TECHNOLOGY CENTRE MONGSTAD

– catching our future

New Insights From CESAR1 Solvent Testing at Technology Centre Mongstad: Thermal Reclaiming and Emissions Control

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Content

- TCM Overview
- CESAR1 Campaigns at TCM
- Thermal Reclaiming
- Emissions Control with RFCC Flue Gas
- Conclusion

TCM Overview

Tested 17 different Technologies

> 40.000 hrs
Proprietary Campaigns

Solvent Technologies

Start 2012

Capturi | ALSTOM | Cansolv 1st campaign | Carbon Clean Solutions | Cansolv 2nd campaign | ION | FLUOR | MITSUBISHI HEAVY INDUSTRIES | RTI INTERNATIONAL | Cansolv 3rd campaign | ION 2nd campaign | Honeywell

>2025

Start 2020

Emerging Technologies

MTR | TDA | SAIPEM ACCSESS | PROSPIN ACCSESS | MOF4AIR | InnoSepra | Svante

Sponsored by TCM Owners, DOE, EC and CLIMIT

> 23.000 hrs
Non-proprietary Campaigns

> 70
Scientific publications

2013

>2025

MEA-1 | MEA-2 | MEA-3 | MEA-4 | MEA-5 | Align-CCUS | CESAR-1 | AURORA | Owners Campaign

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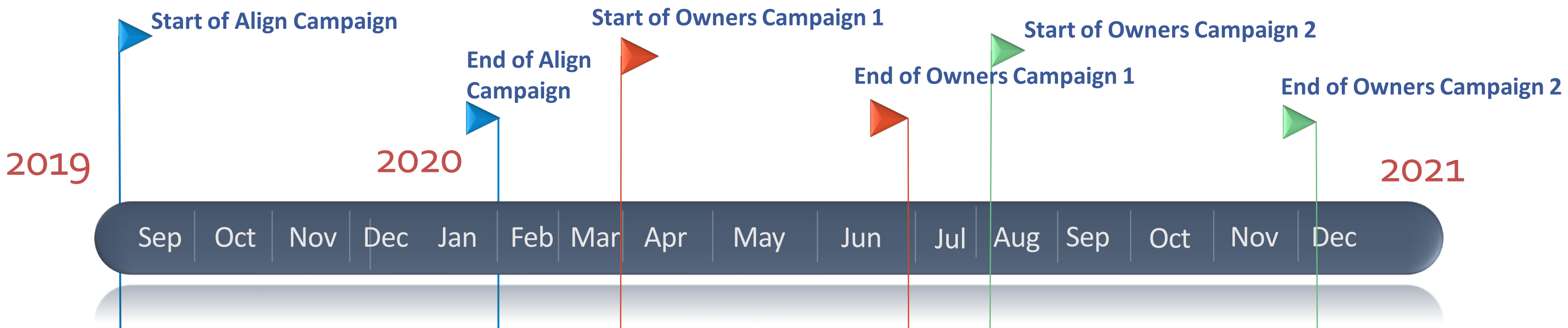
TCM's CESAR1 Campaigns Overview

TCM CESAR 1 CAMPAIGNS 2019-20



- Testing with CHP Flue Gas (FG)
- Some CO_2 recycling tests
- Precipitation tests
- Capture Rates of 85, 90 & 98%
- 12m, 18m & 24m packing height

- Testing with CCGT FG
- 1st Thermal reclaiming
- Parametric testing
- 5% CCGT Flue Gas
- EPRI Baseline (CCGT)

- Testing with “SMR” FG
- 2nd Thermal reclaiming
- Testing with RFCC FG
- EPRI Baseline (RFCC)
- Transient testing (ICL/SSE)

ALIGN CCUS

CESAR1 OWNERS 1

CESAR1 OWNERS 2

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Thermal Reclaiming

Main sources of amine degradation

Thermal degradation

Oxidative degradation

Reaction with NO_x

Metal catalysed

Other mechanisms e.g., degradation in the presence of SO_2 and sulfite

E. Alhseinat et al., International Journal of Greenhouse Gas Control 37 (**2015**) 280.

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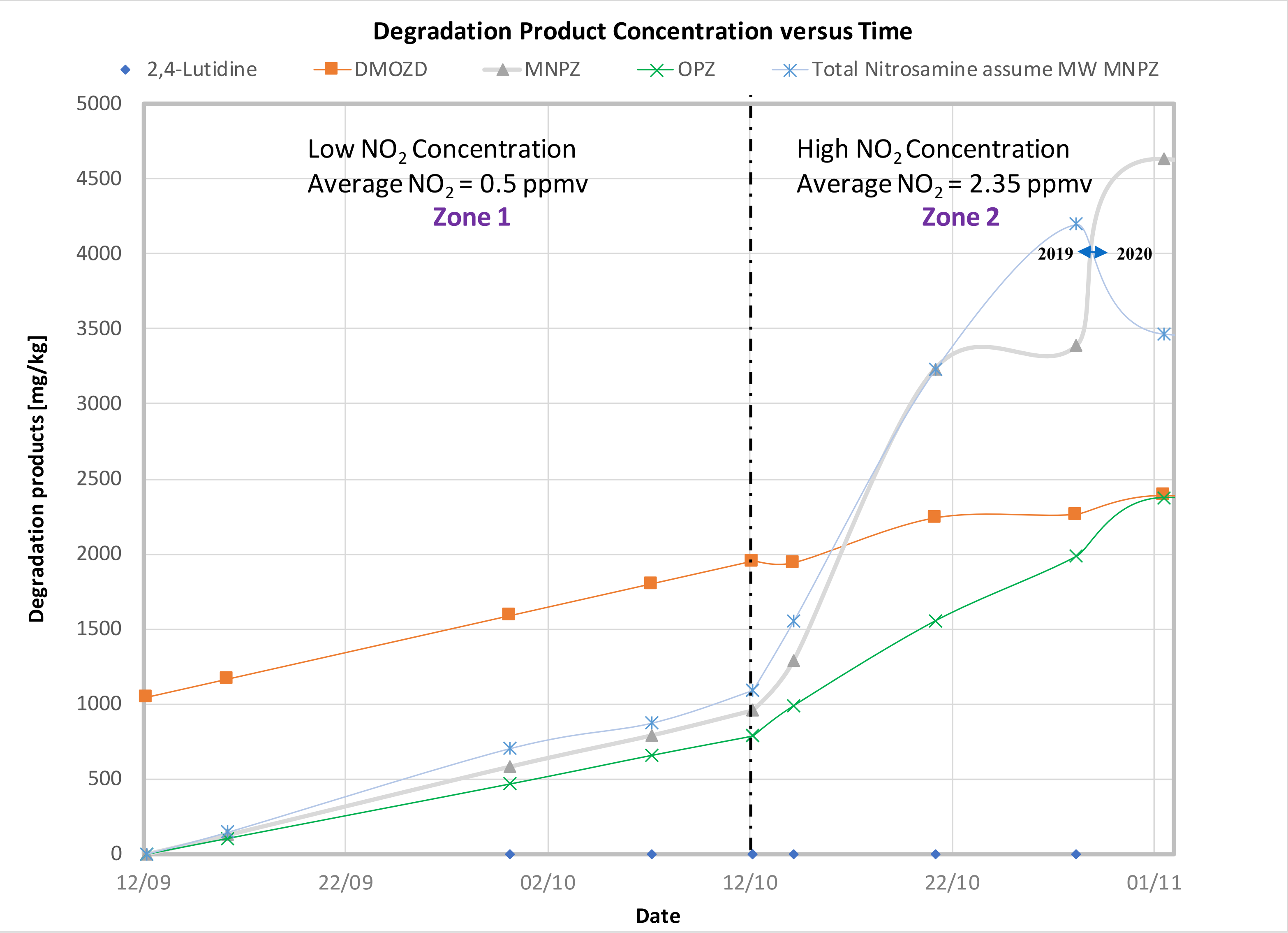
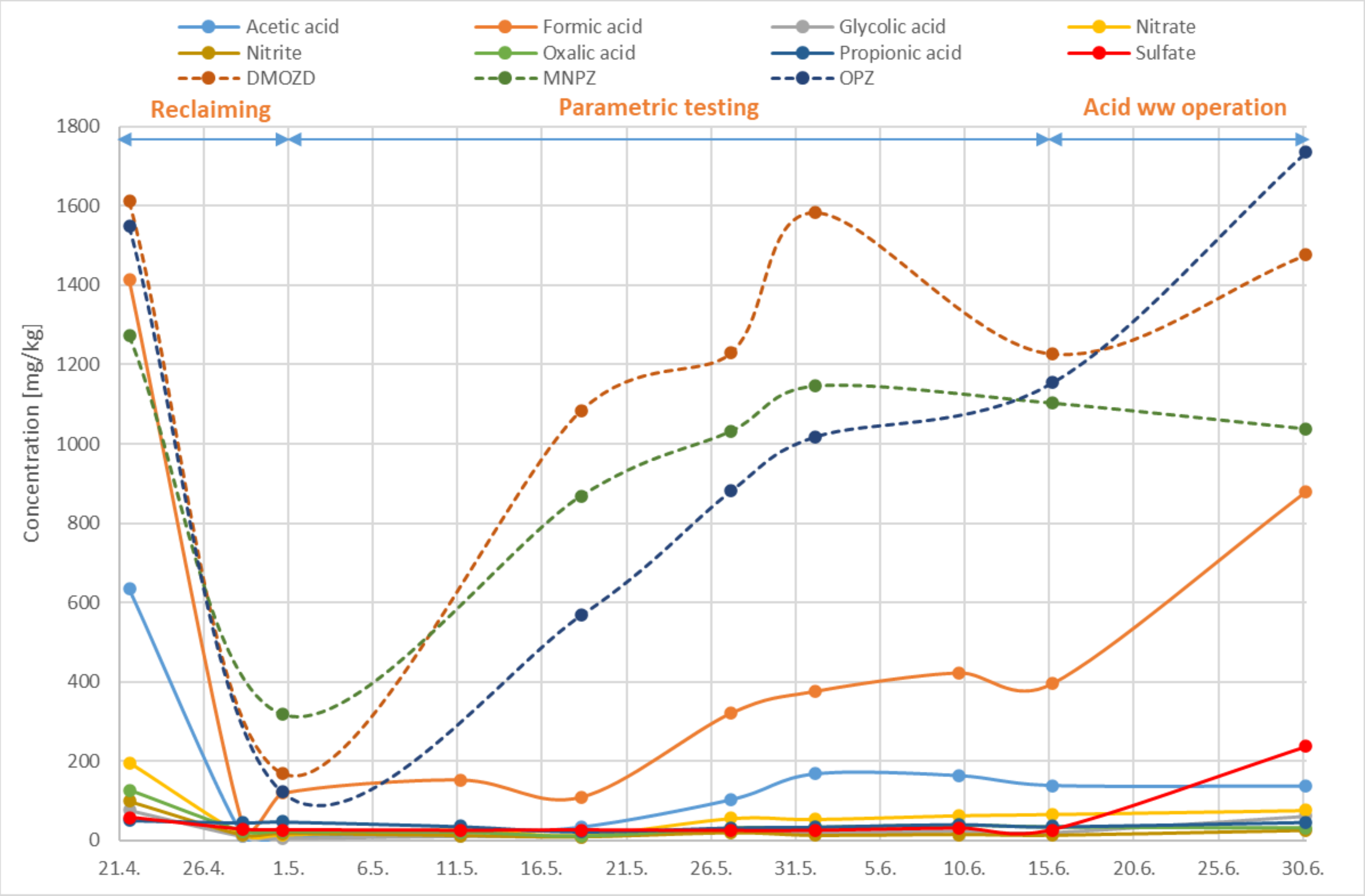
CESAR1 solvent degradation profiles during ALIGN-CCUS



