Quantitative Risk Analysis (QRA) Report

for

Dangote Fertilizer Project,

Lekki, Nigeria

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1 GENERAL

1.1 Scope

Scope of this Quantitative Risk Analysis (QRA) is:

1) Identify worst case scenarios associated with the plant and the potential likelihood of such occurring;

2) Undertake consequence modelling to determine the impacts associated with identified scenarios including the extent of any off-site impacts, specifically those on the public;

3) Based on the findings of the above, define mitigation measures if applicable allied to residual risks if any.

2 EXECUTIVE SUMMARY

This Quantitative Risk Analysis (QRA) is focused on the identification and assessment of major accidental scenarios, that have a significant potential of affecting areas outside the boundary of Dangote Fertilizer Plant.

The worst case scenarios evaluated in this QRA have been selected considering the equipment where ammonia is handled with the highest concentration, inventory, and pressure, based on the following considerations:

1. In case of an accidental release, toxic substances are dangerous at lower concentration than flammable substances, and have a greater potential of affecting offsite locations; in addition no ignition source is necessary to cause damage to people health, therefore the frequency of toxic scenarios is generally higher than flammable scenarios..
2. The main toxic substance handled in the Dangote units is ammonia, both in liquid and in vapor phase.

In particular, the following release cases have been identified for the Dangote Fertilizer Plant:

- Release from the line connecting the Ammonia Unit to Urea Unit (from the E-512 Ammonia Product Heater to the S-04 B.L. Ammonia Filters)
- Release from the line connecting the Ammonia Storage to the Urea Unit (from Pump 30-P01 Ammonia Process Transfer Pump to S-04 B.L. Ammonia Filters)

Two classes of leak sizes have been evaluated:

- Minor leak, characterized by hole size of 10 mm
- Major leak, characterized by a hole size of 50 mm

The more credible release scenarios (leak release size 10 mm) have been taken into consideration for the development of the Emergency Response Procedure (spc. n° 00-ZA-E-85009). The toxic concentration limit considered for the purposes of the emergency escape plan is IDLH (immediate dangerous to life and health).

Given the area extension at 300ppm (about 1000 meters), the emergency plan shall evacuate people from the affected area within 30 minutes from the accidental event occurrence.

Finally, In order to assess the impact of the evaluated ammonia release scenarios on the off-site area, the Local Specific Individual Risk (LSIR) have been estimated. Individual Risk is defined as the frequency with which, at a given location, conditions for lethality may exist, considering all the accident scenarios evaluated.

Results of this QRA in terms of Individual Risk contours map have been evaluated with reference to acceptance risk criteria adopted in United Kingdom and Netherlands.

Individual Risk contours map relevant the assessed scenarios of Dangote Fertilizer Project shows that Individual Risk to the Public is lower than 10-6, hence accetable.

Moreover, the assessed scenarios generate inside the plant a Local Specific Individual Risk (LSIR) lower than 10-3, which can be classified as “tolerable”.

3 REFERENCES

[1] OGP (International Association of Oil & Gas Producers), Risk Assessment Data Directory, 434-1 Process release frequencies, March 2010.

[2] Center for Chemical Process Safety (CCPS), “Guidelines for Developing Quantitative Safety Risk Criteria”, American Institute of Chemical Engineers (AIChE), 2009.

[3] “Lees’ Loss Prevention in the Process Industries” – 3rd ed. (2004) Butterworth-Heinemann.

[4] “Guidelines for Quantitative Risk Assessment”, TNO Purple Book, CPR18E, 2005.

4 WORST CASE SCENARIO IDENTIFICATION

The hazardous substances handled in the Dangote Fertilizer are mainly the following:

- Ammonia;
- Natural Gas;
- Process Gas;
- Synthesis gas;
- Carbon dioxide.

In case of an accidental release, toxic substances are dangerous at lower concentration than flammable substances, and have a greater potential of affecting offsite locations; in addition no ignition source is necessary to cause damage to people health, therefore the frequency of toxic scenarios is generally higher than flammable scenarios..

The main toxic substance handled in the Dangote Fertilizer units is ammonia, both in liquid and in vapor phase. Toxic properties of ammonia are reported in the attached Material Safety Data Sheet.

Based on the above considerations, the worst case scenarios evaluated in this QRA have been selected considering the equipment where ammonia is handled with the highest concentration, inventory, and pressure.

In particular, the following release cases have been identified:

- Release from the line connecting the Ammonia Unit to Urea Unit (from the E-512 Ammonia Product Heater to the S-04 B.L. Ammonia Filters)
- Release from the line connecting the Ammonia Storage to the Urea Unit (from Pump 30-P01 Ammonia Process Transfer Pump to S-04 B.L. Ammonia Filters)

In normal operation, the Ammonia is sent to Urea from Ammonia Unit (11/21-E-512), via 8" line at 25 barg and 20°C.

The length of the line is about 200 m (each Ammonia-Urea Train), and the inventory feeding an accidental release from the line is the liquid hold up of the Let Down Vessel V-502 (36 m^3).

In case of Ammonia Unit out of service, ammonia is sent to Urea from storage tank 30-T01 through the pump 30-P-01.

The line downstream 30-P-01 is a 8" line at 26.4 barg and -33°C; the total length of the line (considering both Urea Trains) is about 1000 m . In case of an accidental release from this line, the outflow rate is limited by the normal flow rate of the ammonia transfer pump; conservatively 120% of this flow rate is considered, allowing for the the shift of the working point of the pump (30 kg/s).

In the analysis the Ammonia-Urea lines have been considered operated 95% of the time, while the lines Storage-Urea only 5% of the time.

4.1 Ammonia release and dispersion

Given the same rupture size, liquid ammonia, compared with vapor ammonia, will give higher release rates and heavier vapor plume clouds, dispersing at ground level, due to both low temperature and liquid droplets entrained in the cloud.

Based on the above considerations, a liquid ammonia release following a random rupture shall be considered as representative worst case event.

Ammonia boiling point is lower than ambient temperature at atmospheric conditions. When liquid pressurized ammonia, stored at a temperature above its normal boiling point, is released to open air, it undergoes a flash, i.e. part of the liquid instantaneously vaporizes; a liquid ammonia release will develop partly in a two phase flashing jet, dispersing and diluting in air, and partly in a liquid evaporating pool.

