growth and emissions, in particular for low and medium droplet number concentrations.
- A multi droplet model representing the initial and final size distributions, as well as more work on defining the inlet particle conditions are needed.

Acknowledgment

The faculty of Natural Science, Norwegian University of Science and Technology, the CLIMIT Demo project Aerosolve (616125) with partners SINTEF Materials and Chemistry, Technology Center Mongstad, Maasvlakte CCS project (ROAD), Uniper, Engie Laborelec and TNO

Thank you

For Questions

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