CCSA Technical Forum

30/09/2025
14:00-16:00 (BST)
15:00-17:00 (CEST)

CCSA

Agenda

	Time (BST / CEST)	Topic	Speaker
1.	14:00 / 15:00 [5 mins]	**Introduction & CCSA competition law policy notice** • Introduction & housekeeping • Approval of April meeting minutes • Technical Forum co-chair nomination process	Suzanne Ferguson, Wood (Co-Chair)
2.	14:05 / 15:05 [30 mins]	**Presentation:** Carbon Intensity Standards	Jonathan Dredge, Exxon Mobil
3.	14:35 / 15:35 [25 mins]	**Metrology Update:** Gas quality & Emissions	Chris Dimopoulos, NPL
4.	15:00 / 16:00 [25 mins]	**External Presentation:** Solid-based materials for CO_2 capture and current Spanish situation in CCUS technologies	Javier Ibañez Castellano, AIMPLAS
5.	15:30 / 16:30 [25 mins]	**Discussion:** CO_2 Odorisation Update	Andy Brown, Progressive Energy (Co-Chair)
6.	15:55 / 16:55 [5 mins]	**Conclusions and AOB**	Suzanne Ferguson, Wood (Co-Chair)

House keeping & Introductions

- Slides & Recording will be available for members after the meeting
- CCSA Competition Law Policy notice is attached to the meeting invite and available on the CCSA website
- If you are not speaking, please mute your microphone
- Please **raise your hand** if you wish to comment, you will be invited to come off of mute, if you can also turn on your camera
- Please also pose any **comments in the chat** and these will be picked up by the secretariat
- **Introductions** of any new members joining the call
- Approval of April minutes

Technical Forum Co-chairs

Nominations now open for up to 4 Technical Forum co-chairs

There may be between 1 – 4 Co-Chairs, to be determined by Forum members.

- Chairing working group meetings. In the case of multiple Co-chairs, this may be done on a rota.
- Influencing and agreeing the agenda and workstream of the Technical Forum with the CCSA secretariat.
- Holding the forum members and CCSA secretariat accountable to the agreed workstream.
- When requested, providing updates to the wider CCSA membership on workstream progress.
- Where appropriate, and requested, representing the Technical Forum at relevant meetings or events outside of the CCSA, such as standard-setting bodies or other technical fora.

Submit your co-chair nominations (*name, company and role*) to despoina.tsimprikidou@ccsassociation.org by **14 October.**

Current co-chairs are also able to re-nominate.

CCSA Flagship Annual Conference, CCUS 2025: Real Projects, Real Impact – Delivering Net Zero

Less than 2 weeks to go!

- **Book your tickets now (conference & dinner)!**
- Member ticket – 50% discount
- Topics include:
    - Reaching FID for CCUS in UK & EU
    - Unlocking investment in CCUS
    - CCUS & low-carbon products markets
    - Scaling CDRs
    - Skills & supply chain
    - CCUS in the power sector
    - CCUS projects & progress around the world

  ...and much much more

Book your member ticket using the code 'Membccus2025'
Book here: https://www.ccus.events/

Presentation: Carbon Intensity Standards

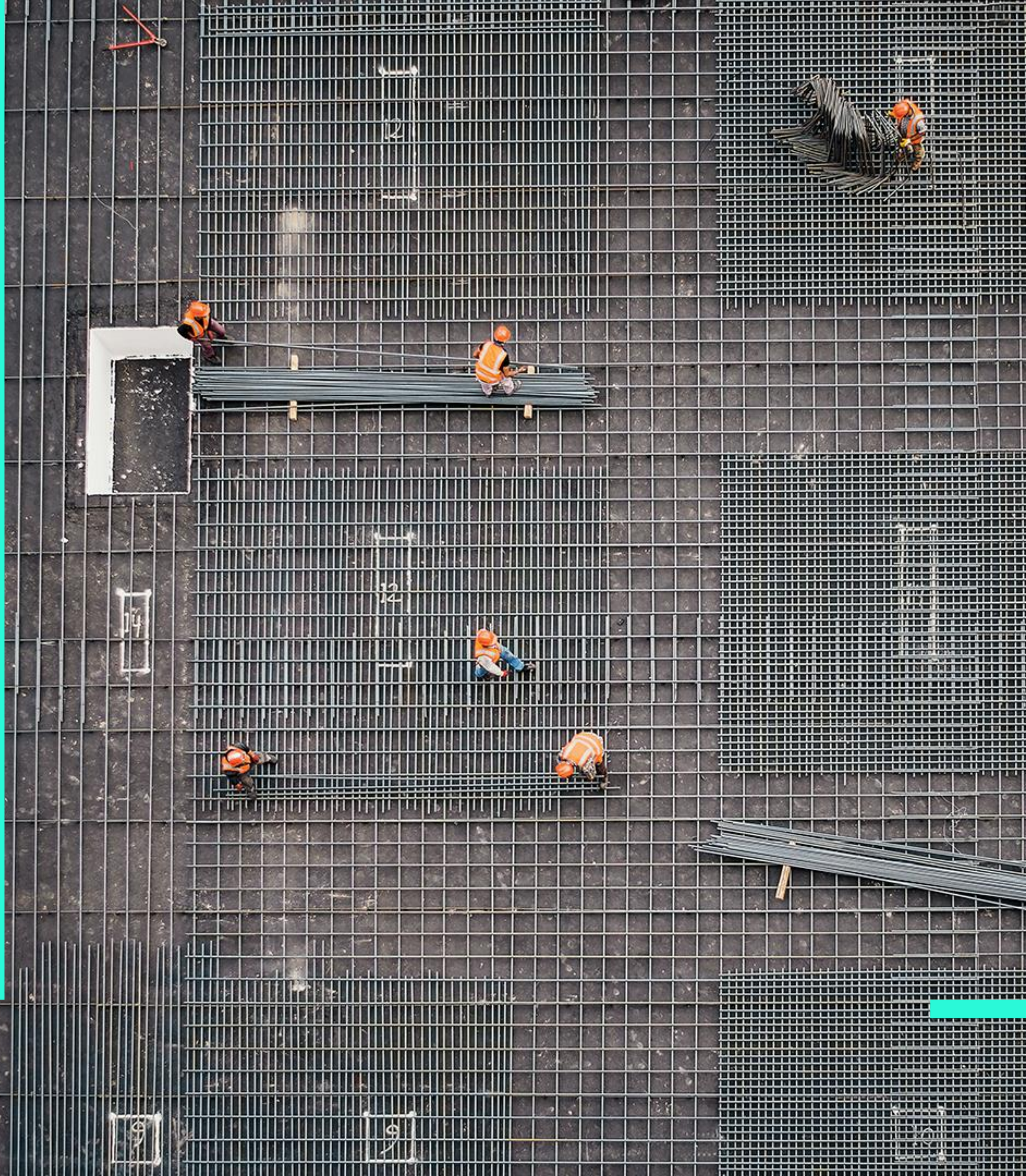
Jonathan Dredge,
Exxon Mobil

CCSA

Metrology Update:

Gas Quality & Emissions

Chris Dimopoulos, NPL



CCSA

NPL
National Physical Laboratory

NPL Activities on CO_2 Quality Assurance: Update

30th September 2025

Manohara Gudiyor
Senior Scientist
EGM, NPL

manohara.gudiyor@npl.co.uk

About NPL

The National Physical Laboratory (NPL) is the UK’s National Measurement Institute.

NPL ensures measurement science and technology is developed to address real-world challenges, supporting businesses across the globe.

