ENVIRONMENTAL STATEMENT (VOLUME III)

Appendix 6.2 Impurities Venting

HyNet Carbon Dioxide Pipeline DCO

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 – Regulations 5(2)(a)

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1. INTRODUCTION

1.1. BACKGROUND

1.1.1. This appendix summarises the methodology and results used to screen air quality impacts from the venting of the CO_2 pipeline and associated trace components (primarily hydrogen sulphide (H_2S)) from the DCO Proposed Development.

1.1.2. The DCO Proposed Development proposes planned venting of the pipeline under the following circumstances at the Stanlow, Ince and Flint Above Ground Installations (AGI).

- Planned maintenance inspections of the pipeline using Pipeline Inspection Gauges (PIGs), hereafter referred to as 'pigging campaigns'; and
- Manifold venting during planned maintenance, which involves the venting of the CO_2 inlet and outlet manifolds at the AGIs.

1.1.3. Both pigging campaigns and manifold venting scenarios are highly infrequent. Pigging campaigns (4 PIG runs over a 2 week period) are not anticipated to take place more than once a year. Manifold venting is also planned to occur once every five years.

1.1.4. The CO_2 within the manifolds and PIG launchers/receivers will be at high pressure before venting. The CO_2 will expand and initially cool before equilibrating with ambient conditions within the vent stack and release to open atmosphere. The rate of venting of the CO_2 will be controlled by a vent valve to limit the amount of released gas that sinks and stays close to the ground, which would increase its potential for impact on humans and the environment.

1.1.5. The transportation of compressed CO_2 is not, at present, specifically addressed by UK health and safety regulations. However, it is effectively regulated under the Health and Safety at Work etc. Act 1974 and Pipelines Safety Regulations 1996. The Detailed Design of the DCO Proposed Development will, under these safety regulations, ensure that risks associated with the release of CO_2 from storage under pressure, including the formation of an asphyxiating atmosphere, are as low as reasonably practicable. Therefore, in line with Planning Policy, this air quality assessment does not directly address the impacts of the release of CO_2 itself, since as stated by Health and Safety Executive (HSE) (**Ref. 1**) "*where the risks are properly controlled the likelihood of a major hazard incident is expected to be very low, as in other similar processes in the energy, chemical and pipeline industries*".

1.1.6. The CO_2 within the pipeline , however, may contain impurities including H_2S. H_2S has potential health effects and is also odorous. By design specification at the CO_2 emitter sources associated with the Project (which are not part of the

DCO Proposed Development), the H_2S content of the pipeline gas will be limited to 5ppm. That is not to say that the H_2S content will be at 5ppm at all times, rather this is a maximum allowable concentration from an emitter.

1.2. HYDROGEN SULPHIDE

1.2.1. H_2S is odorous and potentially dangerous to human health. At low levels it can cause irritation of the eyes, nose and throat, with moderate levels causing headaches, nausea, vomiting and difficulty with breathing. Exposure to high levels of H_2S can be fatal, although the maximum concentration of H_2S within the pipeline itself (5ppm) will be below the levels at which significant health effects are likely (20ppm, Public Health England, **Ref. 2**).

1.2.2. There are no statutory ambient air quality standards set for H_2S. The HSE sets workplace exposure limits (WELs) (**Ref. 3**) to protect the health of workers. For H_2S, two WELs are set:

- Long Term WEL (time weighted average over 8 hours) – 5ppm
- Short Term WEL (peak exposure over 15 minutes) – 10ppm

1.2.3. Since the concentration of H_2S in the Newbuild Carbon Dioxide Pipeline itself is limited to 5ppm, there is no potential for exceedance of either the long or short term WELs for H_2S following the release, and dispersion (even as a dense gas), of the CO_2 to air.

1.2.4. WELs are, however, designed specifically to protect healthy adults in the workplace. They may not, necessarily, be protective for the more vulnerable population, including the very young and the old. Indeed, Public Health England (**Ref. 4**) state that sensitive members of the population may be affected at H2S concentrations of 2ppm.

