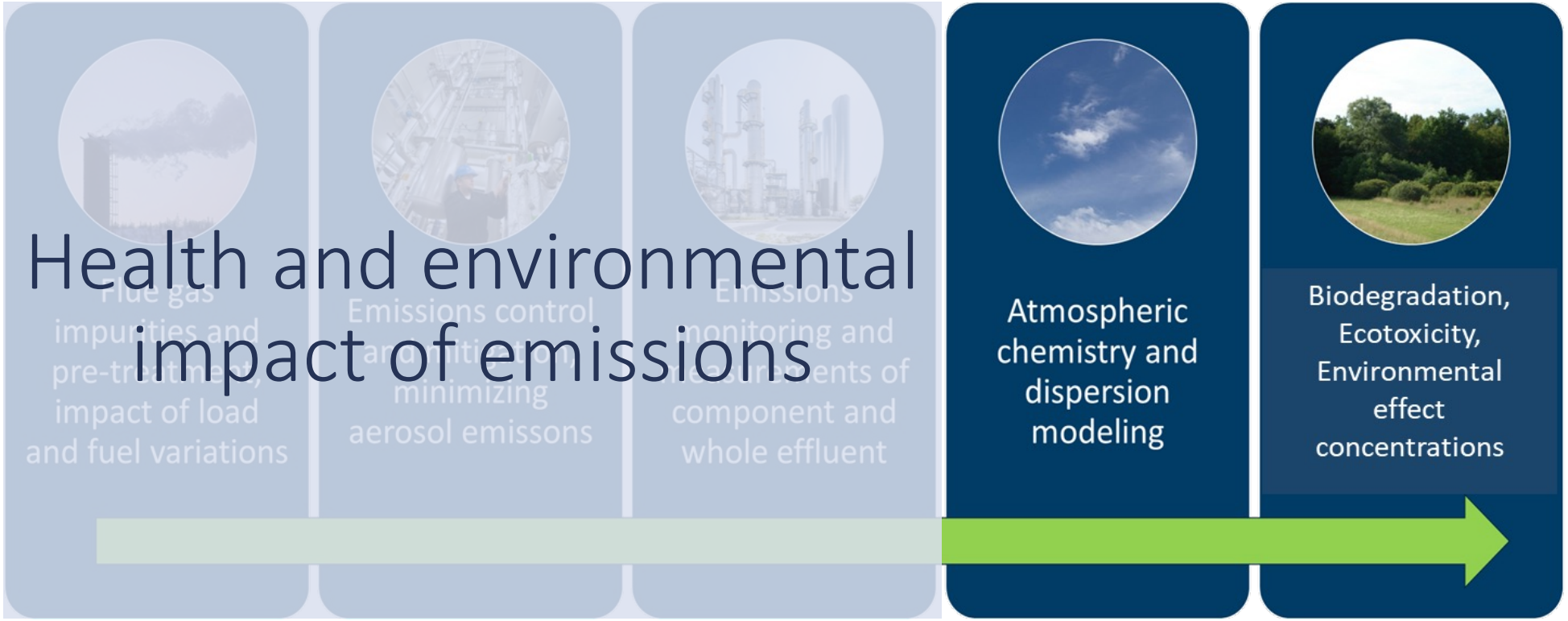
Project number 327341
ACT – Accelerating CCS Technologies



Health and environmental impact of emissions

Sprint #4 Trondheim

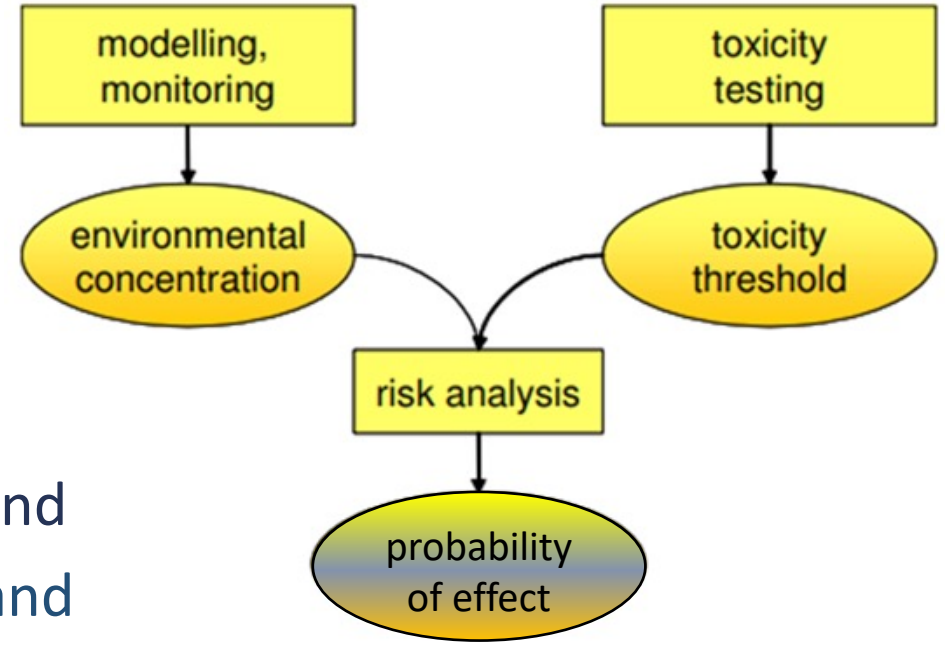
22 June 2023

Environmental quality standards, impacts and risk assessment

Objectives

Develop and establish methods and rules for risk assessment of emissions from flue gas of CO_2-capture facilities from industry that exhibit large variations in emission content.

Methodologies and rules should allow plant operators and technology suppliers to meet approved environmental and health acceptance criteria when developing and establishing technologies, and during monitoring of regular flue gas emissions.

