Toxic Clouds: Dispersion & Monitoring



Workshop on Emergency Response in Offshore Hydrocarbon Installations

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About Hatch

- Employee-owned
- Serving energy, metals, and infrastructure sectors for more than 6 decades with corporate roots extending over 100 years
- Projects in more than 150 countries
- More than 9,000 professionals
- **EU served by offices in Dorking, London, and Manchester**
- More than US$50 billion of projects and assignments under management

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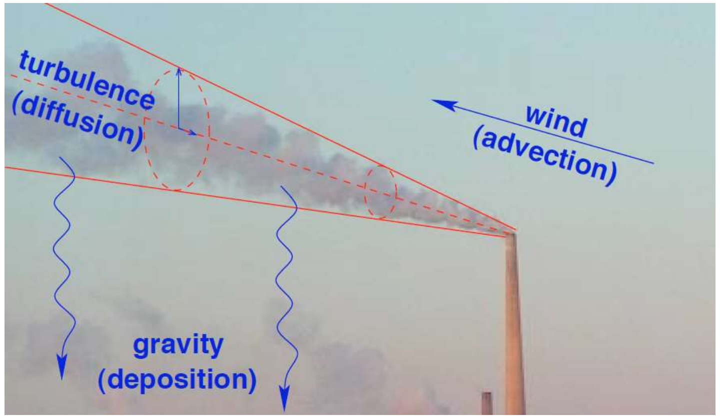
Toxic Gas Dispersion Fundamentals

- Toxic gas dispersion regimes:
  - Initial turbulent expanding jet mixing (negligible impact from wind)
  - Dense spreading and mixing due to initial momentum of jet
  - Slumping dense cloud (spreads under gravity, cloud touching down)
  - Passive dispersion (mixing due to atmospheric turbulence & advection)
- Neutrally buoyant versus denser or lighter than air
- Aerosols and two-phase mixtures
- Short duration (<1 hr) or continuous release (> 1hr)
- Atmospheric stability (enhance or resist vertical motion)
  - Usually stable on clear nights, unstable on sunny days, and neutral on cloudy/windy days
- Meteorological conditions (wind speeds/directions, temperature, inversions, etc.)
- Use meteorological data for several years or consider two scenarios for dispersion modeling:
  1. Stable atmosphere with low wind typically occur at night
  2. Neutral atmosphere with higher wind speeds
- Surface roughness or terrain data



Source: Stockie, J. M., The Mathematics of Atmospheric Dispersion Modelling, SIAM Review, Vol. 53, No. 2, pp. 349-372

H2S Releases from Platforms

- Toxic gas release from:
  - accidental events, leaks from topsides process equipment and piping, including platform wellheads. Noted that the release is also likely to be flammable depending on the composition of the leaked fluid;
  - normal operations or emergency flaring, during flare flame-out;
  - cold venting, if applicable.
- Release duration of 30 – 60 mins usually considered to ensure hazard zone is fully established in the model.
- Dispersion models consider the whole fluid composition and track the H2S component.
- Concentrations of interest determined by operator/owner and/or local regulatory trigger levels.

Threshold Limits for H2S

ppm	Description
0 - 10	Irritation of eyes, nose and throat
< 1	Detectable odour
10 - 50	Headache, dizziness, nausea, vomiting, coughing, difficulty breathing
Up to 30	Rotten egg odour
30 to 100	Sweet odour
Above 100	Detection by smell affected by paralysis of olfactory nerves, resulting in loss of smell
150 -250	Olfactory paralysis, loss of smell
150 - 200	Severe respiratory tract irritation, eye irritation / acute conjunctivitis, shock, convulsions, coma and death in severe cases.

ppm	Threshold	Reference
0.1	Emergency response planning guideline (ERPG)-1, maximum concentration below which nearly all individuals could be exposed without more than mild, transient adverse health effects or receiving a clearly objectionable odour.	Cameo Chemicals, NOAA
5	Workplace exposure limit - Long term exposure limit (LTEL), 8hr time weighted average. Restricts total intake by inhalation over one or more shifts	EH40/2005, HSE
10	Workplace exposure limit - Short term exposure limit (STEL), 15 min time weighted average. Restricts harmful effects from brief exposure .	EH40/2005, HSE
30	ERPG-2, ≤1 hr exposure without irreversible or other serious health effects or symptoms which could impair ability to take protective action.	Cameo Chemicals, NOAA
100	Immediately dangerous to life and health (IDLH); above IDLH only supplied air respirators should be used, air purifying respirators maybe used below IDLH if appropriate.	NIOSH, 2016
100	(ERPG) – 3, ≤1 hr exposure without experiencing or developing life-threatening health effects.	Cameo Chemicals, NOAA

Important Parameters for Dispersion of H2S from Platforms to Coastal Onshore Areas