1.2.5. The Environment Agency (**Ref. 5**) has set non-statutory Environmental Assessment Levels (EALs) for various pollutants including H_2S. These are:

- Annual Mean - 140µg/m^3 (equivalent to 0.09ppm)
- Hourly Mean - 150µg/m^3 (equivalent to (0.10ppm)

1.2.6. Furthermore, the US Environmental Protection Agency sets Acute Exposure Guideline Levels (AEGLs) that are intended to protect the general population, including those that might be particularly susceptible to the harmful effects of exposure to chemicals in air (**Ref. 6**). AEGL-1 (the lowest AEGL) is defined as:

"*the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure*"

1.2.7. The AEGLs for H_2S range from 0.75ppm (for 10-minute exposure) to 0.33ppm (for 8 hr exposure). The AEGLs are intended for application to situations where exposure is transient and rare and are, hence appropriate for use in the assessment of the venting of gas but, moreover, indicate that the Environment Agency EALs are conservative and protective against health effects, including transient and reversible ones. Therefore, the hourly mean EAL (150μg/m^3 or 0.1ppm, **Ref. 5**) is used for the assessment of potential health impacts from venting operations.

1.2.8. The odour threshold for H_2S, assessed in a laboratory setting, is reported to be very low, in the range 0.0001ppm (0.2μg/m^3) to 0.0013ppm (2μg/m^3) (**Ref. 1**). However, the threshold at which the characteristic, rotten egg, odour becomes apparent is several times higher. HSE (**Ref. 1**) state that the odour identification threshold for H_2S is 7ug/m^3 (0.0047ppm). Similarly, the World Health Organisation (WHO) (**Ref. 7**) consider that there is the potential for odour annoyance where H_2S concentrations exceed 7μg/m^3 as a 30-minute average. This threshold is used for the assessment of potential odour impacts.

2. METHODOLOGY

2.1. MODEL

2.1.1. The screening of air quality impacts arising from operational venting was undertaken using the ADMS dispersion model (v5.2) developed by CERC (**Ref. 8**). This model is widely used for dispersion model studies in the UK.

2.1.2. The ADMS model was developed to simulate the dispersion of neutral or buoyant plumes in the atmosphere. Since the CO_2 will cool on venting, it is likely to have an initial density that is greater than the surrounding air.

2.1.3. However, whether density effects are important in determining the dispersion of the vented gas is not simply a function of this density difference; the behaviour of the vented plume is also dependent on the dimensions of the exhaust and the level of turbulence in the atmosphere.

2.1.4. At the outset of the dispersion calculation, ADMS determines whether it is appropriate to model the release as a neutral gas. If the release fails this test, then ADMS reports an error and no calculation is made. For all scenarios tested, the ADMS model determined that density effects would not significantly influence the dispersion of the gases and, as such, it is an appropriate model for this screening assessment.

2.2. MODEL SETUP

EMISSION SOURCE

2.2.1. The estimates of the CO_2 inventories for the pigging and manifold venting scenarios are provided in **Table 1** below.

Table 1 – Pigging and Manifold Venting Emissions

Facility	Vent Description	Peak Flow (Nm^3/hr)	Average Flow (Nm^3/hr)	Diameter
Ince	Manifold	3746	859	4”
	Pig Launcher	1066	254	2”
Stanlow	Manifold	3942	952	4”
	Pig Receiver	1119	265	2”
	Pig Launcher	2521	567	3”
Flint	Manifold	4303	1073	4”

Facility	Vent Description	Peak Flow (Nm^3/hr)	Average Flow (Nm^3/hr)	Diameter
	Pig Receiver	1548	376	3”
	Pig Launcher	668	168	2”

METEOROLOGY

2.2.2. For the modelling of pigging and manifold releases, ADMS was run for 3 meteorological conditions, with arbitrary wind direction, designed to be indicative of the range of meteorological conditions likely to be experienced at the site. These meteorological conditions are used to identify the theoretical risk zone around the temporary vent stack within which impacts might occur. However, the actual impacts during a planned maintenance venting operation would depend on the meteorological conditions at the time of venting and, in particular, the wind direction during the event. Not all properties within the risk zone would be impacted during any given venting event.