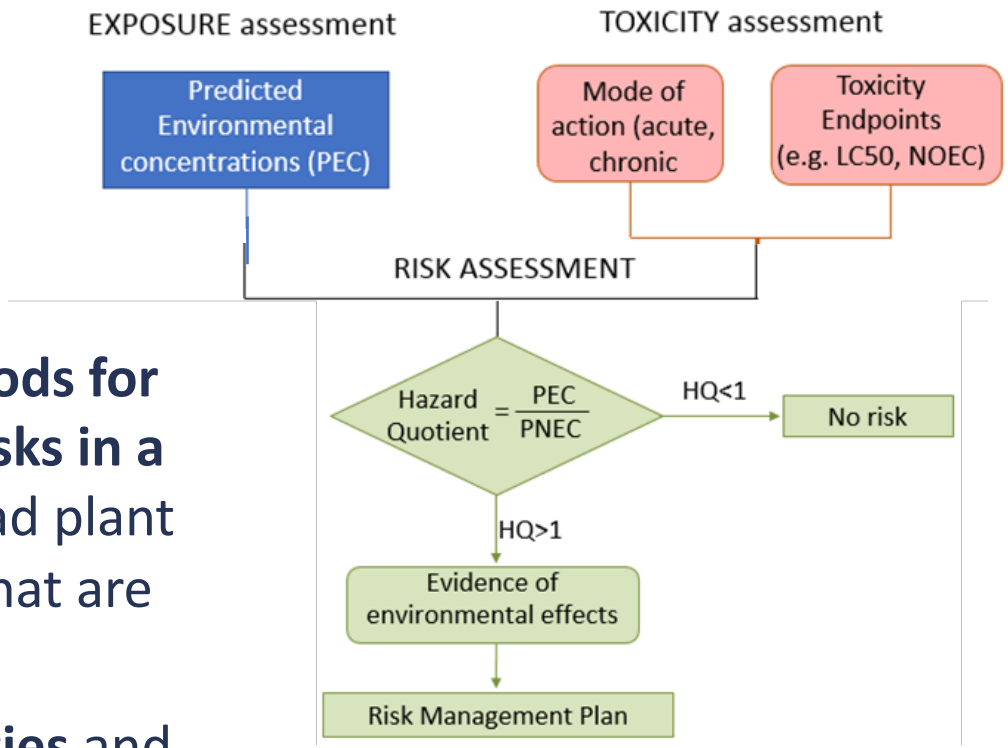


Specifically ….

Environmental quality standards, impacts and risk assessment

Objectives

- Establish a **H&E hazard database** for flue gas constituents, including amine solvents, degradation products, and other flue gas components



- Establish and implement **robust risk assessment methods for monitoring, modelling and assessing emissions and risks in a regional context**, considering the effects of variable load plant operations and impurities from a number of facilities that are co-located in a given region.
- **Establish dialogue between the industry and authorities** and advice on robust Environmental and Health Quality Standards and criteria (emission limits, design concepts and risk management), aiming to make these practices internationally accepted.

Activity team

IMPERIAL	Anna Korre, Sevket Durucan, Maria Lathouri, Quentin Wolf
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IITKGP	A. K. Patra, Pinaki Sar
MIPL	Purvil Khakharia

Several colleagues across the partnership to be involved in regional case studies

Methods and guidelines for environmental and health risk assessment

M1-M32

The work conducted involves the following activities:

- Describe a) relevant industrial environmental and health guidelines and practices, including risk-based approaches based on internationally accepted methods, b) collected health and environmental information on amine-based CO_2-capture technologies, including data on solvents and degradation products, c) identify information gaps.
- Prepare H&E hazard database on CO_2-capture flue gas constituents in collaboration with WP1 and WP2.
- Design emission hazard assessment and toxicity assessment protocols related to amine solvent systems. Assessment on flue gas emissions will be based on input from WP1 and WP2.
- Develop emission monitoring methodologies and protocols.

Methods and guidelines for environmental and health risk assessment

M1-M32

Environmental hazard method description and development

(**SINTEF OC, EA,** IITKGP, GGS IPU) M1-M12

A: Methods for hazard assessment of solvents and degradation products: additional standard single compound ecotoxicity testing; additive toxicities of single emission compounds vs toxicities of selected mixtures; toxicity data from aquatic studies; use assessment factors to determine toxicity threshold levels as Predicted No-Effect Environmental concentrations (PNECs).

B: Based on environmental hazard assessments, the risk of emissions of potential persistent, bioaccumulative and/or toxic compounds (PBTs) will be addressed. Internationally approved criteria for defining PBT compounds will be used.

Complete

Review available data from previous environmental studies of amine solvents and degradation products and include data in a hazard database to be used for monitoring and modelling purposes.

Methods and guidelines for environmental and health risk assessment

M1-M32

Environmental hazard method description and development

(SINTEF OC, EA, **IITKGP, GGS IPU**) M1-M12

C: Impact of amine-rich waste streams on local ecosystem components & biogeochemical function, microorganisms and their natural attenuation will be assessed (microcosms, mesocosms and field-based studies). The impact of amines and other toxic compounds on major biotic components (e.g. bacteria and algae) along with their biodegradability will be assessed. In silico and in vitro methods will be developed to assess the impact of various amines and their biodegradability by natural microorganisms.

Complete

Methods and guidelines for environmental and health risk assessment

M1-M32

Health-related hazard assessment – data for dispersion models

(**NILU, IMPERIAL,** GGS IPU) M1-M12

Review available human related toxicology data

Assess exposure to nitrosamines/nitramines and adverse health effects in humans.

Explore dose-response assessment for individual compounds for suitability for emission mixtures.

Complete

Establish a reliable and transparent human health hazard assessment strategy with focus on the emissions from amine-based scrubbing solvents and their degradation products to air.