- Testing with CCGT flue gas type
- Rate of Piperazine degradation products increased in High NO_2 region
- Higher NO_2 caused by reduction in ammonium injection into SCR

Solvent degradation during CESAR1 campaign 1

- Solvent degradation products increase after ALIGN campaign.
- Significant decrease during reclaiming.
- Degradation products increased after reclaiming at different rates:
  - Some back to levels before reclaiming.
  - Most kept at relatively low levels.



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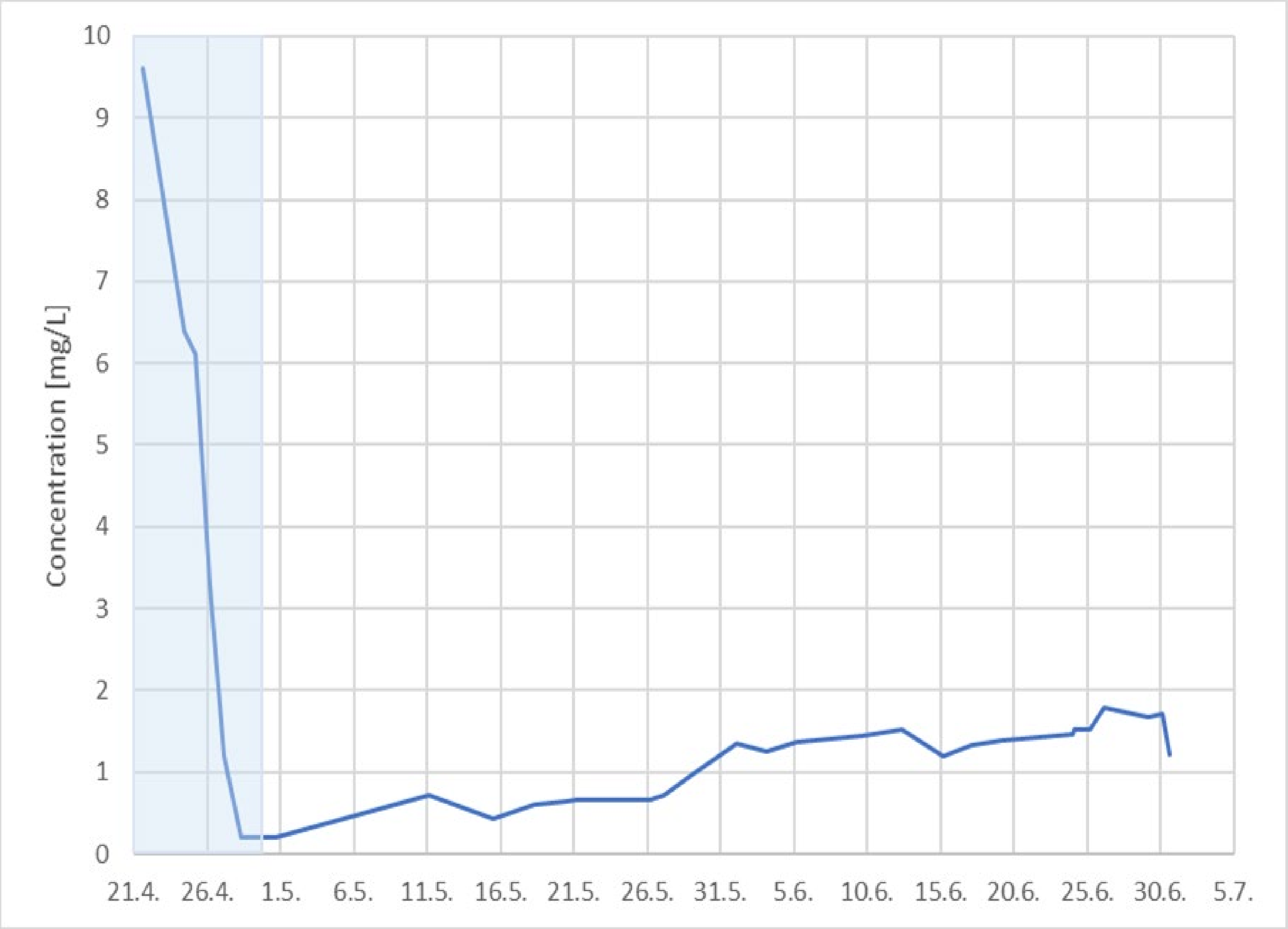
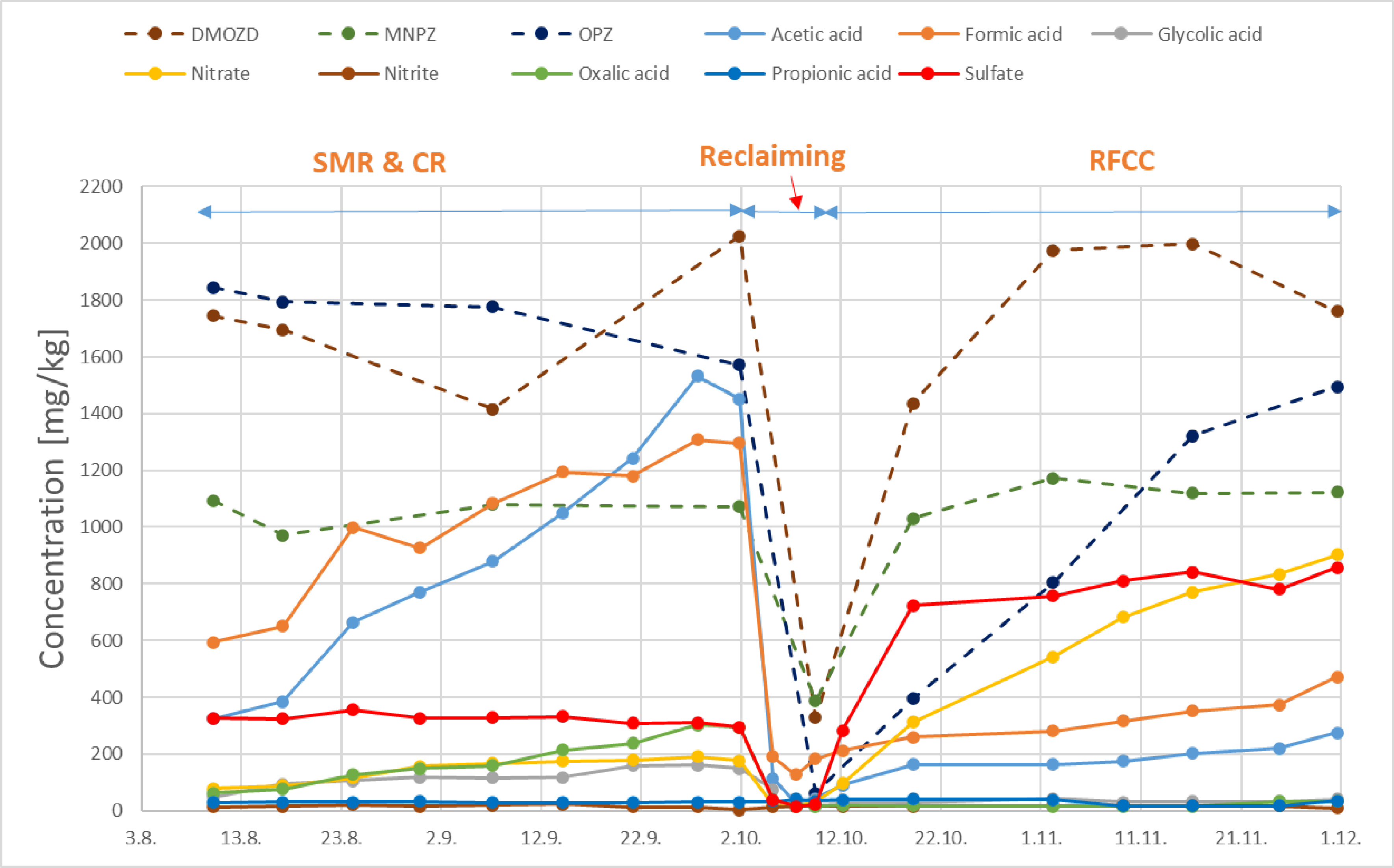
Iron content during CESAR1 campaign 1