2.2.3. The individual meteorological conditions were derived on the basis of the descriptors of the stability of the atmosphere defined by Pasquill - the so called Pasquill stability classes A to G. A is the most unstable class, in which turbulent eddies are encouraged by the effects of thermal buoyancy (air being heated from the surface). G is the most stable, in which turbulent eddies are suppressed. The former conditions are characterised by dry, clear days with relatively light winds and strong sunshine; the latter are characterised by clear nights with light winds. Between these extremes are varying degrees of stability or instability, where class D is a neutral class, characterised by moderate or higher winds, and cloudy skies. In the UK, neutral class D occurs most frequently, but highly stable or unstable conditions are also likely to occur.

2.2.4. The meteorological conditions used in the assessment were:

- **A1**: Stability Class A representing clear, daytime (unstable) conditions
  - Wind Speed 1m/s, Boundary Layer Height 1300m, Surface Heat Flux 907W/m^2
- **D5**: Stability Class D representing overcast, windy (neutral) conditions
  - Wind Speed 5m/s; Boundary Layer Height 800m, Surface Heat Flux 0W/m^2
- **F2**: Stability Class F representing clear, night-time (stable) conditions
  - Wind Speed 2m/s; Boundary Layer Height 100m, Surface Heat Flux -15W/m^2
- **G1**: Stability Class G representing clear, night time (very stable) conditions

- Wind Speed 1m/s; Boundary Layer Height 100m, Surface Heat Flux -1W/m^2

2.2.5. Stability class G has been included in the assessment to show the worst-case impacts of the different venting activities. However, the conditions this meteorological class represents are rare.

ASSESSMENT LEVELS

2.2.6. The assessment levels used for the study are set out in **Table 2** below and are represented for screening purposes, as hourly mean concentrations. It is acknowledged that peak concentrations within the hour could be higher than the hourly average. However, the key metrics are the WHO odour nuisance threshold (set with a 30-minute averaging period) and the Environment Agency EAL (set with an hourly averaging period). The variation between peak and mean concentrations at 30-minute averaging period is not significant within the context of this screening assessment.

Table 2 – Assessment levels of H_2S

Threshold	H_2S µg/m3 (ppm)	Origin
Odour Detection Threshold	7µg/m^3 (0.0047ppm)	HSE (Ref. 1) – odour detection threshold WHO (Ref. 7) – odour nuisance threshold, 30 mins average
Environmental Assessment Level (Protection of health and ecosystems)	150µg/m^3 (0.1ppm)	Environment Agency (Ref. 5), hourly mean

3. SCREENING RESULTS

3.1.1. Emissions from the pigging campaigns and manifold venting were run for the four meteorological conditions stated earlier in this appendix: **A1**, **D5**, **F2** and **G1**. To take into account the potential warming of the gas to ambient conditions, 2 temperature scenarios were considered:

- Venting at ambient temperature – likely to be representative of venting after the initial rapid reduction in pressure within the system; and
- Venting at a cold temperature (-60°C) – representative of the temperature of the exhaust gas during the early stages of the venting.

3.1.2. As well as the two temperature scenarios, the peak volume flow (representative of the flow directly after the valve is opened) and average volume flow were modelled.

3.1.3. The results in **Table 3** summarise the maximum hourly concentration of H_2S for any met condition and release temperature using a 10m release height and the various vent diameters stated in **Table 1**. The maximum modelled concentrations for all met stability classes A to G are presented in **Section 4 – Full Model Results**.

Table 3 – Pigging and Manifold Venting Results Summary

Above Ground Installation Site	Process Description	Maximum Hourly H_2S Concentration ($\mu g/m^3$)[a]	Meteorological Condition[b]	Flow Condition[c]	Worst-case Odour Zone (m)[d]
Ince	Manifold	**20.4**	G	Average, Cold	100 – 160*
	Pig Launcher	4.3	G	Average, Cold	-
Stanlow	Manifold	**21.1**	G	Average, Cold	100 – 140*
	Pig Receiver	4.7	G	Average, Cold	-
	Pig Launcher	**10.8**	G	Average, Cold	30 – 80
Flint	Manifold	**24.0**	G	Average, Cold	120 – 150*

	Pig Receiver	4.9	G	Average, Cold	-
	Pig Launcher	3.8	G	Average, Cold	-

[a] Concentrations emboldened represent an exceedance of the odour threshold of 7µg/m^3

[b] Indicative meteorological conditions are modelled that represent the possible states of the atmosphere, termed A to G. These conditions range from unstable conditions (typical of sunny days with light winds, A to C) through neutral conditions (cloudy/windy periods, C to E) to stable conditions (clear nights with light winds, F to G)

[c] Flow conditions refer to state of the vented gas giving rise to maximum ground level concentrations, defined as:

- Peak = Maximum flow sustained for the hour (usually occurring directly after opening the valve)
- Average = Average flow sustained for the hour
- Ambient = Temperature of the release is the same as the ambient air
- **C**old = Temperature of the release is set to -60°C

[d] Range given as maximum over all flow and meteorological conditions. Zones marked with a '*' occur during peak flow conditions.