Methods and guidelines for environmental and health risk assessment

M1-M32

Atmospheric dispersion and fate of emissions

(**IMPERIAL, CERC,** SINTEF OC) M1-M18

In progress

Use the theoretical model developed at Imperial to investigate the reaction mechanisms and evaluate reaction kinetics of generic amines with atmospheric radicals (volatility, polarity, hygroscopic nature and great affinity to surfaces) and consider the modelling and experimental results from WP1 and WP2 to update the rate constants.

Use CERC's atmospheric dispersion model ADMS to quantify the photochemical production of nitrosamines/nitramines from emitted amines in the region around a PCC plant.

Methods and guidelines for environmental and health risk assessment

M1-M32

Atmospheric dispersion and fate of emissions

(**IMPERIAL,** CERC, SINTEF OC) M1-M18

A number of modifications to the ADMS amine module functionality has been implemented to improve versatility (allowance for multiple sources and more than one amine in each source, as well as allowance for hygroscopic particulate emissions).

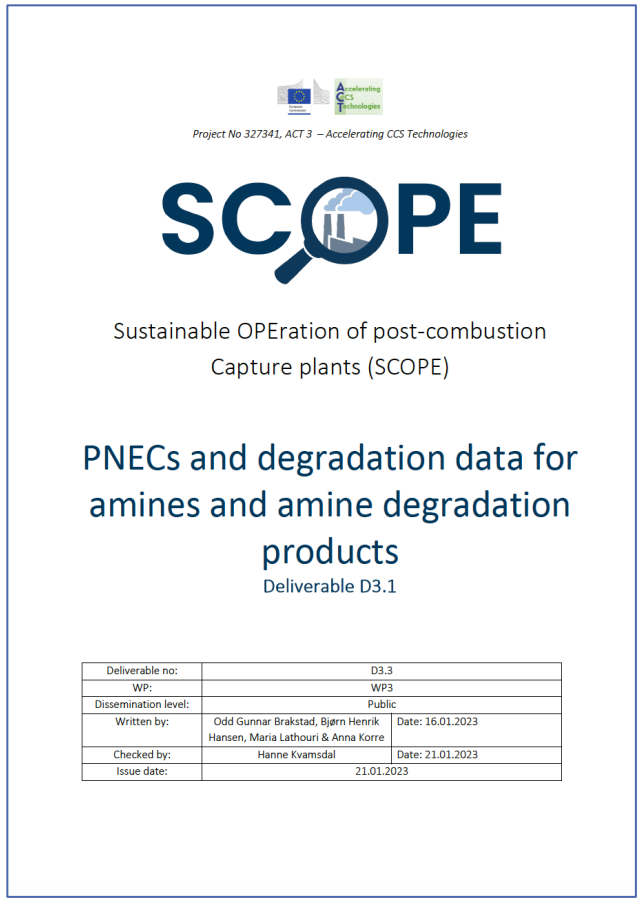
Development of specification, testing and verification using the project case studies is beeing implemented before releasing the new code.

On this basis, the atmospheric ground-level concentrations of these emitted substances, varying as a function of distance from the emitting PCC facility will be estimated for all single facility studies and the regional industrial decarbonisation clusters (Task 3.2).

CERC has updated the ADMS code, Imperial is working on emissions modelling

Key outcomes

three public deliverables have been completed which form the essential backbone in the development of methods and rules for risk assessment of emissions from flue gas of CO_2-capture facilities.



Project No 327341, ACT 3 – Accelerating CCS Technologies

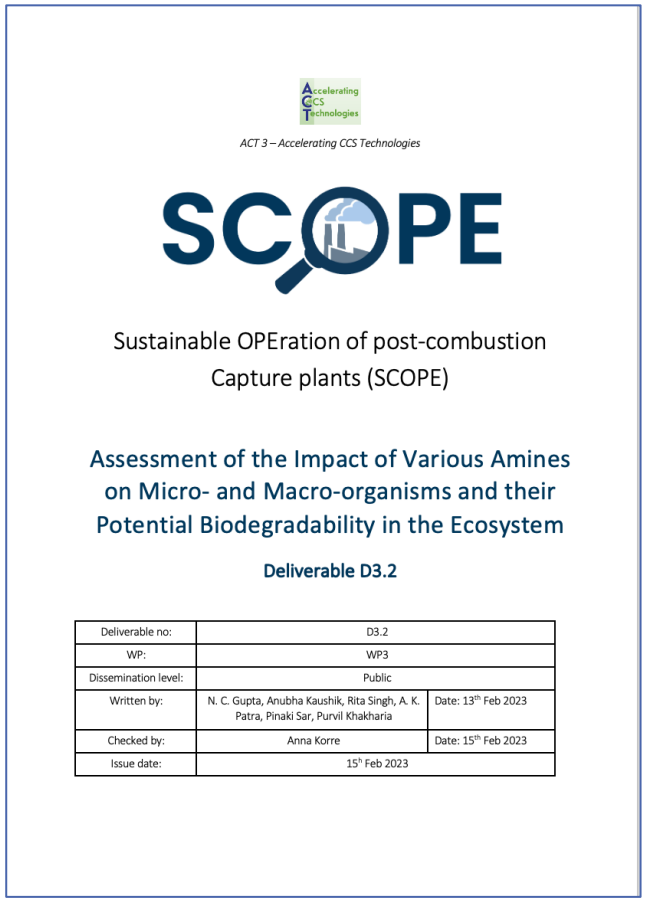
SCOPE

Sustainable OPEration of post-combustion Capture plants (SCOPE)

PNECs and degradation data for amines and amine degradation products

Deliverable D3.1

Deliverable no:	D3.3	
WP:	WP3	
Dissemination level:	Public	
Written by:	Odd Gunnar Brakstad, Bjørn Henrik Hansen, Maria Lathouri & Anna Korre	Date: 16.01.2023
Checked by:	Hanne Kvamsdal	Date: 21.01.2023
Issue date:	21.01.2023	



