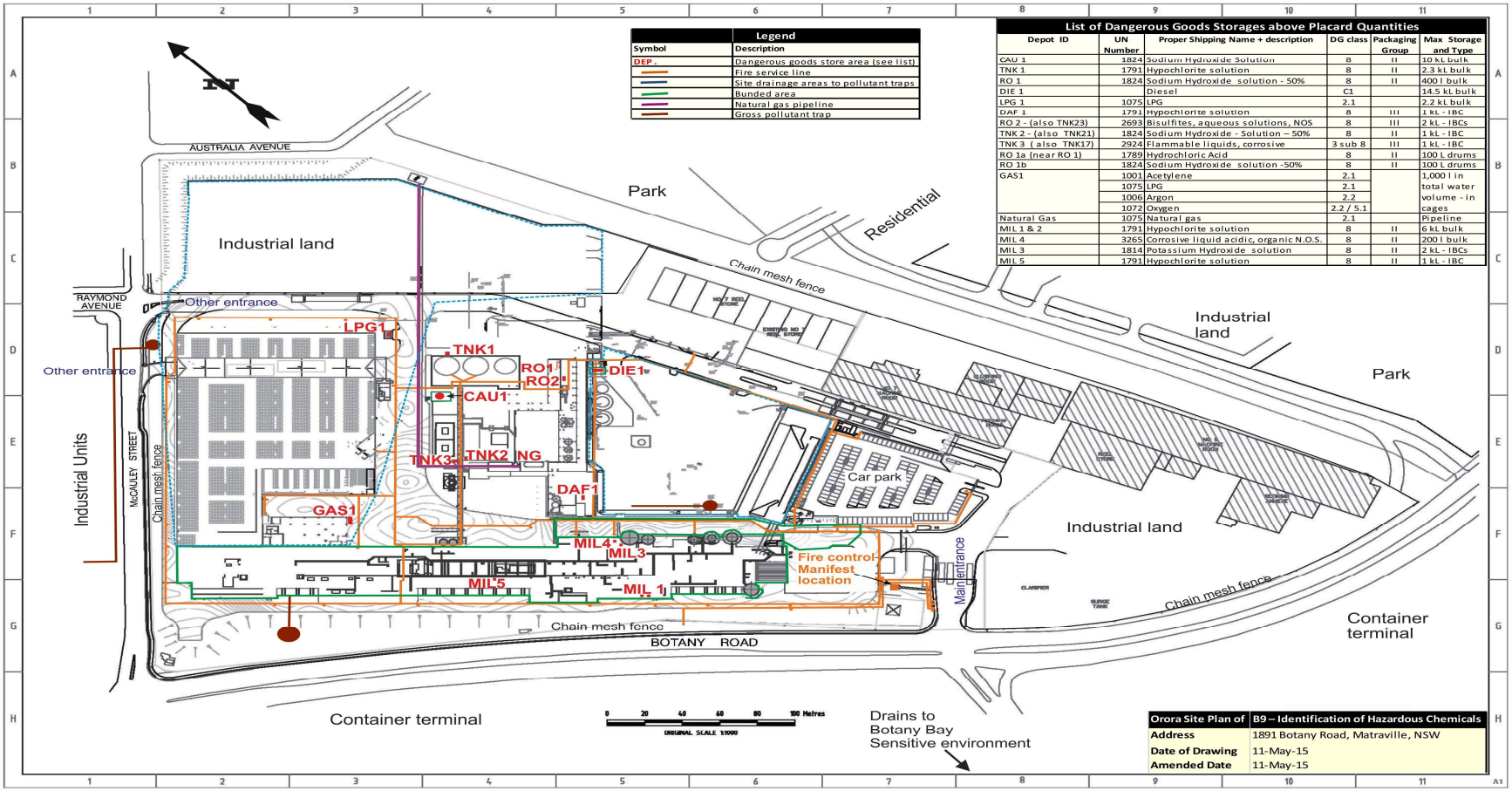
Appendices

Appendix A1 List of Existing Dangerous Goods Storages & Locations

List of Dangerous Goods Storages above Placard Quantities					
Depot ID	**UN Number**	**Proper Shipping Name + description**	**DG class**	**Packaging Group**	**Max Storage and Type**
CAU 1	1824	Sodium Hydroxide Solution	8	II	10 kL bulk
TNK 1	1791	Hypochlorite solution	8	II	2.3 kL bulk
RO 1	1824	Sodium Hydroxide solution - 50%	8	II	400 l bulk
DIE 1		Diesel	C1		14.5 kL bulk
LPG 1	1075	LPG	2.1		2.2 kL bulk
DAF 1	1791	Hypochlorite solution	8	III	1 kL - IBC
RO 2 - (also TNK23)	2693	Bisulfites, aqueous solutions, NOS	8	III	2 kL - IBCs
TNK 2 - (also TNK21)	1824	Sodium Hydroxide - Solution – 50%	8	II	1 kL - IBC
TNK 3 (also TNK17)	2924	Flammable liquids, corrosive	3 sub 8	III	1 kL - IBC
RO 1a (near RO 1)	1789	Hydrochloric Acid	8	II	100 L drums
RO 1b	1824	Sodium Hydroxide solution -50%	8	II	100 L drums
GAS1	1001	Acetylene	2.1		1,000 l in total water volume - in cages
	1075	LPG	2.1		
	1006	Argon	2.2		
	1072	Oxygen	2.2 / 5.1		
Natural Gas	1075	Natural gas	2.1		Pipeline
MIL 1 & 2	1791	Hypochlorite solution	8	II	6 kL bulk
MIL 4	3265	Corrosive liquid acidic, organic N.O.S.	8	II	200 l bulk
MIL 3	1814	Potassium Hydroxide solution	8	II	2 kL - IBCs
MIL 5	1791	Hypochlorite solution	8	II	1 kL - IBC

Key
Flammable or combustible
Corrosive alkali
Corrosive acid

Orora Site Map showing location of Dangerous Goods



Legend	
Symbol	Description
DEP.	Dangerous goods store area (see list)
	Fire service line
	Site drainage areas to pollutant traps
	Bunded area
	Natural gas pipeline
	Gross pollutant trap

List of Dangerous Goods Storages above Placard Quantities

Depot ID	UN Number	Proper Shipping Name + description	DG class	Packaging Group	Max Storage and Type
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TNK 1	1791	Hypochlorite solution	8	II	2.3 kL bulk
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DAF 1	1791	Hypochlorite solution	8	III	1 kL - IBC
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RO 1a (near RO 1)	1789	Hydrochloric Acid	8	II	100 L drums
RO 1b	1824	Sodium Hydroxide solution -50%	8	II	100 L drums
GAS1	1001	Acetylene	2.1		1,000 l in total water volume - in cages
	1075	LPG	2.1		
	1006	Argon	2.2		
	1072	Oxygen	2.2 / 5.1		
Natural Gas	1075	Natural gas	2.1		Pipeline
MIL 1 & 2	1791	Hypochlorite solution	8	II	6 kL bulk
MIL 4	3265	Corrosive liquid acidic, organic N.O.S.	8	II	200 l bulk
MIL 3	1814	Potassium Hydroxide solution	8	II	2 kL - IBCs
MIL 5	1791	Hypochlorite solution	8	II	1 kL - IBC

Orora Site Plan of	B9 – Identification of Hazardous Chemicals
Address	1891 Botany Road, Matraville, NSW
Date of Drawing	11-May-15
Amended Date	11-May-15

Appendix A2 Gas Holder Blast Curve Selection

Blast Curve Selection by Kinsella (1993)

Kinsella [1993] provides guidance on curve selection based on review of major accidents. It has been found that the major influencing factors on blast strength (curve selection) are:

- Degree of obstruction by obstacles inside the vapour cloud.
- Ignition energy.
- Degree of confinement.

Increasing obstructions gives rise to increased blast strength due to the turbulence created by the obstructions. This increased turbulence at the blast front promotes an increased rate of combustion due to the exposure of more uncombusted fuel to the flame front.

These three blast source strength factors are defined as follows.

1. Ignition Energy: **High** or Low
   - High
     The ignition source is, for instance, a confined vented explosion. This may be due to the ignition of part of the cloud by a low energy source, for example, inside a building or in this case the gas holder enclosure
   - Low
     The ignition source is spark, flame, hot surface, etc., such as a nearby car

     Hence Ignition energy strength is considered **HIGH** in this case

2. Degree of Obstruction: **High** , Low or None
   - High
     Closely packed obstacles within gas cloud giving an overall volume blockage fraction (i.e. the ratio of the volume if the obstructed area occupied by the obstacles and the total volume of the obstructed area itself) in excess of 30% and with the spacing between obstacles less than 3 m
   - Low
     Obstacles in gas cloud but with overall blockage fraction less than 30% and/or spacing between obstacles larger than 3 m.
   - None
     No obstacles within gas cloud.

