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A Succinct Critical Review

By: Dr. E. Stern (21.01.18)

On

AMMONIA DISPERSION STUDY

Initial Dispersion Analysis

Haifa Municipality

DNV GL Report No.: Haifa-NH3-001, Rev. A

Date: 2017-11-21

1. General

1.1 This concise review outlines some observations and comments made by the undersigned (hereinafter ES) concerning the above mentioned draft report (hereinafter DNV Report, or Study).

1.2 As DNV has defined its report as *initial*, the following observations and comments should be considered *preliminary*.

2. PHAST and SAFETI - General

2.1 DNV Report is based on case by case application of PHAST and SAFETI computer codes, the detailed knowledge of which, by any reviewer, is taken for granted. However, since no detailed description of the codes nor any User Guide are available in the public domain, it is suggested to add some clarifications as to several critical assumptions and calculations mentioned throughout the report.

2.2 This is important, since reality has proven that well known, widely accepted, accident analysis, source term and dispersion codes, may differ *significantly* in their “built in” *modeling*, as well as in their both covert and overt *parametric* assumptions.

3. Accident Scenarios

3.1 The failure *scenarios* selected for the Study, concerning the “bulk carrier” and the isotanks, as listed and explained in tables 4.1-4.2, are generally acceptable, except for some minor comments, outlined hereby

(a) To the best of ES’s knowledge, in our case, a loading arm rupture is, most probably, far from being capable of causing a 750 mm hole. The most severe would be 250 mm. Thus

(b) A 750 mm hole may be relevant only to an *extremely* severe hostile event. A 250 mm hole can be associated with both routine operational and hostile accidental events.
(c) An isotank *does not* contain 25 te ammonia. The correct value is 12.5 te.
(d) Obviously, each Option (namely "bulk carrier" and "isotanks") includes a large variety of activities, such as handling, transportation, transfer through pipelines etc. Those activities, totally ignored in DNV's report) involve additional potential catastrophic and moderate accidental events, which should be analyzed as an integral part of each of the pertinent options.

3.2 A rather sharp distinction should be made between operational and hostile events (see sections 7.3 and parts of 8 below).

4. Source terms

4.1 Catastrophic failures of isotanks (25 te for a single isotank and 125/250 te for 5/10 isotanks) were analyzed assuming a large spill onto water and concrete. The source term was estimated as "kg/sec" evaporating from a puddle/pool surface, apparently considering heat transfer from water and concrete. However, this approach seems *erroneous*, since ammonia in the isotank is pressurized (up to app. 150 psig), and the only scenario of a *sudden loss* of the entire tank's content is a *flash* scenario. This means, that about 19%-20% of the content will be released to the environment *instantaneously* and directly, by mode of an instantaneous, rather than continuous, release. This observation holds not only for a single tank catastrophic failure, but also for multiple tank failures.

4.2 In relation to *both* catastrophic spills *and* major *and* moderate leaks from the "bulk carrier" tanks

(a) About half of the inventory reaching sea water is expected to dissolve immediately in water, thus getting out of the "atmospheric dispersion game". Only 50% of the inventory could be subject to evaporation processes. This is not mentioned in DNV's report, which sheds doubt on whether this significant fractionation was considered at all.
(b) DNV assumes that anhydrous ammonia evaporating from the water/concrete surfaces disperses as a heavy gas, "crawling" downwind in close contact with either sea water or land (having a pre assumed roughness coefficient). See e.g. fig. 5.10. It is definitely unclear, how come anhydrous ammonia being *much* lighter than air, is not expected (in DNV's opinion) to undergo plume rise processes *at all*.
(c) Quantitatively, one does not have to assume plume rises of several hundred meters, as was claimed in our catastrophic case by worldwide leading dispersion experts as well as by a well-known ADL study, performed for the USCG in 1994. According to ES's calculations, plume rise heights as low as 100 m or so, are sufficient to ensure *significantly* lower downwind air concentrations, compared to those apparently calculated by DNV.
(d) Also, remarkable quantities of the evaporating ammonia are expected to hydrolyze with air humidity, producing hydrous ammonia (NH_4OH), which is

expected to disperse as aerosol droplets/particles (indeed with almost no plume rise; see important note in section 5.4 below).

(e) Anyhow, the sizes of the puddles estimated in DNV's report, are similar to those estimated by ES, especially as far as catastrophic failures are considered.

5. <u>Health impact Criteria</u>

5.1 The main health impact criterion implemented by ES is PAC3. This criterion serves as a leading criterion for accident analysis for existing situations by the MOEP. Going further, towards LDx, is ruled out in most cases. This means that PAC3 contours around potential hazardous materials sources are, in most cases, the preferred criteria for assessing the acceptability/tolerability of a proposed design/option. This holds for *single* option analyses as well as for *multiple* options *comparative* studies.

5.2 Therefore, within our context, DNV's results, related to 0.1, 10, and 90 percent lethality, are of limited validity.

5.3 In addition, hereby is a crucial comment concerning DNV's PAC3 estimations. For most analyzed scenarios, the *durations of releases* (especially from catastrophic failures in the "bulk carrier" and isotanks), turned out to be extremely short (in the ranges of 1-2 to a few minutes, as were ES's estimations). This means, that obviously, exposure times of outdoor public receptors are also very short – in most relevant cases, not greater than 10 minutes or so. In such cases, using the 60 min value of PAC3 (i.e. 1100 ppm) is highly and unnecessarily over-conservative. The value that *should* be used for those catastrophic cases, is the 10 min value of PAC3, namely 2700 ppm. This modification *by itself* would, most probably, lead to *significantly* lower distances for PAC3 contours.

