Optimization of a sour compression unit for CO_2 purification applied to flue gases coming from oxy-combustion cement industries

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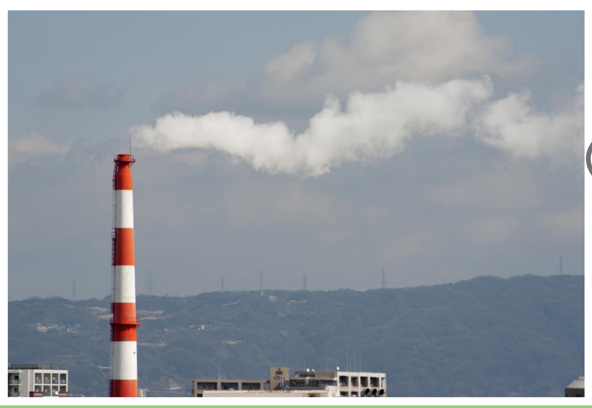
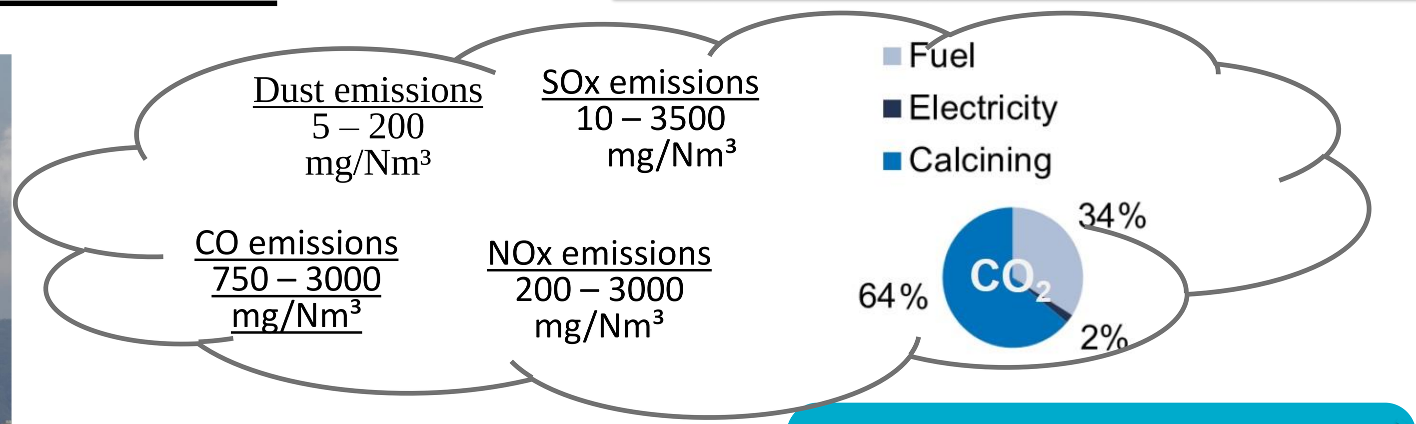
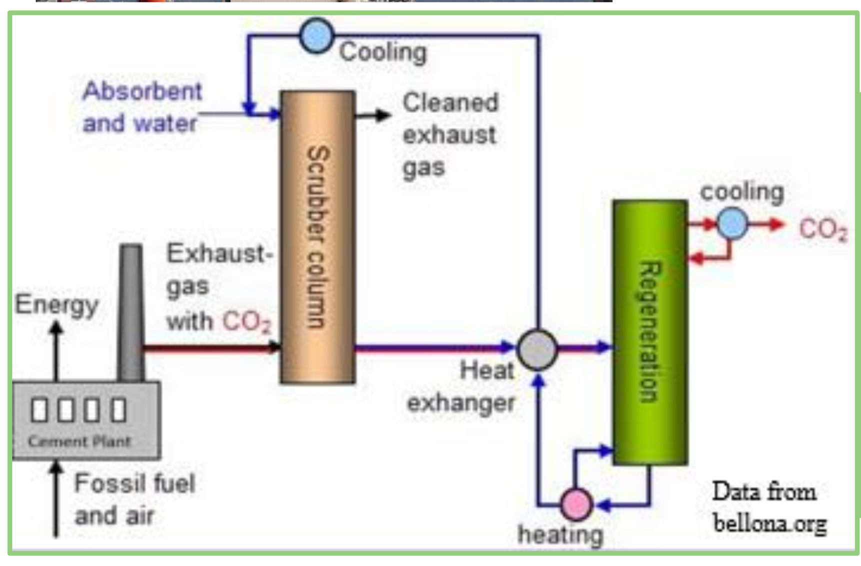
CONTEXT OF THE STUDY