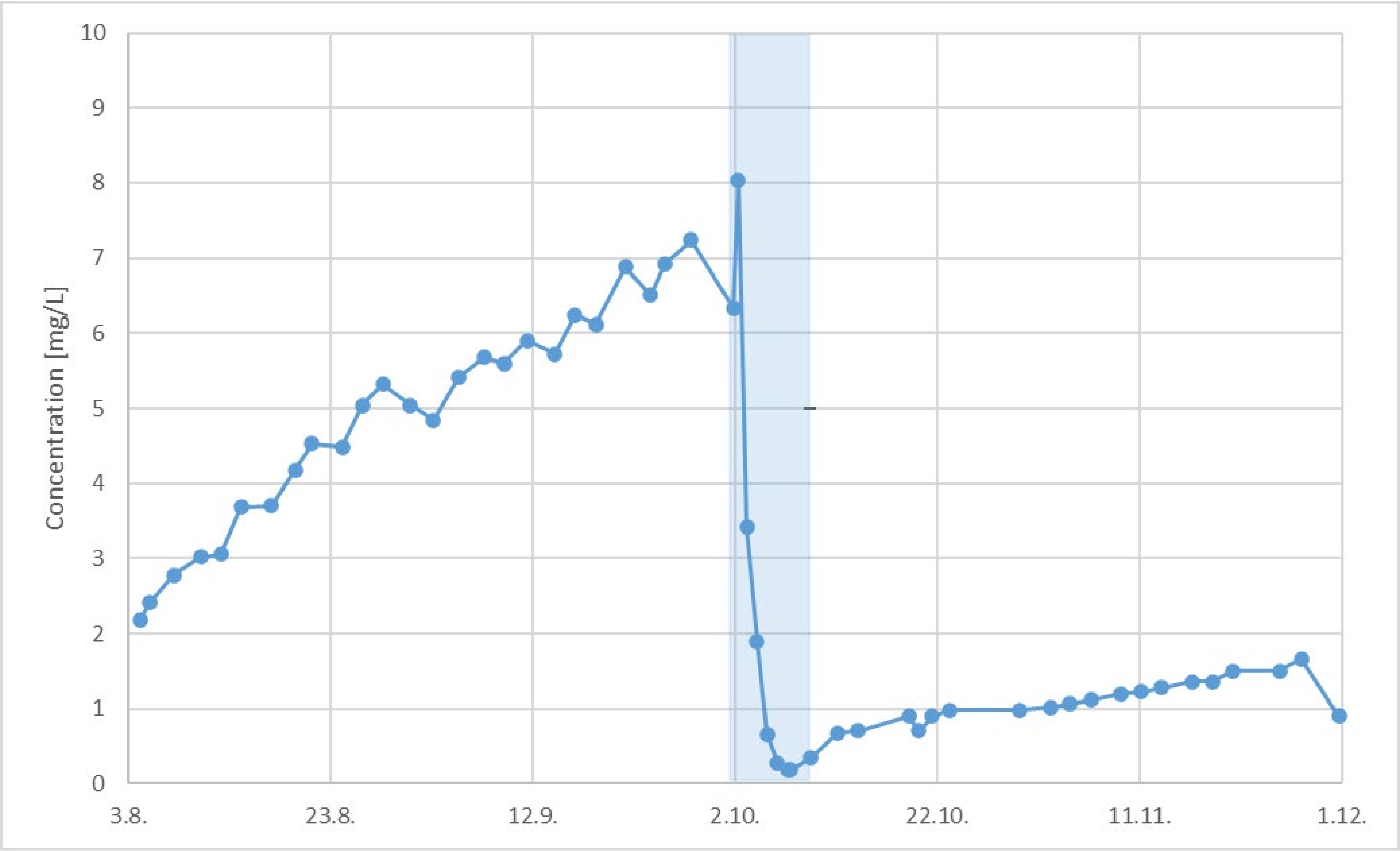
- Iron content increase during ALIGN campaign.
- Significant decrease during reclaiming.
- Iron has been increased steadily throughout the campaign at relatively low levels < 2 mg/L.



HSS and degradation products during CESAR1 campaign 2



Iron content during the Owners campaign 2



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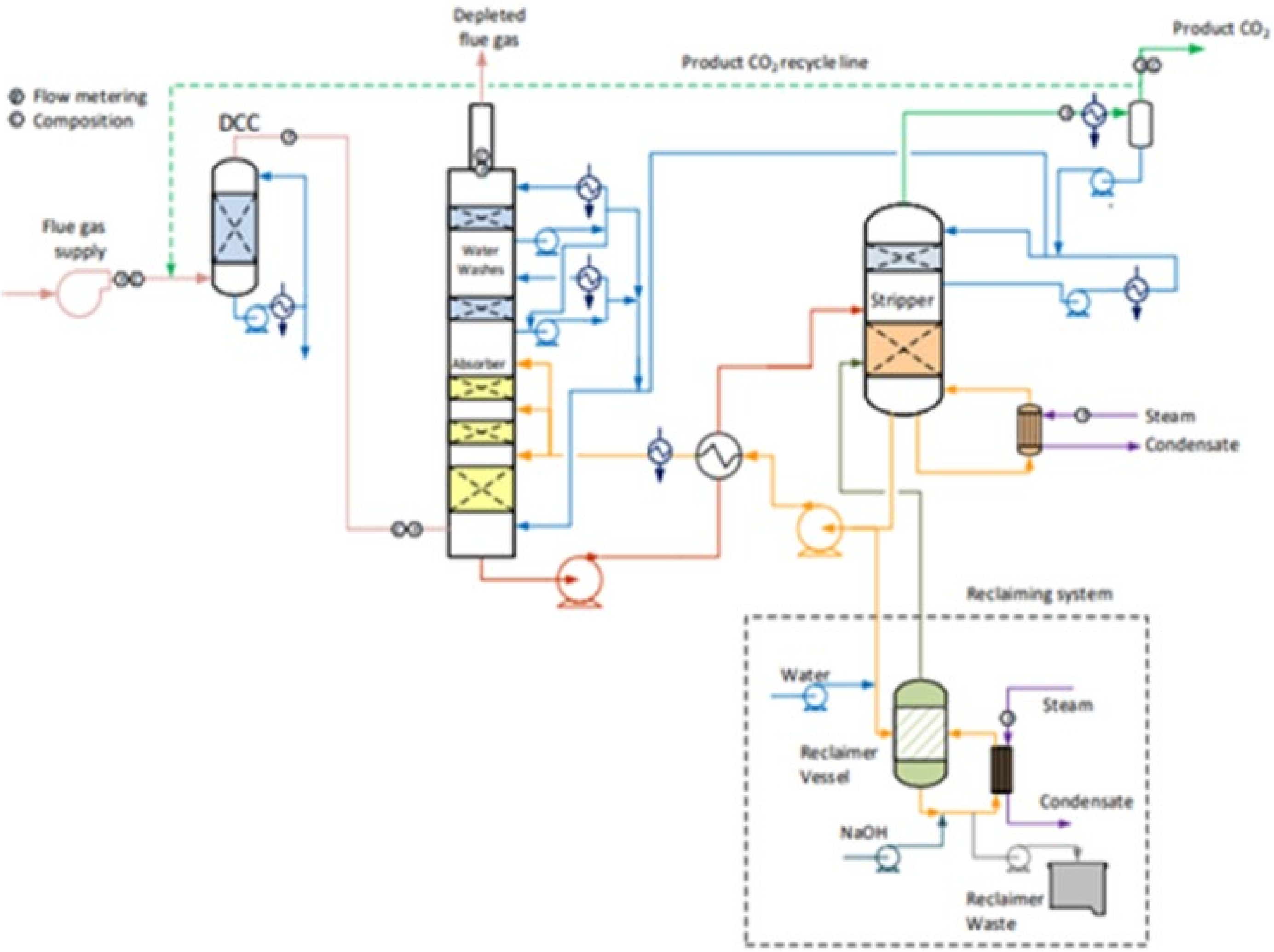
The Reclaiming Process

- Batchwise → semi-continuous reclaiming
- Slip stream of lean amine circulated to reclaimer vessel
- The solvent is heated by steam
- Caustic is added to liberate amine
- Slip stream is stopped and water added during boil-off
- Amines are boiled off and led back to stripper
- Degradation products and metals are accumulated in the vessel during amine feed and removed after the boil-off



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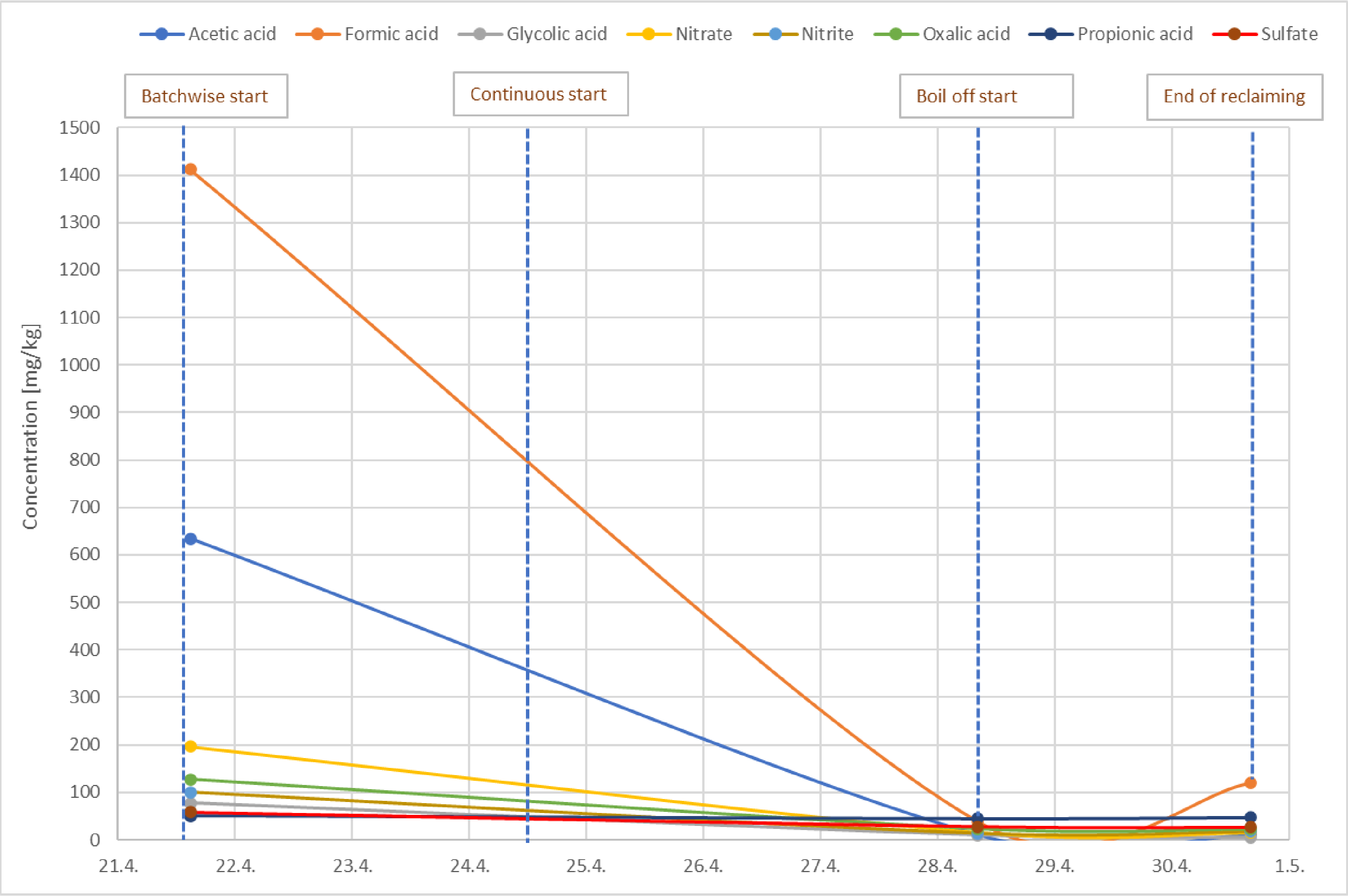
Anions concentration during Reclaiming.



