Carbon dioxide carriage and dangerous goods

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Setting the scene (1)

Carbon capture and storage (CCS)

- Capture
- **Delivery**
- Storage

Delivery

- Pipelines
- **Shipping of carbon**
  - Emissions trading
  - Waste regime (planned disposal / dumping)
  - **Cargo safety rules** (accidental discharge / emission)

Setting the scene (2)

- Focus on **cargo safety concerns**
  - Adjacent areas are of relevance
    - Release from the pipelines (delivery phase),
    - Release from the storage location (storage phase)
  - Common issues: type of release
    - Instantaneous / short exposure
    - Continuous / long exposure

Setting the scene (3)

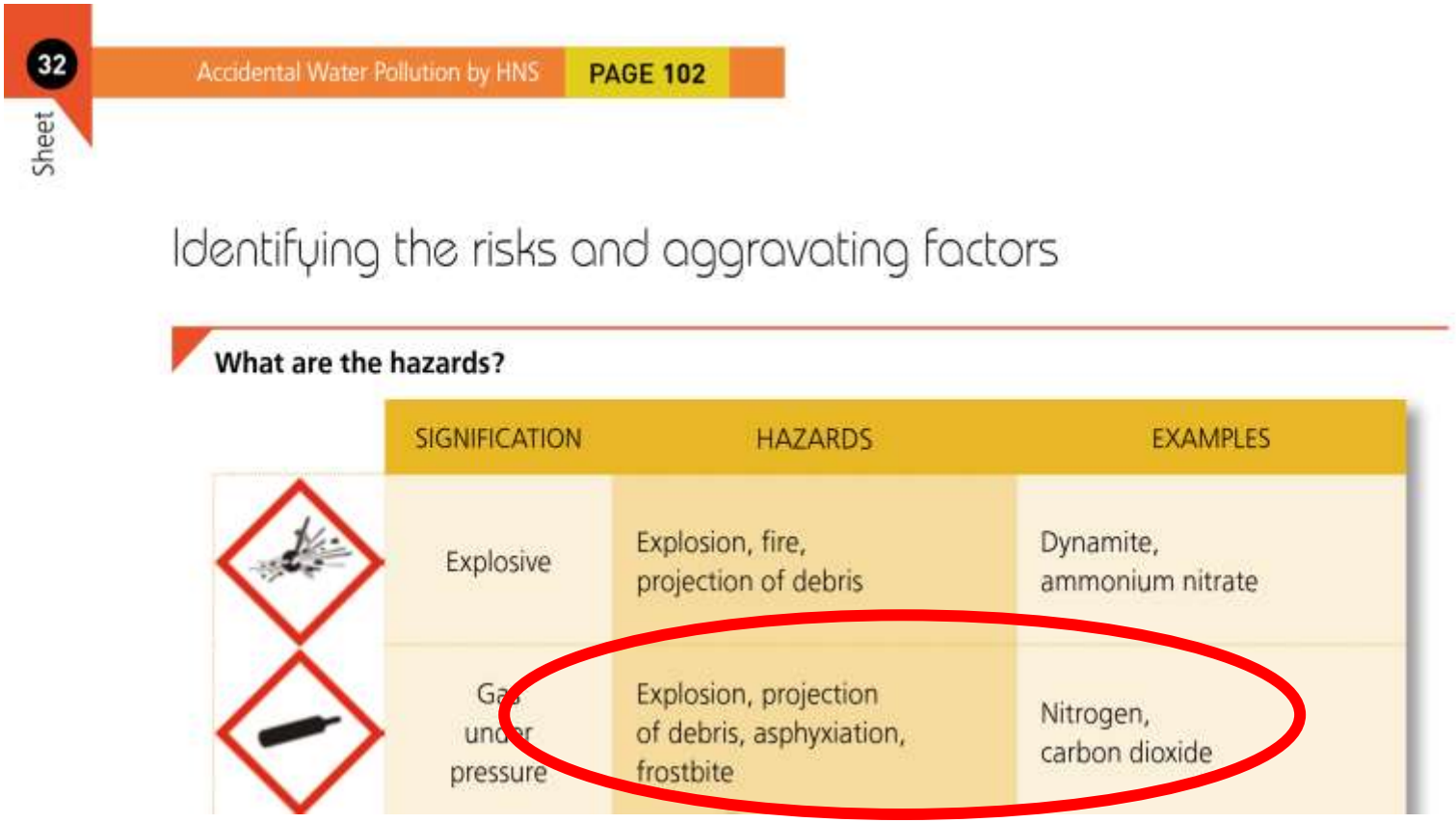
- Different but intertwined angles of cargo safety
  - **Subjects / objects** of protection
    - Uncertainty relating to the **empirical assessment**

    Often by means of experiments or industry assessments

    Worth supporting the inquiry, but with a need for special training (*multidisciplinarity research?*)

  - **Regulatory framework**

CO_2 as gas under pressure



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Sheet

Identifying the risks and aggravating factors

What are the hazards?