Emissions from cement industries:







Post-Combustion Capture

y_{CO2} = 20 to 30 %

→ End of pipe technology where the CO_2 in the flue gas is captured at the outlet of the industrial process.

SOLUTION: CO_2 Capture

Partial Oxyfuel Combustion Capture

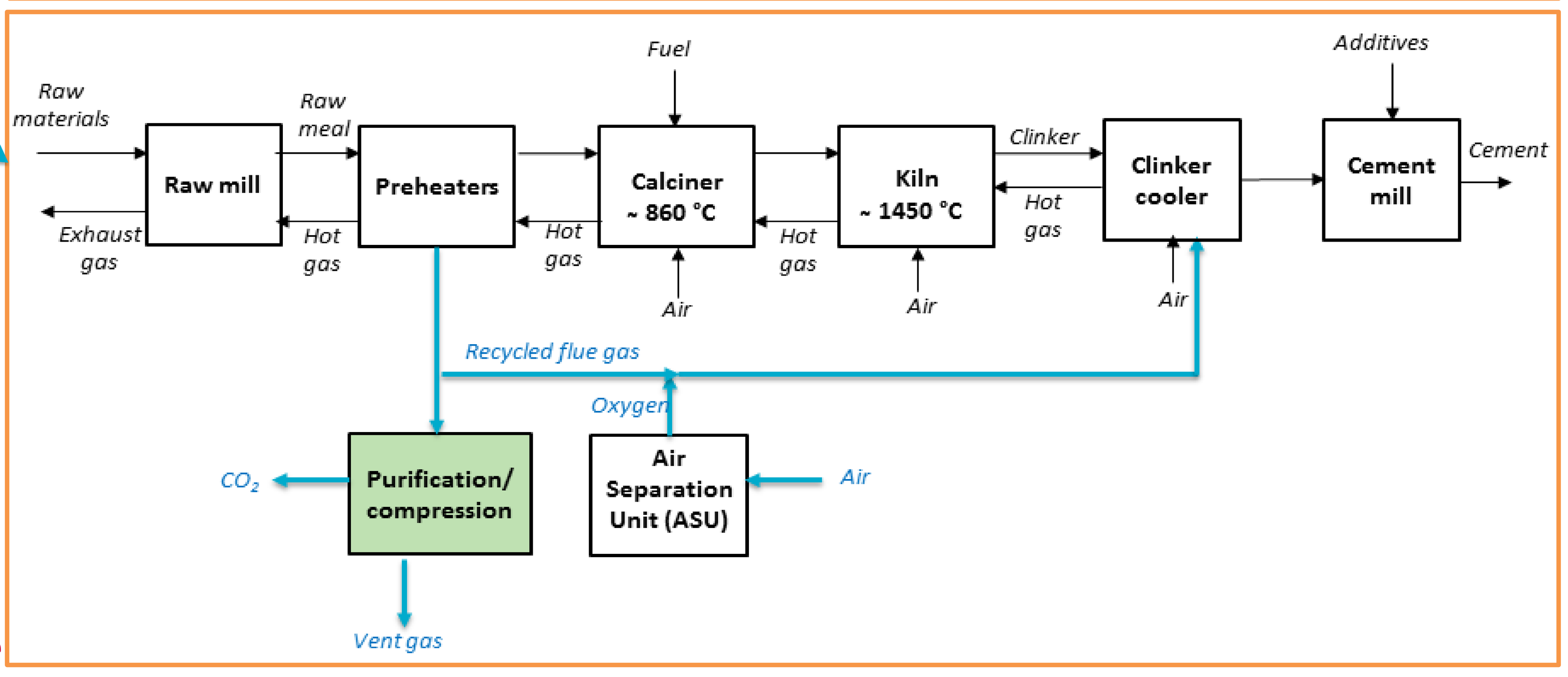
30 %<y_{CO2}<70 %

INNOVATION FOR THE CEMENT INDUSTRY !