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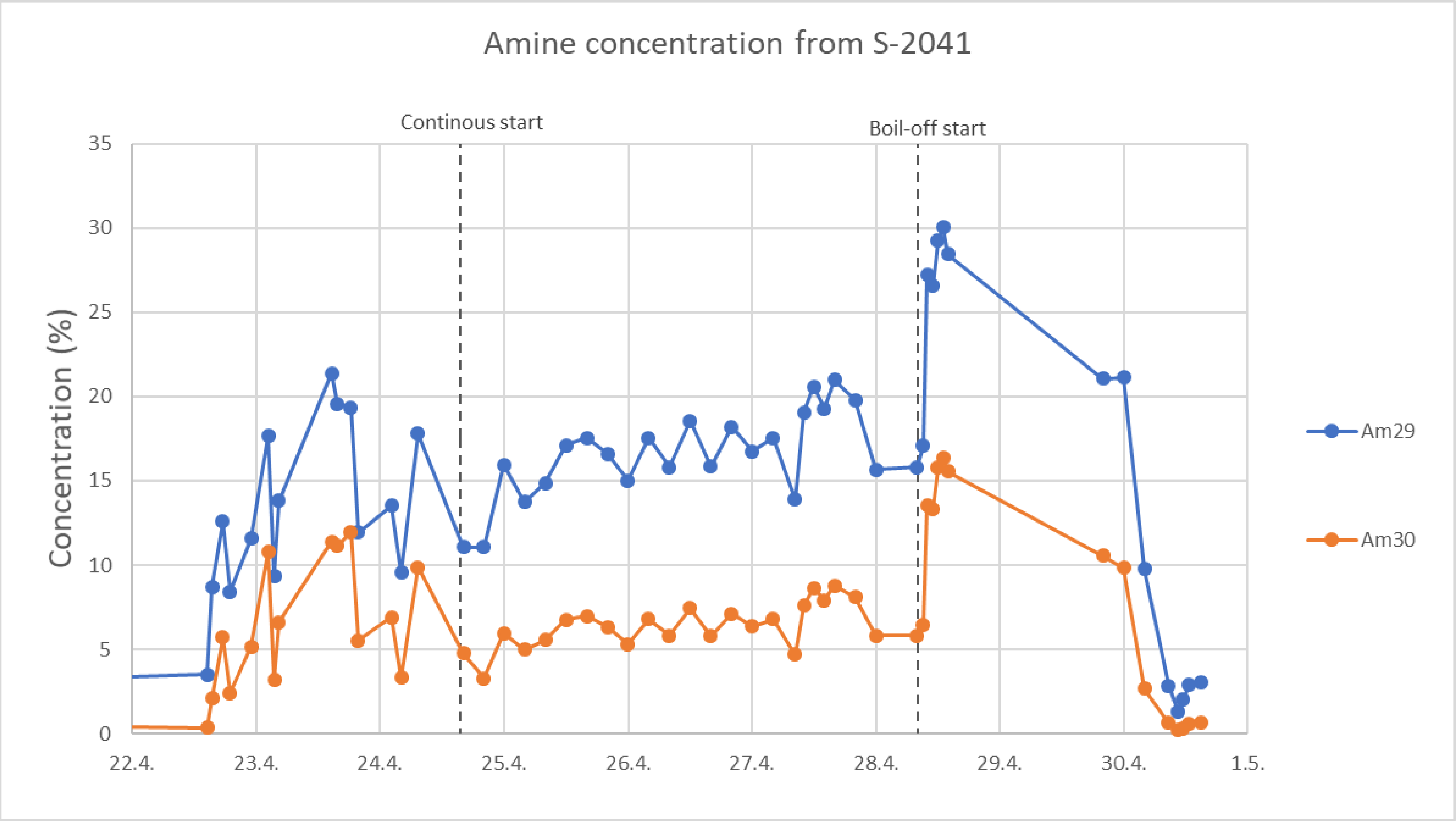
Individual AMP and PZ Concentration From Reclaimer back to the process



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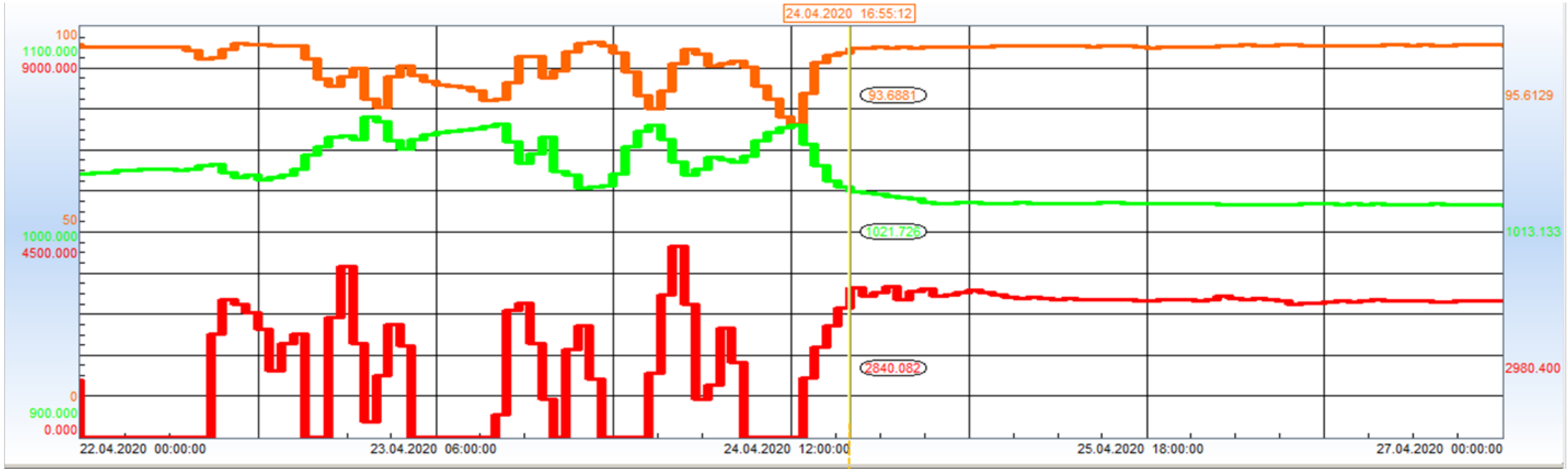
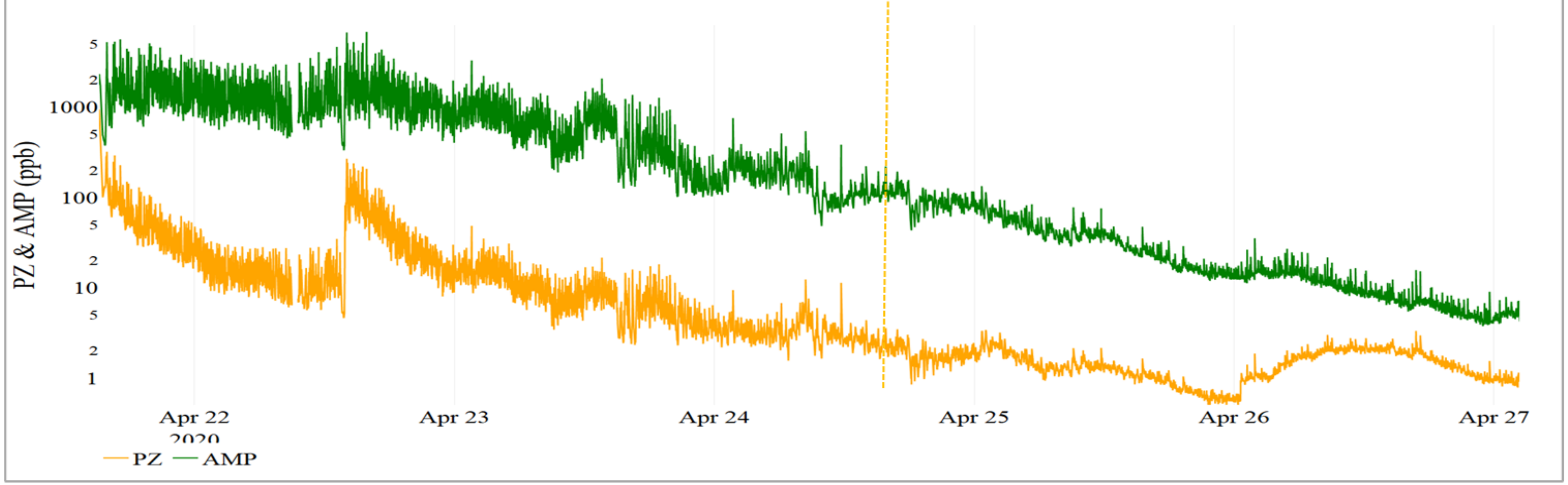
Solvent color change

AMP & PZ Emissions during Reclaiming



	Name	I	Description	Value	I	Aut	Plot Min	Plot Max	Units	S	TZ	Type	Period	N	Ste	Ext
	=(1-{8610-AI-2030A}/{8610-AI-2004A})*100	:	Ad-hoc Calculation	95.6129	(	☐	0	100	Undefined	0		Average	1 Hour	V	☑	☐
	8611-dt-2143	:	Mager Amin Til Absorbator	1013.13:	(	☐	900.000	1100.000	kg/m3	0		Average	1 Hour	V	☑	☐
	8655-Ft-2491	:	Til ReklamasjonsEnh	2980.40(	(	☐	0.000	9000.000	kg/h	0		Average	1 Hour	V	☑	☐



Amine emission during reclaiming. AMP in green (•) and PZ in yellow (•) steadily decline throughout reclaiming.