- Founded in 1900, located in Teddington, South West London
- ~1,200 employees across 440 laboratories
- Maintain SI units
- Develop new measurement standards and test-methods to support emerging technologies and economies
- Part of UK’s National Quality Infrastructure (NQI) (with BSI, OPSS, and UKAS)
- Deliver the UK’s National Measurement Strategy, partly via a government funded programme – the National Measurement System (NMS)

Importance of CO_2 purity

NPL
National Physical Laboratory

Capture performance:
Can provide information to allow for process optimisation and more efficient capture. MEA impurities can indicate degradation of sorbent beds

Transport infrastructure:
H_2O and H_2S impurities can react to form sulphuric acid which is corrosive and can damage pipelines. Glycol can also damage seals and other components

CO_2 purity

Storage integrity:
Non-condensable gases such as O_2, N_2, Ar, CH_4 and H_2 can reduce possible amount of CO_2 storage capacity. This can cause pipeline ductility issues and lower oil recovery

Utilisation:
The many different uses of CO_2 within industry have varying quality requirements, e.g. C_6H_6 requires analysis for food/beverage grade CO_2 as it spoils the flavour

NPL have provided recommendations on CO_2 purity for CCS processes:

	Rationale	Pipeline	Storage		
			Saline reservoir sequestration	*Unmineable coal seams*	*Oil and gas recovery*
H_2O[a]	Reacts with sulphur to produce sulphuric acid which is corrosive	Use same maximum limits as storage method	300 µmol mol^{-1}	300 µmol mol^{-1}	300 µmol mol^{-1}
H_2S[b]	Toxic		5 µmol mol^{-1}	5 µmol mol^{-1}	5 µmol mol^{-1}
CO[b]	Toxic		20 µmol mol^{-1}	20 µmol mol^{-1}	20 µmol mol^{-1}
O_2	Non-condensable gas, thinning of pipeline, reacts with hydrocarbons, enhances growth of aerobic bacteria		4 cmol mol^{-1}	4 cmol mol^{-1}	100 µmol mol^{-1}
CH_4[c]	Non-condensable gas, pipeline ductility issues, flammable		4 cmol mol^{-1}	4 cmol mol^{-1}	1 cmol mol^{-1}
N_2[c]	Non-condensable gas		4 cmol mol^{-1}	4 cmol mol^{-1}	1 cmol mol^{-1}
Ar[c]	Non-condensable gas		4 cmol mol^{-1}	4 cmol mol^{-1}	1 cmol mol^{-1}
H_2[c]	Non-condensable gas, lower recovery of oil		4 cmol mol^{-1}	4 cmol mol^{-1}	1 cmol mol^{-1}
SO_x[b]	Toxic		0.5 µmol mol^{-1}	0.5 µmol mol^{-1}	0.5 µmol mol^{-1}
NO_x[b]	Toxic		0.5 µmol mol^{-1}	0.5 µmol mol^{-1}	0.5 µmol mol^{-1}
NH_3[b]	Toxic		25 µmol mol^{-1}	25 µmol mol^{-1}	25 µmol mol^{-1}
C_2H_6	Flammable, might cause asphyxiation at high temperatures		1 cmol mol^{-1}	1 cmol mol^{-1}	1 cmol mol^{-1}
C3+	Flammable, might cause asphyxiation at high temperatures		1 cmol mol^{-1}	1 cmol mol^{-1}	1 cmol mol^{-1}
Particulates	Not specified		1 µmol mol^{-1}	1 µmol mol^{-1}	1 µmol mol^{-1}
HCl[b]	Toxic		1 µmol mol^{-1}	1 µmol mol^{-1}	1 µmol mol^{-1}
HF[b]	Toxic		1.8 µmol mol^{-1}	1.8 µmol mol^{-1}	1.8 µmol mol^{-1}
HCN[b]	Toxic		0.9 µmol mol^{-1}	0.9 µmol mol^{-1}	0.9 µmol mol^{-1}
Hg[b]	Toxic		0.02 mg m^{-3}	0.02 mg m^{-3}	0.02 mg m^{-3}
Glycol	Damage to seals and other components		46 nmol mol^{-1}	46 nmol mol^{-1}	46 nmol mol^{-1}
MEA[b]	Toxic		1 µmol mol^{-1}	1 µmol mol^{-1}	1 µmol mol^{-1}

Report available here:
http://eprintspublications.npl.co.uk/8258/1/ENV23.pdf

Why PRMs Matters!

- Calibration of analysers/detectors (online and offline)
- Validation of analysis results
- Calibration of flow meters (fiscal metering)
- Method development and validation
- Proficiency testing (accreditation and regulatory compliance)
- Performance assessment of material properties
- Validation of calibration reference materials (CRMs) & secondary reference materials.

NPL's Measurement Capability

NPL National Physical Laboratory

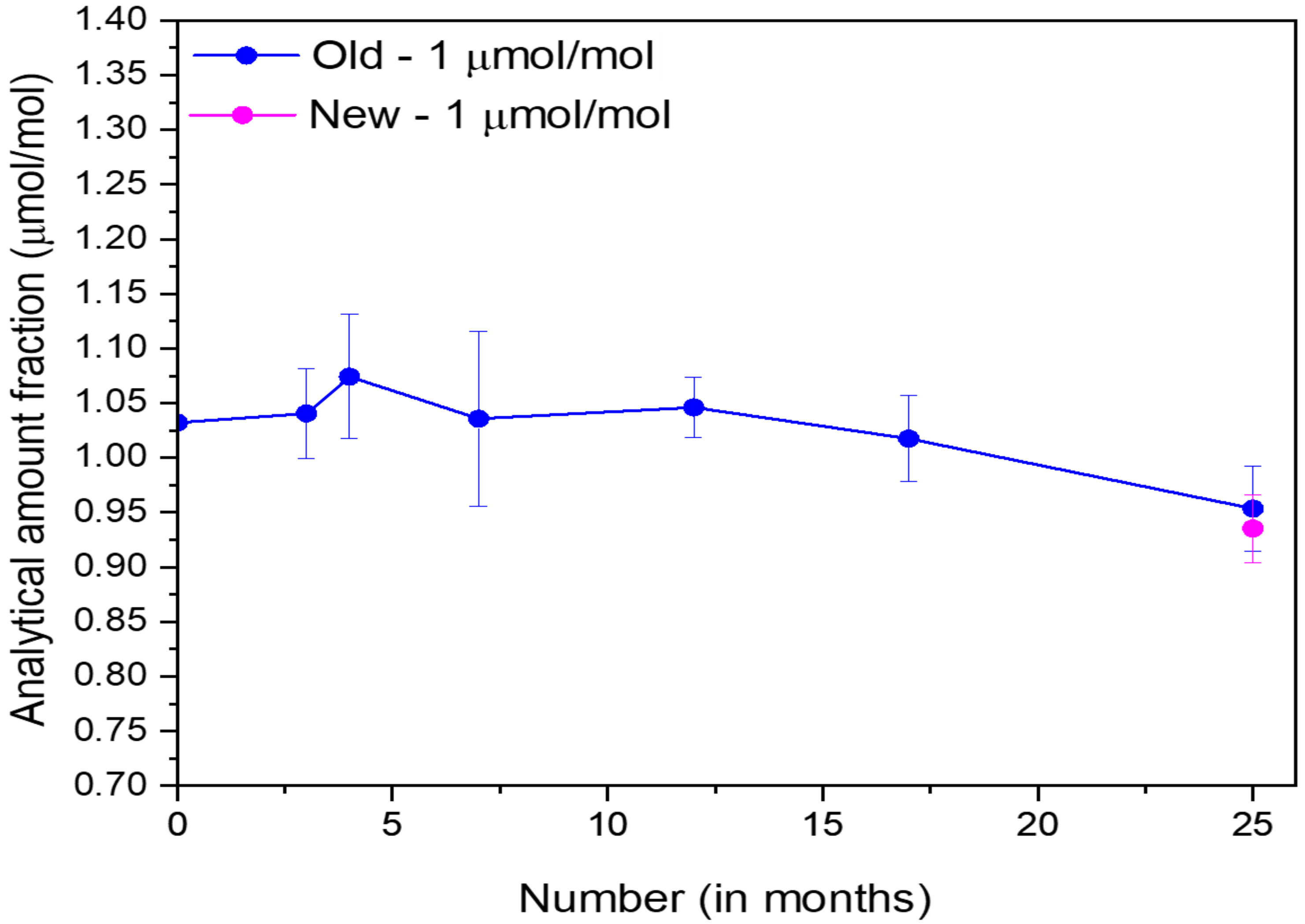
Component	ISO 27913		UK CCUS projects specifications Summary			NPL measurement capability		
	Units	Limit	Units	Limit (Min)	Limit (Max)	Units	Lower limit	Upper limit
CO_2	mol%	≥ 95.0						
N_2 (1)	mol%	4	mol%	1	4	mol%	0.03	4
H_2 (1)	mol%	1	mol%	0.05	2	mol%	0.04	2.0
Ar (1)	mol%	4	mol%	1	4	mol%	0.005	4
CO (1)	mol%	0.2	mol%	0.01	0.2	mol%	0.0003	0.1
Methane (1)	mol%	4	mol%	1	4	mol%	0.023	4
Ethane (1)	mol%	4	mol%	1	4	mol%	0.005	0.5
Propane & Other Aliphatic Hydrocarbons (2)	mol%	0.15 in total	mol%	0.15	2	mol%	0.005	0.01
H_2O	ppm mol	50	ppm mol	20	50	ppm mol	1	500
O_2	ppm mol	10	ppm mol	10	20	ppm mol	5	1000
NOx (NO, NO_2) (3)	ppm mol	10	ppm mol	1	100	ppm mol	0.5	500
SOx (SO, SO_2, SO_3) (4)	ppm mol	10	ppm mol	0.1	50	ppm mol	0.5	100
H_2S	ppm mol	5	ppm mol	5	20	ppm mol	0.02	100
COS	ppm mol	100	ppm mol	0.02	10	ppm mol	0.01	100
CS_2	ppm mol	20	ppm mol	0.2	10			
NH_3	ppm mol	10	ppm mol	10	1500	ppm mol	10	1000
BTEX (5)	ppm mol	15 in total	ppm mol	0.001	50	ppm mol	1.4	80
Methanol	ppm mol	350	ppm mol	10	500	ppm mol	50	350
VOCs (8) - DMS	mg/Nm^3	48 in total	ppm mol	20	60	ppm mol	0.5	10
VOCs (8) - Ethanol	mg/Nm^3	48 in total	ppm mol	20	60	ppm mol	4.5	1000
Amines (10,11)	ppb mol	100 in total	ppm mol	0.08	10			
Nitrosamines and Nitramines (13)	µg/Nm^3	3 in total	µg/Nm^3	0.1	5			
Naphthalene (14)	ppb mol	100	ppb mol	5	250			