4.2 Release case selection

Based on a "random rupture" approach, a rupture could occur on any component of the considered systems. In particular, in this analysis it has been assumed that a release can occur at any point along the identified lines, from the Ammonia units to Urea units, and from Storage to Urea units.

Two classes of leak sizes have been evaluated:

- Minor leak, characterized by hole size of 10 mm
- Major leak, characterized by a hole size of 50 mm

The following systems, where pure ammonia is handled, have not been selected as representative worst cases, for the reasons illustrated below.

Releases form the Ammonia storage tank have not been analysed, since the tank is a double wall – double integrity type, designed so that both the primary and secondary self-supporting containers shall be capable of independently containing the stored liquid. A leakage from tank is very remote, since it would imply the double jeopardy of simultaneous release from both internal and external walls.

Ammonia vapour displacement blower – ammonia is processed in vapor phase at low operating pressure of 3.5 barg. No ammonia release from this system will been considered as representative worst case for the unit.

Ammonia storage flare – ammonia in this system is in vapor phase only. No ammonia release from this system will been considered as representative worst case for the unit.

Liquid ammonia from ammonia unit to ammonia tank is through a 8" line at 5 barg, via 11-P-501A/B, operated only in case of Urea unit out of service. This system has not been considered, for both low pressure and low frequency.

Ammonia refrigeration package – both vapor and liquid ammonia is processed in this system. Liquid ammonia is routed to ammonia tank through a 4" pipe at 35 barg. The consequences of a release from this system are similar to the ones already analyzed for the 8" ammonia line.

5 QRA METHODOLOGY

The risk analysis of the selected scenarios has been carried out through the following steps:

- Evaluation of the leak frequency
- Calculation of the consequences of the releases
- Estimation of the probability of damage / lethality for an individual exposed to an ammonia toxic release
- Calculation of the risk of fatality, i.e. the frequency with which a fatality is exected to occur throughout the area affected by the ammonia releases evaluated.

The Leak Frequency has been calculated, based on the Parts Count summarizing the items identified as potential release points, and the leak frequency database OGP (International Association of Oil & Gas Producers), Risk Assessment Data Directory, 434-1 Process release frequencies, March 2010.

The consequences and the risk have been calculated using the software Phast Risk 6.7.

5.1 Meteorological conditions

The meteorological condition considered are:

- Medium wind speed of 5 m/s, associated to a Pasquill category D (typical day/sunny condition, neutral atmosphere);

- Low wind of 2 m/s, associated to Pasquill category F (typical night/cloudy condition, stable atmosphere, implying less mixing and dilution with air and longer toxic distances).

The D5 and F2 conditions have been assumed to exist 50% of the time each.

The wind direction probabilities have been set considering the site prevailing wind, considering 55% probability of the wind blowing to NE sector.

Temperature: 20 °C;

Humidity: 70%.

5.2 *Ammonia Thresholds*

The distances to the following ammonia concentration thresholds have been evaluated:

IDLH (Immediately Dangerous to Life and Health), is the maximum concentration to which an operator may be exposed for 30 minutes without suffering irreversible health damage, or impairing the possibility of escape or self protection.

ERPG-2 (Emergency Response Guideline) is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

For Ammonia, ERPG-2 value is 150 ppm; IDLH value is 300 ppm, ERPG-3 value is 750 ppm.

5.3 *Ammonia Vulnerability*

The probability of fatality following the exposure to an Ammonia releases has been calculated through the “Probit model” included in the software Phast Risk.

The program calculates the dose absorbed by an individual at any given location, depending on the ammonia concentration and exposure time.

Then the probability of fatality, as a function of the absorbed dose, is calculated, using the probit coefficients defined in the Phast risk database for the ammonia:

$Probit = a + b\ LN(C^n\ T_{exp})$;

a = -16.21, b = 1, n = 2.

Based on the used probit equation, the following vulnerabilty is calculated:

- 50% vulnerability, for an exposure to 7400 ppm for 30 minutes;
- 1% vulnerability, for an exposure to 2300 ppm for 30 minutes .

6 FREQUENCY ANALYSYS

The Parts Count of the items (flanges, valves, instruments) considered as potential release points is relevant to the following lines:

Line downstream Ammonia Product Heater (11/21-E-512) to Urea Unit:

8"-11-AL5027-13P-F;

Line downstream Ammonia Process Transfer Pump 30-P-01 to Urea Unit:

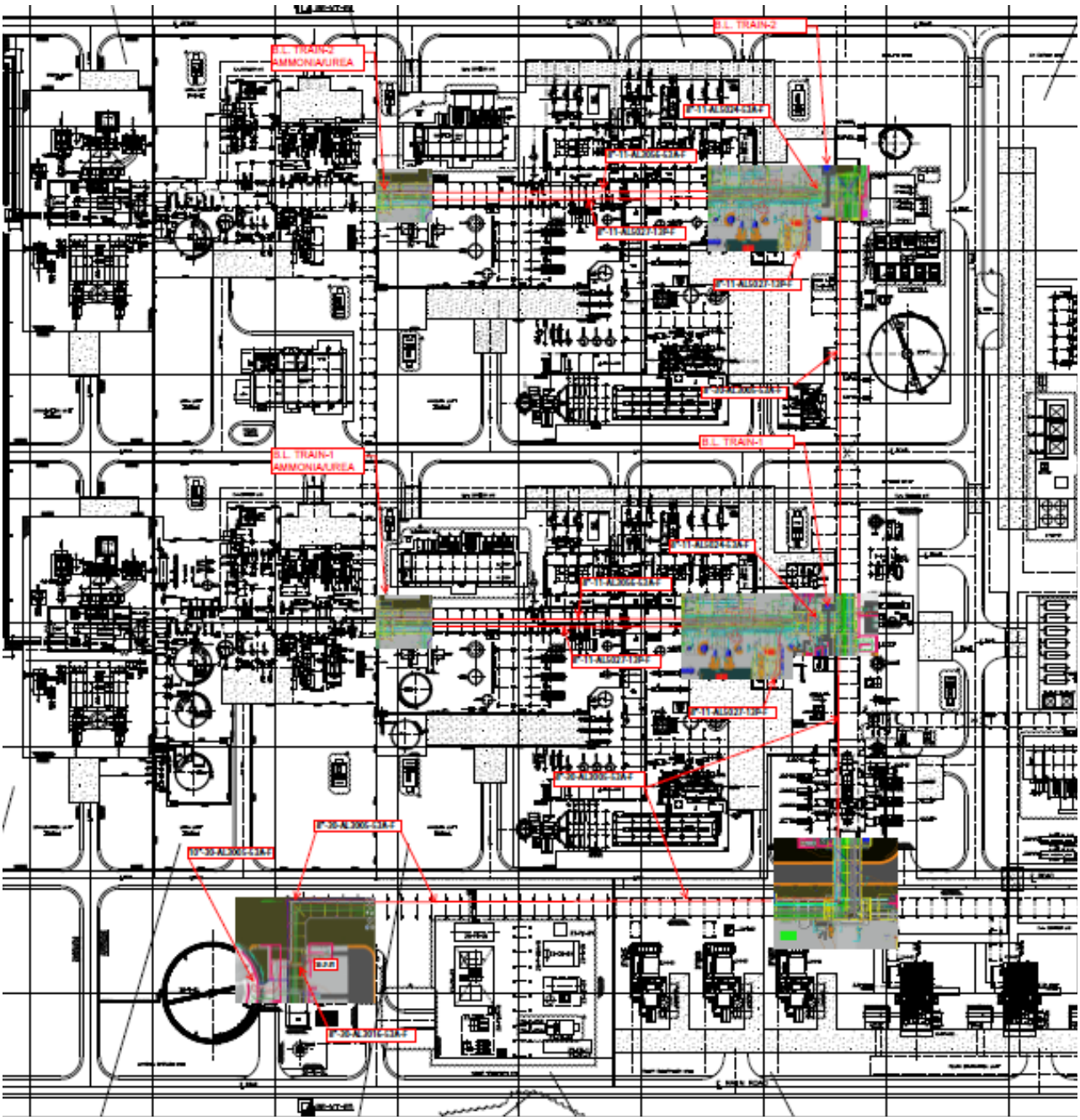
8"-30-AL3015-53A-F;