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CESAR1 Reclaiming Summary

- Batchwise reclaiming is ineffective at TCM.
- Semi-continuous reclaiming is recommended with long boil off time with water addition.
- 4-5 times the overall plant inventory was circulated through the reclaimer.
- NO_2 has a significant impact on CESAR1 degradation.
- Promising CESAR1 thermal reclaiming results.

CESAR1 Reclaiming's Summary

Goal for 2nd reclaiming:

1) Remove degradation products and metals with minimum solvent loss

2) Reproduce the first reclaiming with CESAR1 (to the extent possible with CHP flue gas unavailable)

	Unit	Reclaiming 1	Reclaiming 2
Batchwise/Continuous	-	Batchwise → Continuous	Continuous
Solvent through reclaimer	times total plant inventory	4.5	5
End boil-off time	hours	56	46
Amine loss	%	<5%	<5%
HSS removal	%	89	89
Metals removal	%	95	93
Degradation products removal	%	84	82

Effective thermal reclaiming operation

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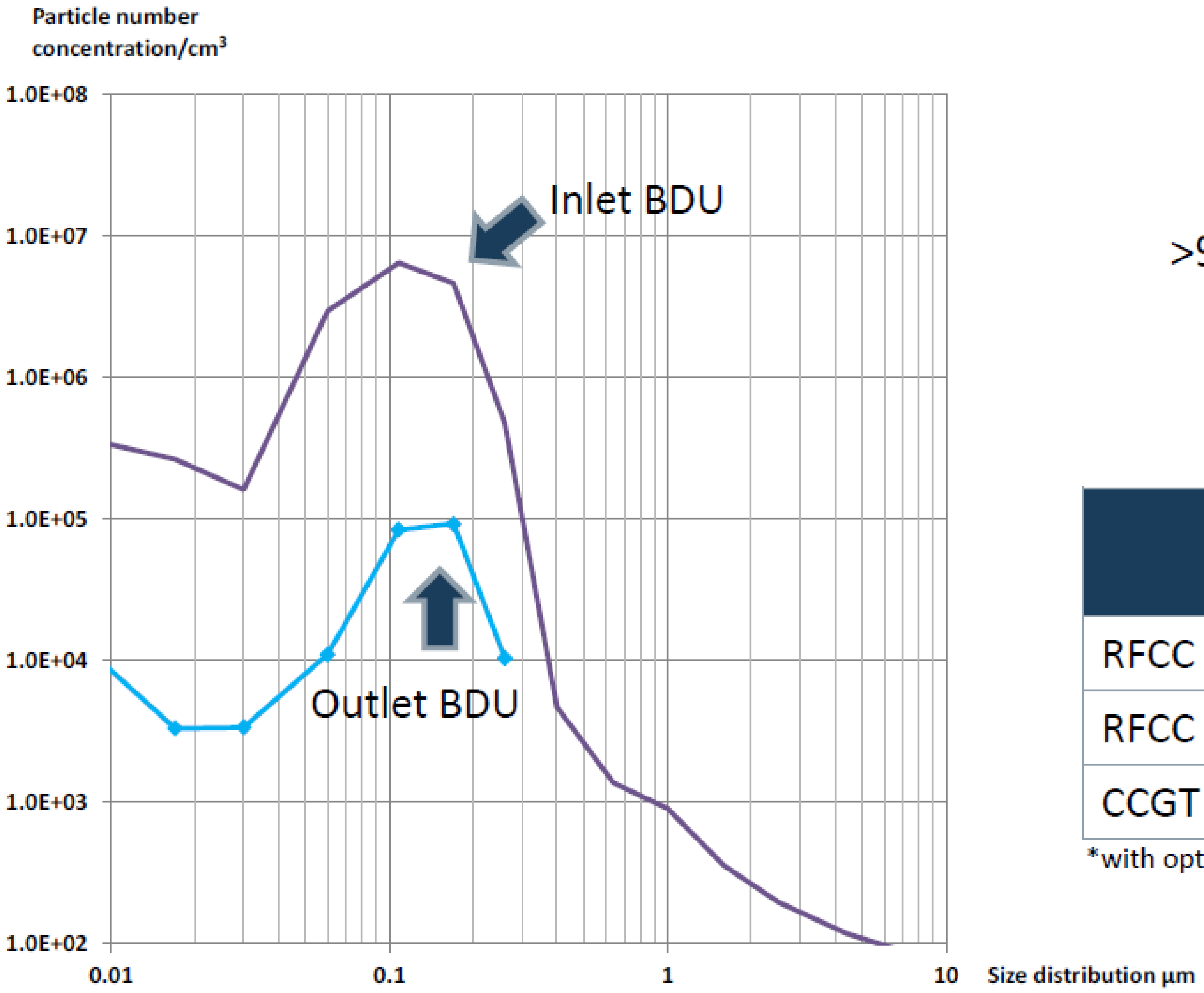
Emission Mitigations