Oxyfuel Combustion Capture 70%<$Y_{CO2, out}$<90%

→ Combustion with only oxygen : utilization of an Air Separation Unit (ASU)

→ High purity level of CO_2 at the outlet of the process



ECRA Chair at UMONS :

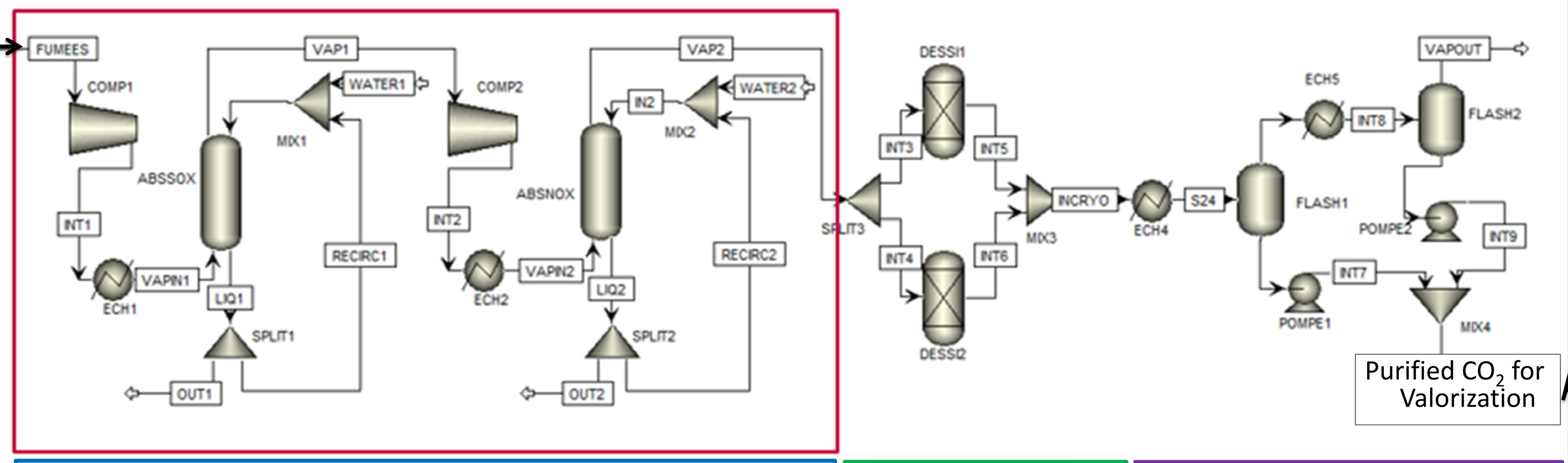
CO_2 Capture → CO_2 Purification → CO_2 re-Use

CO_2 PURIFICATION UNIT (CPU)

Purpose of the study: Optimization of the CPU applied to oxyfuel cement plants thanks to Aspen Plus[TM] simulations

Oxygen production Unit → O_2 → Oxyfuel Cement Plant → CO_2 to purify → CO_2 Pretreatment Dedusting (FF/BH/ESP)