ACT 3 – Accelerating CCS Technologies

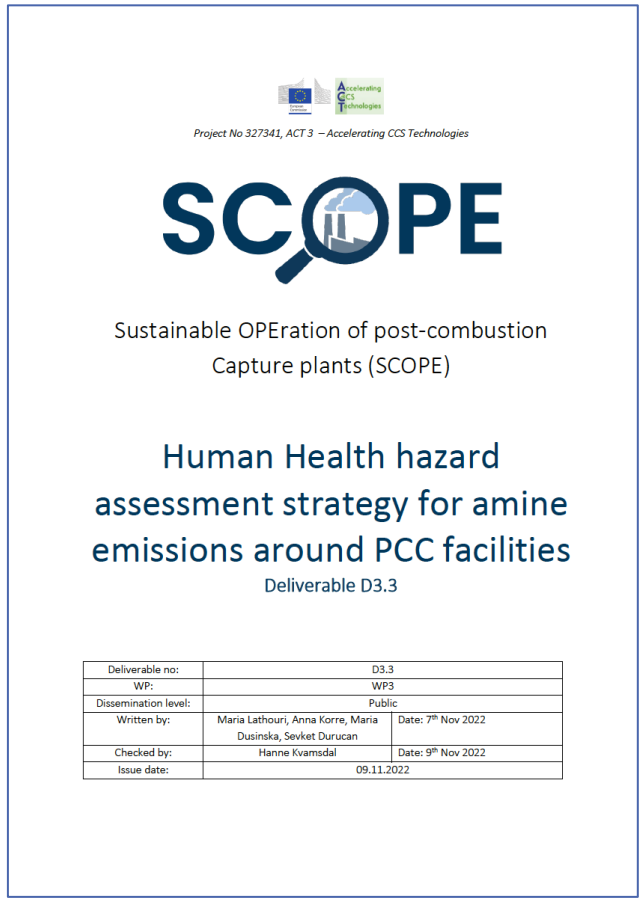
SCOPE

Sustainable OPEration of post-combustion Capture plants (SCOPE)

Assessment of the Impact of Various Amines on Micro- and Macro-organisms and their Potential Biodegradability in the Ecosystem

Deliverable D3.2

Deliverable no:	D3.2	
WP:	WP3	
Dissemination level:	Public	
Written by:	N. C. Gupta, Anubha Kaushik, Rita Singh, A. K. Patra, Pinaki Sar, Purvil Khakharia	Date: 13th Feb 2023
Checked by:	Anna Korre	Date: 15th Feb 2023
Issue date:	15h Feb 2023	



Project No 327341, ACT 3 – Accelerating CCS Technologies

SCOPE

Sustainable OPEration of post-combustion Capture plants (SCOPE)

Human Health hazard assessment strategy for amine emissions around PCC facilities

Deliverable D3.3

Deliverable no:	D3.3	
WP:	WP3	
Dissemination level:	Public	
Written by:	Maria Lathouri, Anna Korre, Maria Dusinska, Sevket Durucan	Date: 7th Nov 2022
Checked by:	Hanne Kvamsdal	Date: 9th Nov 2022
Issue date:	09.11.2022	

The partners reviewed the principles and methodologies of environmental risk assessment (ERA), including underlying laboratory methods to address persistence (P) bioaccumulation (B) and ecotoxicity (T) of chemicals.

In the deliverable report produced, internationally approved criteria for defining PBT compounds have been used to classify amines, solvents, and their degradation products.

			Persistence (abiotic)		Biodegradation			Bioaccumulation		Toxicity				
Substance	Abbr.	CAS no.	Hydrolysis	Photodegradation Half life (days)	Primary Estimated time factor	Ultimate Estimated time factor	Ready biodegradable Yes/No)	Octanol-water logPow	Bioconcentration BCF	Algae (EC50 (mg/L)	Daphnids EC50(mg/L)	Fish LC50(mg/L)	PNEC µg/L)	PNEC (mg/L)
Acetic acid		64-19-7	No data	17.2	4,1467 (days)	3,4311 (days-weeks)	Yes	-0.17	0.7494	4403	12270	25786	4403	4.403
Oxalic acid		144-62-7	No data	10.3	4,4890 (hours-days)	3,7294 (days-weeks)	Yes	-1.74	0.894	4403	12270	25786	4403	4.40
Bicine		150-25-4	No data	0.1	3.9688 (days)	3,2683 (days-weeks)	Yes	-3.27	0.893	164000	58956	913000	58956	58.96
1-hydroxythane-1,1-phosphonic acid	HEPO	2809-21-4	No data	8.8	3,3970 (days-weeks)	2,5318 (weeks-months)	No	-0.01	0.9172	No data*	No data*	No data*	No data	No data
N-(2-hydroxyethyl)glycine	HeGly	5835-28-9	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
Ammonia		7664-41-7	No data	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	100	263	545	100	0.1
Formaldehyde		50-00-0	No data	1.3	4,0011 (days)	3,1551 (weeks)	Yes	0.35	1.056	48	46	13	13	0.013
Acetaldehyde		75-07-0	No data	0.6	3,9808 (days)	3,1241 (weeks)	Yes	-0.34	0.9265	152	163	34	34	0.034
Ethyleneglycol		107-21-1	No data	1.3	4,0171 (days)	3,3819 (days-weeks)	Yes	-1.36	0.894	3536	16104	38110	3536	3.536
Acetone		67-64-1	No data	52.4	3,7417 (days-weeks)	3,0483 (weeks)	Yes	-0.24	0.929	4852	2241	711	711	0.711
Acetonitrile		75-05-8	No data	414	3,7233 (days-weeks)	3,0261 (weeks)	Yes	-0.34	0.9244	436	1327	2850	436	0.436
Methylamine		74-89-5	No data	0.5	3,8462 (days)	3,1550 (weeks)	Yes	-0.57	0.9144	43	28	323	28	0.028
Dimethylamine		124-40-3	No data	0.2	3,8260 (days)	3,1240 (weeks)	Yes	-0.38	0.9306	29	21	232	21	0.021
Ethylamine		75-04-7	No data	0.4	3,8260 (days)	3,1240 (weeks)	Yes	-0.13	0.9559	28	21	223	21	0.021
Diethylamine		109-89-7	No data	0.1	3,7855 (days)	3,0620 (weeks)	Yes	0.58	1.262	10	9	85	9	0.009
Ethyl-methylamine		624-78-2	No data	0.1	3,8057 (days)	3,0930 (weeks)	Yes	0.15	1.026	17	14	145	14	0.014
Propylamine		107-10-8	No data	0.3	3,8057 (days)	3,0930 (weeks)	Yes	0.48	1.167	17	14	139	14	0.014
2-methyl-2-(methylamino)propane-1-ol		27646-80-6	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
Nitromethane		75-52-5	No data	1.3	3,7597 (days)	3,0643 (weeks)	Yes	-0.35	0.9181	545	1592	3385	545	0.545
Nitroethane		79-24-3	No data	71.8	3,7394 (days-weeks)	3,0333 (weeks)	Yes	0.18	0.9914	306	742	1508	306	0.306
N-(2-hydroxyethyl)-ethylenediamine (HEED)	HEED	111-41-1	No data	0.09	3,9135 (days)	3,1779 (weeks)	Yes	-2.13	0.8934	1617	758	10282	758	0.758
Formamide		75-12-7	No data	5.3	3,9882 (days)	3,0454 (weeks)	Yes	-1.51	0.8936	74	29875	5140	74	0.074
Acetamide		60-35-5	No data	5.4	3,9629 (days)	3,0114 (weeks)	Yes	-1.26	0.8941	51	15220	3220	51	0.051
N-(2-hydroxyethyl)acetamide	HEA	142-26-7	No data	0.7	4,0338 (days)	3,0770 (weeks)	Yes	-1.67	0.8934	185	77427	12972	185	0.185
Hydroxyethylamine acetamide	HEHEAA	44236-35-5	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data