- Distances are large (tens to hundreds of km)
- Although H2S is heavier than air, expect most toxic gas releases to be initially buoyant due to high temperature & light hydrocarbons in released gas. At some distance downwind of platform, toxic cloud may be considered neutrally buoyant due to temperature reduction from cloud dilution, then dispersion dominated by atmospheric turbulence and advection
- Seawater surface is relatively smooth & uniform compared to land terrain
- Generally more stable atmospheric conditions (which tend to cause toxic gases to remain closer to sea level subject to initial buoyancy of release):
  - Atmospheric mixing layers are thinner over water compared to over land
  - Less diurnal temperature change less over water compared to over land
- Atmospheric conditions change abruptly in coastal area where sea meets land (changes in mixing layers, sea-land breezes, etc.)
- Constant source of moisture in marine boundary layer
- Precipitation can change cloud composition as H2S reacts with water

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Toxic Gas Dispersion Modeling

- *Many* different dispersion models exist to predict the transport and dispersion of toxic gases throughout the atmosphere
- Different levels of modeling exist:
  1. Empirical models, quick and easy to use, for hazard assessment, to estimate the potential for onsite and offsite personnel fatalities and potential for impairment of 'safe areas'
  2. More complex models, taking detailed account of atmospheric mixing and valid over longer distances, for air quality assessment
  3. Comprehensive, first principles based models, taking account of complex local geometry, to specify gas detector locations and ventilation requirements in confined or congested regions)
- Model predictive capability and accuracy improve from 1 to 3, but also complexity of inputs required and level of specialization to run models

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Comparison of Dispersion Models

Model	Developer	Method	Steady or Transient, i.e., continuous vs. short duration release?	Includes the effect of changing meteorological conditions (wind, etc) spatially and with time?	Neutrally buoyant vs. dense or light gas ?	Handle complex geometry & obstructions (terrain, topography, buildings, process equipment, etc.	Includes effects of sea on dispersion (surface water flow, temp., etc.)	Complexity of Inputs	Level of specialization required to use software	Time to run simulations	Transport distance where model is applicable
Phast	DNV-GL	Integral based	Both	Yes (spatially only)	Both	No	No	Low	Low	Low	Generally less than 5 km from source
ALOHA	US EPA	Integral based	Both	Yes	Both	No	No	Low	Low	Low	Generally less than 10 km from source
Flaresim	Softbits, UK	Gaussian	Steady	No	Both	No	No	Low	Low	Low	Generally less than 1 km from source
AERMOD	AMS & US EPA	Gaussian	Steady	Yes (spatially only)	Both	Yes	No	Low	Low	Low	<50 km from source
ADMS	CERC UK	Gaussian	Both	Yes	Both	Yes	Yes	Low	Low	Low	< 50 km from source
ADMS-STAR/PUFF	CERC UK	Lagrangian	Both	Yes	Both	Yes	Yes	Low	Low	Low	<300 km
CALPUFF	SRC / TRC	Lagrangian	Both	Yes	Both	Yes	Yes	Medium	Medium	Medium	<300 km
CFD	Ansys, Siemens, etc	Eulerian & Lagrangian	Both	Yes	Both	Yes	Yes	High	High	High	Generally less than 1 km from source (but can handle all distances)

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General Recommendations for Dispersion Prediction of Toxic Gases

- To assess the impact of a toxic gas release on personnel on the facility and those in the local vicinity (for onshore releases), dispersion models such as Phast are generally recommended.
- CFD models can be used if complicated interaction with process equipment and structures need to be assessed to determine ventilation requirements (confined or congested spaces) or gas detector locations
- For greater distances downwind of the source (i.e., from platforms to coastal areas) and lower concentrations of interest:
  - Hybrid approach can be used: Phast for immediate vicinity around platform, and at suitable distance downwind of platform, use a passive dispersion model (e.g. ADMS) to predict the longer distance transport to coastal areas
  - Refined dispersion models (e.g. ADMS-STAR/Puff, CALPUFF) recommended if longer range impacts are required to be assessed

Monitoring Aspects

- Provision of continuous H2S monitoring devices (range of 0.003 ppm to 50 ppm) at strategic locations onshore to inform authorities of toxic cloud hazard before it reaches inhabited areas. Drawbacks include:
  - Cost of implementation
  - Limited time available for onshore emergency response

OR

- Carry out H2S modelling for a range of offshore release scenarios to determine bounding conditions which result in an unacceptable impact onshore, factors to be considered include:
  - Wind speed and direction, atmospheric conditions
  - Leak rate
  - Initial H2S concentration in release
- Offshore installations required to alert onshore emergency services in case of an offshore toxic gas release
- Onshore emergency response requirements can be determined based on comparison of release scenario with identified bounding conditions
- Targeted H2S detection onshore, potentially using portable devices
- Drawbacks include:
  - Provision of adequate data from offshore in the event of a toxic gas release
  - Does not cover any fugitive emissions

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Thank you.

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