     Typically the degree of obstruction for a gas holder can be considered an enclosed– hence **HIGH** is selected here. Not also there are a number of structures close by (existing boiler house, etc.)

3. Degree of (Parallel Plane) Confinement:
   - With presence of confinement
     Gas clouds, or parts of it, are confined by walls/barriers on two or three sides.
   - Without presence of confinement
     Gas cloud is not confined, other than by the ground.

Given the location of the Gas Enclosure, and noting other building potentially buildings in the flame path then we would set the degree of parallel confinement as **(C) - i.e. confined,**

From Kinsella Blast Energy Strength table we find the Blast Curve selected is 7 – 10. Hence to be conservative we would select a Blast Strength of 8.

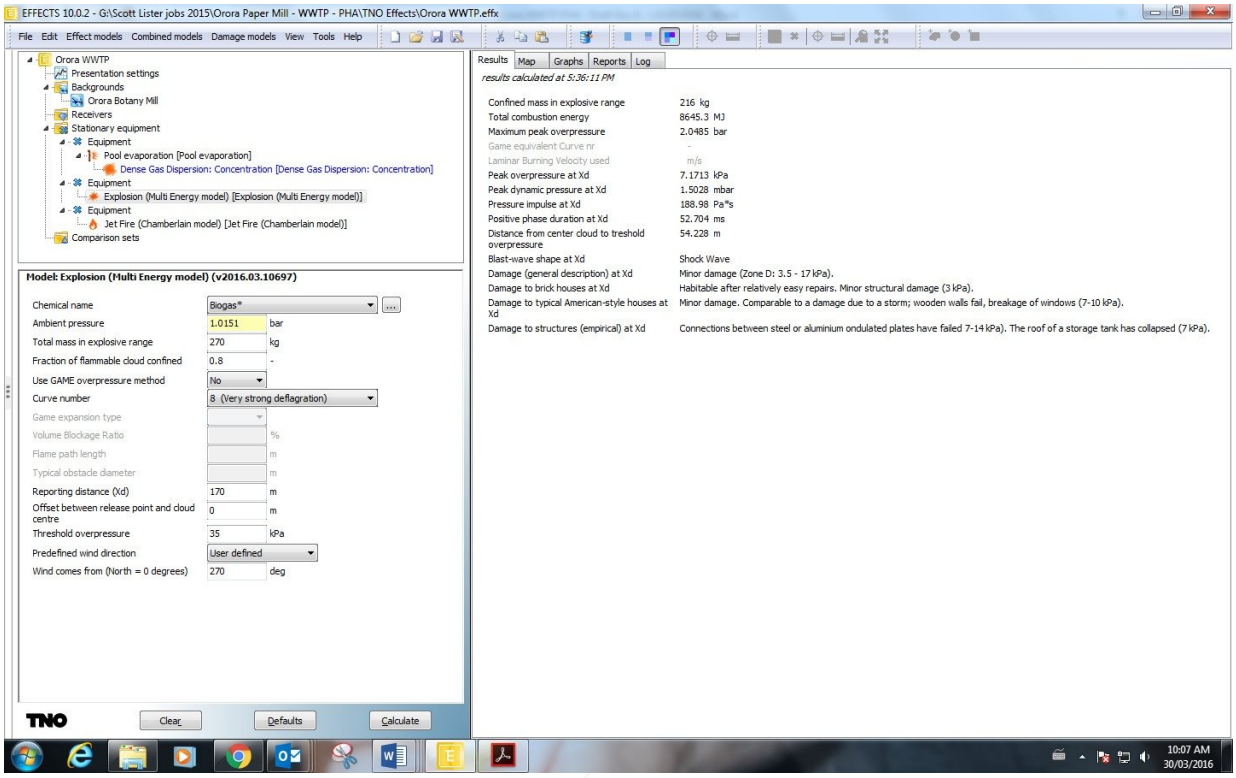
Blast Curve Selection Table from Kinsella (1993)

Blast strength category	Ignition energy		Obstruction			Parallel plane confinement	Multi-Energy Unconfined	Class
	Low	High	High	Low	No			
	(L)	(H)	(H)	(L)	(N)	(C)	(U)	
1		H	H			C		7-10
2		H	H				U	7-10
3	L		H			C		5-7
4		H		L		C		5-7
5		H		L			U	4-6
6		H			N	C		4-6
7	L		H				U	4-5
8		H			N			4-5
9	L			L		C		3-5
10	L			L			U	2-3
11	L				N	C		1-2
12	L				N		U	1

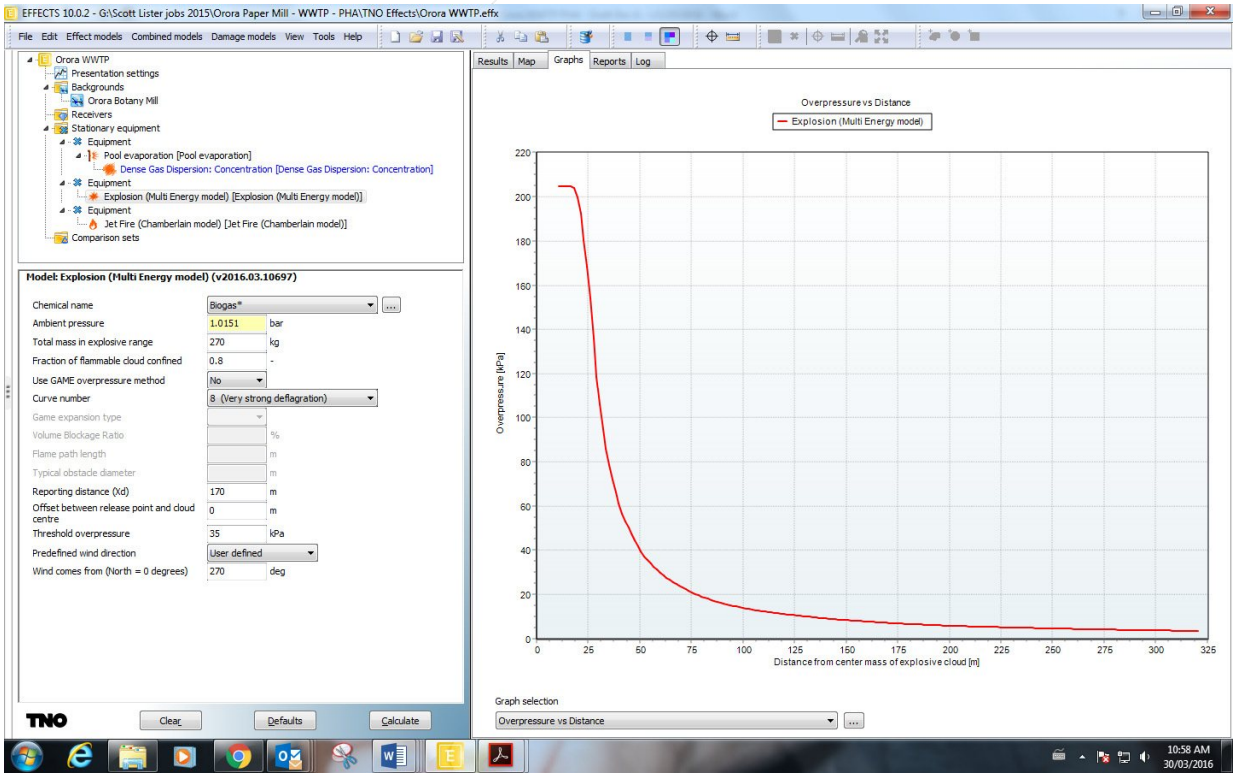
Model: Explosion (Multi Energy model)
version: v2016.03.10697 (29/03/2016)
Based on the yellow book
State: the model is tested
Reference: Yellow Book CPR14E 3rd Edition - Chapter 5: Vapour cloud explosions Mercx, W.P.M, van den Berg, A.C., van Leeuwen, D, "Application of correlations to quantify the source strength of vapour cloud explosions in realistic situations Final report for the project GAMES, October 1998, TNO- report PML 1998-C53 (1998)