NPL measurement capability covers ISO 27913 threshold limit

NPL measurement capability exists but doesn't cover ISO 27913 threshold limit. Additional work required to extend working range

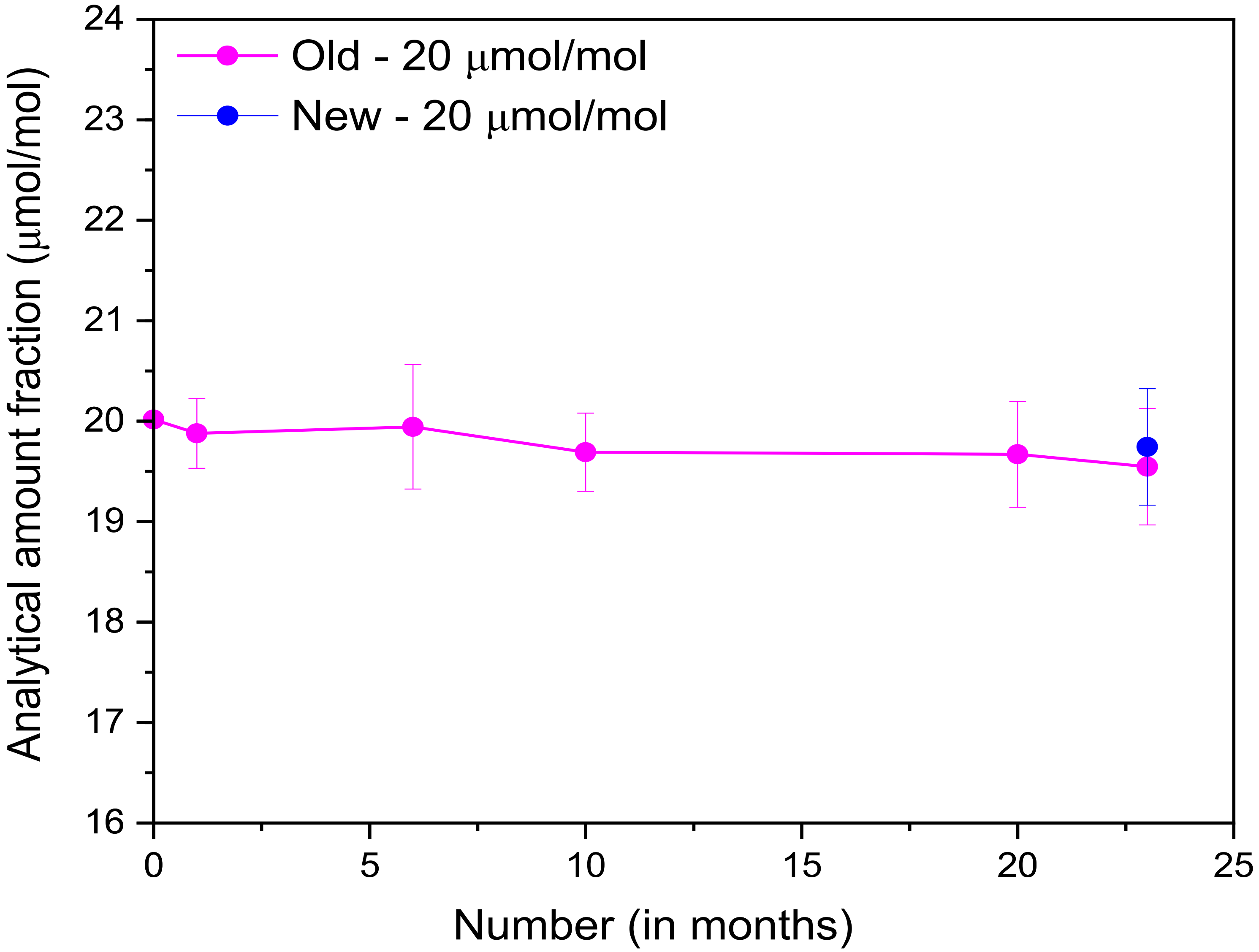
NPL measurement capability development in progress 25/26