Electrolysis of water 6.3 MWh/t(CO_2) capt



1) Sour-Compression Unit | 2) Dehydration Unit | 3) Cryogenic Unit

CO_2 Capture & Storage **CCS**

CO_2 Capture & re-Use **CCU** **ECRA CHAIR** → CO_2 Conversion into CH_3OH

Hydrogen production by electrolysis using renewable energy

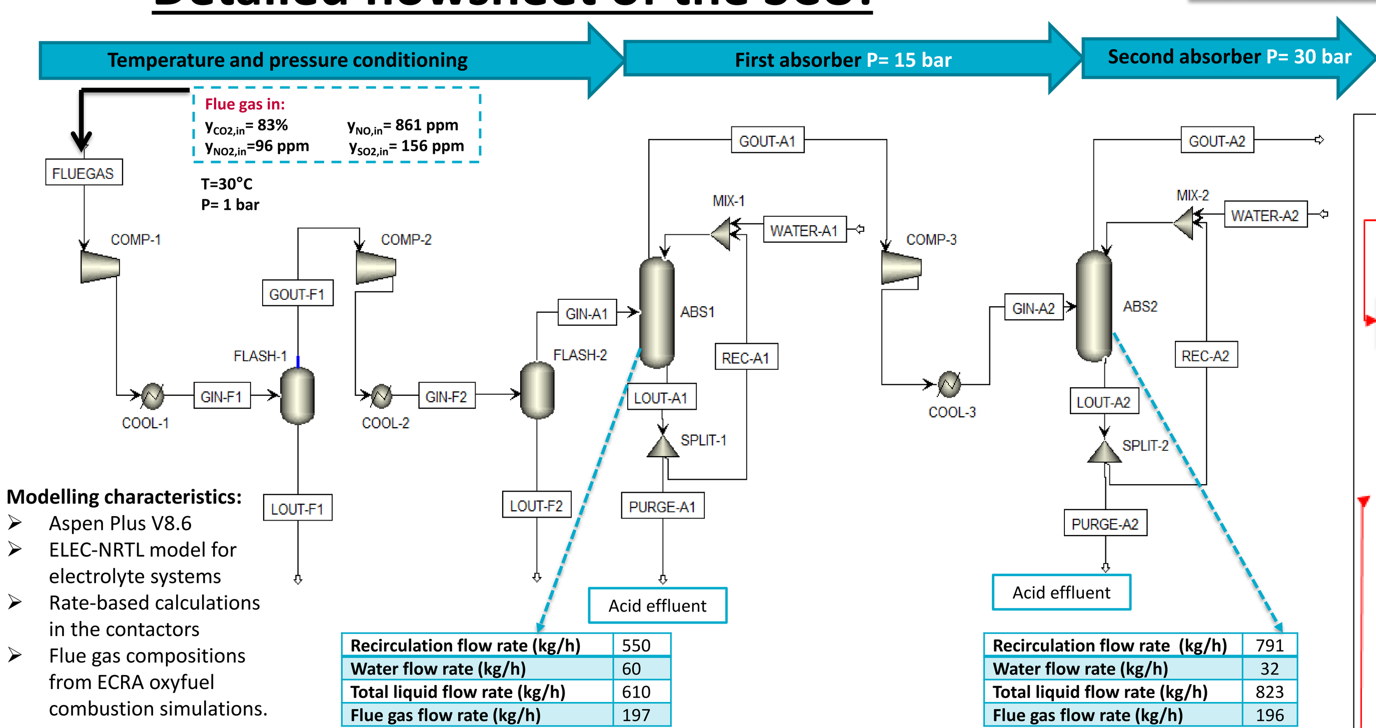
1) Sour Compression Unit (SCU): the CO_2 is compressed and separated from its NOx and SOx components.

2) Dehydration unit : Temperature Swing Absorption (TSA) dual-bed where water is absorbed at high pressure (30 bar) onto a solid adsorbent which can be silica gel, activated alumina or molecular sieve alumina.

3) Cryogenic unit: it fixes the CO_2 purity of the final product and the CO_2 recovery of the overall process. The gas coming from the dehydration unit is cooled and flashed in a first flash at 30 bar. The vapor stream is then cooled and flashed anew in a second flash with a lowest temperature of -55°C to avoid the formation of dry ice (solid CO_2) at this pressure. Liquid streams from both flashes are mixed and compressed to 110 bar for transport or storage.