8"-30-AL3016-53A-F;

8"-30-AL3005-53A-F;

8"-11-AL3056-53A-F.

The following figure shows the routing of the above lines.



The following tables summarize the Parts Count for the considered systems, with the leak frequency calculated from the OGP database.

For risk assessment purposes, the leak frequency of the classes 3-10 mm and 10-50 mm have been summed and associated to the 10 mm consequences, while the frequency of the classes > 50 mm have been associated to the 50 mm consequences.

- Leak Frequency of line connecting the Ammonia Unit to Urea Unit

Isolatable Section TAG	
Isolatable Sections	
Description	From Ammonia Units to Urea Units
Ref. PFDs	-
Ref. P&IDs	11-GD-B-06830; 10-GD-4C-06416

					Leak Frequency				
Item TAG	Description	Sub-section	Item Type	Quantity	1 to 3 mm	3 to 10 mm	10 to 50 mm	50 to 150 mm	>150 mm
8"-11-AL5027-13P-F	FROM 11/21-E-512 to UREA (10/20-S-04)	1	Steel Process Pipe 6" DIA (150mm)	200	5.20E-03	1.70E-03	5.40E-04	1.20E-04	0.00E+00
		1	Flanged Joints 6" DIA (150mm)	6	2.22E-04	6.60E-05	1.80E-05	1.20E-05	0.00E+00
		1	Manual Valves 6" DIA (150mm)	2	6.20E-05	2.40E-05	9.40E-06	4.80E-06	0.00E+00
		1	Instruments < 2" DIA (50mm)	3	5.40E-04	2.04E-04	7.50E-05	0.00E+00	0.00E+00
		1 Totale			6.02E-03	1.99E-03	6.42E-04	1.37E-04	0.00E+00

- Leak Frequency of line connecting the Ammonia Storage to Urea Unit

Isolatable Section TAG	
Isolatable Sections	
Description	Line from Storage to Urea Units
Ref. PFDs	-
Ref. P&IDs	30-GD-B-86366; 00-GD-B-6200; 30-GD-B-86364; 11-GD-B-06831; 10-GD-4C-06416

					Leak Frequency				
Item TAG	Description	Sub-section	Item Type	Quantity	1 to 3 mm	3 to 10 mm	10 to 50 mm	50 to 150 mm	>150 mm
8"-30-AL3015-53A-F	FROM 30-P-01 TO AL3016	1	Steel Process Pipe 6" DIA (150mm)	14	3.64E-04	1.19E-04	3.78E-05	8.40E-06	0.00E+00
		1	Flanged Joints 6" DIA (150mm)	8	2.96E-04	8.80E-05	2.40E-05	1.60E-05	0.00E+00
		1	Manual Valves 6" DIA (150mm)	2	6.20E-05	2.40E-05	9.40E-06	4.80E-06	0.00E+00
		1	Instruments < 2" DIA (50mm)	5	9.00E-04	3.40E-04	1.25E-04	0.00E+00	0.00E+00
8"-30-AL3016-53A-F	FROM AL3016 TO AL3005	1	Steel Process Pipe 6" DIA (150mm)	20	5.20E-04	1.70E-04	5.40E-05	1.20E-05	0.00E+00
8"-30-AL3005-53A-F	FROM AL3016 TO AL3056	1	Steel Process Pipe 6" DIA (150mm)	342	8.89E-03	2.91E-03	9.23E-04	2.05E-04	0.00E+00
		1	Flanged Joints 6" DIA (150mm)	8	2.96E-04	8.80E-05	2.40E-05	1.60E-05	0.00E+00
		1	Manual Valves 6" DIA (150mm)	1	3.10E-05	1.20E-05	4.70E-06	2.40E-06	0.00E+00
		1	Actuated Valves 6" DIA (150mm)	1	2.20E-04	6.60E-05	1.90E-05	8.60E-06	0.00E+00
8"-30-AL3005-53A-F	to train 2 Urea	1	Steel Process Pipe 6" DIA (150mm)	167	4.34E-03	1.42E-03	4.51E-04	1.00E-04	0.00E+00
		1 Totale			1.59E-02	5.23E-03	1.67E-03	3.74E-04	0.00E+00
8"-11-AL3056-53A-F	FROM 11-AL-5024 to UREA (10-S-04)	2	Steel Process Pipe 6" DIA (150mm)	220	5.72E-03	1.87E-03	5.94E-04	1.32E-04	0.00E+00
		2	Flanged Joints 6" DIA (150mm)	8	2.96E-04	8.80E-05	2.40E-05	1.60E-05	0.00E+00
		2	Manual Valves 6" DIA (150mm)	2	6.20E-05	2.40E-05	9.40E-06	4.80E-06	0.00E+00
		2	Instruments < 2" DIA (50mm)	1	1.80E-04	6.80E-05	2.50E-05	0.00E+00	0.00E+00
		2 Totale			6.26E-03	2.05E-03	6.52E-04	1.53E-04	0.00E+00
8"-11-AL3056-53A-F	to train 2 Urea	3	Steel Process Pipe 6" DIA (150mm)	220	5.72E-03	1.87E-03	5.94E-04	1.32E-04	0.00E+00
		3	Flanged Joints 6" DIA (150mm)	8	2.96E-04	8.80E-05	2.40E-05	1.60E-05	0.00E+00
		3	Manual Valves 6" DIA (150mm)	2	6.20E-05	2.40E-05	9.40E-06	4.80E-06	0.00E+00
		3	Instruments < 2" DIA (50mm)	1	1.80E-04	6.80E-05	2.50E-05	0.00E+00	0.00E+00
		3 Totale			6.26E-03	2.05E-03	6.52E-04	1.53E-04	0.00E+00
		Totale complessivo			2.84E-02	9.33E-03	2.98E-03	6.79E-04	0.00E+00