Pollution Reduction for RFCC FLUE GAS

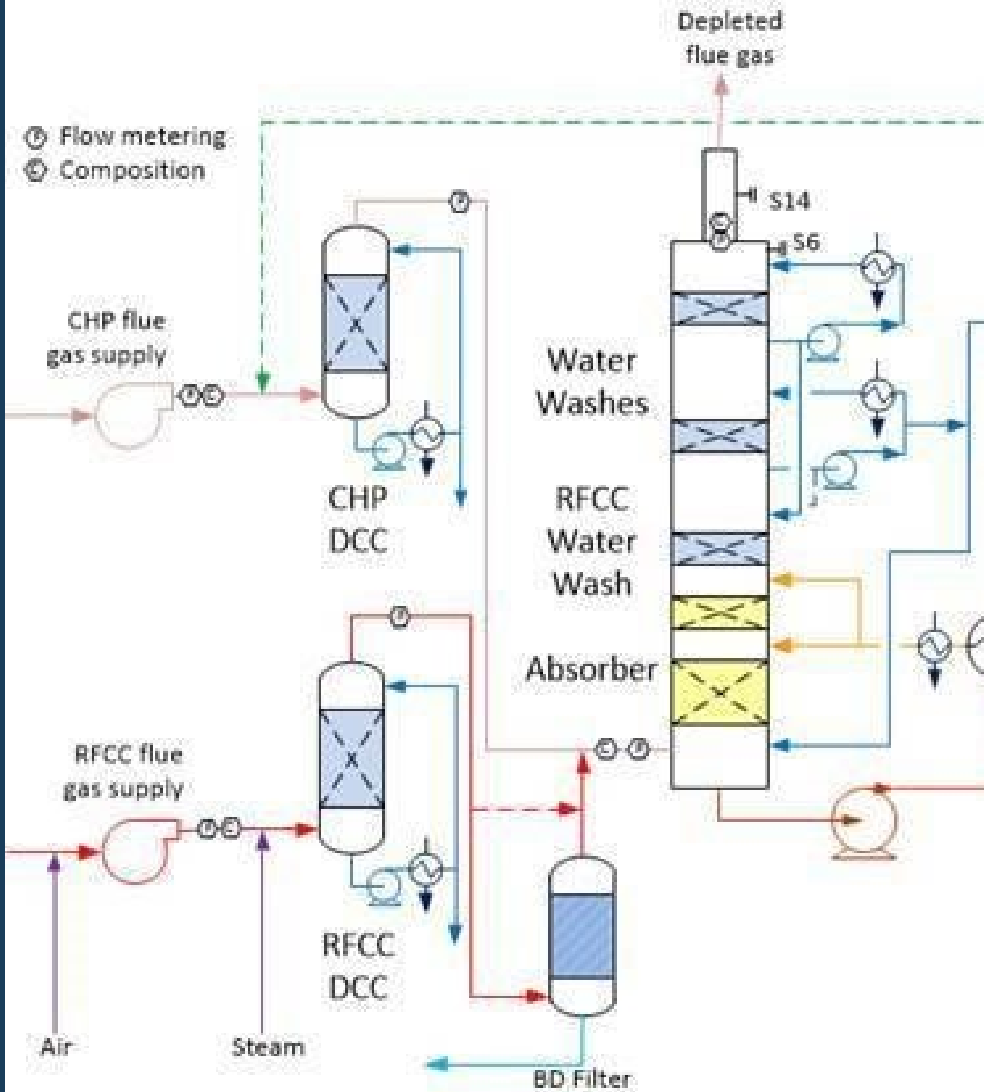


>99 % reduction of PM 2.5 & SO_2

Impact on MEA emissions

Flue gas	MEA emissions (ppmv)
RFCC (wo BDU)	> 100
RFCC (w BDU)*	< 1.0
CCGT	< 0.5

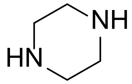
*with optimal BDU operation



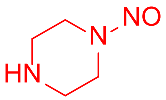
Emission mitigation - RFCC

Impact of aerosols on emission

1. Piperazine emission is proportional to aerosols
   – High concern due to Nitrosamine formation(1)



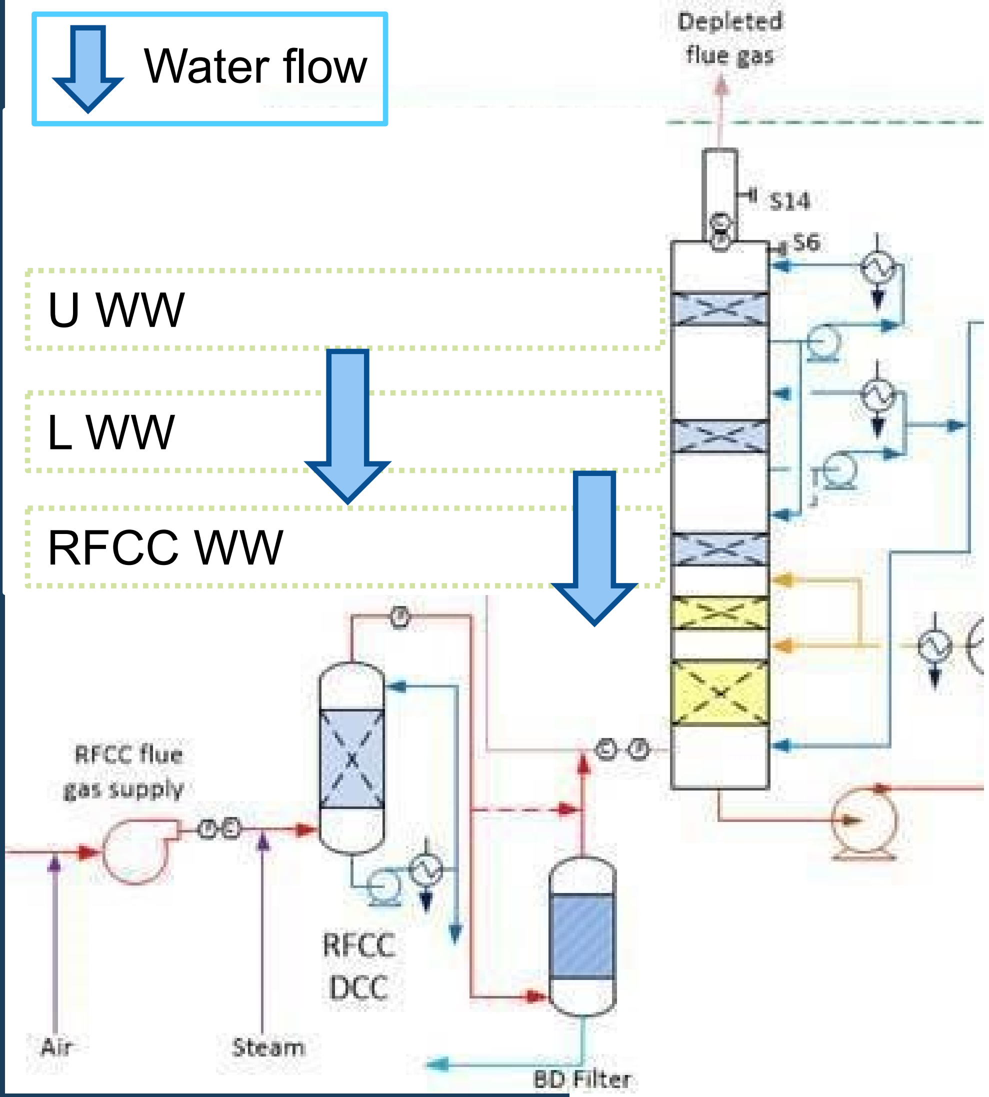
piperazine



1-nitrosopiperazine

2. BD filter, Primary removal of SO_2 aerosols
   – Operation not possible without!

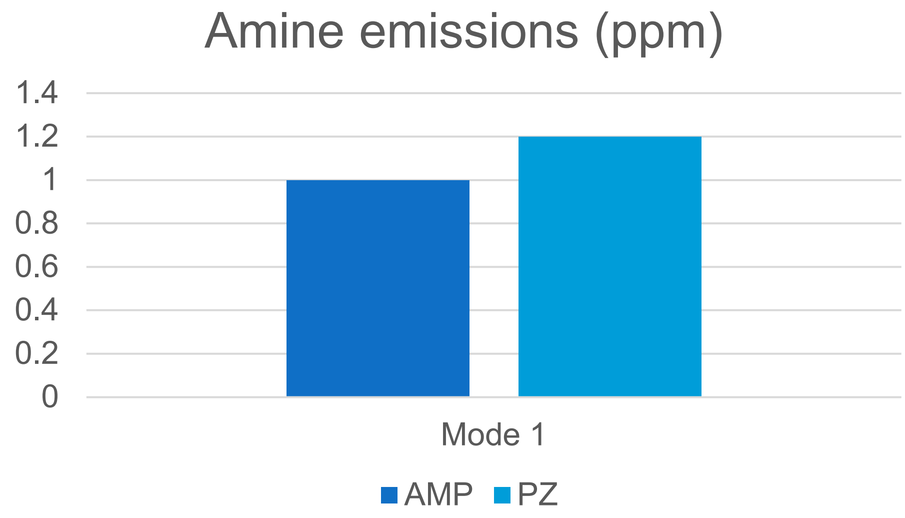
C. J. Nielsen et al., *J Phys Chem A*., **2021**, Jan 14; *125*(1): 411–422.



Emission mitigation - RFCC

Operational changes to reduce emissions

- Standard mode
  - Max. cooling on upper water wash (U WW)
  - Min. cooling on lower water wash (L WW)
  - Upper packing used as water wash (RFCC WW)