	SIGNIFICATION	HAZARDS	EXAMPLES
	Explosive	Explosion, fire, projection of debris	Dynamite, ammonium nitrate
	Gas under pressure	Explosion, projection of debris, asphyxiation, frostbite	Nitrogen, carbon dioxide

Source: *Accidental Water Pollution by Hazardous and Noxious Substances*. Canada: Cedre, 2020. https://wwz.cedre.fr/en/Resources/Publications/Operational-Guides/HNS-Accidental-Water-Pollution.

Subjects and objects of protection
A short summary

- Humans
  - Own crew / crew on the colliding vessel
  - Coastal population
- Animals
  - Maritime animals
  - Coastal animals
- Environment more broadly
- Machinery

Humans – Risks (1)

- Frostbites
- Asphyxiation
  - Many examples from earlier accidents involving CO_2
    - Sataria pipeline (Missisippi, 2020): 46 hospitalizations and 200 evacuees
    - Mönchengladbach (Germany, 2008): 107 people were intoxicated, 19 of whom were hospitalised
    - Lake Nyos disaster (Cameroon, 1986): 1,746 people and 3,500 livestock; plants destroyed
    - Fire suppression systems (US, 1975-2000): 72 deaths and 145 injuries

Humans – Risks (2)

- Medical literature review (2017): a rare but serious case for emergency rooms
  - Permentier K, Vercammen S, Soetaert S, Schellemans C. Carbon dioxide poisoning: a literature review of an often forgotten cause of intoxication in the emergency department. Int J Emerg Med. 2017 Dec;10(1):14. doi: 10.1186/s12245-017-0142-y. Epub 2017 Apr 4. PMID: 28378268; PMCID: PMC5380556.

- However: additional risks if CO_2 is impure (contamination)
  - Example: H_2S has much lower tolerance levels

- Neurological effects
  - Headaches, dizziness, confusion and loss of consciousness

Humans – Emergency response (2)

FACT SHEET 5.25

Portable gas detectors for first responders — Response

What to measure

The table below describes different variables, reference measures and response actions, in brief and limited to some common issues related to gas. Further training on these variables and appropriate response actions should be provided to all first responders, including the use of gas monitors and confined spaces training.

Measure to be detected Gas detected	Ambient level	Action to be taken
O_2 (oxygen)	< 19.5%	Monitor wearing SCBA. *Caution: combustible gas readings are not valid in atmospheres with < 19.5% oxygen.*
	19.5% - 22%	Continue investigation with caution. SCBA not needed, based on oxygen content alone.
	> 22.0%	Discontinue inspection; fire hazard potential. Consult specialist.
CO_2 (Carbon dioxide)		Evacuate immediately if detected. Monitor only wearing SCBA.

Source: MARINE HNS RESPONSE MANUAL: Multi-Regional Bonn Agreement, HELCOM, REMPEC. Project West MOPoCo, 2021. (p. 200)

Risks for animals and the environment

- Risk of dissolution of seashells

But: the negative impact was not confirmed in a 2014 experiment

'Here we investigate the detectability and environmental impact of leakage from a controlled sub-seabed release of CO_2. **We show that the biological impact and footprint of this small leak analogue (<1 tonne CO_2 d^{-1}) is confined to a few tens of metres.** Migration of CO_2 through the shallow seabed is influenced by near-surface sediment structure, and by dissolution and re-precipitation of calcium carbonate naturally present in sediments.'

(from the article abstract) Blackford, J., Stahl, H., Bull, J. *et al.* Detection and impacts of leakage from sub-seafloor deep geological carbon dioxide storage. *Nature Clim Change* **4**, 1011–1016 (2014).

https://www.scientificamerican.com/article/leaking-co2-fails-to-cause-marine-catastrophe/

Risks to the machinery

"CO2 would behave differently from LNG, because liquid CO2 in a tanker is not as cold as LNG but much denser. Its interactions with the sea would be complex: hydrates and ice might form, and temperature differences would induce strong currents. Some of the gas would dissolve in the sea, but some would be released to the atmosphere. **If there were little wind and a temperature inversion, clouds of CO2 gas** might lead to asphyxiation and **might stop the ship's engines."**

Source: IPCC Special Report on Carbon dioxide Capture and Storage (2005), p. 189

URL: https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_chapter4-1.pdf

Regulatory framework

Can be systematized by the **focus**:

- Safety
- Environment

By the **geographical scope** of regulation:

- Global scope
- Regional scope
- National scope

Regulatory framework of global scope – Safety (1)

- Historically, safety concerns were recognized *before* the environment

Dangerous goods can be landed or destroyed without liability in some conditions (lack of consent of the carrier, or if they present danger)

- 1924 Hague Rules, Article 4(6)
- 1978 Hague/Visby Rules, Article IV (6)

Regulatory framework of global scope – Safety (2)

- 1974 International Convention for the Safety of Life at Sea (SOLAS)

  Chapter VII - Carriage of dangerous goods

  Regulation 13 - Requirements for gas carriers

  1 **A gas carrier shall comply with the requirements of the International Gas Carrier Code** *(IGC Code)*