The partners collected and compiled available and reliable data on degradation, bioaccumulation and ecotoxicity of amines, solvents, and degradation products relevant for carbon capture technologies and summarised the information from well-grounded databases

Key findings

- Additional ecotoxicity data will likely lead to reduced Predicted No Effect Concentrations for amines.
- Additivity may be used to explain mixture toxicity of amines in binary mixtures, but more complex emissions need to consider degradation products.
- The environmental fate of nitrosamines during winter periods is more critical, noting that they are relatively more acutely toxic to phytoplankton than to invertebrates and fish.
- Nitramines would likely be less of concern from a toxicological perspective.

Key findings

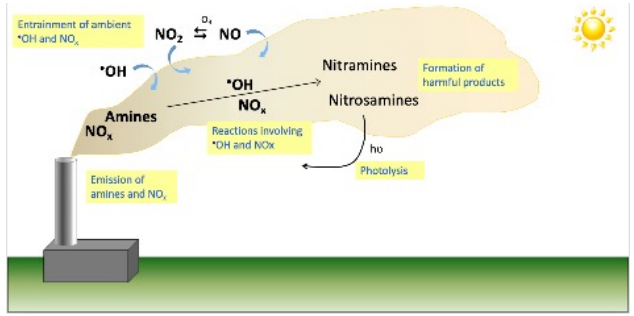
- With regard to human health hazard assessment, the majority of the nitrosamines are classified to either group 2B – possibly carcinogenic to humans – or group 2A – probably carcinogenic to humans.
- Nitramines are considered as highly toxic, although they seem to be less potent as mutagens and carcinogens than their corresponding nitrosamines.
- Special attention should be given to sensitive populations.
- Although several organisations and institutions have established different public health thresholds for different nitrosamines and nitramines, there is need for a continuing effort in toxicity data for both to derive more realistic levels that are protective of the human health.

