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External safety distances for bunkering hydrogen in Germany

Consequence assessment in accordance with KAS-18

RH2INE Sub-study 1b, SuAc B3

09 April 2021

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Introduction

- Determination of external safety distances has to be based on national legislation and guidelines.
- To calculate the safety distances, a recommendation of the **Kommission für Anlagensicherheit** (KAS; commission of plant safety) of the federal government has been devised (**KAS-18)**, which describes all details for the required calculation.
- **KAS-18**: Guideline: Recommendations for distances between operational areas according to the Hazardous Incident Ordinance and areas in need of protection in the context of urban land use planning - implementation of § 50 BImSchG („Leitfaden: Empfehlungen für Abstände zwischen Betriebsbereichen nach der Störfallverordnung und schutzbedürftigen Gebieten im Rahmen der Bauleitplanung - Umsetzung § 50 BImSchG; Kommission für Anlagensicherheit beim Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit; 2. überarbeitete Fassung; November 2010“)

Methodology / LUP-approach in Germany

- The KAS-18 is a “guideline” that helps especially authorities responsible for the LUP to determine safety distances and to comply with § 50 BImSchG.
- The intention of the KAS-18 guideline is not to predict, describe and evaluate a real accident scenario (also if you have detailed information this is not the intention of the guideline).
- The frequency of an accident scenario will not be considered at all and it is also not important whether a bunkering activity takes place day and night all the week or only for some hours 1-2 times per week.
- The condition/maintenance of an operation will also not be considered, e.g. the safety distance is the same for poorly maintained operations and operations with good maintenance practices.
- The number of vessels does not have an influence on the safety distance. If you have an operation A with 2 pressure vessels and an operation B with one pressure vessel (same as in operation A) the safety distances would be the same. That means the risk potential is taken out of the consideration in KAS-18.
- The different steps described in KAS-18 (source term, dispersion, evaluation) are defined as (simple) requirements in order to assure comparability and reproducibility for all cases.

Bunkering scenarios

Bunkering scenarios are based on the outcomes of RH2INE Sub-study 1a, SuAc 1.1b

Scenario	Description
1a	Swapping containers with pressurized hydrogen (300 bar, 20 °C) at container terminals (start-up case) – no storage in stack
1b	Swapping containers with pressurized hydrogen (500 bar, 20 °C) at container terminals (future case) – storage in stack
2a	Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case) (500 bar*, 20 °C)
2b	Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case) (380 bar*, 20 °C)
3	Truck-to-ship bunkering of liquid hydrogen (7 barg*, -246 °C)
4a	Truck-to-ship bunkering of refrigerated liquid ammonia (5 barg*, -34 °C)
4b	Truck-to-ship bunkering of pressurized liquid ammonia (12 barg*, 20 °C)
5	Truck-to-ship bunkering of methanol (5 barg*, 20 °C)

*Bunker pressure

Parameters and assumptions

- KAS-18 uses a deterministic approach by calculating the consequences of a release with a fixed hole size of 25 mm diameter (leak area 490 mm^2) based on operating experience with deviations allowed based on specific plant design and special hazard considerations
- Effect distances are calculated for the following end-point (threshold) values and the maximum value is taken for the external safety distance:
  - 1.6 kW/m2 for thermal radiation, in case of direct ignition (resulting in jet fire) or a pool fire,
  - 0.1 bar for max. side-on overpressure for explosions and
  - the ERPG-2 value as toxic criterion.
- Usually, a release time of 30 minutes is used.
- If detailed knowledge of the actual scenarios (such as bunker pressure and temperature, possible release time etc.) is known, it may be used in the calculations.

Results of consequence calculations

Scenario	Material released	Distance to max jet / pool fire radiation of 1.6 kW/m² [m]	Distance to 50% LFL (flash fire) [m]	Distance to 0.1 bar overpressure [m]	Distance to ERPG-2 [1h] [m]
1a	Hydrogen	55	88	182	n/a*
1b	Hydrogen	68	104	230	n/a*
2a	Hydrogen	63	96	n/r*	n/a*
2b	Hydrogen	61	96	n/r*	n/a*
3	Hydrogen	70	52	n/r*	n/a*
4a	Ammonia	81	28	n/r*	205
4b	Ammonia	81	24	n/r*	395
5	Methanol	67	19	n/r*	n/r*

* n/r = not reached; n/a = not applicable

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Results for external safety distances

Scenario	Description	External safety distance (m)
1a	Swapping containers with pressurized hydrogen (300 bar, 20 °C) at container terminals (start-up case) – no storage in stack	182
1b	Swapping containers with pressurized hydrogen (500 bar, 20 °C) at container terminals (future case) – storage in stack	230
2a	Truck-to-ship bunkering of gaseous hydrogen via hose to fixed tanks on board (start-up case) (500 bar*, 20 °C)	96
2b	Bunker station to ship, bunkering of gaseous hydrogen via hose to fixed tanks on board (future case) (380 bar*, 20 °C)	96
3	Truck-to-ship bunkering of liquid hydrogen (7 barg*, -246 °C)	70
4a	Truck-to-ship bunkering of refrigerated liquid ammonia (5 barg*, -34 °C)	205
4b	Truck-to-ship bunkering of pressurized liquid ammonia (12 barg*, 20 °C)	395
5	Truck-to-ship bunkering of methanol (5 barg*, 20 °C)	67

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Conclusions (1/2)

- The external safety distances for swapping containers at container terminals are about a factor 2 larger than for bunkering gaseous hydrogen with a hose.
- The reason for this difference is related to the potential for explosions with high overpressures due to the level of confinement present at a container terminal.
- Typically, this level of confinement (&congestion) is expected to be much less for truck-to-ship bunkering and bunker stations (scenario 2a&2b) as bunkering will typically take place in an open area where the gas cannot accumulate in confined areas. If this is not the case, the safety distances for scenario 1a/1b may be more appropriate.
- For truck-to-ship (TTS) bunkering of liquid hydrogen and methanol result in safety distances of approximately 70 m, which are in line with previously calculated distances for TTS bunkering of LNG. In comparison, the external safety distance for TTS LNG bunkering to inland vessels was calculated at 83 m in the LNG Masterplan study of 2015 (Source: http://www.lngmasterplan.eu/, D 2.4.2. Part C).

Conclusions (2/2)

- For bunkering ammonia, the safety distances are very large and go up to 395 m, which are determined by the toxic consequences. The distances for pressurized ammonia are about a factor 2 larger than for bunkering refrigerated ammonia.
- It will be challenging to introduce ammonia as a fuel in IWT due to the large safety distances for bunkering ammonia with a hose.
- This could be showstopper for bunkering ammonia in inland ports and waterways where residential areas and industries etc. could be nearby.

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