Stability studies of PRMs in CO_2



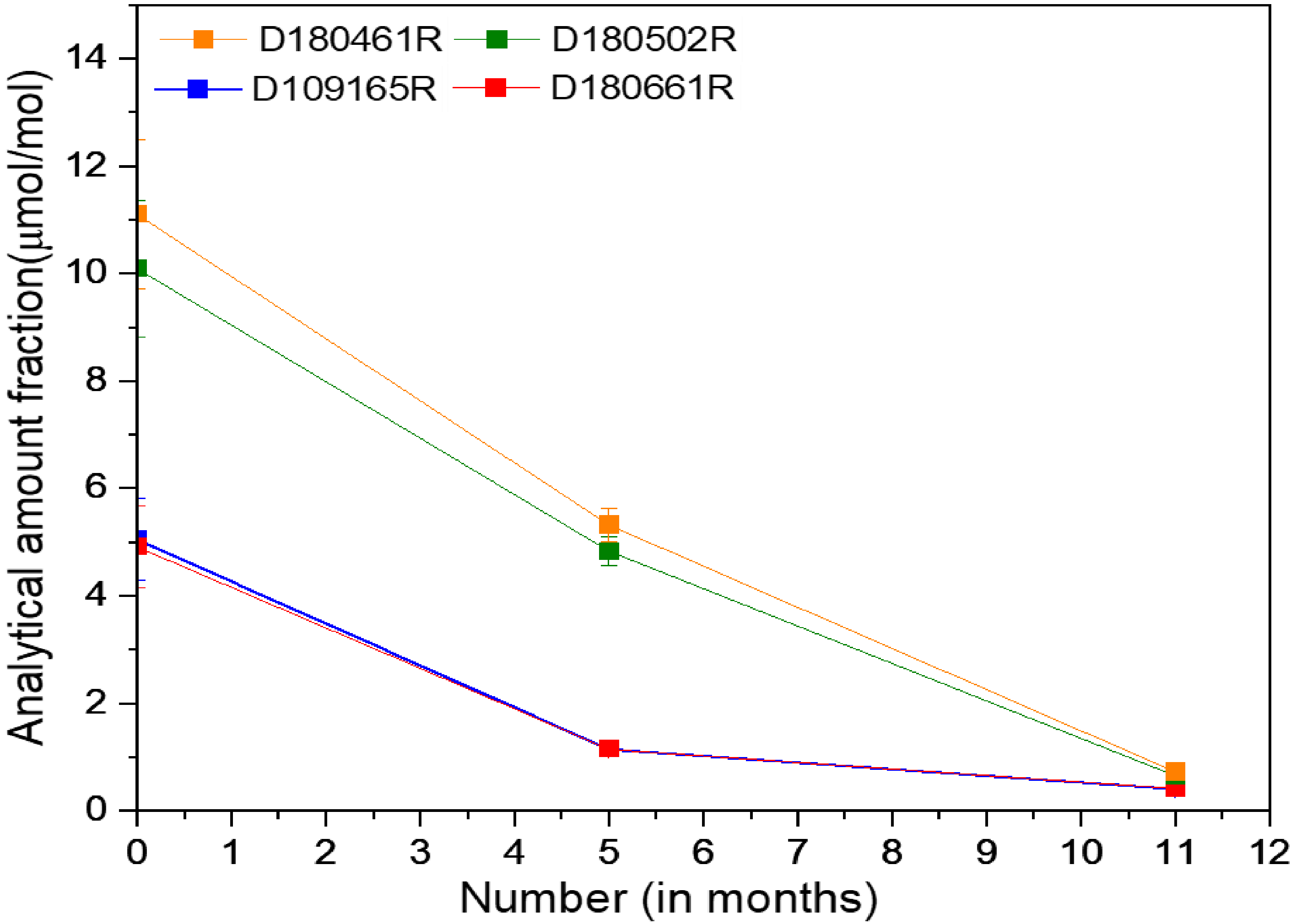
Stability of 1μmol/mol of Dimethyl sulphate binary PRM

Stability studies of PRMs in CO_2



Stability of 20 µmol/mol of Ethanol in binary PRM

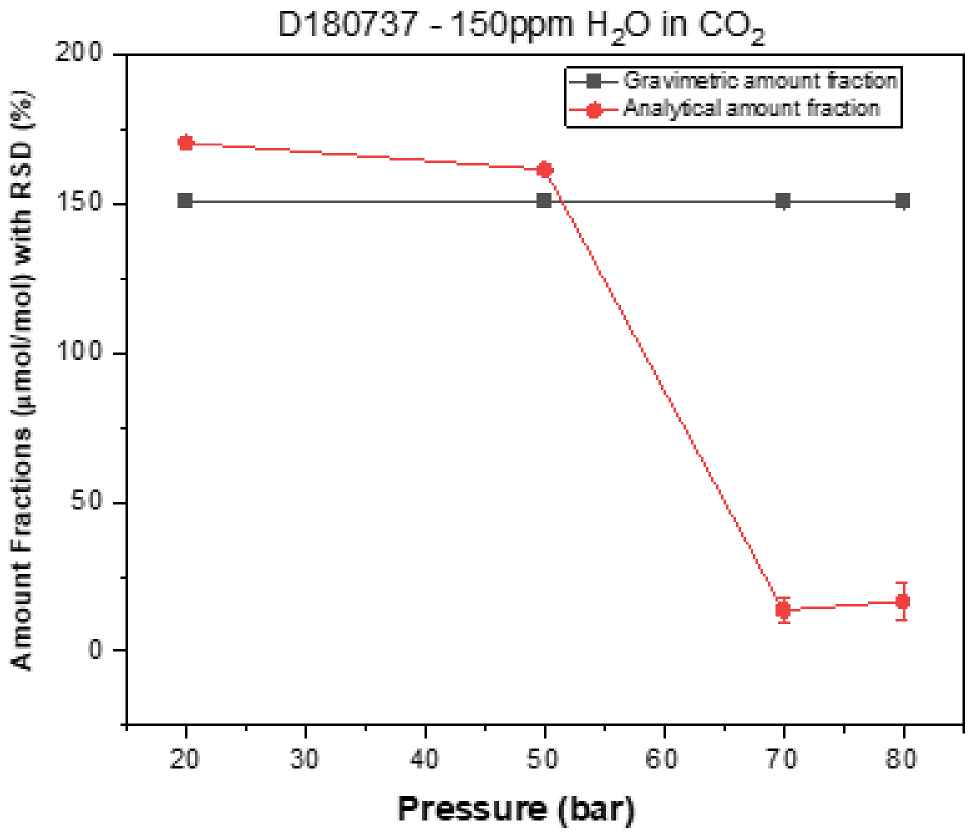
Stability studies of PRMs in CO_2



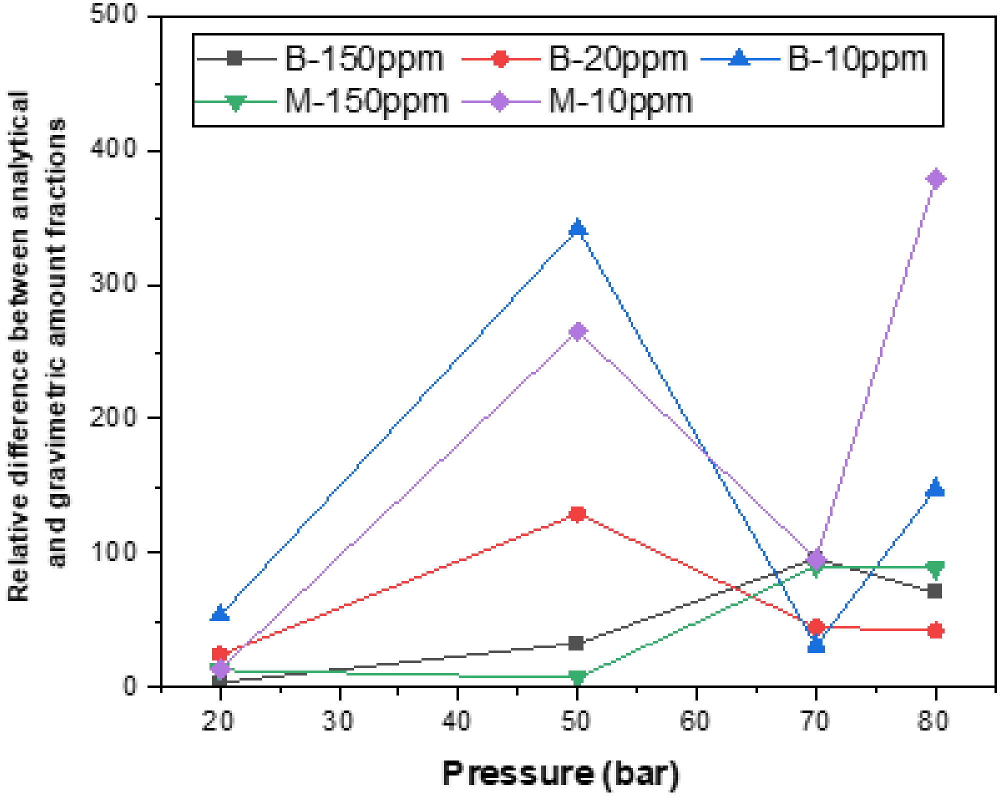
Stability of 10 & 5 µmol/mol of NOx in multicomponent PRMs