Key findings

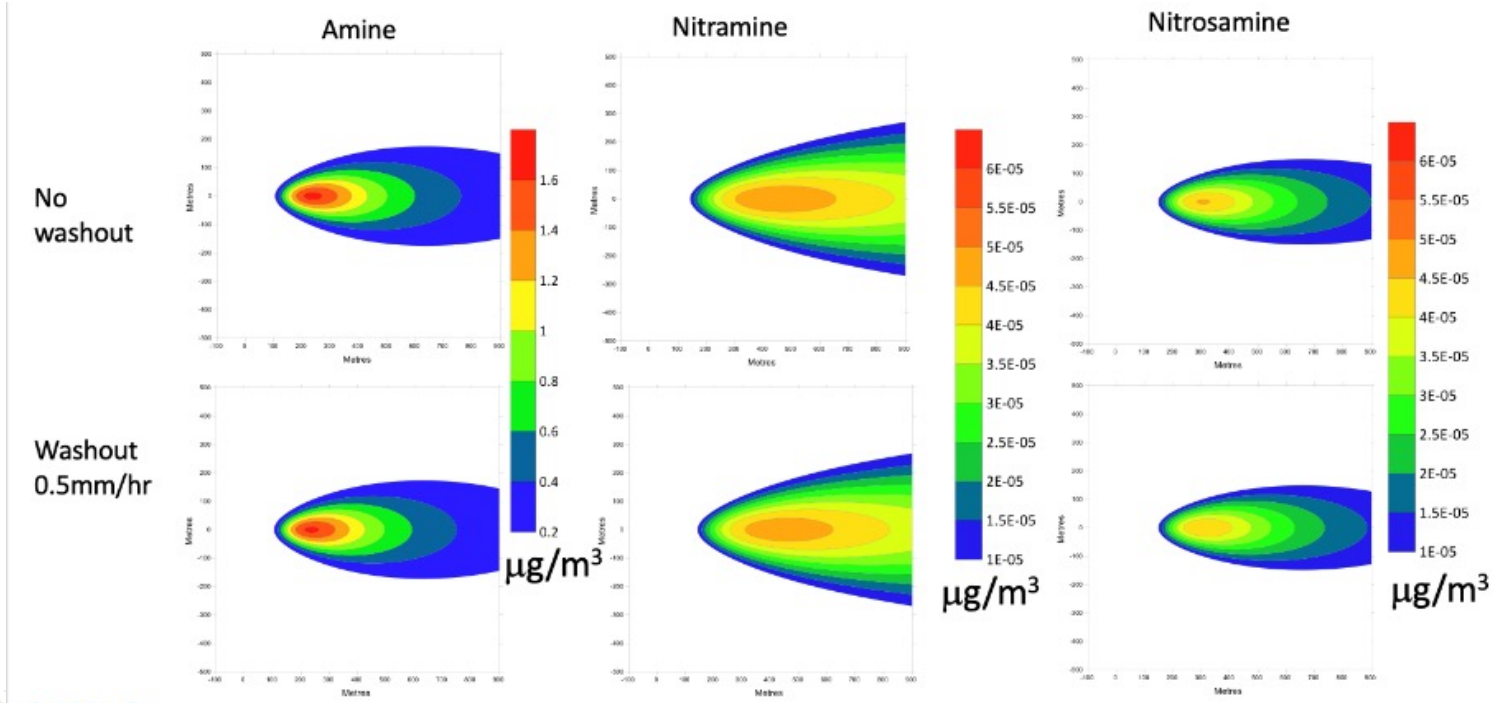
- There is lack of comprehensive and systematic studies on impacts of the amines and their derivatives on various types of living organisms and ecosystems.
- A few studies have indicated that certain environmental factors play a significant role, while others are not so important.
- It is likely that the potential for toxic impacts in different regions may be highly variable due to substantial variations in ecological and environmental conditions.

Modifications to the ADMS 6 amine module functionality

Improved versatility in modelling, reduced the need for post-processing of separate runs, allows interaction between species, considers amine uptake into liquid water as some amine species are highly soluble and the absorption of amines into the aqueous phase can reduce peak nitramine and nitrosamine concentrations by limiting chemical reactions.



Example output of ground level concentrations for a test case



Case studies around facilities - emissions modelling and risk assessment

M15-M32

(**SINTEF OC, NILU, IMPERIAL, TCM, EA**)

The case studies around facilities and regional clusters that will be studied are

Single sources:

Technology Centre Mongstad, Norway; Twence, Netherlands; a full scale capture facility next to an industrial cluster in Germany; the Tuticorin and Vindhyachal single emission facilities, India.

Regional assessment cluster studies for multiple sources:

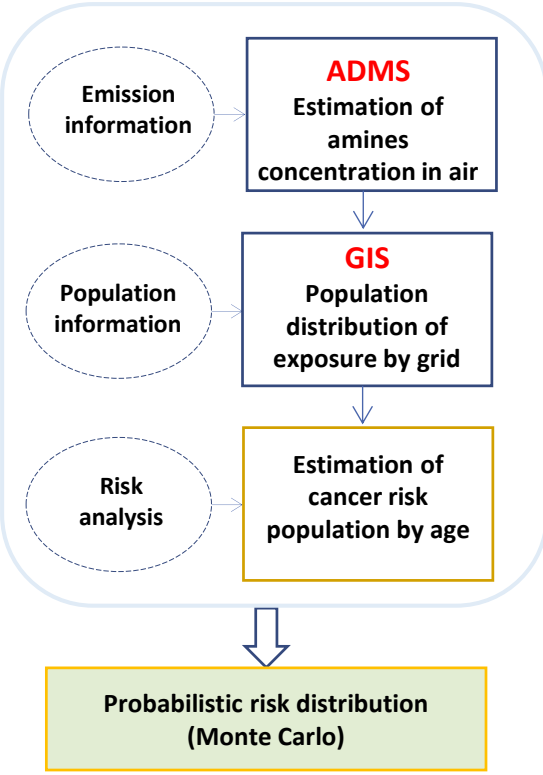
West coast cluster (Mongstad) and Grenland in Norway; the Net Zero Teesside cluster, the South Wales Industry Cluster, and the Grangemouth cluster in the UK; multiple sources in the Rotterdam region, Netherlands.

Methodology of general assessment

Baseline map & regional data collection:

- Map data: Edina OS
- Meteorological data: Visual Crossing (includes further stations if data is missing)
- Background pollution: UK Air, Defra (several pollutants including NOx, NO_2, NO, O_3, and missing data processing: average from before & after)

1. PCCC plants' location & individual specifications (Environment Agency, Industry reports)
2. Dispersion modelling of the emissions in ADMS:
   - Amines (MA, DMA, MEA and others)
   - Nitrosamines & Nitramines
   - NO_x, NO_2, NO and others
3. Assess receptor distribution and location (population, nature)
   - Local distribution: Edina population and building data
   - Age distribution: Edina population
4. Create Intake model based on air pollution model + population distribution
5. Assess Intake Distribution statistically
6. Develop solutions for mitigation