7 CONSEQUENCE ANALYSIS

7.1 Line downstream Ammonia Product Heater(11/21-E-512) to Urea Unit (10/20-S-04) - 10 mm

In case of a 10 mm leakage from the 8" liquid ammonia piping, the initial ammonia flow-rate (2.9 kg/s) will last until, upon toxic gas detection, the line is isolated by the operator through manual valves (assumed intervention time: 20 minutes), after which the line continues to be emptied at a lower release rate.

The exposure time for risk calculation has been assumed 30 minutes.

For the 10 mm release case, the liquid ammonia flashes to atmospheric conditions,and the flashed liquid will break up in small droplets entrained in the two-phase jet, dispersing as a heavy cloud.

Input Data

Leak size : 10mm;

Operating pressure: 25 bar;

Operating temperature: 20 °C;

Release height: 1m;

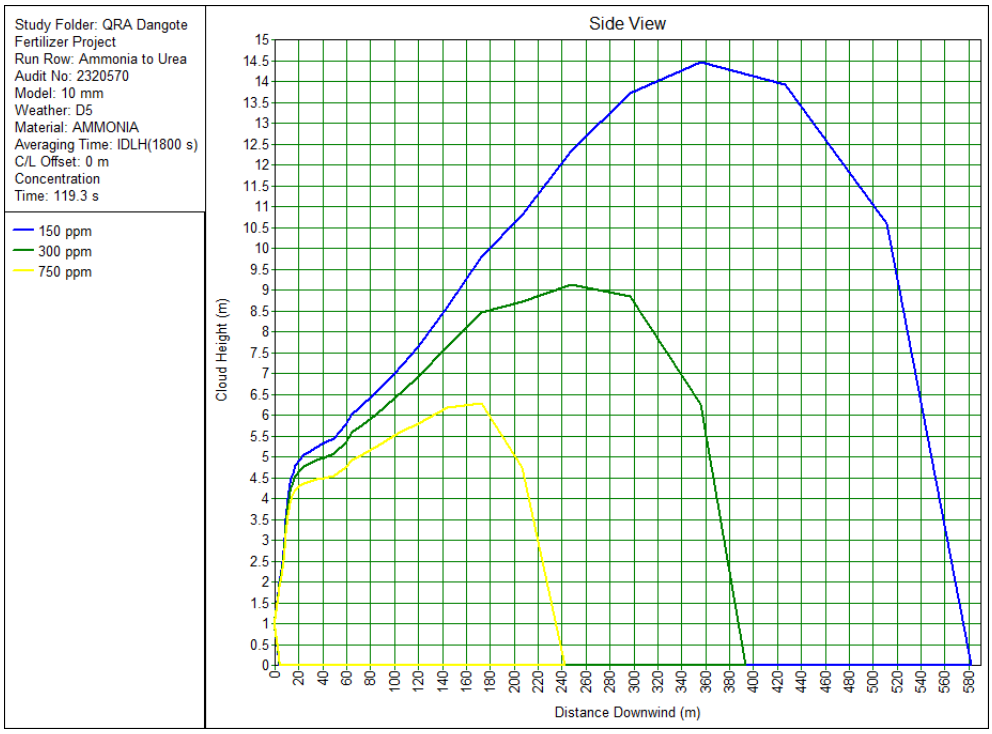
Meteorological conditions :Pasquill F & 2m/s ; Pasquill D & 5 m/s.

Results

The following figures show the toxic cloud contours at three threshold concentrations: 150ppm (ERPG-2); 300ppm (IDLH); 750ppm (ERPG-3), for both meteorological conditions considered. Both side view and footprint view are shown in the figures.

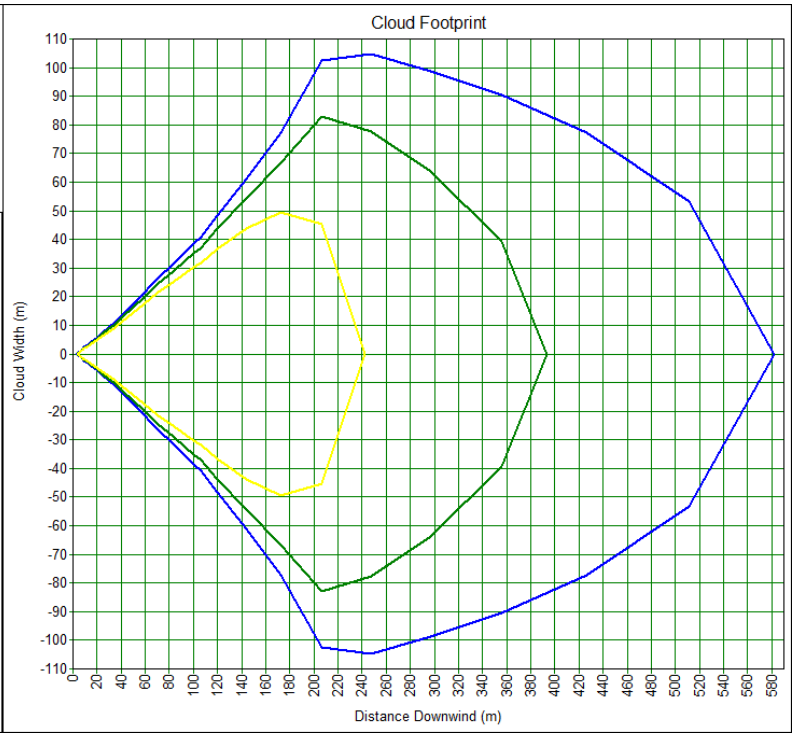
The concentration contours refer to the steady state of the plume. Distances are summarized in the table below.