Appendix A3 Gas Holder Explosion Modelling

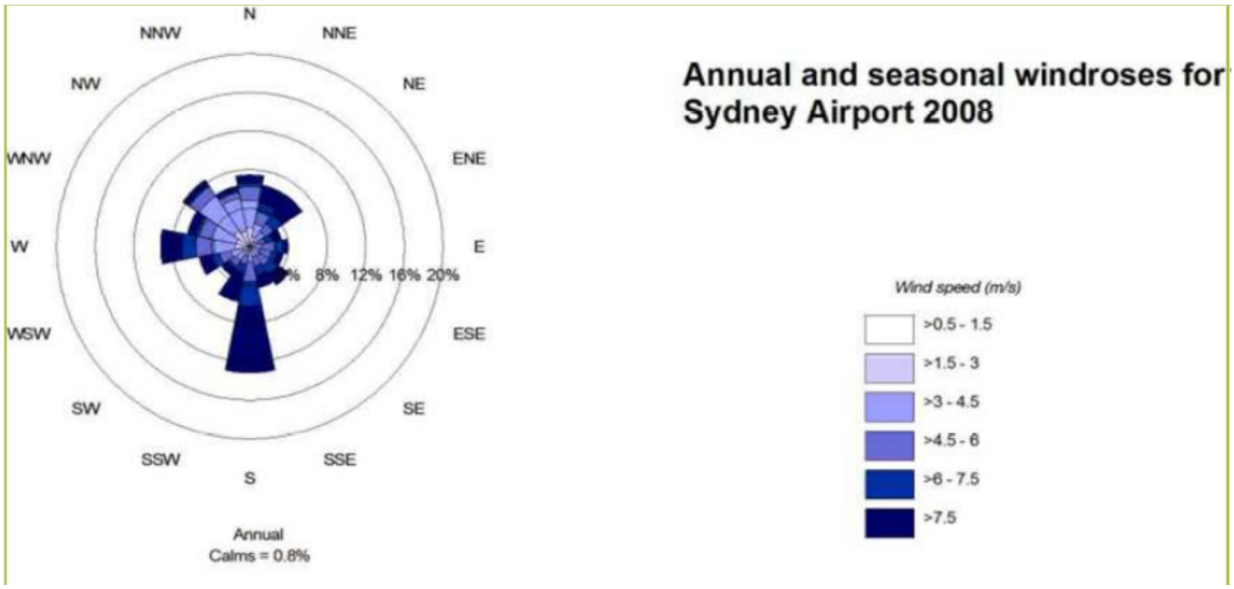
TNE Effects V10.0.3 Inputs for Gas Holder of 60m3 at 6 bar



Overpressure versus distance graph

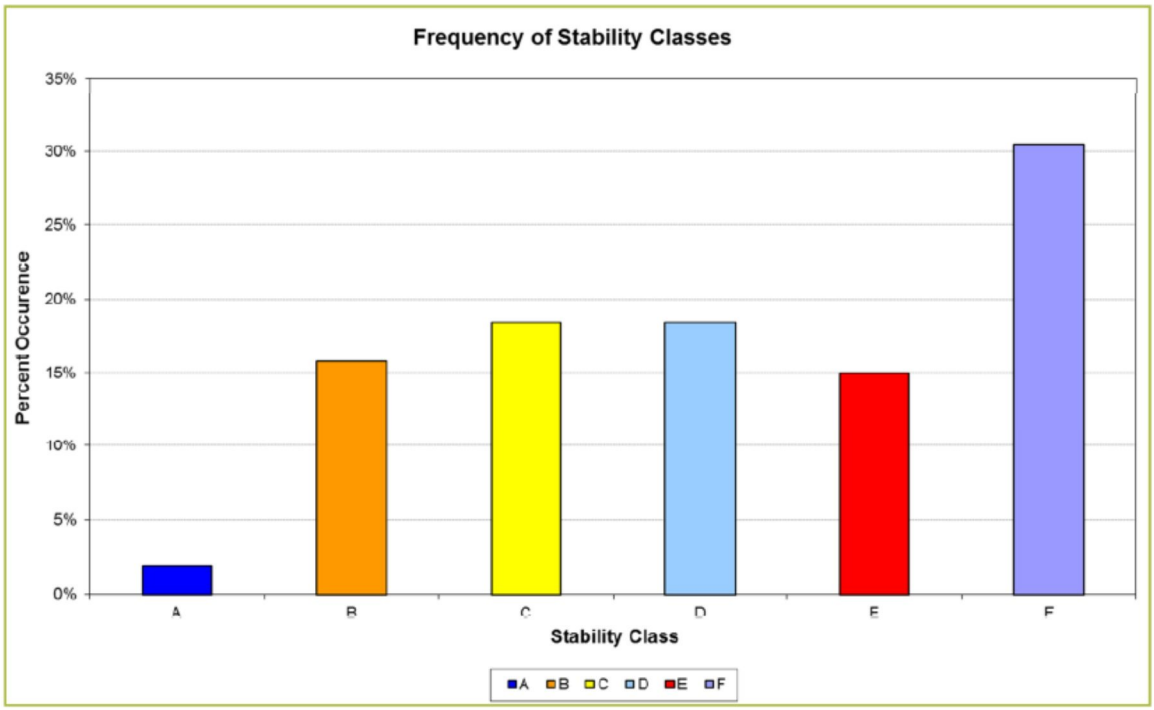


Appendix A3 Botany Wind Rose



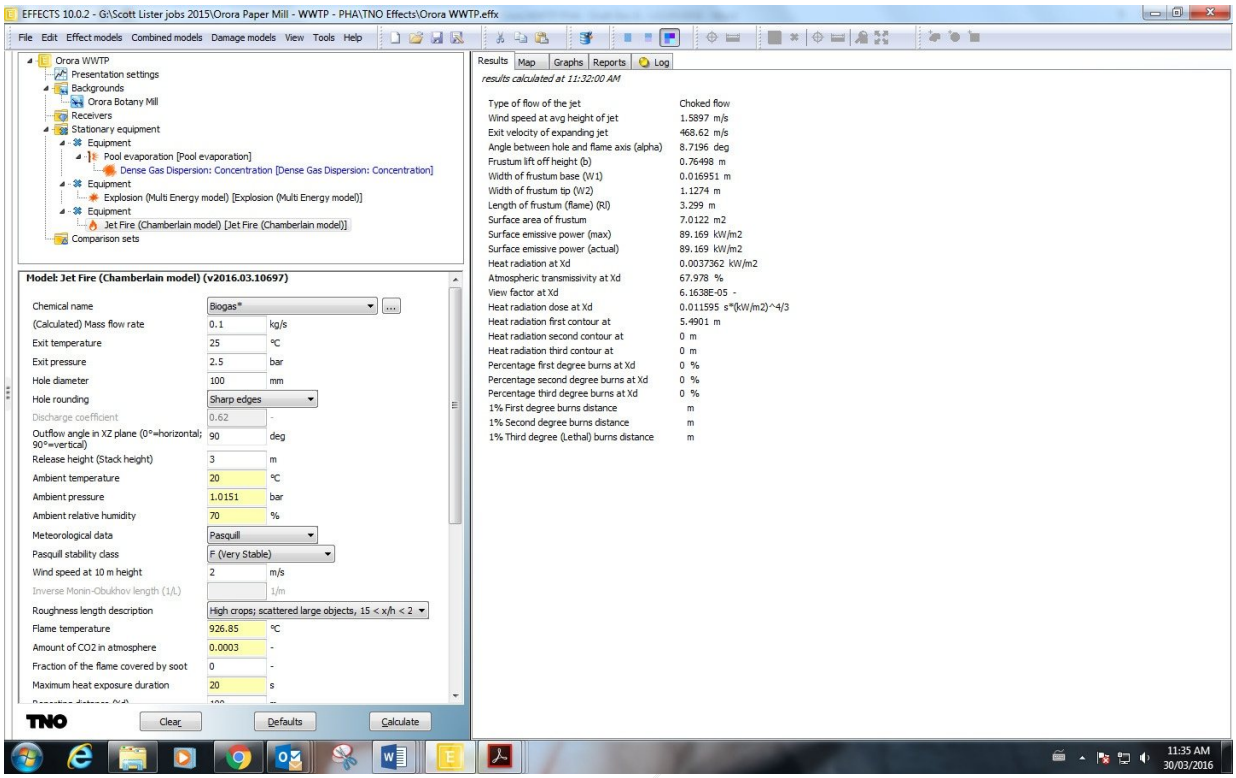
On an annual basis the predominant wind direction is from the south (i.e., SSW-S-SSE-6% +13%+4%) – at about 21%.