Effect of pressure on H_2O amount fractions

a



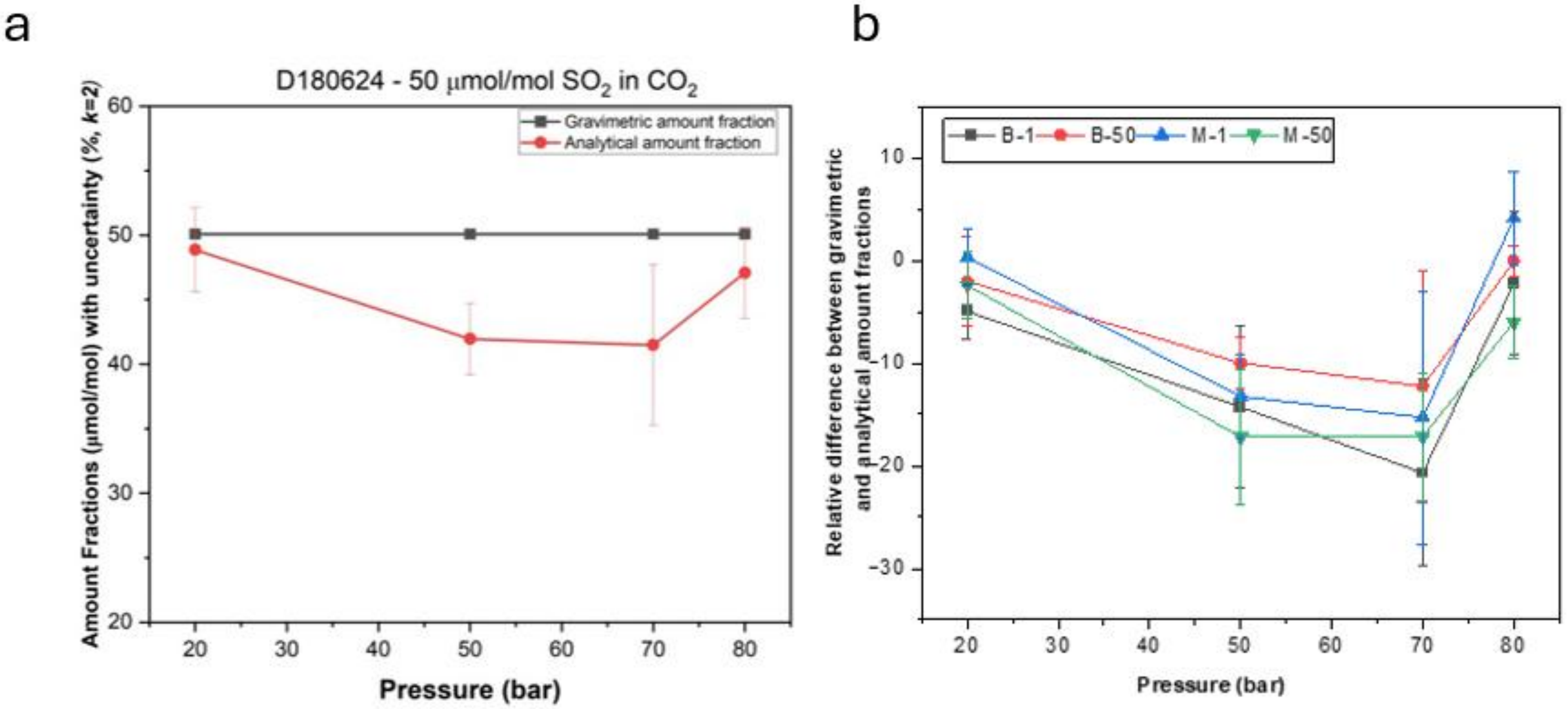
b



(a) Analytical vs gravimetric amount fractions (µmol/mol) of H_2O in D180737 as a function of pressure and (b) relative difference of gravimetric and analytical amount fractions (µmol/mol) of H_2O at 20, 50, 70 and 80 bar for all the five PRMs tested.

Effect of pressure on SO_2 amount fractions

NPL National Physical Laboratory



(a) Analytical vs gravimetric amount fractions (µmol/mol) of SO_2 in D180624 as a function of pressure and (b) relative difference of gravimetric and analytical amount fractions (µmol/mol) of SO_2 at 20, 50, 70 and 80 bar for all the four PRMs tested.

Summary

- We have extended our PRMs capability to support CO_2 quality assurance and further capability development under progress.
- Binary mixtures of DMS and ethanol are stable over 24 months.
- NOx in multicomponent PRMs has shown rapid and massive decay.
- Pressure has significant impact on the analytical amount fractions of crucial impurities.
- Further work is necessary to understand the effect of pressure on other key impurities

NPL National Physical Laboratory

Thank you for your attention

Questions?

Department for
Science, Innovation
& Technology

The National Physical Laboratory is operated by NPL Management Ltd, a wholly-owned company of the Department for Science, Innovation & Technology (DSIT).

NPL
National Physical Laboratory

CCSA TECHNICAL FORUM
Metrology Update – Point Source Emissions

Chris Dimopoulos

30th September 2025

Environmental Emissions Metrology Group

NPL

CCUS Activities have been focussed on the measurements of both point and fugitive emissions.

Funded through METCCUS, the NMS and the Environment Agency:

- Guidance documents on leak detection and fugitive measurement of CO_2 from CCUS equipment and infrastructure – in process - https://metccus.eu/
- Simulation of CO_2 leaks and assessment of measurement techniques
- **Development of measurement method and guidance document for amine breakdown products emitted from PCC stacks – published - https://ukccsrc.ac.uk**

METROLOGY PARTNERSHIP | EURAMET

UK National Measurement System

Environment Agency

METCCUS

Department for Science, Innovation & Technology

Measurement challenges

NPL

Flue gas characteristics:

- Gas temperature: < 100^{o}C.
- Moisture content: saturated with droplet entrainment. - Saturation, aerosol - multi point isokinetic sampling, also limits effectiveness of dynamic dilution – not effective if gas already saturated, droplets present.
- Droplets potentially containing absorbing solution and therefore potentially reactive.

Pollutant characteristics:

- Amine based absorber solution degrades thermally above 120^{o}C - Limits sample system heating temperature.
- Ongoing reaction with other components of exhaust gas – e.g. NOx
- Secondary pollutant composition in flue gas also dependent on age of solvent.
- Wide range of physical characteristics of breakdown products – vapour pressure, solubility.
- Lack of available validated measurement methods - Nitrosamines and some amines are not typically measured in industrial stacks.

Analysis of samples :

- Lack of accredited analytical laboratories with analysis capability for the wide range of breakdown products and with adequate limit of detection and uncertainty.

NPL - Research

Measurement of amine solvent degradation products

Specifically, nitrosamines.