Meteorological conditions	Distances to threshold concentrations (m)		
	ERPG-3	IDLH	ERPG-2
2/F	480	1090	1950
5/D	240	395	580



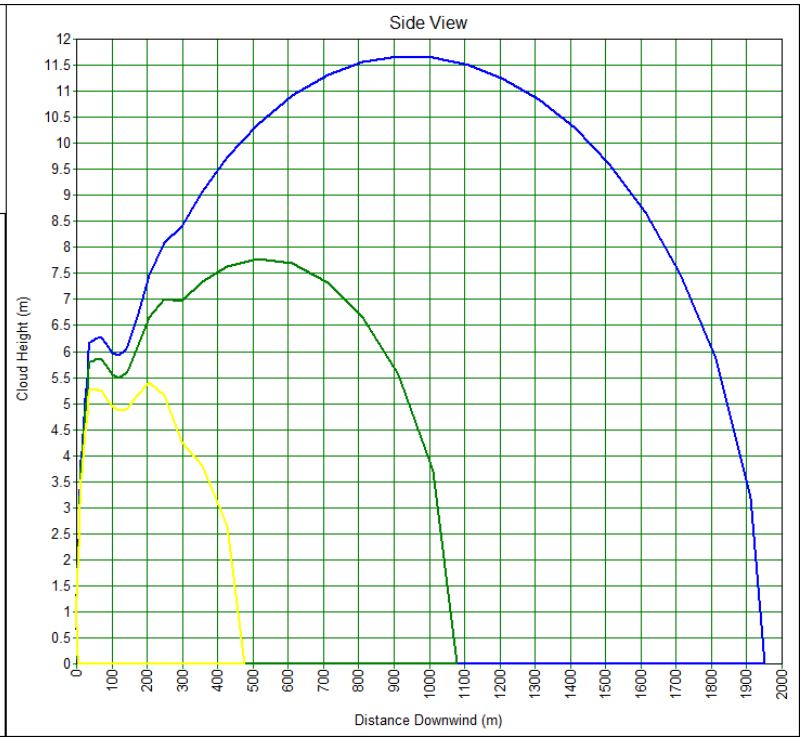
Study Folder: QRA Dangote Fertilizer Project
Run Row: Ammonia to Urea
Audit No: 2320570
Model: 10 mm
Weather: D5
Material: AMMONIA
Averaging Time: IDLH(1800 s)
Height: 0 m
Concentration
Time: 119.3 s

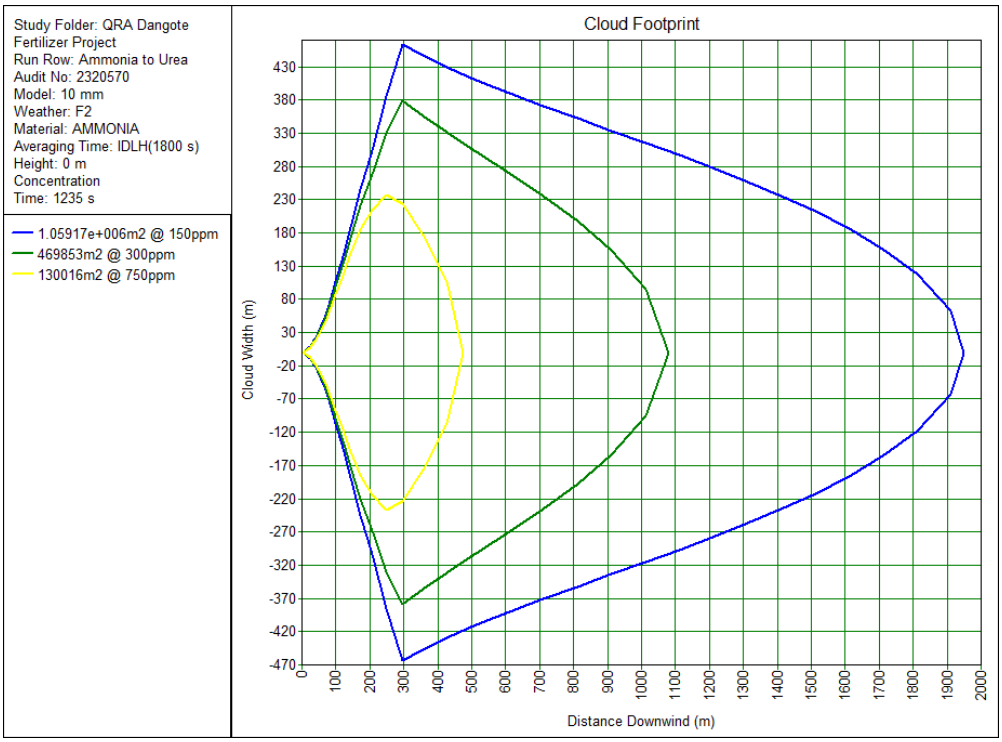
74421.4m2 @ 150ppm
36869.9m2 @ 300ppm
13667.2m2 @ 750ppm



Study Folder: QRA Dangote Fertilizer Project
Run Row: Ammonia to Urea
Audit No: 2320570
Model: 10 mm
Weather: F2
Material: AMMONIA
Averaging Time: IDLH(1800 s)
C/L Offset: 0 m
Concentration
Time: 1235 s

150 ppm
300 ppm
750 ppm





7.2 *Line downstream Ammonia Product Heater(11/21-E-512) to Urea Unit (10/20-S-04) - 50 mm*

In case of a 50 mm leakage from the 8" liquid ammonia piping, the initial ammonia flow-rate is 73.4 kg/s, greater than the operating inlet flow rate to the Let Down Vessel V-502 (25.5 kg/s). In this case the vessel is emptied in about 8 minutes.