SOUR COMPRESSION UNIT (SCU)

Detailed flowsheet of the SCU:



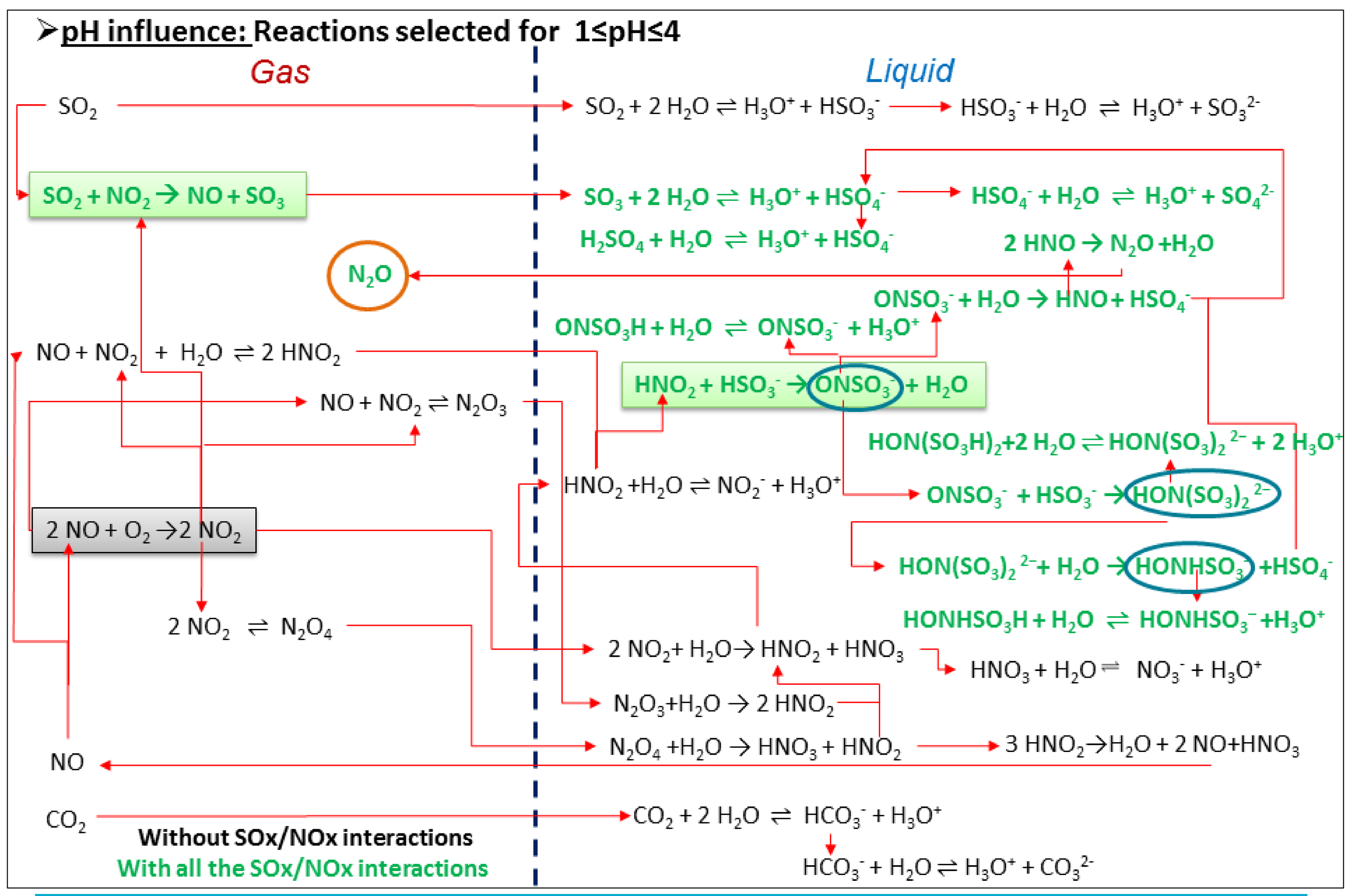
Recirculation flow rate (kg/h)	550
Water flow rate (kg/h)	60
Total liquid flow rate (kg/h)	610
Flue gas flow rate (kg/h)	197

Recirculation flow rate (kg/h)	791
Water flow rate (kg/h)	32
Total liquid flow rate (kg/h)	823
Flue gas flow rate (kg/h)	196

Modelling characteristics:

- Aspen Plus V8.6
- ELEC-NRTL model for electrolyte systems
- Rate-based calculations in the contactors
- Flue gas compositions from ECRA oxyfuel combustion simulations.