Regulatory framework of global scope – Safety (3)

- Hazardous and Noxious Substances Convention (**HNS Convention**; 1996, as amended 2010; not in force)

  Article 1(5):

  Hazardous and noxious substances (HNS) means:

  (v) **liquefied gases as listed in chapter 19 of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk**, as amended, and the products for which preliminary suitable conditions for the carriage have been prescribed by the Administration and port

Regulatory framework of global scope – Safety (4)

International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (2014, previously 1983)

- Chapters 17.21-22 (CO_2)

17.21 Carbon dioxide: high purity
17.22 Carbon dioxide: reclaimed quality

- Chapter 19 Summary of Minimum Requirements

Type 3G carry the **least hazardous products** (e.g. nitrogen, **carbon dioxide**).

Art. 2.1.2.4: A *type 3G ship* is a gas carrier intended to carry the products indicated in chapter 19 that **require moderate preventive measures to preclude their escape.**

Regulatory framework of global scope – Environment (1)

- General environmental protection
  - The core climate change bundle
    - 1992 UN Framework Convention on Climate Change (UNFCCC)
    - 1997 Kyoto Protocol to UNFCCC
    - 2015 Paris Agreement
  - Convention on long-range transboundary air pollution (Geneva, 1979; EIF: 1983):
    - "Air Pollution" means the **introduction** by man, directly or indirectly, of **substances or energy into the air resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems** and material property and impair or interfere with amenities and other legitimate uses of the environment, and "air pollutants" shall be construed accordingly;
  - Waste law regime
    - 1974 Convention on the Prevention of **Marine Pollution** by **Dumping** of Wastes and Other Matter
    - 1996 London Protocol (Art. 6 – Cross-border movement of waste)

Regulatory framework of global scope – Environment (2)

- **International Convention for the Prevention of Pollution from Ships**, 1973, as modified by the Protocol of 1978 relating thereto (**MARPOL**)

Definitions

(2) "Harmful substance" means **any substance** which, if introduced into the sea, is **liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea,** and includes any substance subject to control by the present Convention.

(a) **"Discharge",** in relation to harmful substances or effluents containing such substances, means any release howsoever caused from a ship and includes **any escape, disposal, spilling, leaking, pumping, emitting or emptying**;

(b) "Discharge" **does not include:**

(i) **dumping** within the meaning of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, done at London on 13 November 1972;

Regulatory framework of global scope – Environment (3)

- **International Convention for the Prevention of Pollution from Ships**, 1973, as modified by the Protocol of 1978 relating thereto (**MARPOL**)

Annex VI - Regulations for the **Prevention of Air Pollution from Ships**

Chapter 4 – Regulations on the **carbon intensity** of international shipping

Regulation 3

Exceptions and exemptions

General

1 **Regulations of this Annex shall not apply to:**

- any emission necessary for the purpose of securing the safety of a ship or saving life at sea; or
- **any emission resulting from damage to a ship or its equipment**

Regional environmental protection agreements

- Nordic Environmental Protection Convention (1974)

Objective: To safeguard environmental interests in the case of nuisances arising from environmentally harmful activities implemented in other Contracting States.

- Agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983

EU plus Norway (**Bonn Agreement**, 1983)

- Convention on Civil Liability for Damage resulting from Activities Dangerous to the Environment (ETS No. 150) - Lugano, 1993

Not in force

National work safety rules

- UK Health and Safety Executive
  - CO2 is classed as a 'substance hazardous to health' under the Control of Substances Hazardous to Health Regulations 2002 (COSHH).
  - EH40/2005 Workplace exposure limits

Danish industry reflections (1)

"**It is not the assessment** of shipping industry stakeholders that **there are any technical barriers** that would make maritime **transport of CO2** on a large scale **more difficult to transport than other gases** currently transported by ship." (p. 20, *translated w/Deepl*)

"As noted earlier in this report, CO2 transport is not expected to become more difficult or complicated compared to other gases." (p. 25)

Source: "Maritim transport af CO2." Aarhus & København: Teknologisk Institut & Maersk Broker Advisory Services, October 2022. https://maerskbroker.com/wp-content/uploads/2022/10/Maritim-transport-af-CO2-final.pdf.

Danish industry reflections (2)

" In order to establish local buffers, there are a number of safety aspects that need to be considered. Although the industry has considerable experience in handling other acutely toxic and flammable gases, **there are still considerations about the safety of storing CO2, especially close to urban areas."** (p. 24)

Source: "Maritim transport af CO2." Aarhus & København: Teknologisk Institut & Maersk Broker Advisory Services, October 2022. https://maerskbroker.com/wp-content/uploads/2022/10/Maritim-transport-af-CO2-final.pdf.

Some preliminary conclusions

- Knowledge gap between the legal framework and the actual demonstratable risk for the subjects / objects of protection
  - Precautionary approach / evidence of the lower degree of danger than presumed
- While more studies are needed, the industry actors seem to be optimistic and proceed towards the realization of carbon shipping projects

Thank you for your attention!

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