3.1.4. The results of the modelling indicate that there is no risk of exceedance of the threshold set for the protection of human health (150µg/m^3).

3.1.5. However, the results show that there is a risk of odours (concentrations above 7µg/m^3) during the following activities:

- Manifold venting at Ince, Stanlow and Flint AGIs; and
- Pig launching at Stanlow AGI.

3.1.6. The largest odour zone of 100m to 160m occurs during manifold venting at Ince AGI. There are no sensitive receptors within any odour zone except a residential caravan park located 130m south of the Stanlow AGI. These receptors may be impacted immediately after the gas is released during manifold venting, which is planned to occur once every five years.

3.1.7. All modelled odours occur during meteorological stability class G, which is representative of clear, stable nights. This met condition is very rare and would mostly happen for a handful of hours in a single year at night. There are no modelled exceedances of the odour threshold in stability classes A – F, as shown in **Section 4 – Full Model Results**.

3.1.8. Based on the proximity of sensitive receptors, the likelihood of the stability class G meteorological conditions and frequency of activities, the venting operations will result in a minor (not significant) adverse impact of odours.

4. FULL MODEL RESULTS

4.1.1. The tables below show the maximum modelled H_2S concentrations in each modelled stability class. All concentrations exceeding the odour threshold of 7µg/m^3 have been emboldened.

Table 4 – Maximum H_2S Concentrations for Stability Classes A-G at Ince AGI

Description	Stability Class	Average, Ambient	Average, Cold	Peak, Ambient	Peak, Cold
Manifold	A1	0.82	1.17	1.12	1.48
Pig Launcher	A1	0.30	0.38	0.53	0.64
Manifold	D5	0.27	0.32	0.42	0.52
Pig Launcher	D5	0.09	0.10	0.18	0.21
Manifold	F2	0.83	2.25	0.56	1.66
Pig Launcher	F2	0.18	0.35	0.20	0.41
Manifold	G1	**8.12**	**20.43**	1.95	**9.29**
Pig Launcher	G1	0.84	4.27	0.31	2.20

Table 5 – Maximum H_2S Concentrations for Stability Classes A-G at Stanlow AGI

Description	Stability Class	Average, Ambient	Average, Cold	Peak, Ambient	Peak, Cold
Manifold	A1	0.88	1.14	1.13	1.45
Pig Launcher	A1	0.54	0.73	0.79	1.05
Pig Receiver	A1	0.30	0.39	0.53	0.65
Manifold	D5	0.28	0.34	0.42	0.52

Pig Launcher	D5	0.18	0.20	0.30	0.37
Pig Receiver	D5	0.09	0.10	0.18	0.21
Manifold	F2	0.84	2.33	0.54	1.60
Pig Launcher	F2	0.44	1.04	0.34	0.85
Pig Receiver	F2	0.19	0.36	0.19	0.41
Manifold	G1	**7.88**	**21.13**	1.83	**8.12**
Pig Launcher	G1	3.45	**10.81**	0.83	4.91
Pig Receiver	G1	0.85	4.65	0.29	2.10

Table 6 – Maximum H_2S Concentrations for Stability Classes A-G at Flint AGI

Description	Stability Class	Average, Ambient	Average, Cold	Peak, Ambient	Peak, Cold
Manifold	A1	0.94	1.15	1.14	1.43
Pig Launcher	A1	0.26	0.33	0.47	0.55
Pig Receiver	A1	0.22	0.31	0.36	0.46
Manifold	D5	0.30	0.36	0.42	0.52
Pig Launcher	D5	0.07	0.07	0.15	0.17
Pig Receiver	D5	0.06	0.07	0.12	0.14
Manifold	F2	0.84	2.38	0.51	1.49
Pig Launcher	F2	0.15	0.27	0.21	0.45
Pig Receiver	F2	0.17	0.37	0.18	0.46