Carried out validation of 2 methods:

- Isokinetic sampling and impingement into 0.1M sulfamic acid
- Dynamic dilution and adsorption onto sorbent cartridge

    Sample stability tests

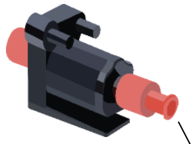
    Lab tests

    Field trials

- Developed guidance and measurement method

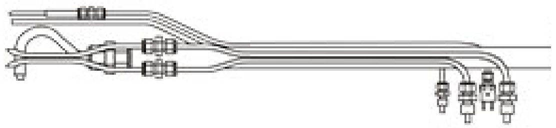
Isokinetic sample train

Thermosorb N sidestream

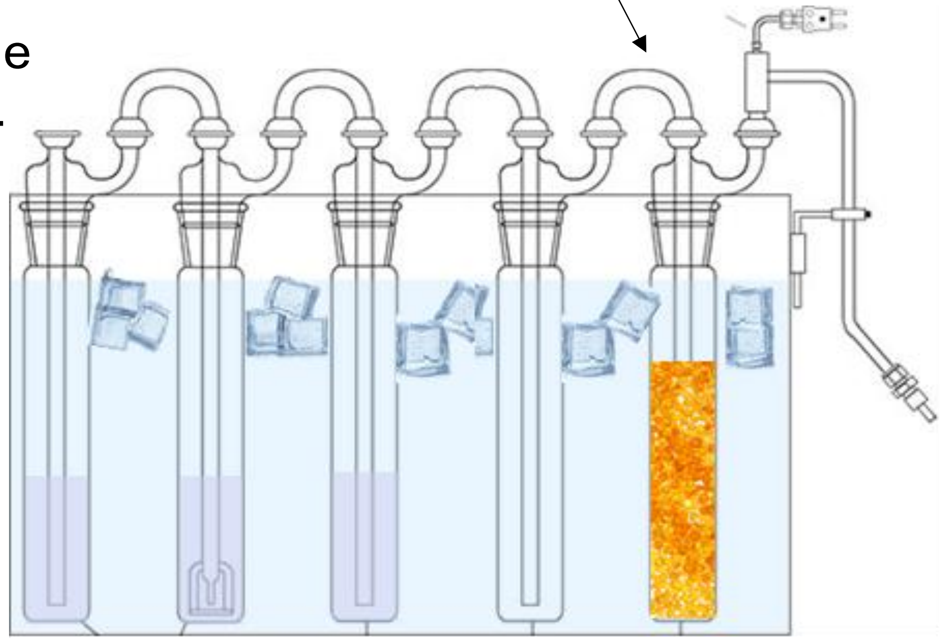


Line

…



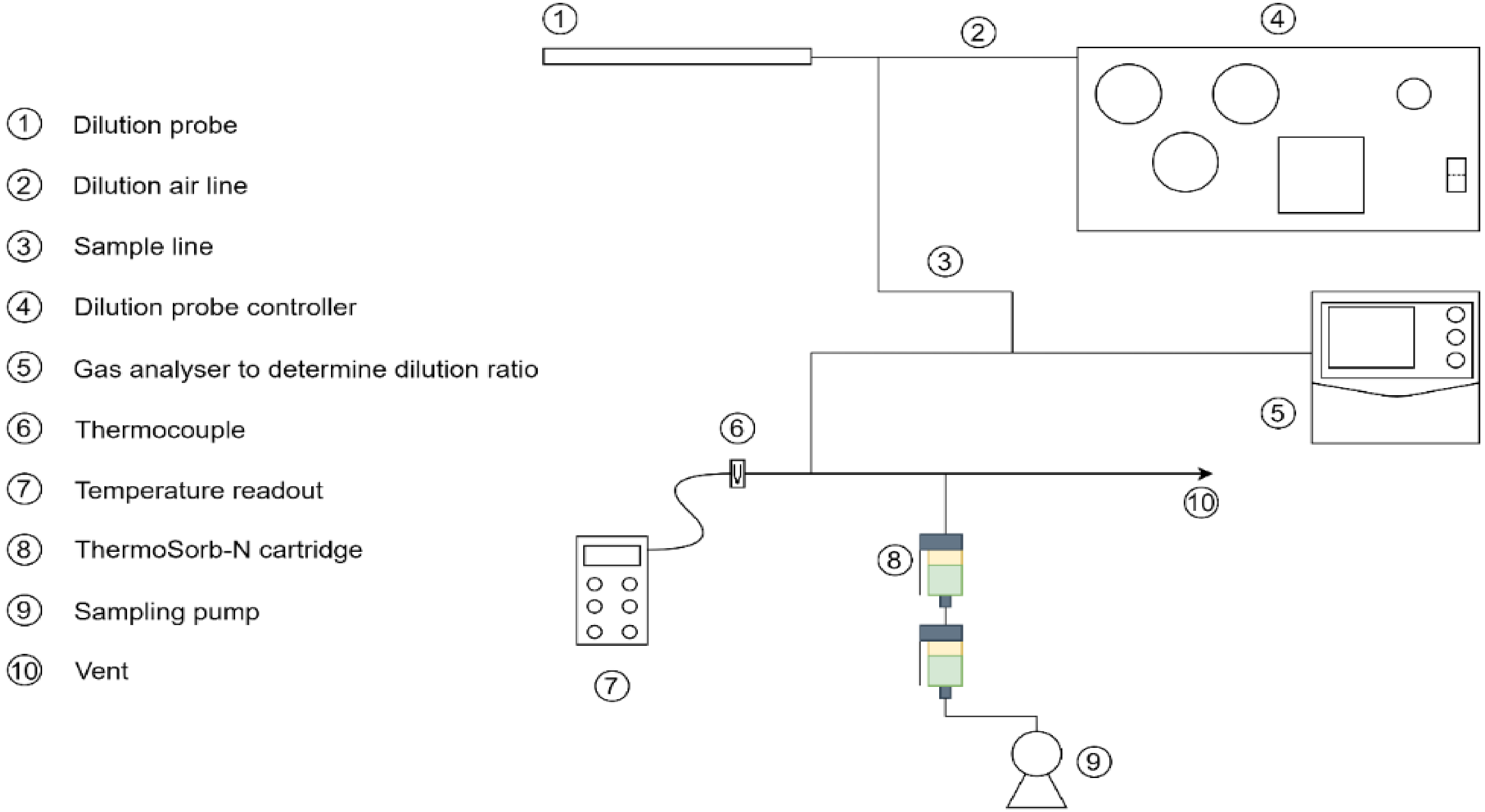
Heated isokinetic probe, liner and nozzle



0.1M H_3SO_3

Sampling limit of detection ~ 0.003µg/m^3 per species

Sorbent capture with dynamic dilution



Sampling limit of detection ~ 0.03μg/m^3 per species

Summary of Findings

- Sample stability - Most consistent results obtained for refrigerated samples (<6^{o}C) analysed within 2 weeks (solutions), 1 week (sorbent cartridges).

- Isokinetic method, lab & field tests – all parts of the sample train were analysed separately. Capture efficiency was adequate for most species, but some species experienced significant breakthrough. Most of the field trial results below LOD.

- Sorbent cartridge method – lab test results lower than expected, samples delayed in transit. Most of field test results below LOD. Difficulties experienced with saturation of dilution system.

Initial Conclusions

NPL

- Sampling must be carried out isokinetically.
- Capture efficiency of sample train needs to be improved for some species.
- Sorbent cartridge method with dynamic dilution not suitable for direct measurement in stack without heating above 120^{o}C threshold.