Progress so far

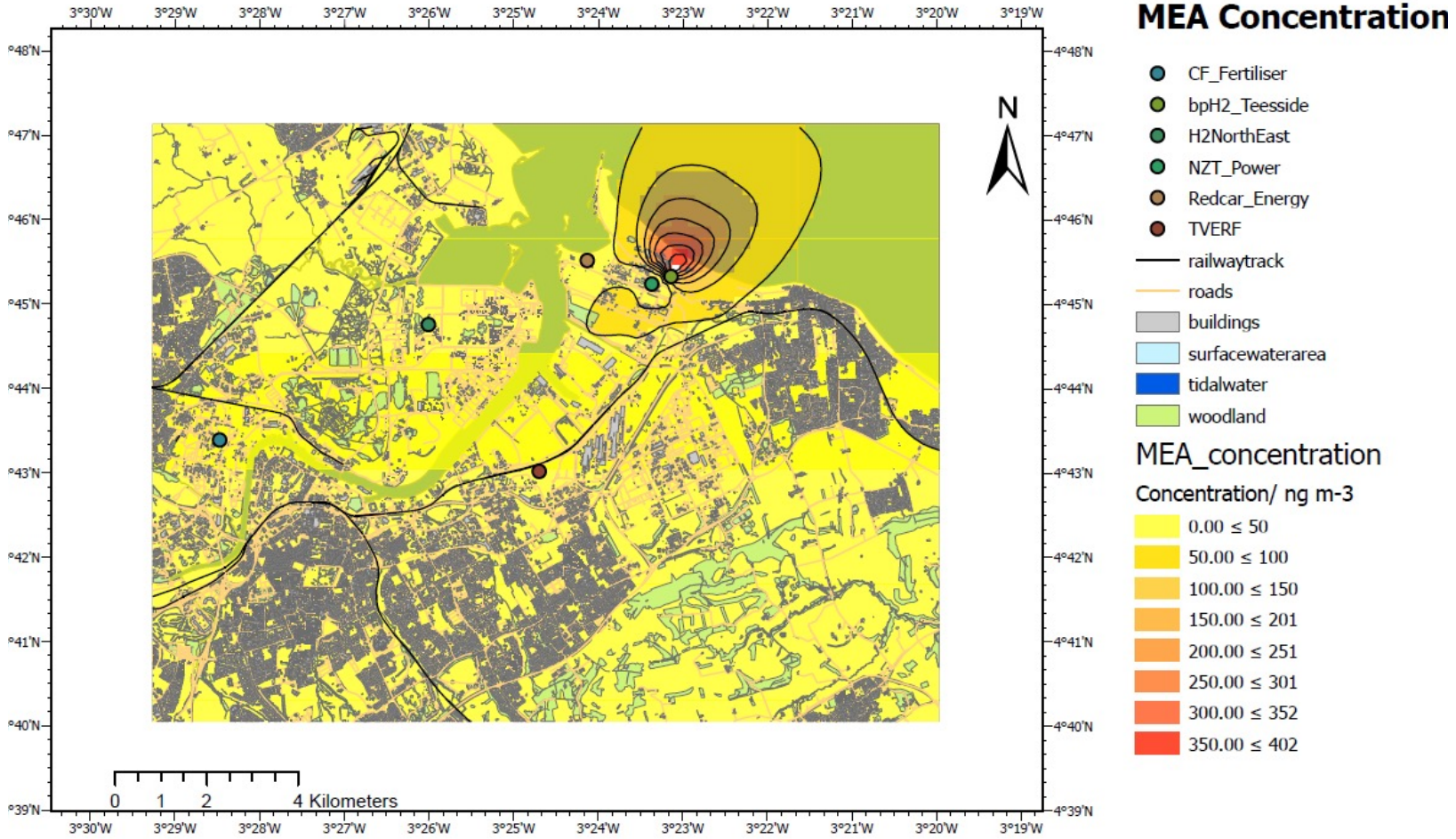
Task	UK	Norway	UK status	Norway status
Get Mapping data	Edina	Geonorge	Completed	Advanced
Get meteorological data	Visual Crossing	seKlima	Completed	Advanced
Get Background pollution data	DEFRA	-	Completed	Planned
PCCC plant specifications	Industry reports, UK EA	TCM publications	Advanced	Started
Plant technology specific emissions profile	Publications	Publications	Advanced	Started
Amine specific data (chemical properties)	Publications		Started	
Preparing data for ADMS	Python based code for ArcGIS Pro (next page)		Advanced	
Run ADMS			Advanced	Started
Analyse, prepare and visualise ADMS results in ArcGIS Pro	Python based code for ArcGIS Pro (next page)		Advanced	
Get population data (and/or building data for allocation)	Edina (UK Census)	Statistics Norway (ssb)	Completed	Started
Allocate population data to uniform location grid for future risk assessment	1. Python based code for ArcGIS Pro (next page) 2. MATLAB code for fast allocation (next page)		Advanced	Planned
Create deterministic human health risk assessment	MATLAB code based on publications		Started	Planned
Create probabilistic hh risk assessment	MATLAB code based on publications		Planned	
Develop solutions for mitigation			Future	
Create environmental risk assessment			Future	
Integrate weather forcasting in the process			Future	

Teesside Industrial Cluster – Example with 1 source

preliminary results

Net Zero Teesside CCUS Project, MEA:

- Max average concentration: 402.5 ng/m^3
- Max hourly concentration: 3,048.8 ng/m^3
- No exceedance of UK limits (7,800 ng/m^3)
- Exceedance of Norwegian limit (2,500 ng/m^3) for 248 grid points by 9.9% on average