The CALMET-generated meteorological data can be used to estimate stability class for the site and the frequency distribution of estimated stability classes is presented in **Figure 6.6**. The data show a large proportion of class F conditions (>30.5% of hours), and a total of 45.5% of hours with either E or F class.

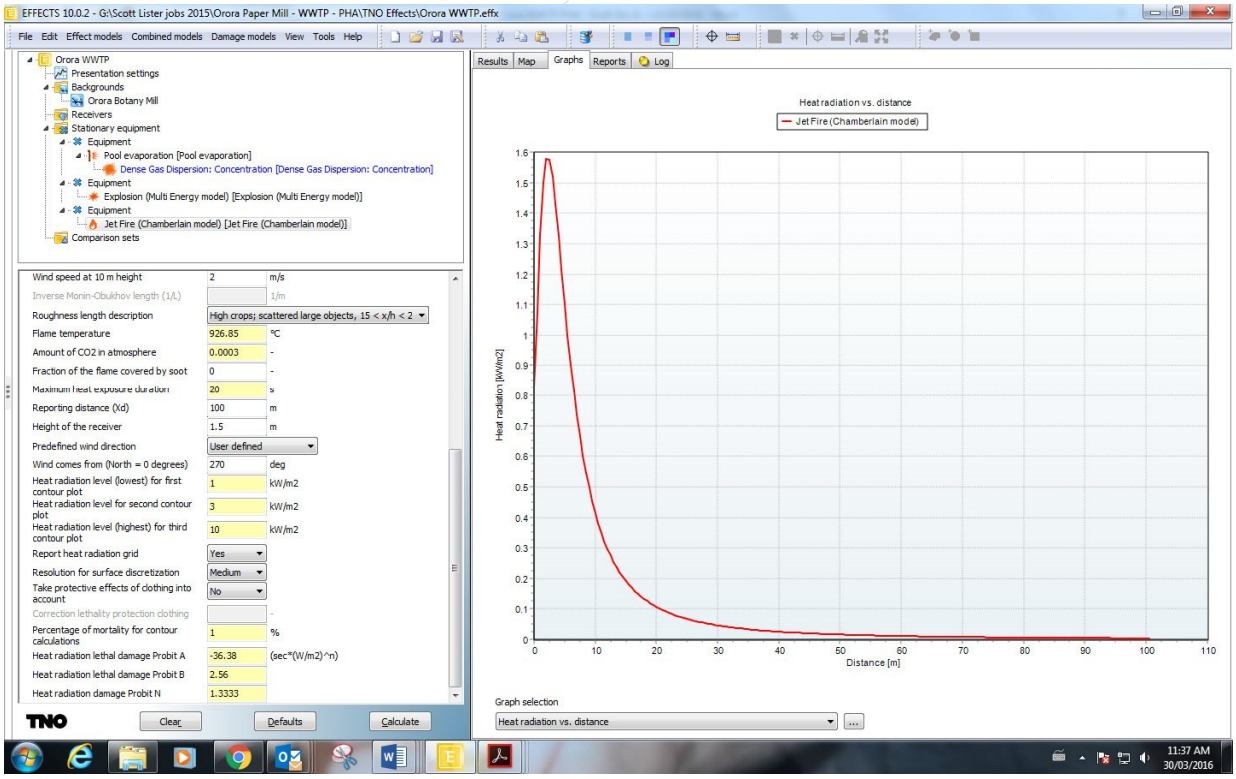


Appendix A4 Flaring Calculation

TNE Effects V10.0.3 Inputs for Flare Calculation at 0.1 kg/s at 2.5 bar

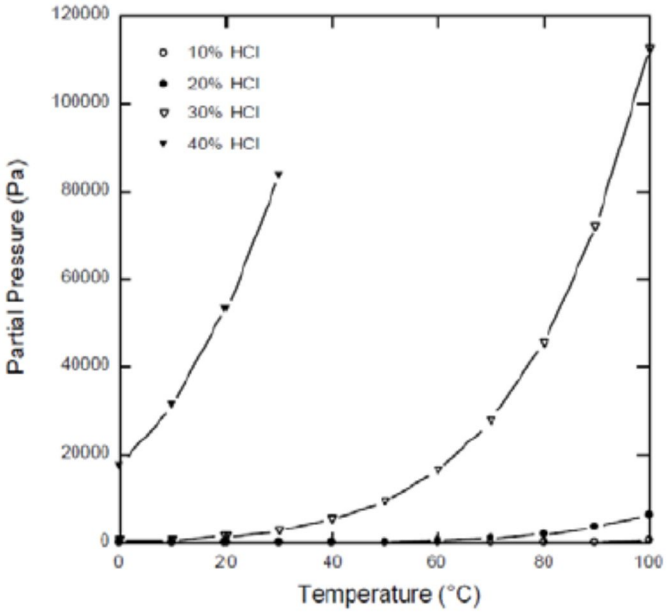


Heat Flux (kW/m2) at Distance (m)

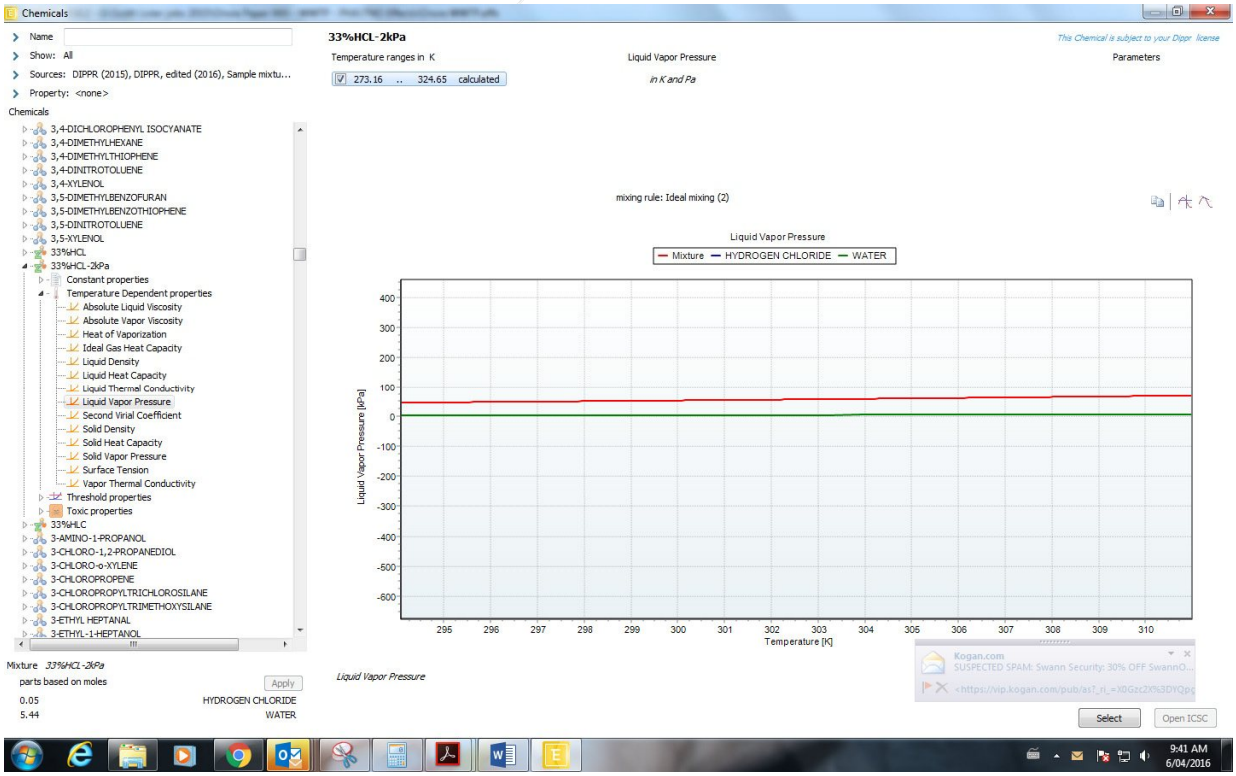


Appendix A5 HCL release

A check of vapour pressure of different strengths of solutions of HCL has revealed that the partial pressure (or vapour pressure of 33%HCL) is around 2000 - 5000 pa) and 40 % HCL as 50,000 Pa as shown in Figure 5 – Partial Pressures of HCL. (Reference 10).