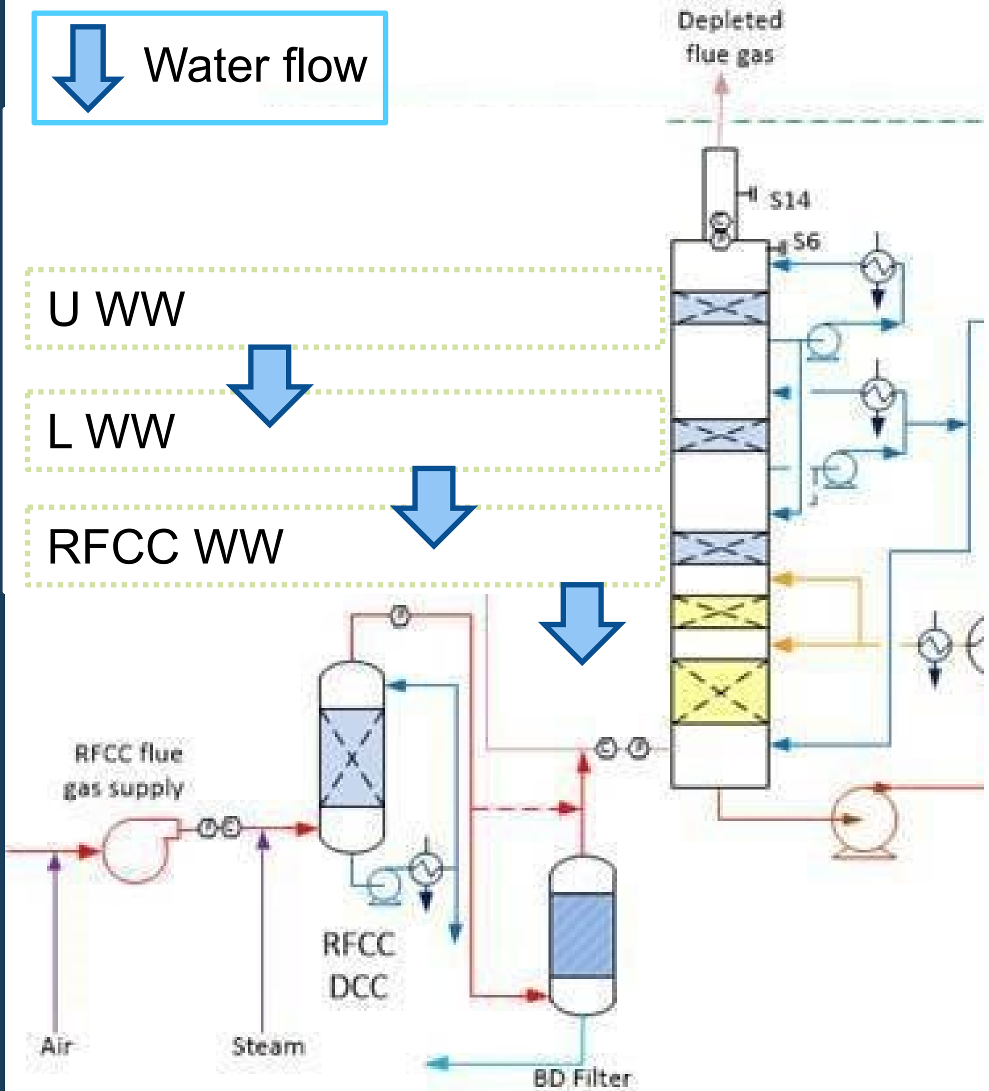


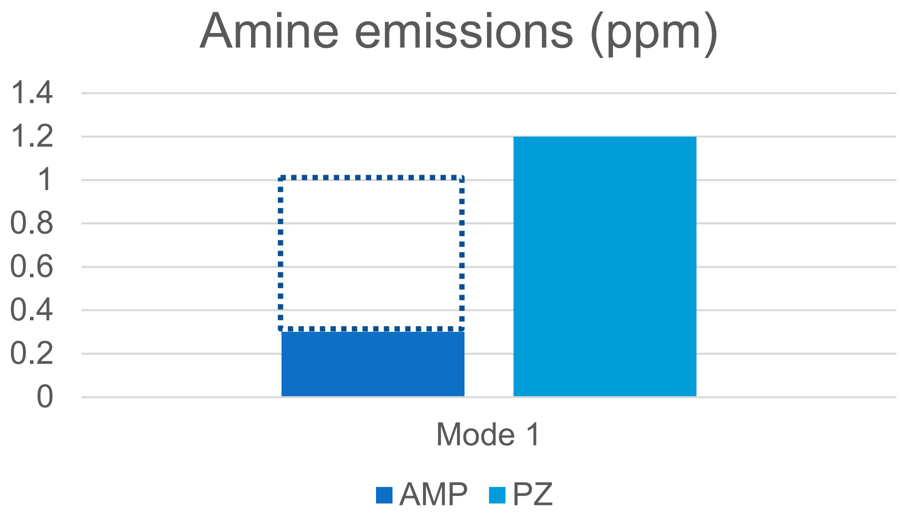
Emission mitigation - RFCC

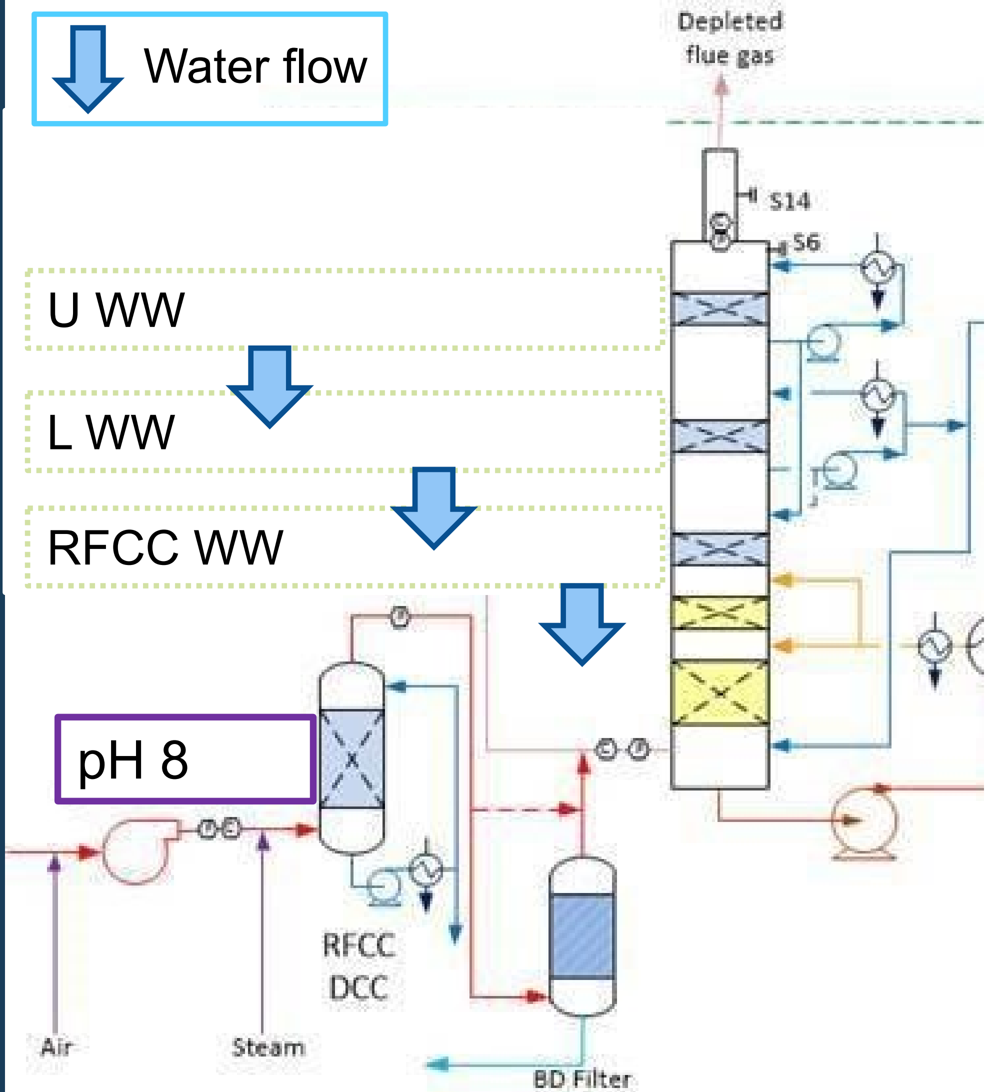
Operational changes to reduce emissions

- Water wash cooling strategy
- Counter current flow

⟶ Removal of volatile emissions



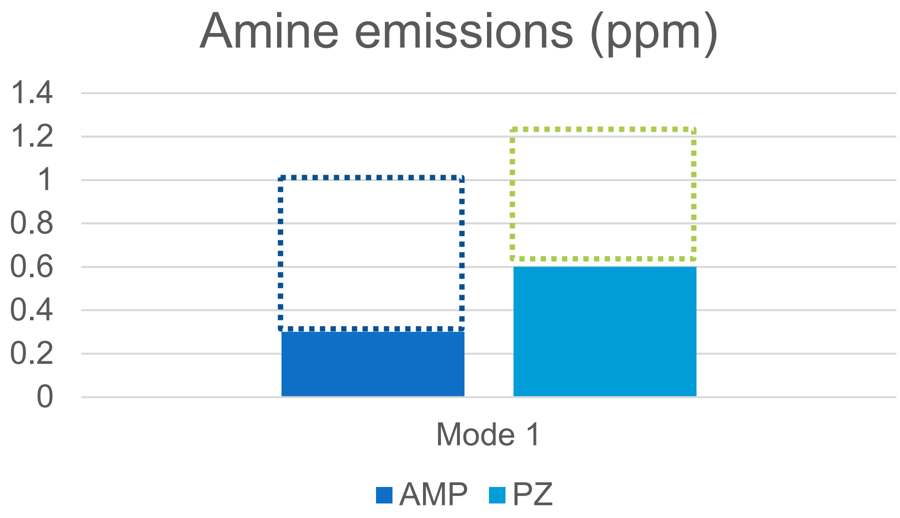


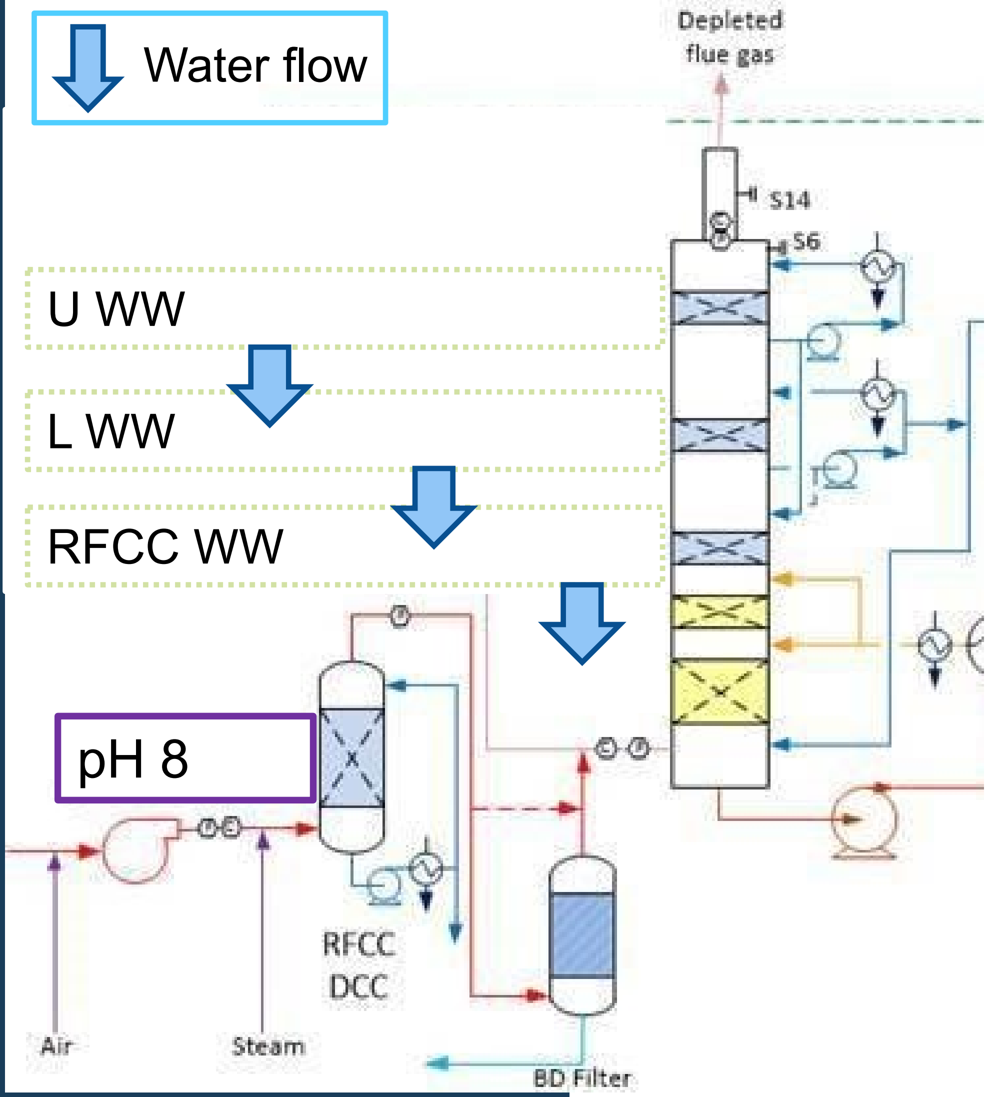


Emission mitigation - RFCC

Operational changes to reduce emissions

- Counter current flow
- NaOH injection in DCC (pH ~8)
  - Removal of acidic SO_2 aerosols