For the 50 mm release case, the liquid ammonia flashed to atmosphere, partly rains out to ground forming a liquid pool. The ammonia vapour cloud developing in air is the result of two contributes: two-phase jet and evaporating pool. Once the leak is over, the pool could still be evaporating, then the contribution to the vapour cloud from the liquid pool could last for a period longer than the release duration (8 minutes).

Input Data

Leak size : 50mm;

Operating pressure : 25 barg;

Operating temperature : 20 °C;

Release height : 1m;

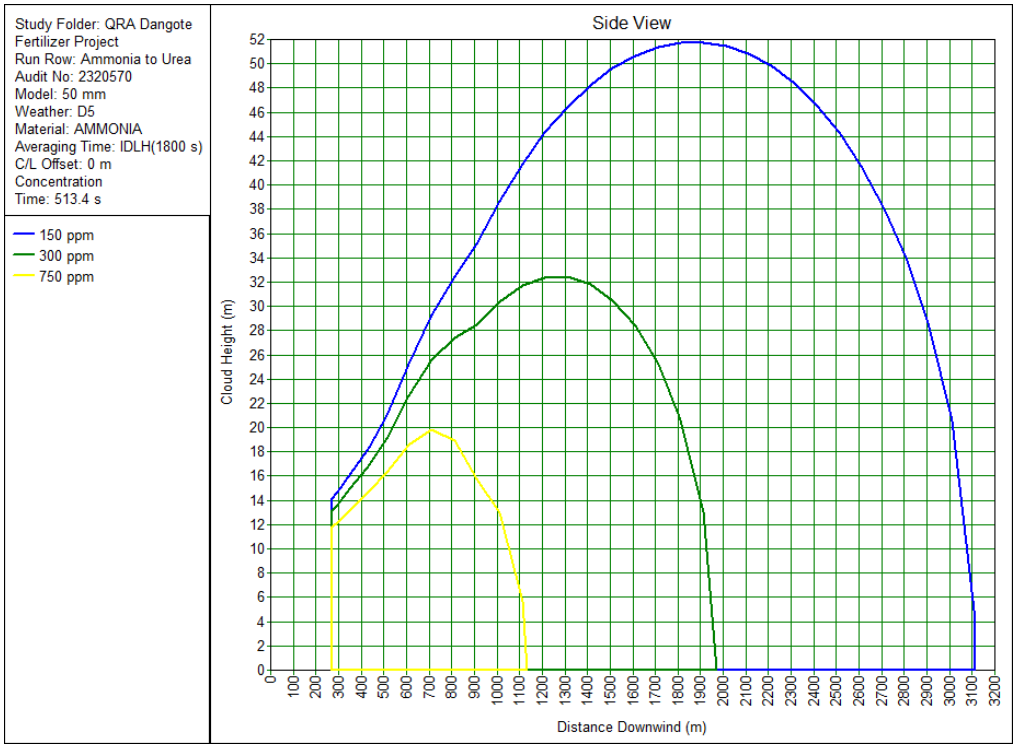
Meteorological conditions :Pasquill F & 2m/s ; Pasquill D & 5 m/s.