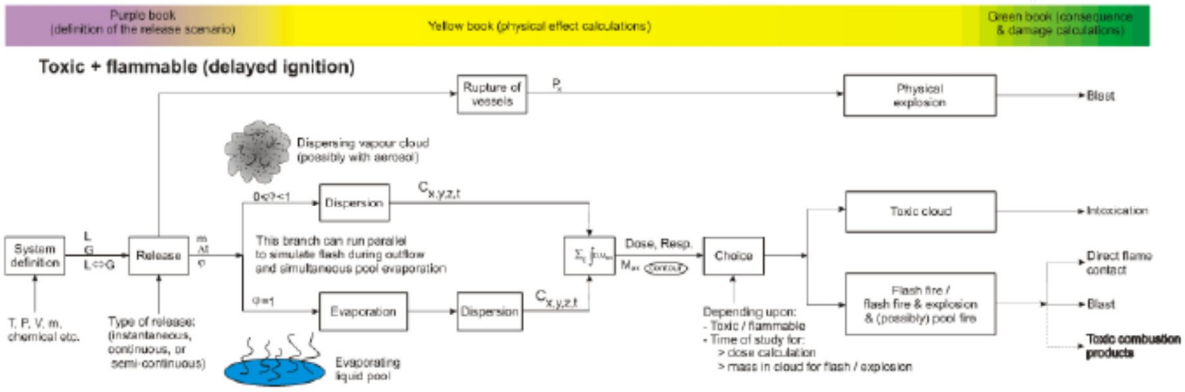
EFFECTS allows the user to input mixtures, in this case we have used 40 % HCL for the SVP to be conservative, (shown below). Which gives a SVP of 50,000 Pa at 27 deg C. (300 deg K)



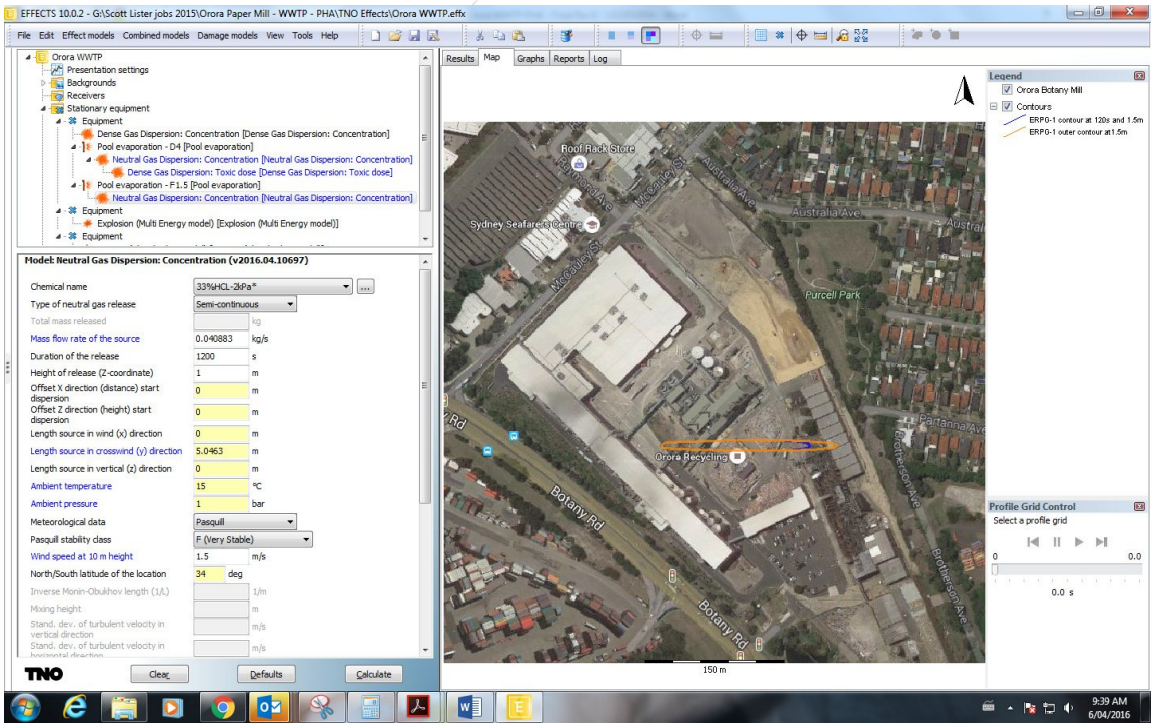
Bund Area used = 36 m2 – (tank area, 3.14 x 2.3 x 2.3 =16) = 20 m2

The type of decisions that have been made along the route of calculating the downwind concentration of 33% HCL, are being presented in the model log shown below. In this case we have run;

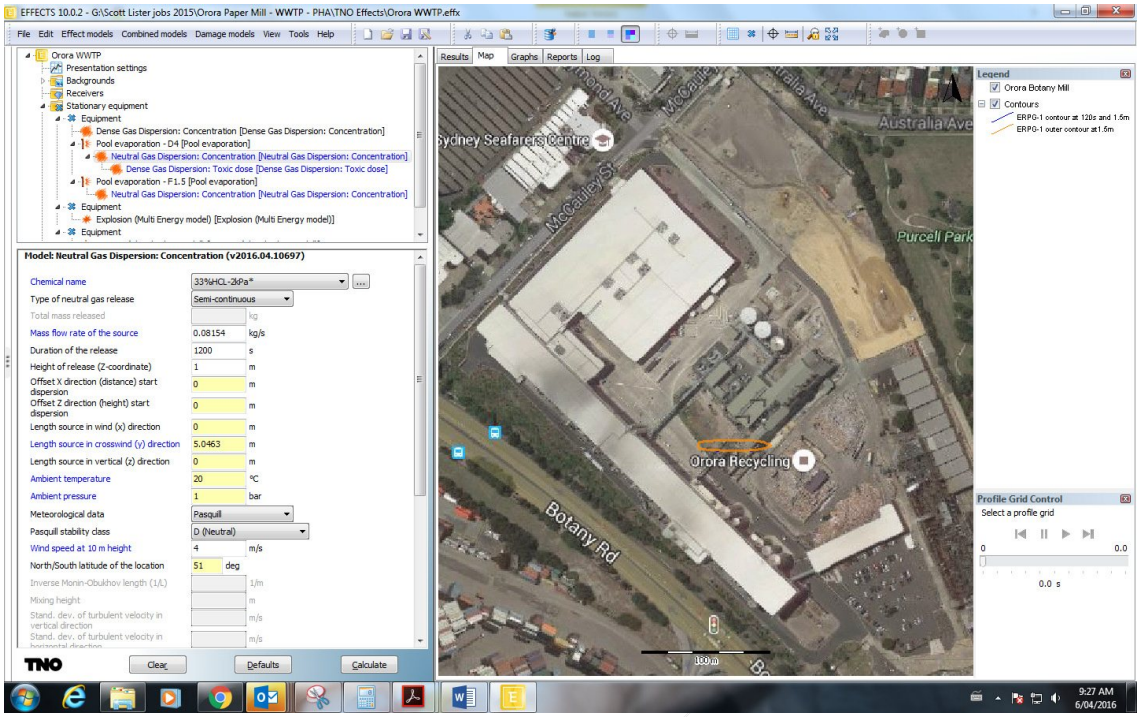
4. The Evaporative pool model, followed by the
5. Neutral Gas Dispersion Modelling



The resulting HCL plumes are for ERPG-1 are shown for Daytime (D4) and Night-time (F1.5) releases. Input / Output data for Night time (F1.5) release - Wind from the west. The ERPG-1 Contour – extends 198 m.