Final selection of SOx/NOx interaction reactions to integrate in Aspen Plus



N-S complexes ionic species	N-S complexes molecular species
Nitrososulfonate	Nitrososulfonic acid
$ONSO_3^-$ alias NSS	$ONSO_3H$ alias NSSH
Hydroxylamine N,N-disulfonate	Hydroxylamine N,N-disulfonic acid
$HON(SO_3)_2^{2-}$ alias HADS	$HON(SO_3H)_2$ alias HADSH
Hydroxylamine N-sulfonate	Hydroxylamine N-sulfonic acid
$HONHSO_3^-$ alias HAMS	$HONHSO_3H$ alias HAMSH

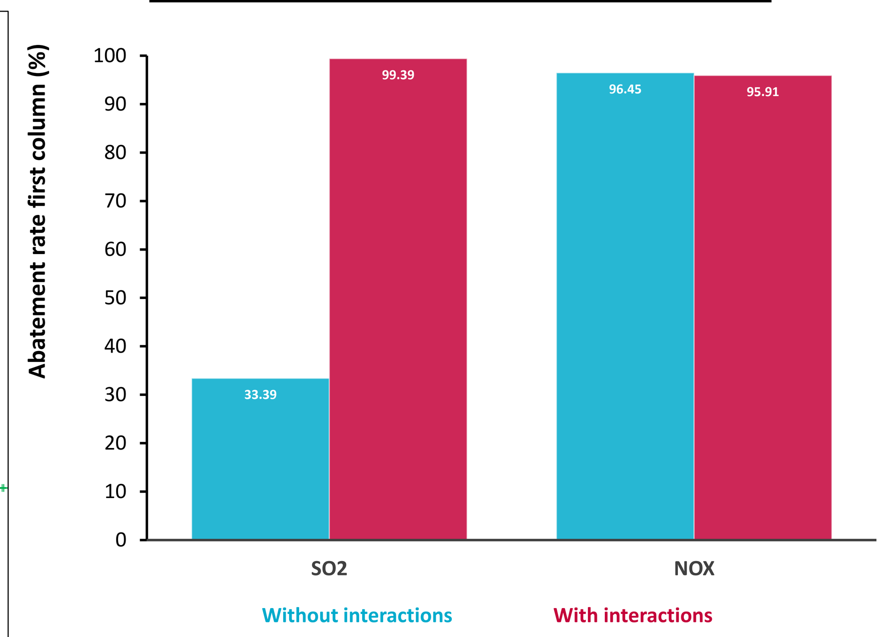
Optimization of the SCU chemical mechanism:

Literature sources indicate that SOx/NOx interactions influence is essential into the absorption chemical mechanism:

- New reactions are chosen considering the reactivity strong dependence on pH.
- Interactions between HNO_2 (and NO_2^-) and hydrogen sulfite (HSO_3^-) considered because they are initiated under acidic conditions for pH<5.
- The important intermediate NSS ($NOSO_3^-$) is formed.
- NSS may react to form either N_2O and H_2SO_4 directly or complex nitrogen-sulphur compounds, e.g., HADS ($HNO(SO_3)_2^{2-}$) and HAMS ($HNOHSO_3^-$).
- Competition between N_2O formation/HADS and HAMS formation at pH=2.

  →So in our case, in the intermediary conditions for 1 ≤ pH ≤ 4, a competition between three reactions were observed: production of N_2O, production of HADS and acidic hydrolysis of HADS.

Simulation of the process with the new chemical mechanism:



- Interactions effect: SO_2 abatement rate ↗
- ~Same NOx abatement rate with and without interactions.

Further studies: parametric study for the optimization of the SCU:

Variation of :

- Recirculation rate
- Water flowrate
- Operational pressures
- SO_x & NO_x initial concentrations

Energetic and economic optimizations → One column process with the same absorption performances

CONCLUSION AND PERSPECTIVES

- ✓ SCU Chemical mechanism completed considering SOx/NOx interactions under 1 ≤pH≤ 4
- ✓ New chemical mechanism implemented in Aspen Plus[TM]
- ✓ Interest of considering interaction reactions proved
- **Further results will include an optimization of the financial, energetical and environmental costs of the global process applied in the cement industry→ Parametric study & One column process with the same absorption performances.**

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