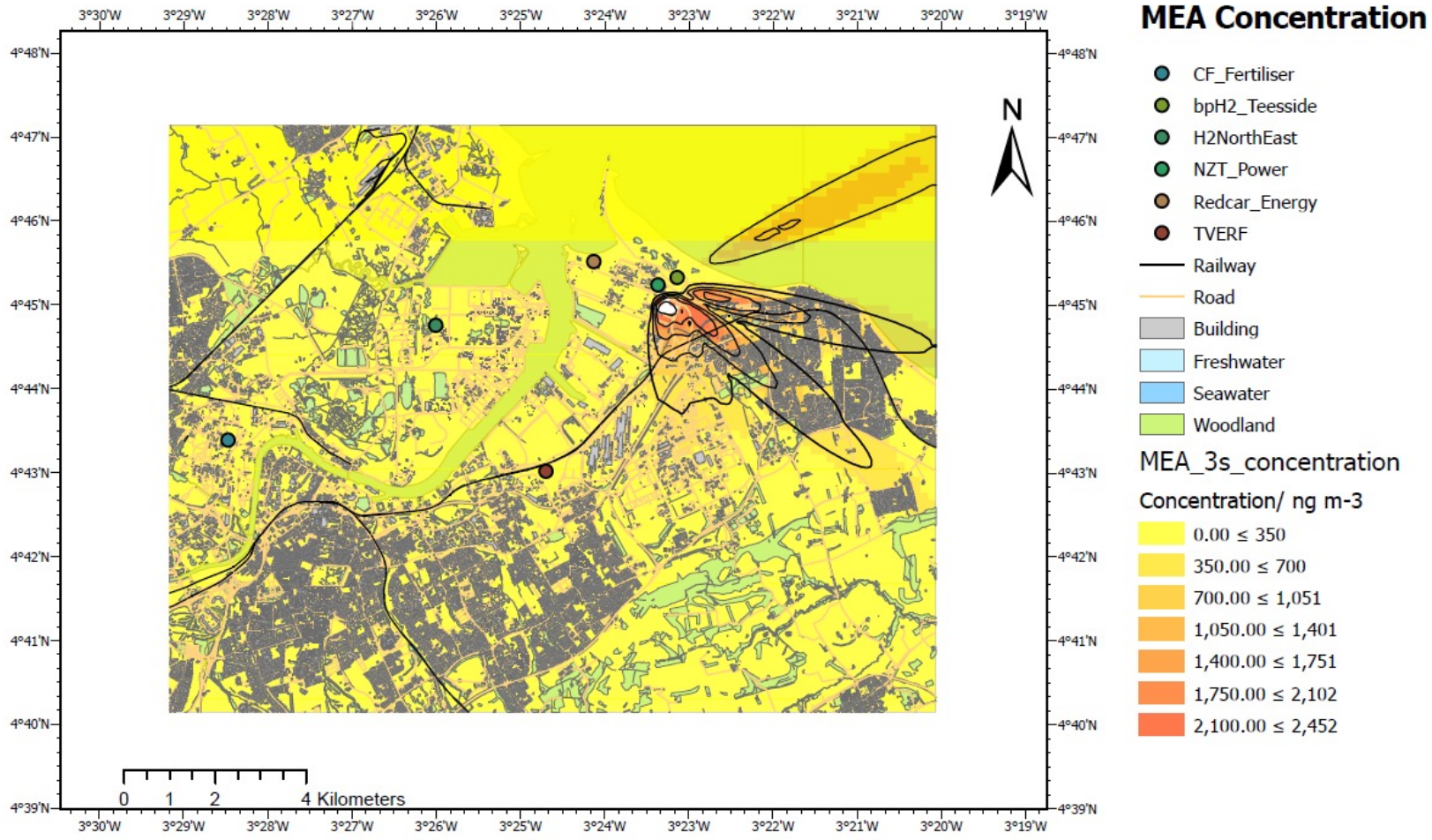
Teesside Industrial Cluster – Example with 3 sources

preliminary results

CCUS Project, MEA:

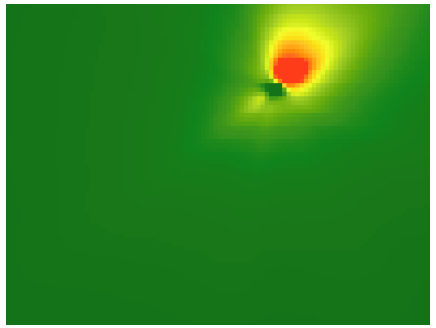
- In progress: max concentration displayed
- 3 MEA sources:

  NZT, Redcar energy, TVERF



Human Health Risk Assessment

Air pollution data

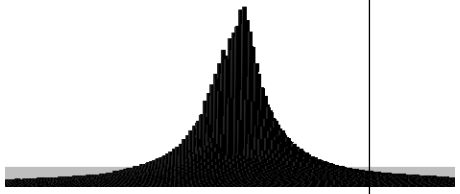


Exposure map

Population data

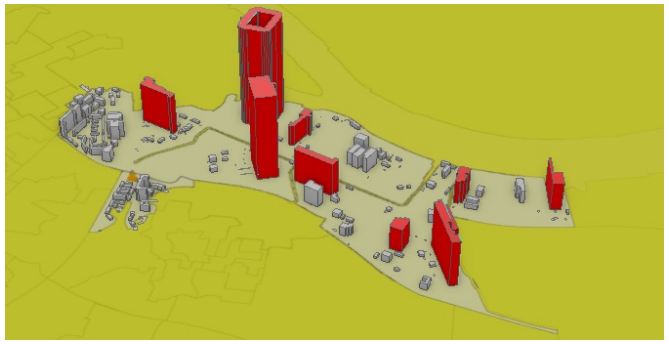
Population map

Intake Model



Intake Distribution

Statistical interrogation



Final risk map

Steps planned:

- First: deterministic risk assessment in MATLAB or Python
- 2nd: Transformation of deterministic to probabilistic risk assessment in MATLAB

Development of Environmental and Health Quality Standards for critical emissions

(**SINTEF OC, NILU, IMPERIAL, TCM, EA**) M24-M35

Based on method development, hazard and risk assessment testing and case studies, environmental and health standards for emissions will be established.

Risk standards for critical levels of emissions will be suggested, based on internationally approved rules, for the industry and for environmental regulators.

In case of emissions associated with risk, Best Available Technique(s) (BAT) and Best Environmental Practice (BEP) of emissions control measures may be used as countermeasures (e.g. change of operation procedures, emission facility design, selectively reducing emissions of compound groups representing risk) to be identified in collaboration with WP1 and WP2.

Acknowledgements

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