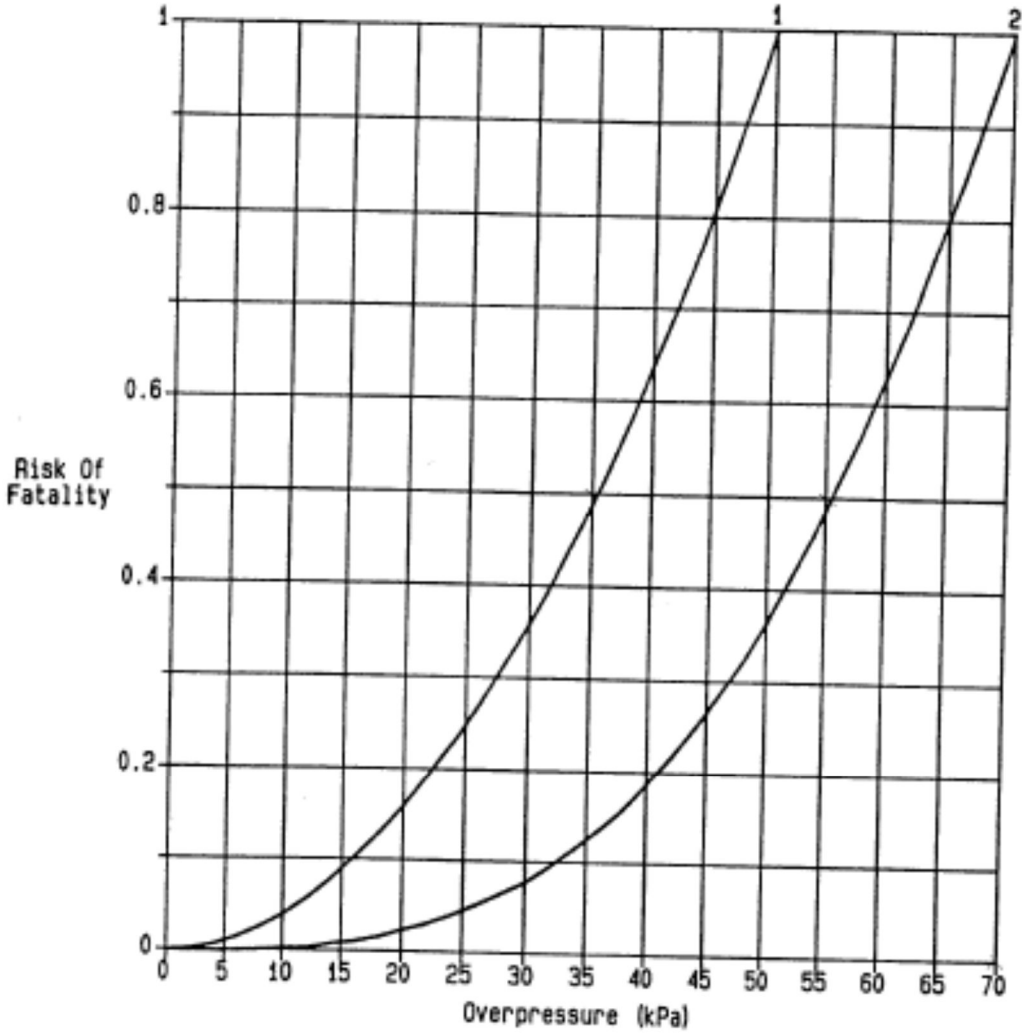


Input / Output data for Day time (D4) release - Wind from the west. The ERPG-1 Contour – extends 58 m.



Appendix A6 Probit – Explosion Overpressure

The Risk of Fatality for exposure to overpressure is taken from FP Les – Loss Prevention in the Process Industries (Reference 12). And for an overpressure of around 7 - 10 kPa at the site boundary for a person in the open gives a Pf = 0.01.



Where Line 1 – is the risk for a person in a conventional building, and

Line 2 - is the risk for a person in the open

Appendix A7 – TNO Effects V10.0.3

TNO innovation for life

EFFECTS is sophisticated, but easy to use software to assist you in performing safety analysis. It calculates the effects and consequences of the accidental release of hazardous materials.

Safety Analysis

EFFECTS is designed for anyone involved with the safe processing, handling and storage of hazardous materials. This advanced program provides safety professionals with an efficient software tool for hazard identification, safety analysis, safety control, quantitative risk analysis (QRA) and emergency planning. In these area's EFFECTS is a valuable tool: it allows users to predict, calculate and present the physical effects of any accident scenario with toxic and/or flammable chemicals.

Transparency and traceability

As an independent research organization, TNO stands for transparency and traceability in the methods used for safety analysis. The "Yellow Book" 1) provides solid scientific information and is recognized internationally as the standard reference work for consequence analysis. The "Green book" 2) describes the relations between physical phenomena (heat radiation, explosion overpressure's, toxic doses) and resulting damage. Models incorporated within EFFECTS are described into detail in these books, making the results both transparent and traceable.

Calculation models and chemical databases

EFFECTS offers over 50 different calculation models of the following types:

- Release
- Evaporation
- Fire
- Explosion
- Dispersion
- Damage

Models can pass their calculation results as input to other models using a method called "linking". With linking the whole chain of a loss of containment scenario can be modeled from the initial release to the end effects like overpressures due to explosions or toxic dose results. The user has full control of each individual model and how it is linked.

Models": in a fully automatic process EFFECTS calculates all possible effects that can occur for a given loss of containment situation by doing the selection of models and linking for you. This will allow you to get results in only a few mouse clicks.

The software comes with a complete and industry standard chemical database, containing over 2200 toxic and flammable values and all thermodynamic properties. An integrated material editor allows the usage of your own chemicals.

Ease of use

The user interface of EFFECTS is suitable for both experts and occasional users. It offers 3 modes of operation (novice/normal/expert) and supplies default settings for all models.
The results are presented as series of graphs, special reports and contours on maps. A sophisticated GIS tool is incorporated within the software, making it easy to overlay results over GIS drawings, Google Earth© screen captures or ESRI shape files. The Windows 7© compliance, and Microsoft Office© integration speeds-up the production of professional reports.

EFFECTS presents the calculation results on maps, as series of graphs and reports. All data can be exported using copy/paste.

EFFECTS, please visit our web site:
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To download the "Coloured Books":
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[ref. 1]
"Methods for the calculation of Physical Effects" (The Yellow book), Committee for the Prevention of Disasters, CPR 14E / PGS2, 2nd rev. print, (2005)

[ref.2]
"Methods for determination of possible damage" (The Green book), Committee for the Prevention of Disasters, CPR 18E / PGS1, 2nd edition (2005)

TNO.NL

www.tno.nl/EFFECTS
EFFECTS is designed for all those concerned with safety processing, handling and storing hazardous materials.

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HazMat Liquid Release Following a Tank Truck Accident: Cross-Check Modelling and Field Data Validation

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In this paper, after discussing QRA uncertainties connected to consequence modeling (release rates, evaporation, and dispersion), we consider an hazardous release of hydrochloric acid due to a loss of containment of a tank truck. Following the source term characterization, we applied widely used integral approaches, providing modeling for the combination of all physical phenomena involved after the release. The applicative phase of this work, representing its main appeal, is the validation of the simulation results against field data sets in the near field, directly collected during emergency response activities. More advanced modeling can be performed by a computational fluid dynamics method (CFD) to solve the Navier-Stokes equations, together with specific model equations. Quantitative conclusions are drawn about the cross-check validation performed. The comparison based on experimental data evidences the ability and limitations of the adopted models in estimating the actual post-release gas behavior, as well as the implications for hazard predictions that support decision makers in emergency planning and response.

1. Introduction

The science of process safety and risk analysis and related approaches require further progress, as illustrated by the sequence of major hazard accidents, e.g. in the downstream oil industry (Fabiano and Currò, 2012). Notwithstanding the use of risk assessment has become rather widespread and more decision making depends on it, as amply recognized the methodology produces still unsatisfactory results: choices, complexity, available computing time, limited knowledge and experience contribute all to unavoidable spread. Variance of outcomes of an analysis is high and can cover in some cases two orders of magnitude in risk, defined as the product of expected event frequency and likely damage. Many of the available consequence models are of the “integral” type, allowing many complex problems to be solved with limited input data. A specific cause of result spread is consequence modelling (release rates, evaporation, dispersion), while reliability of software forms a sector of science in itself (Pasman and Fabiano, 2008). Ditali et al. (2006) reported examples of how outcomes of pure physical models of release, vaporisation and dispersion can differ with at least a factor 2. Starting from it, in Table 1, some results are reproduced and updated with results modelled by EFFECTS 5.5 (TNO, The Netherlands) and PHAST, thus contributing to obtain an overall picture. Mean value and standard deviation are calculated as well, evidencing the significant output variability. The relative error of the near and far field estimation, by adopting suitable dispersion simulation, can be quantified in a first approximation as the sum of the relative error of the source term and of the dispersion model. In addition, damage probit parameters, based on dose-response rates obtained by experimental trials and actual accidents, are also object of much discussion. Furthermore, from one side the probit constants for a given toxic compound differ according to different authors, so that the extent of hazard range varies substantially (Fabiano and Pasman, 2010). From the other side, the knowledge of the fluctuations around the average concentration induced by turbulence is required for the accurate application of a toxicity model sensitive to the time dependence of the exposure.