Manifold	G1	**7.24**	**24.04**	1.64	**7.95**
Pig Launcher	G1	0.83	3.76	0.49	3.42
Pig Receiver	G1	1.70	4.89	0.63	3.36

5. STACK HEIGHT TESTING

5.1.1. As part of the screening an exercise was undertaken to understand if there is any risk of exceeding the threshold for protecting human health (150µg/m^3, **Ref. 5**. The manifold venting at the Flint AGI produced the highest concentrations of H_2S (as per **Tables 4 to 6**) so this was used, as the worst case, for stack height sensitivity testing.

5.1.2. The following vent stack heights were modelled for the Flint AGI manifold venting scenario:

- 2m
- 3m
- 4m
- 6m
- 8m
- 10m

5.1.3. **Table 7** below summarises the maximum predicted concentrations of H_2S using the various stack heights stated above for stability classes A to G.

Table 7 – Stack Height Testing Results (Stability Classes A to G)

Stack Height (m)	Maximum Hourly H_2S Concentration	Meteorological Condition	Flow Condition	Worst-case Odour Zone* (m)
2	**89.5**	G1	Average, Cold	70 – 190
3	**76.2**	G1	Average, Cold	80 – 170
4	**83.2**	G1	Average, Cold	80 – 180
6	**41.5**	G1	Average, Cold	90 – 180
8	**30.3**	G1	Average, Cold	100 – 150
10	**24.0**	G1	Average, Cold	120 – 150

Concentrations in **bold** indicate an exceedance of the odour threshold (7µg/m^3) * The largest odour zone occurs during the peak flow, indicative of concentrations upon release of the gas

5.1.4. For stability classes A to G the results of the testing indicate that odours potentially occur at all modelled stack heights, using an average venting rate under cold conditions. There is, however, no risk of health effects during venting with any stack height modelled.

5.1.5. As stated earlier in this Appendix, stability class G is not a common meteorological condition in the UK, and occurs during very calm, clear nights. **Table 8** summarises the concentrations of H_2S experienced during manifold venting at the Flint AGI in stability classes A to F, which is more representative of normal meteorological conditions in the UK.

Table 8 – Summary of Stack Height Testing Results (Stability Classes A to F)

Stack Height (m)	Maximum Modelled H_2S Concentration in Stability Classes A to F		
	A1	**D5**	**F2**
2	4.39	4.97	**20.91**
3	4.01	2.60	**14.99**
4	3.55	1.71	**11.87**
6	2.58	0.90	**6.98**
8	1.74	0.67	4.04
10	1.43	0.52	2.38

5.1.6. For stability classes A to F the results of the height testing indicate that the risk of odours is removed with a stack height of at least 6m. If the stack height is less than 6m odours may still be detected.

6. REFERENCES

- **Ref. 1** – Health and Safety Executive (2009) Managing hydrogen sulphide detection offshore (Offshore Information Sheet No. 6/2009). Available at https://www.hse.gov.uk/offshore/infosheets/is6-2009.htm
- **Ref. 2** – Public Heath England (2016) Compendium of Chemical Hazards: Hydrogen Sulphide, Toxicological Overview. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/576935/hydrogen_sulphide_toxicological_overview.pdf
- **Ref. 3** – EH40/2005 Workplace exposure limits (2020) Health and Safety Executive. Available at https://www.hse.gov.uk/pubns/priced/eh40.pdf
- **Ref. 4** Public Heath England (2016) Compendium of Chemical Hazards: Hydrogen Sulphide, Toxicological Overview. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/576935/hydrogen_sulphide_toxicological_overview.pdf
- **Ref. 5** – Environment Agency (2021) Air emissions risk assessment for your environmental permit. Available at: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit
- **Ref. 6** – Acute Exposure Guideline Levels (AEGLs) Values (2010) United States Environmental Protection Agency. Available at: https://www.epa.gov/aegl/hydrogen-sulfide-results-aegl-program
- **Ref. 7** – World Health Organisation Air Quality Guidelines for Europe, 2nd edition, 2000. Available at: [redacted]
- **Ref. 8** – Cambridge Environmental Research Consultants Ltd. ADMS dispersion model. Available at: [redacted]