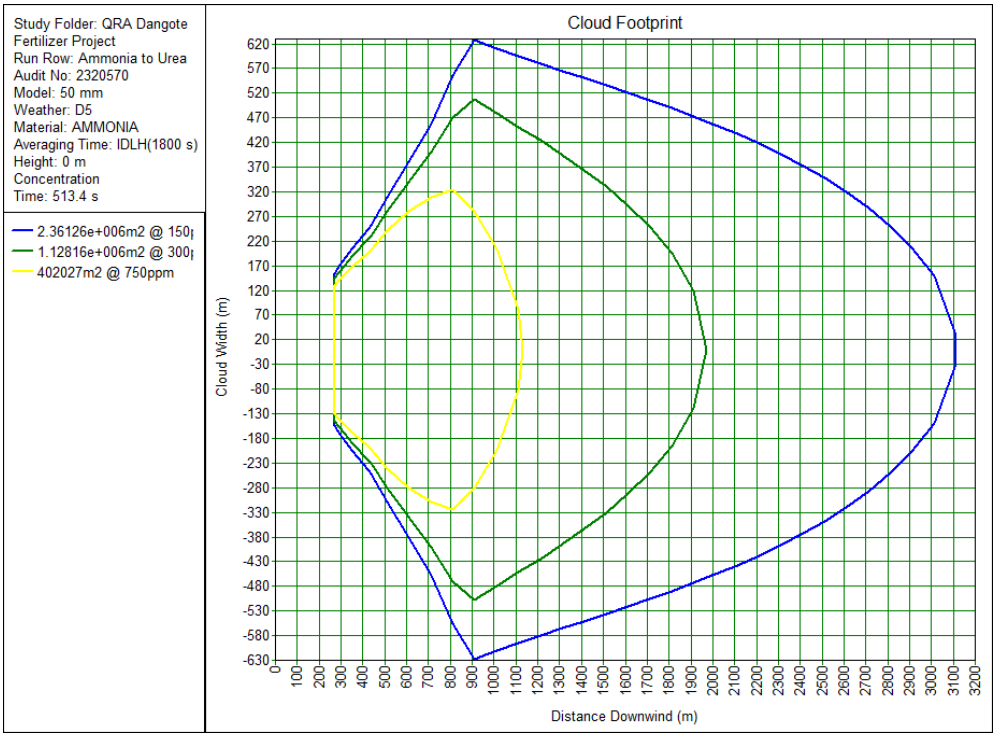
Results

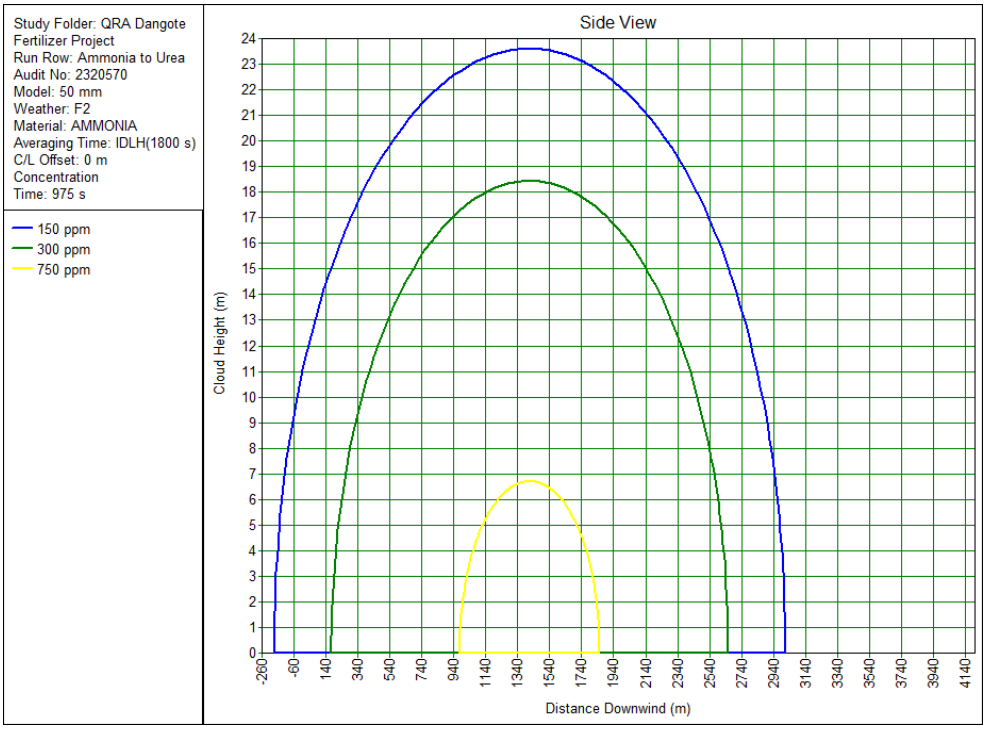
The following figures show the toxic cloud contours at three threshold concentrations: 150ppm (ERPG-2); 300ppm (IDLH); 750ppm (ERPG-3), for both meteorological conditions considered. Both side view and footprint view are shown in the figures.

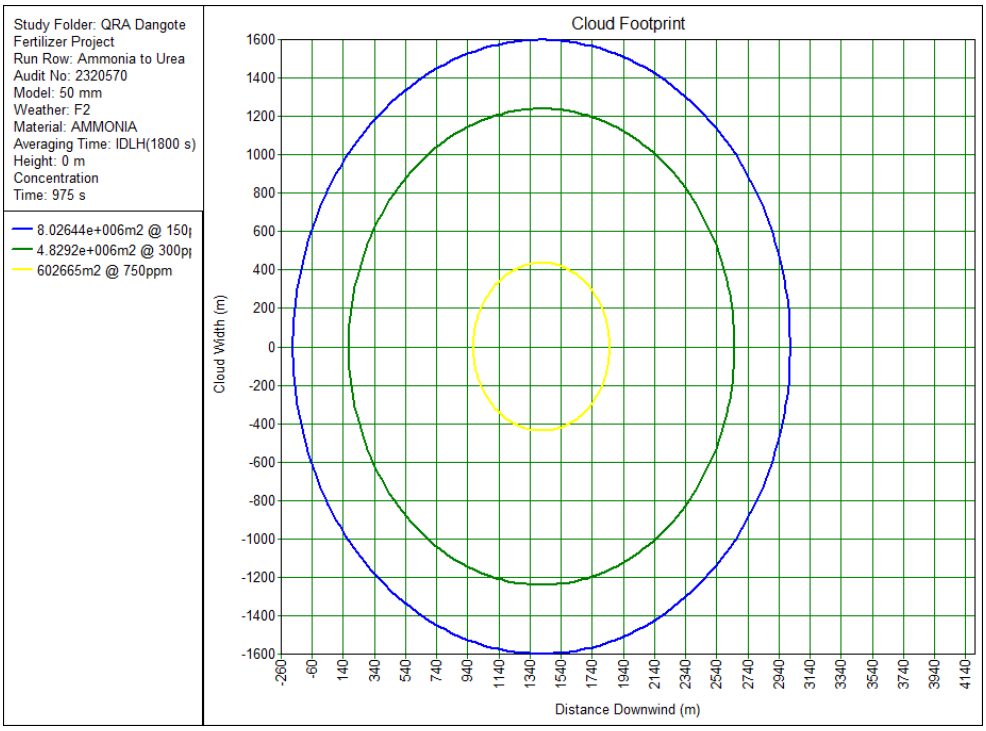
Due to the short duration of the release, and the formation of an evaporating pool, the dispersion contours do not reach a steady state, so the graph refer to representative instant time, generally selected in correspondence of the maximum overall extension of the cloud. Maximum distances reached by the unsteady dispersion are summarized in the table below.

Meteorological conditions	Distances to threshold concentrations (m)		
	ERPG-3	IDLH	ERPG-2
2/F	2090	2650	4150
5/D	1130	1960	3100









7.3 *Line downstream Ammonia Process Transfer Pump 30-P-01 to Urea Unit (10/20) - 10 mm*

In case of a 10 mm leakage from the 8" liquid ammonia piping, the initial ammonia flow-rate (3.2 kg/s) will last until, upon toxic gas detection or low flow / low pressure indications on the line , the pump is stopped by means of remote shutdown button, and the line isolated by the operator through the closure of manual valves (assumed intervention time: 20 minutes), after which the line continues to be emptied at a lower release rate.

The exposure time for risk calculation has been assumed 30 minutes.

For the 10 mm release case, the liquid ammonia flashes to atmospheric conditions,and the flashed liquid will break up in small droplets entrained in the two-phase jet, dispersing as a heavy cloud.

Input data

Leak size : 10 mm;

Operating pressure : 26.9 bar;

Operating temperature : -33 °C;

Release height : 1m;