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Table 1: Hazardous substance loss of containment effect calculations with different integral models.

Scenario	Variable	EFFECTS 4	PHAST	GASP	EFFECTS 5.5	Mean value	Standard deviation
Toluene confined pool	Max evaporation rate, [kg s^{-1}]	0.21	0.15	0.11	0.21	0.17	0.05
Toluene unconfined pool	Max evaporation rate, [kg s^{-1}]	3.5	1.2	1.1	3.5	2.3	1.4
	Max pool area, [m^2]	2005	995	1042	2000	1510	568
Scenario	Variable	DISPGAS	PHAST	PHAST 6.53.1	EFFECTS 5.5	Mean value	Standard deviation
Dense gas dispersion (10%w/w H_2S)	Vertical max. distance to 100 ppm H_2S, [m]	625	275	205-380	367	370	159
	Horizontal max. dist. to 100 ppm H_2S, [m]	150	205	215-400	372	268	111

Even if minimizing hazards or fostering inherent safety based on the use of chemicals that reduce or eliminate hazards started already in the early 1980's and is nowadays applied also to non-conventional chemical processes (Fabiano et al., 2011), still large quantities of hazardous materials (HazMat) are continuously transported, stored and handled worldwide. Loss of confinement on storage tank, vessel or piping implies atmospheric dispersion of pollutants and, depending on the compound inherent hazard, requires considering the source term, local environment and meteorological parameters. As amply reported, the accidental release of a toxic compound into a residential area may pose acute and long term hazards in addition to tremendous public anxiety.

In this paper, we consider a real hazardous release of hydrochloric acid connected to an accidental loss of containment of an ADR tank truck. After a detailed characterization of the source term, we firstly applied a widely used integral approach, providing modelling for the combination of all physical phenomena involved after the release. The applicative phase of this work, representing its main appeal, is the validation of the simulation results against field data sets directly collected during emergency response activities, in the near field. More advanced modelling can be performed by means of a computational fluid dynamics method (CFD) to solve the Navier-Stokes equations, together with specific model equations. As expected, the CFD modelling allows obtaining more refined results, when compared with integral model outputs, clearly under the constraints of a larger amount of effort and computer time. Quantitative conclusions are drawn about the cross-check validation performed. The comparison based on experimental data evidence the ability and limitations of the adopted models in estimating the actual post-release gas behaviour, as well as the implications for hazard predictions that support decision makers in emergency planning and response. From the evidence of this study, in view of public health protection, the decision of evacuating or sheltering people potentially exposed to the chemical can be based, with enough reliability, on proper integral modelling, provided that the validation is limited to the near field and in the absence of local geometrical/orographic complications.

2. Case-study description

On January 19, 2007, in the first hours of the day, a tank truck carrying concentrated aqueous hydrogen chloride (30 % w/w) parked at a parking area just in the proximity of the exit toll of Rapallo (Highway A12 - Genoa District, Italy) started a low flow rate, continuous spilling, due to a loss of containment connected to a weld failure. The discharged liquid formed a pool, vaporizing and diffusing into the ambient atmosphere, transported by a light wind within an area of plain terrain. The emergency team of the Genoa Fire Brigade unit in connection with the Regional Protection Agency promptly responded and applied all technical measure to stop and contain the release. As a cautious approach, nearly 20 people in the lightly populated surrounding area were evacuated, mainly from caravans and trailers, while other residents were advised to shelter and stay inside their homes. The same sheltering measure was taken for a school in the neighbourhood. In the subsequent modelling inter-comparison, we used meteorological data from a nearby

station to run the models, so as to predict the average pollutant concentration, within the context of emergency planning.

2.1 Materials and Methods

Hydrogen chloride is a colourless gas with a pungent odour, and has a vapour pressure of 42,200 hPa at 20°C and a water solubility of 823 g/L at 0°C. Its aqueous solution (hydrochloric acid) possesses strong acidity, and reacts with most metals producing explosive hydrogen gas. Hydrogen chloride is readily dissociated in water into hydrated protons and chloride ion. The physico-chemical properties indicate that hydrogen chloride released into the environment is distributed into air and water. Hydrochloric acid can pose a moderate to severe risk to users due to its predisposition to emit significant amounts of HCl fumes even with moderately dilute solutions. Inhalation exposure to high concentrations of HCl fumes may result in coughing, choking sensation, burning of the respiratory tract, and pulmonary edema (Proctor et al., 1991). Short-term exposure to airborne concentration up to 1.8 ppm did not cause irritation to the respiratory tract of sensitive asthmatic volunteers (Stevens et al. 1992). The American Industrial Hygiene Association (AIHA) lists the Emergency Response Planning Guideline – 1 (ERPG-1) for HCl to be about 3 parts per million (ppm); the ERPG-1 is the highest concentration where a worker can be exposed to it for up to an hour and have no perceivable negative consequences acute or chronic. The AIHA lists the Emergency Response Planning Guideline – 2 (ERPG-2) for hydrochloric acid to be 19 ppm. The ERPG-2 is a measurement of the highest concentration at which 1 hour of exposure will not cause permanent or life threatening injury. Finally, the National Institute for Occupational Safety and Health (NIOSH) has set the Immediately Dangerous to Life or Health (IDLH) limit for hydrochloric acid at 48 ppm. The IDLH is the minimum level at which life threatening or permanently debilitating injuries would occur immediately on exposure (ACGIH, 2001). Gaseous samples were taken on a triplicate basis and analyzed by different techniques. We use chemical tubes (Dreager, Aqua Air Industries, Louisiana, USA) to carry out a preliminary air testing. In addition to personal sampling, fixed-point sampling was carried out at a number of positions to determine the concentration of hazardous substances in the air at these positions and to compare the performance of different methods for sampling HCl. it was hoped that the results would give an indication of the likely inter-comparability of results obtained by the different methods. Airborne hydrogen chloride samples were collected according to the method n° 7903 (inorganic acids) (NIOSH, 1994) using a treated silica gel tube at a flow rate of 0.5 L/minute and subsequent analysis by ion chromatography. Each analysis was made in triplicate with the median of HCl measurements performed by the two methods not dissimilar especially in the immediate proximity of the source term.

2.2 Integral model comparison

The well-known ALOHA program (Areal Location of Hazardous Atmospheres) developed in USA with first publication in 1989, is primarily intended for emergency planning and is developed on the basis of well established sub-models. In order to properly apply the model to the considered release it was adopted a sequential procedure making reference as starting point to the partial pressure of aqueous solutions of hydrogen chloride calculated starting from the experimental data reproduced in Figure 1.

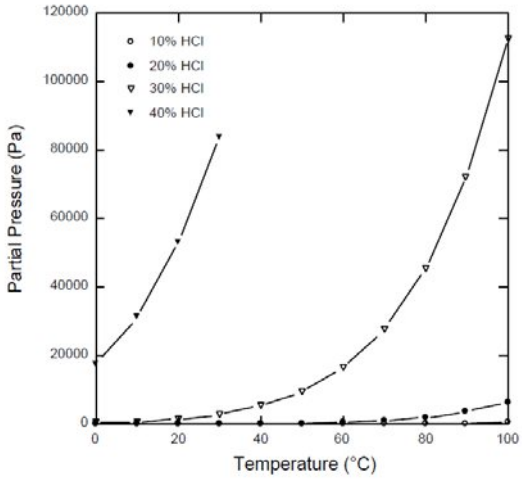

Figure 1: Partial pressure of different solutions of hydrochloric acid (w/w) as a function of the temperature.

Starting from the accidental event, we considered as the source term a circular pool resulting from field observation and proper definition of the pool spread according to Webber (1990). Following local and meteorological conditions were considered, according to BNL (Brookhaven National Laboratory):

wind speed: 5 m/s
atmospheric stability: class D
surface roughness: rural type
ground temperature: 293 K
relative humidity: 50%
cloudy conditions.

The evaporation rate was calculated adopting eq. (1) (Kawamura and Mackay, 1985):

$$E = A K_M \left(\frac{M_W P_V}{RT} \right) \quad (1)$$

where:

E = evaporation rate kg/s;
A = pool area, m^2;
M_W= molar mass (HCl =36.5 kg/kmol);
P_V = vapour pressure, Pa
R = universal gas constant, 8314 J/kmol K;
T = temperature, K.