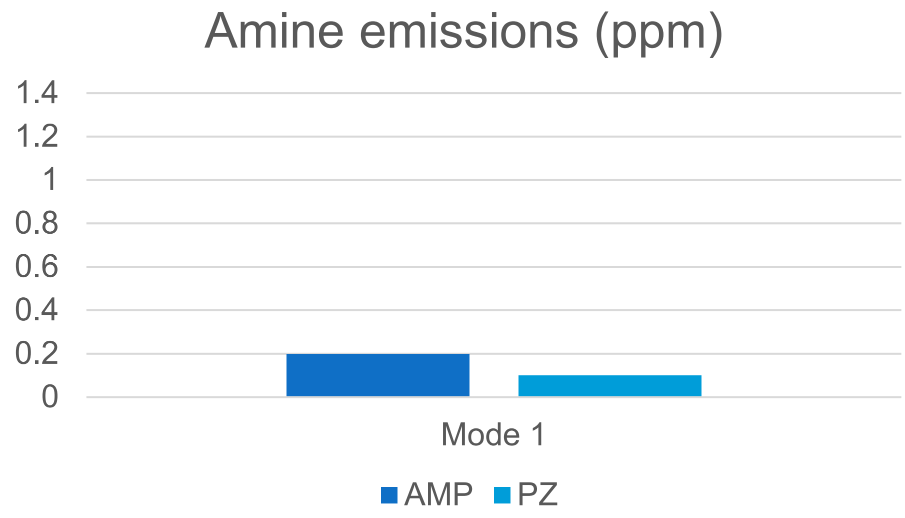




Emission mitigation - RFCC

Operational changes to reduce emissions

- Refinement of operational parameters including high lean solvent temperature further reduced emissions



Connect with TCM
Partnering for CCS Deployment

<u>Why TCM?</u>

- ❖ +60,000 operational hours → proven, bankable performance
- ❖ 17 post-combustion capture technologies tested and derisked for commercial deployment → unmatched track record
- ❖ Neutral, independent test center → trusted by industry, investors & policy makers

<u>What We Offer:</u>

- ❖ **Advisory services**: technology screening, selection & scale-up
- ❖ **Project support**: from feasibility through FID
- ❖ **CO_2 quality expertise**: Characterization, specifications & impurity impacts on compression, Liquefaction, transport & storage
- ❖ Open for **new test campaigns,** Tailored **advisory services,** Strategic **partnerships & joint projects**

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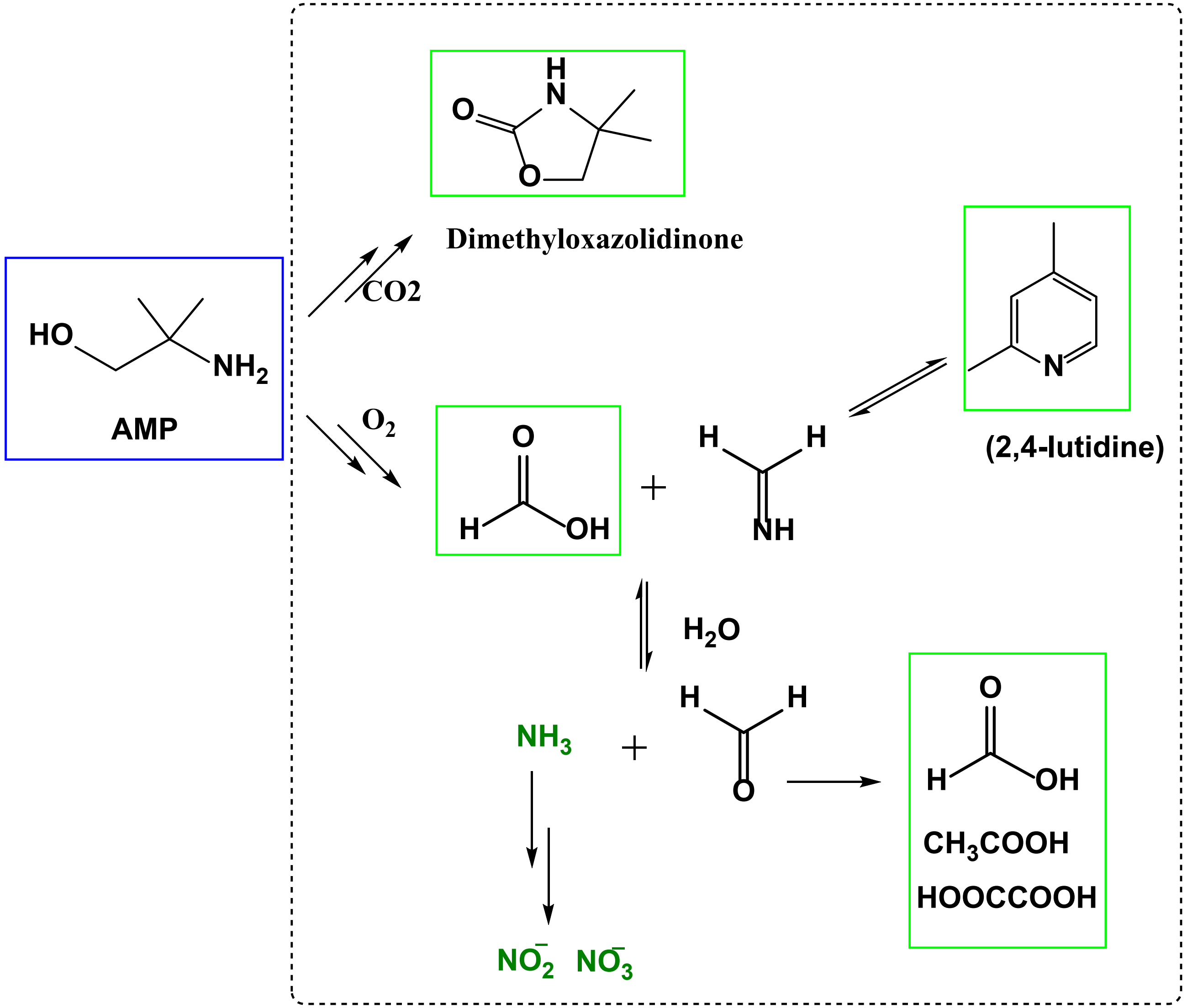
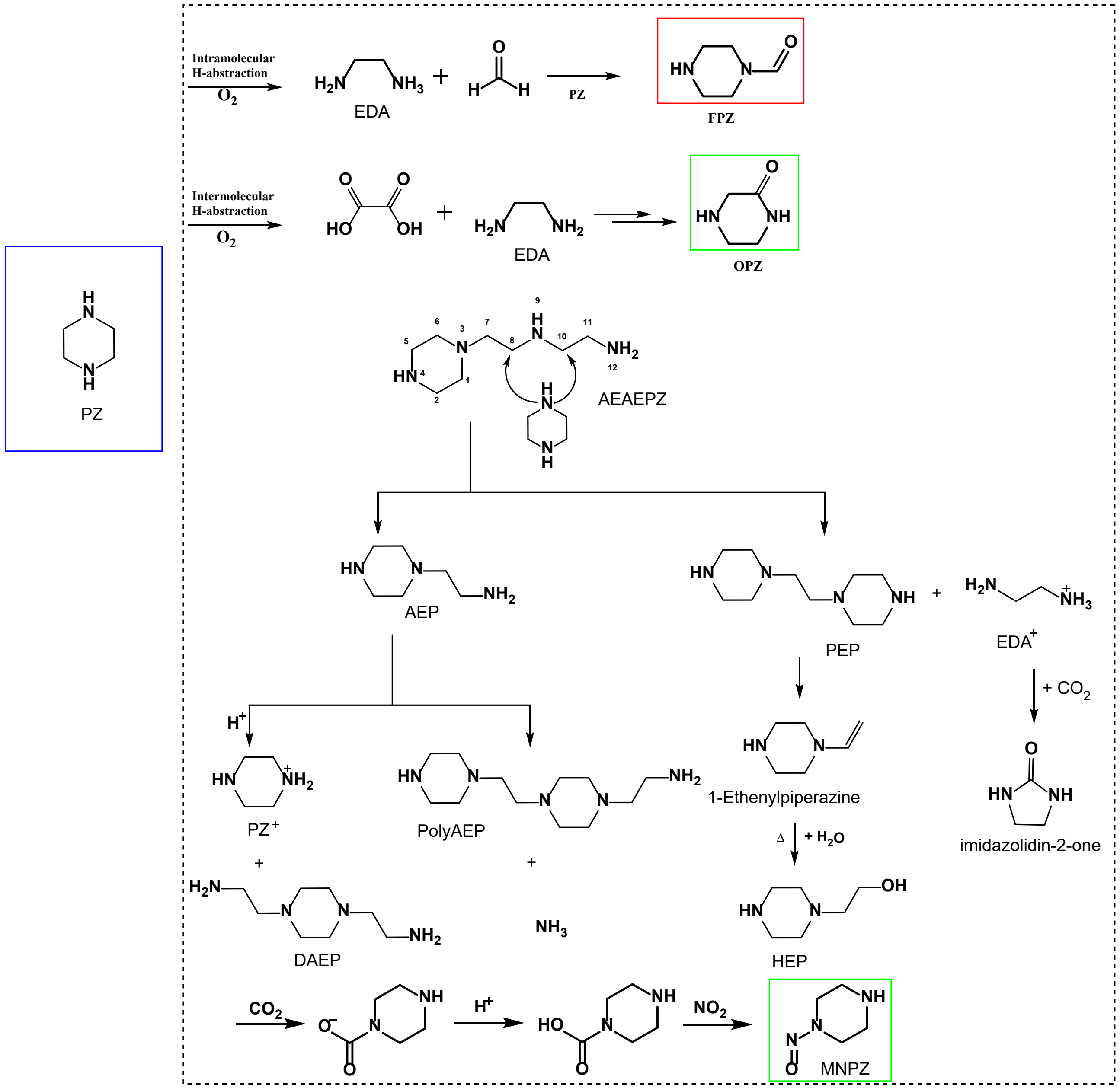
BACK-UP SLIDES



AMP degradation

Most common AMP degradation products are

1. 4,4-dimethyl-2-oxazolidinone (DMOZD)
2. 2, 4-Lutidine
3. Acetone
4. Formic acid



PZ degradation

The most common PZ degradation products:

1. Ethylene diamine (EDA),
2. 2-oxopiperazine (OPZ),
3. *N*-formyl piperazine (FPz),
4. Mononitrosopiprazine (MNPZ),

Other minor products include carboxylate ions, amides, glycolate, nitrite and nitrate.