5.4 Also, as far as hydrous ammonia is concerned (see section 4.2 (d) above), PAC3 values turn out to be four times greater than those of anhydrous ammonia, driving the pertinent PAC3 values up to several thousand ppm for 60 min exposures; and up to 10,000 ppm (!) for 10 min exposures.

6. <u>Dispersion Estimates</u>.

6.1 Following the above discussion on duration of releases, the modes of dispersion estimates utilized by DNV have to be clarified. E.g., releases from catastrophic scenarios are expected to be calculated considering instantaneous ("puff") release modes, whereas the major and moderate leaks - by consideration of continuous release modes.

6.2 Of course, the above statement holds both for Gaussian dispersion equations as well as for heavy gas dispersion modeling used by DNV. Obviously, clarifying the actual dispersion estimations as performed in DNV's study, seems imperative.

6.3 Also, it is not clear how plume dispersion from very large *area sources* was actually considered by DNV. As shown in DNV's report, huge puddles are expected in catastrophic and even moderate leak scenarios (up to a radius of 380 m, meaning an area source of 450,000 m^2 (!)). However, although the plume shapes close to the sources, as shown e.g. in fig. 5.9, are quite characteristic for area source considerations, the reader may still wonder whether the sources were treated as point sources or as area sources (using “virtual source” methodologies or integrations (over area) of multiple point sources, etc.). Needless to mention that assuming a point source to “cover” an area source, may lead to enormous air-concentration overestimations (this may turn out a minor comment, just pointing at the need to explain shortly DNV’s method(s) of handling area sources).

7. Additional Miscellaneous Observations

7.1 Ambiguous figures. Some of the figures appear to be vague and unclear, to say the least; hereby are few examples

(a) Fig. 5.7 Four weather conditions are listed in the legend. Only three curves are shown.

(b) Ibid. Referring e.g. to the red curve (D5) – approximate straightforward integration over time, yields overall emission (from the giant puddle) to the environment, of approximately 800 te. Where did the significant rest (i.e. 1700 te) “disappear”??

(c) Fig. 5.8 Absolutely incomprehensible. What is meant by “actual” Vs. “effective” radius (see legend)? Also, the curves themselves are unclear.

(d) Fig. 5.9 needs further clarification regarding both “pool effect” and curves’ patterns which are expected to reflect the heavy gas distances up to which enough air is entrained to cause the plume to become neutrally buoyant.

7.2 Gravitational and Diffusional Deposition

These phenomena are known to have enormous impact on plume depletion, especially when F (or D2) non – plume rise stability condition prevails. This means significant reductions in air concentrations during dispersion, in particular for those stability conditions yielding the longest health impact distances. It is not clear whether those parameters, with appropriate sub-modeling, were taken into account in DNV’s Study.

7.3 Scenario Probabilities

(a) DNV’s approach to risk assessment, has been utterly deterministic. No probabilities whatsoever were associated with each selected scenario. Moreover, operational and hostile accident scenarios have been “intermingled” in the report.

(b) Needless to mention the importance of probabilities (including meteorological probabilities) for both assessing the overall acceptability/tolerability of each particular option; and, if both turn out to be acceptable – which would be the preferred one. In other words, applying probabilistic considerations may influence not only the acceptability of an option but also its ranking within pertinent outputs of comparative analyses.

(c) The probabilistic approach applies mainly in analyses of operational accidents, due to relatively known probabilities of occurrence. These should be *separated* from hostile acts scenarios, which have to be judged using other, different, methodologies.

(d) In other words, the present DNV Study does not enable any *assessment of the overall individual and societal risks* involved in each option; nor does it consider/discuss the unavoidable distinctions between operational and hostile events, to which probabilities cannot be attached.

8. Final remarks

8.1 In light of the above comments and observations, DNV's Report is far from being conclusive. In fact, ES fully agrees with DNV's statements, at the very end of section 3.1, pointing at various steps being *essential* for making the present *initial* report capable of yielding *any practical conclusions*.

8.2 In particular,

(a) The phenomenology an anhydrous cold ammonia spill onto water (and concrete) deserves additional research and insights compared to the straightforward "heavy gas, no plume rise" assumptions made in DNV's study. As mentioned, such insights were recently proposed by ES, as well as by other experts

(b) Operational accidents and meteorological probabilities should be incorporated in any analysis of a single, particular, option to enable *risk oriented* analyses, as well as classification and prioritization of any proposed *variety* of possible options.

(c) Obviously, the "bulk carrier" and "isotank" options include a large variety of equipment and activities (e.g. pipelines, bulk containers, transportation and handling – each of these being a significant hazard by itself), which have not been analyzed at all in DNV's Report.

8.3 It is strongly recommended, that the observations and comments appearing in sections *3.1 (a)-(d), 3.2, 4.1, 4.2 (a), 4.2(b), 4.2(d), 5.3, 5.4, 6.3, 7.1-7.3* above, should be considered critical.

8.4 Thus, it is concluded, that in the light of the above observations and comments (as well as DNV's own position), DNV's initial Study, cannot serve as an ultimate tool for analyzing the acceptability of each of the analyzed options, nor can it serve as a tool for any prioritization process within the given set of options.

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