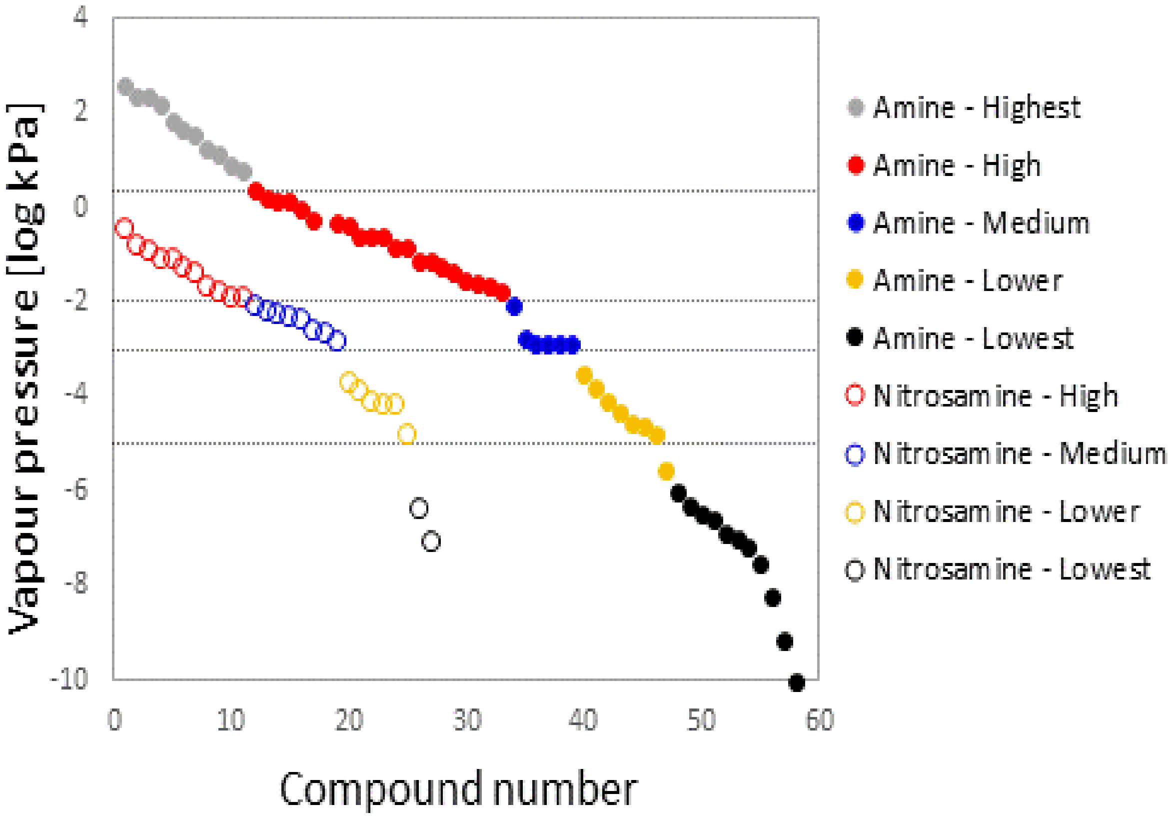
Next Steps

1. Assess whether the isokinetic method can be used to sample other amines.
2. Identify amine species likely to be produced.
3. Categorise according to physical properties – vapour pressure, volatility.
4. Improve design of sample train.
5. Assess measurement solutions for continuous ammonia measurements.

Identification

- Desktop study of all amine species identified in lab experiments and pilot plant field studies.
- Identified potentially 120 species of amines, 20 species of nitrosamines and 10 nitramines of interest.
- Illustrates the complex chemical processes and the wide range of variables affecting solvent breakdown:
  - Solvent age
  - Nitrogen oxide levels
  - Metal particles from corrosion
  - Oxygen levels & stack gas temperature

Classification - vapour pressure



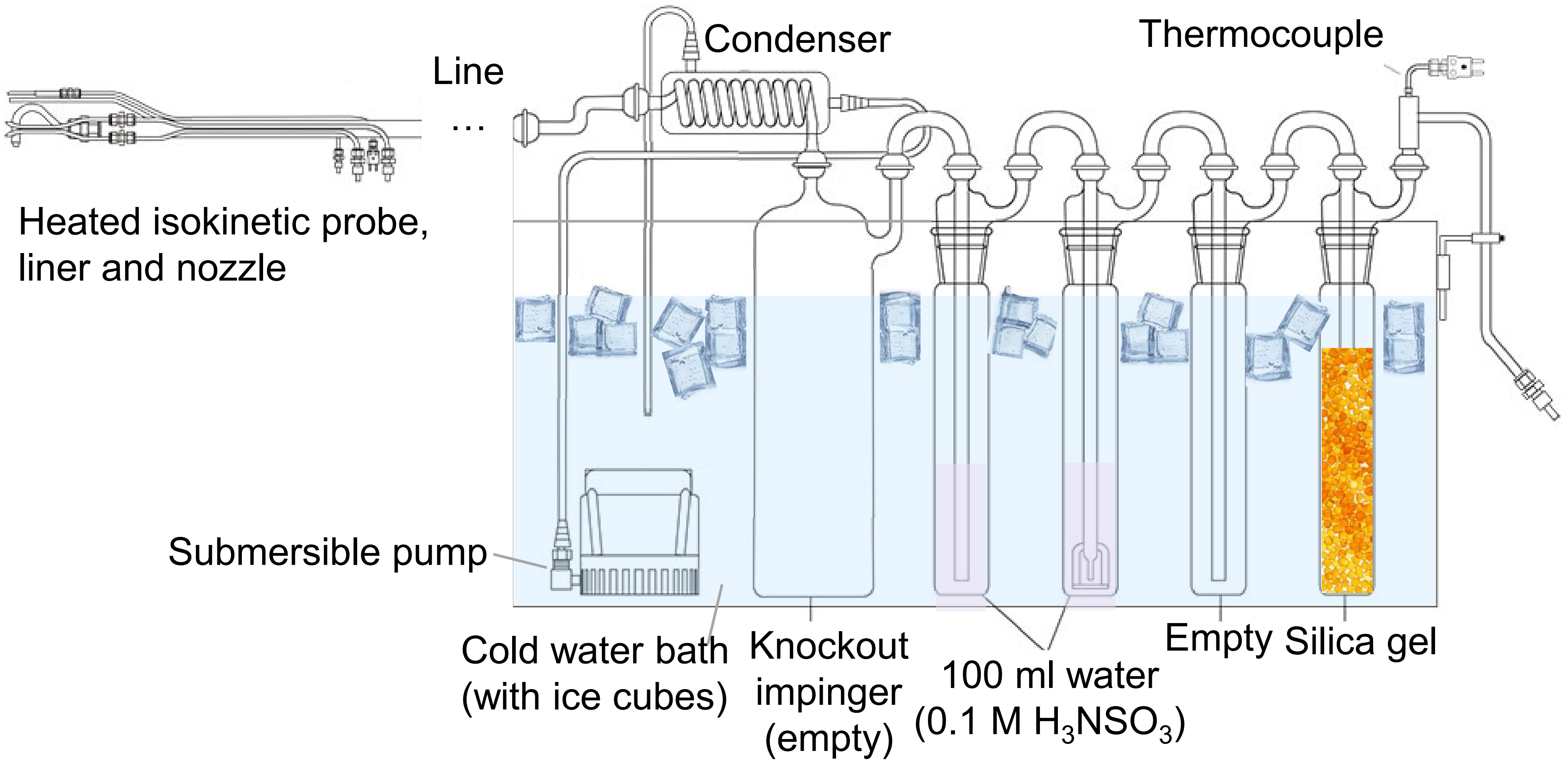
Range of vapour pressures (@20^{o}C):