The mass transport coefficient of hydrochloric acid K_M [m/s] was evaluated according to eq. (2) (Mackay and Matsugu 1973):

$$K_M = 0.0048 u^{7/9} Z^{1/9} Sc^{-2/3} \quad (2)$$

where:

u = wind velocity at 10 m, m/s;
Z = pool diameter, m;
$S_C = v/D_M$
v = air kinematic viscosity, m^2/s;

The diffusivity in air, D_M [m^2/s] is evaluated by eq (3), (Thibodeaux 1996), starting from the water diffusivity $D_{H2O} = 2.4 \cdot 10^{-5}$ m^2/s at 281 K ,

$$D_M = D_{H_2O} \sqrt{\frac{M_{W\,H_2O}}{M_{W\,M}}} \quad (3)$$

The second integral model utilized was EFFECTS 5.5, mainly based on the well-known Yellow Book (TNO, The Netherlands). The employed sub-model allowed direct evaluation of the dispersion from the evaporating pool. In addition, we performed also a calculation of the spread of hydrochloric liquid on ground, utilizing the suggested Webber model, solving a self similar pool surface profile. Comparing experimental evidence with calculated pool spread it was evidenced an overestimation by a large factor (ca. 30 %) of the pool spreading, even in the rather simplified geometry here considered. As a general observation, when dealing with small spills, the momentum of the falling liquid can become the driving factor in determining the spreading.

3. Results and discussion

It must be observed that the theory of pool evaporation adopted by the utilized models do not take into account the reduced vapour pressure of hydrophilic compounds in water.

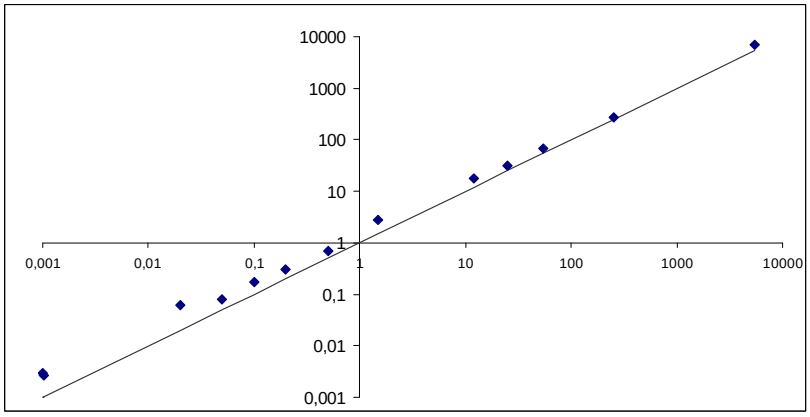

Figure 2: Correlation between atmospheric concentrations of hydrochloric acid experimentally obtained and calculated by ALOHA.

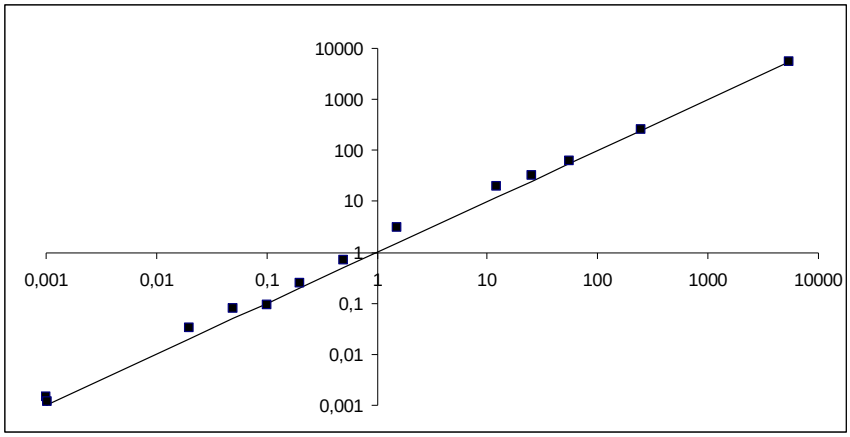

Figure 3: Correlation between atmospheric concentrations of hydrochloric acid experimentally obtained and calculated by EFFECTS 5.5.

So the utilization in case of strong acid aqueous solutions can introduce significant uncertainties when performing a QRA study. In case of small spill and to the purpose of emergency planning the results summarized in visual graphs of immediate readability evidence a fairly good agreement between calculated and experimental data. An overall high degree of correlation between experimental results obtained by on-site sampling and calculated values for both approaches is clearly evidenced in Figures 2 and 3. In Figure 4, an overall high degree of correlation (R>0.99) in the near-field evaluation between the two modelling approaches is evidenced, in connection with the explored small liquid release, during HazMat transportation. Figure 5 shows the relative error between predictions and experimental concentrations detected in the near field, up to a distance corresponding to a value lower at least by an order of magnitude than ERPG-1.
Experimental data are compared also with results obtained by the short range dispersion model ADMS 5 (Cambridge Environmental Research Consultant Ltd., UK), describing the boundary layer by the well-known boundary layer height and Monin-Obukhov length. One can notice that the maximum error corresponds to a distance of nearly 100 m, for all the tested simulation models. In any case, the integral models allow obtaining conservative estimates of airborne concentrations, globally within the range of experimental uncertainty, at least in the limited time and spatial scale here explored. In case of a detailed QRA study, including a range of risk reduction measures, a more advanced and accurate approach is possible, starting from an integral or analytical model and combining it, at a second level of refinement , with computational fluid dynamics modelling, appropriately tuned with experimental data.

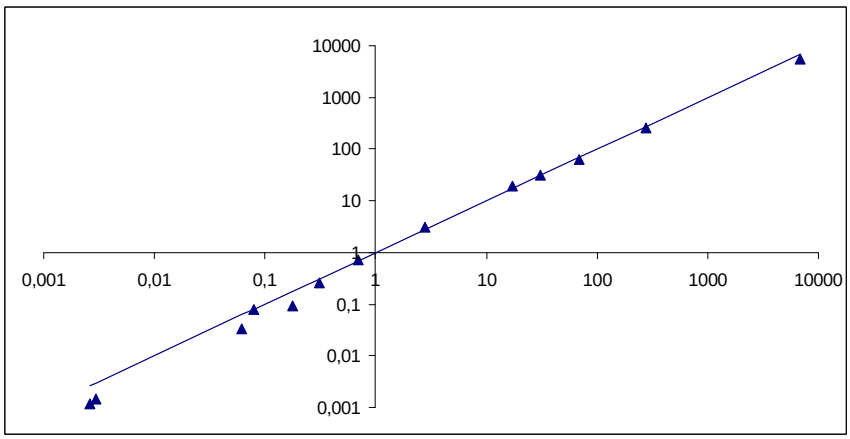

Figure 4: Correlation between hydrochloric acid atmospheric concentrations in the near field, calculated by the integral models ALOHA and EFFECTS 5.5.

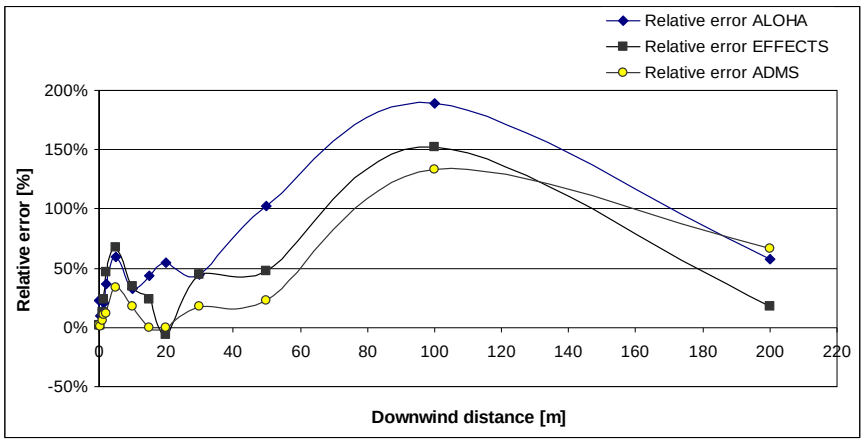

Figure 5: Relative percentage error between experimental and calculated data by the two selected integral models and by ADMS model.

4. Conclusions

The investigated small HCl spill scenario would lead to limited impact on emergency units, or nearby population, since concentration levels stay below critical threshold at distances as low as two hundred meters. The tested approaches predict conservatively the consequences of the atmospheric toxic release in the short range. The approaches can help decision-makers to prepare recommendations for emergency response support and consequent evacuation or sheltering decisions, without resorting to more complex and time expensive modelling, e.g. CFD.

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