Nitrosamines - 7 orders of magnitude

Amines – 10 orders of magnitude

Water – 2.3kPa @20^{o}C

Modified isokinetic sample train

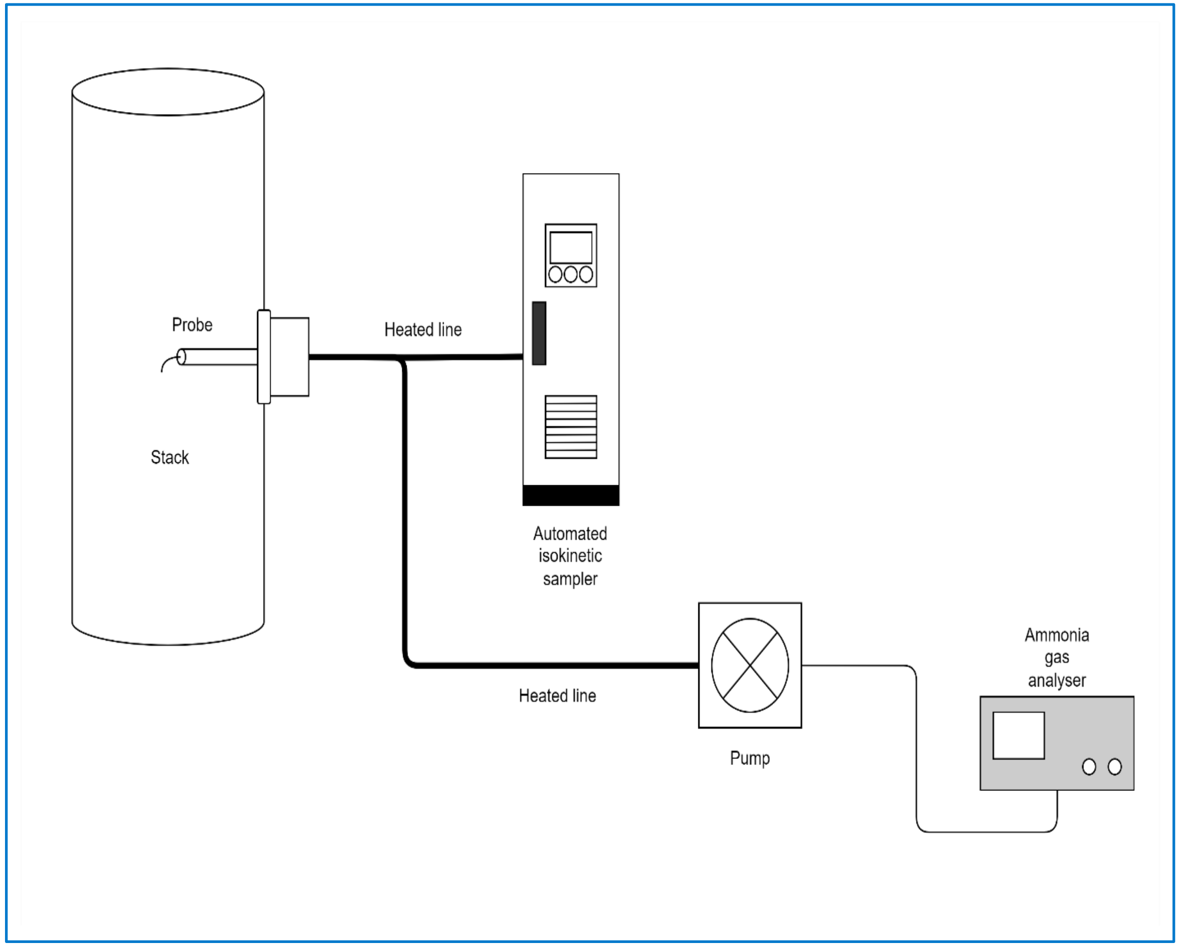


Continuous Real-Time Ammonia Measurements

- Levels of ammonia emissions can vary
  - a few mg/m3 to around 50-55 mg/m3 spikes have been measured at above 75 mg/m3 (Environmental permitting emission limit values in the UK are between 1-23 mg/m3)
  - Depend on a lot of factors: such as solvent degradation, flue gas content, temperature and flow rate
- Ammonia Continuous Emission Measurement Systems (CEMS) - valuable tool for measuring ammonia emissions and providing indication of solvent degradation.
  - Certification ranges need to improve
  - Presence of droplets and the lack of isokinetic sampling technology for ammonia CEMS may lead to measurement bias
  - The extent of the problem is not fully known, - some studies carried out have shown good correlation between manual isokinetic sampling measurements and CEMS type instrument measurements
  - Longer duration studies are needed for different PPC plants designs and operational conditions.

Automated isokinetic sampling systems technology coupled with ammonia CEMS

- Potential Solution:
  - Automated isokinetic sampling systems technology with a side stream ammonia CEMS may allow continuous ammonia isokinetic sampling to be carried out.
  - Further design and experimental validation needed on this approach



Further research

- Validation of condenser sample train for nitrosamine and amine measurement - over a range of vapour pressures

- Assessment of impact of sample train temperatures on amine breakdown. Is it possible to heat the sample train to >120°C without biasing result – would facilitate the use of side streamed dynamic dilution and solid sorbent capture for most volatile amines.

- Further design and experimental validation of continuous isokinetic ammonia system.

Thank you!

Chris Dimopoulos
chris.dimopoulos@npl.co.uk

Environmental Emissions Metrology Group
National Physical Laboratory

External Presentation:

Solid-based materials for CO2 capture and current Spanish situation in CCUS technologies

Javier Ibañez Castellano, AIMPLAS

CCSA

Discussion: CO2 Odorisation Update

Andy Brown, Progressive Energy

CCSA

Natural Gas Odourisation: UK Background

- Odourisation was introduced in 1960s to replace Town Gas, the odour of which was familiar and associated with the potential for explosion and injury or death by inhalation.
- Natural gas does not have the same distinctive odour as Town Gas.
- Odourisation similar to that of Town Gas was introduced in the 1970’s as a safety measure: distinctive “rotten egg” smell of mercaptons
- Odourisation is a legal requirement under Gas Safety (Management) Regulations

Natural gas odourisation: UK Background

- The current blend is t-butyl mercaptan + dimethyl sulphide
  - Smells very similar to the mercaptan-based odourant
  - Detectable at concentrations as low as 1 ppm (for most people)
- Injection targeted at the (low pressure, <7barg) distribution level where there are recipients (people in homes, smaller businesses), where:
  - The majority of end points are open to atmosphere
  - The concentration of people is greater, hence a greater risk of exposure
- Odourisation is not applied to high-pressure pipelines:
  - The population density is lower
  - The risks are very different (user negligence/Third Party Interference)

Natural gas odourisation situation in Europe

- Most countries do not odourise the natural gas at high pressure.
- Exceptions include Netherlands, Finland, Norway, Italy, and a trial(s) in Germany.
- France odourises at <~ 19bar.

Comparison of hazards, natural gas and CO_2

Natural Gas

- Explosion + asphyxiation risks
- Lower Explosion Limit: 5% methane in air
- Ignition possible from small sparks
- Methane is non-toxic, but high climate impact

Carbon Dioxide

- Asphyxiant, but not explosive
- Health effects by exposure:
  - 3%: headache, reduced hearing, deeper breathing
  - 5–10%: impaired judgement, breathing difficulty
  - >10%: unconsciousness /death within minutes
- Risk of respiratory acidosis at high concentrations

Pros and Cons of odourisation

Pros

- Odourisation offers early public warning before harm occurs
- Tangible safety measure → builds public confidence
- Could aid acceptance of new CO_2 infrastructure

Cons

- Different risks from natural gas: should not “read across”
- May complicate CO_2 re-use
- No suitable odourant currently identified → delays
- Potential for pipeline corrosion or store damage (to be assessed)
- Increases cost with no reduction to risk benefit
- Public education required
- False alarms → operational and public disruption

Risk: Preventative and Mitigative controls

- Natural gas: odourant is mitigative (alerts after leak), appropriate for end-use, where the risk is greatest
- Principal risk for pipelines is Third Party Interference
- Accepted risk-based approach for CO_2 streams is based is on prevention, by (examples):
    - Conservative engineering design
    - Operational procedures
    - Protective measures*
    - Pipeline monitoring
- CO_2 odourants are unlikely to provide a timely or practical warning

Examples of preventative measures

- Preventative measures could include:
  - Deep burial
  - Thicker pipeline walls
  - Concrete covers
  - Pipeline routing away from population centres
  - Lower CO_2 stream pressure (e.g. HyNet, East Coast Cluster, Peak Cluster)
  - Leak detection linked to control centres
  - Line markers
  - “Dial before you Dig” requirements
  - Regular inspection and monitoring
- Emphasis is on prevention rather than mitigation

Risk: Other points

- Large CO_2 leaks are likely to be audible/visible anyway
- Small buried leaks may disperse before atmospheric levels reach the point of causing harm to people
- Non-Pipeline transport: continuous odour may cause crew desensitisation

AOB & Conclusions

- Review actions arising from meeting
- Next Working Group Meeting: **8 December 2025**
- AOB