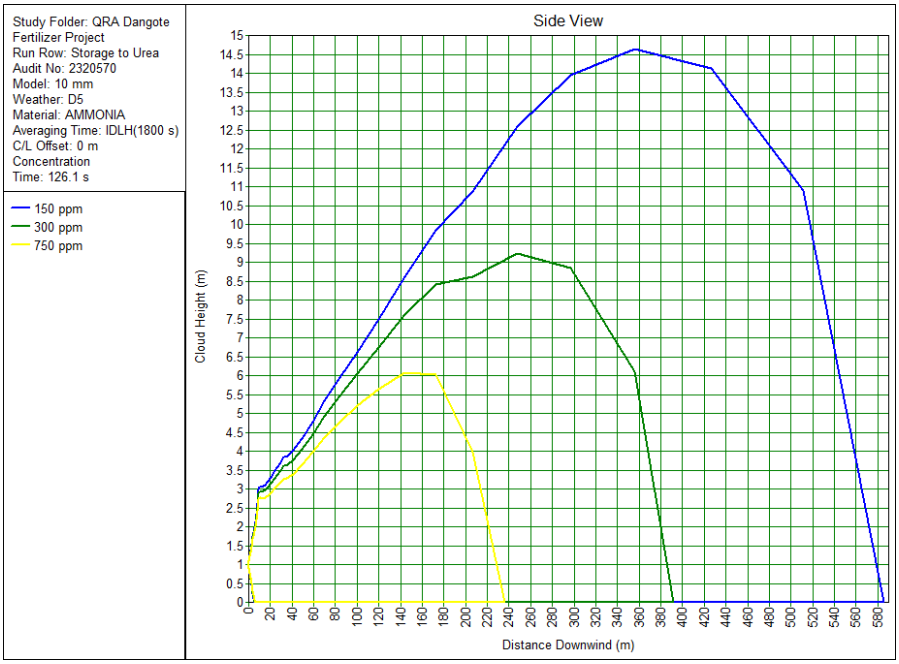
Meteorological conditions :Pasquill F & 2m/s ; Pasquill D & 5 m/s.

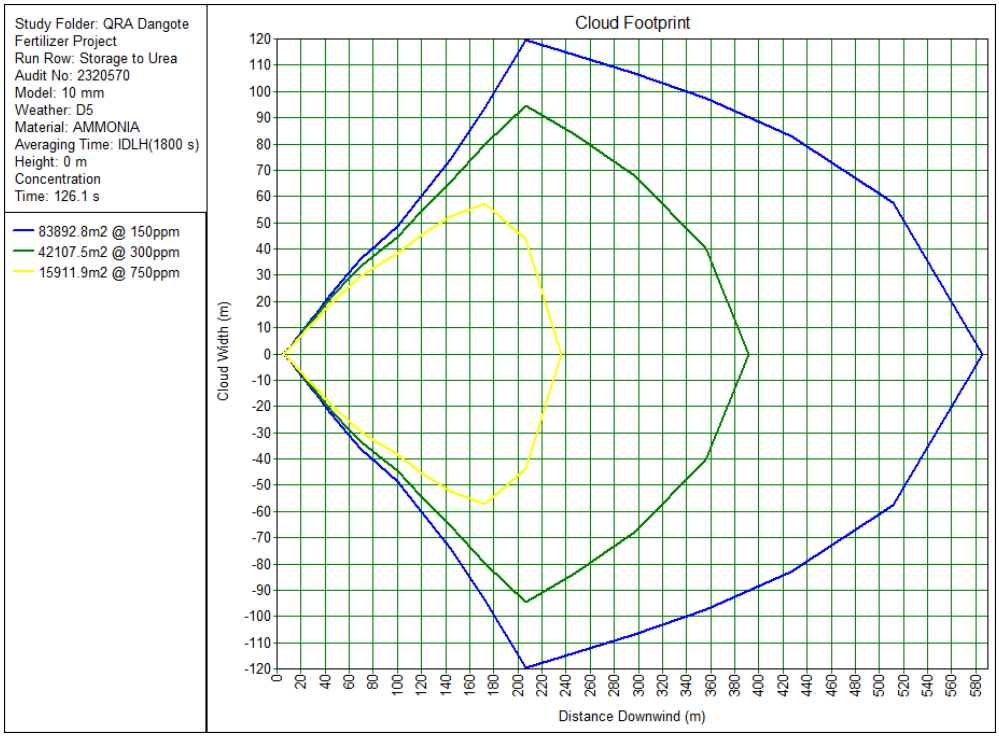
Results

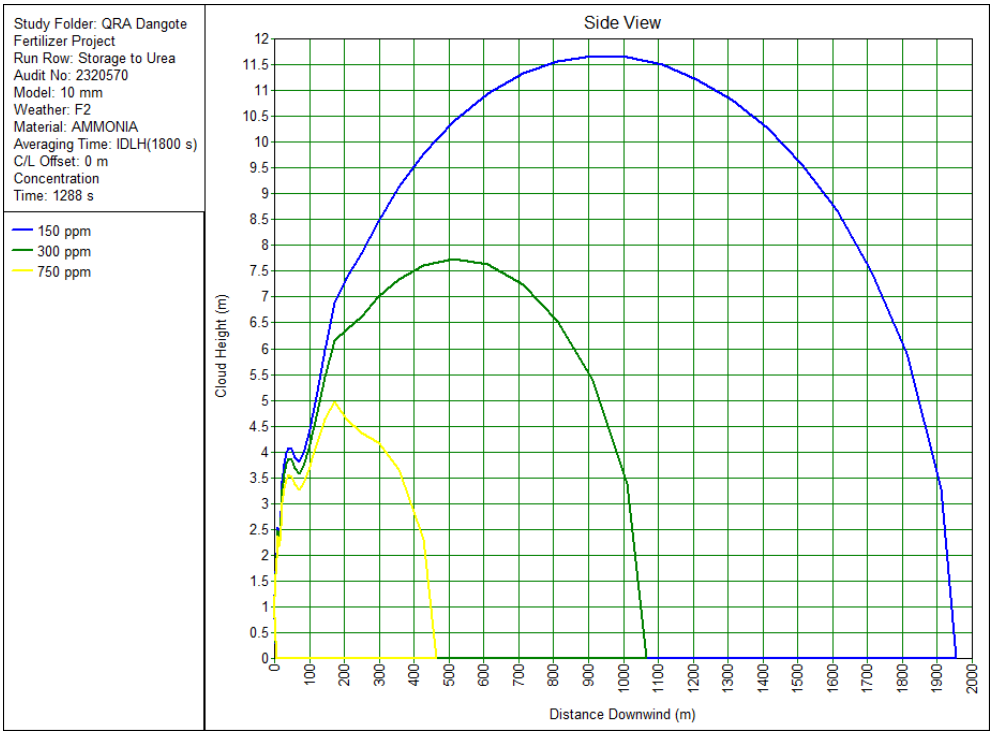
The following figures show the toxic cloud contours at three threshold concentrations: 150ppm (ERPG-2); 300ppm (IDLH); 750ppm (ERPG-3), for both meteorological conditions considered. Both side view and footprint view are shown in the figures.

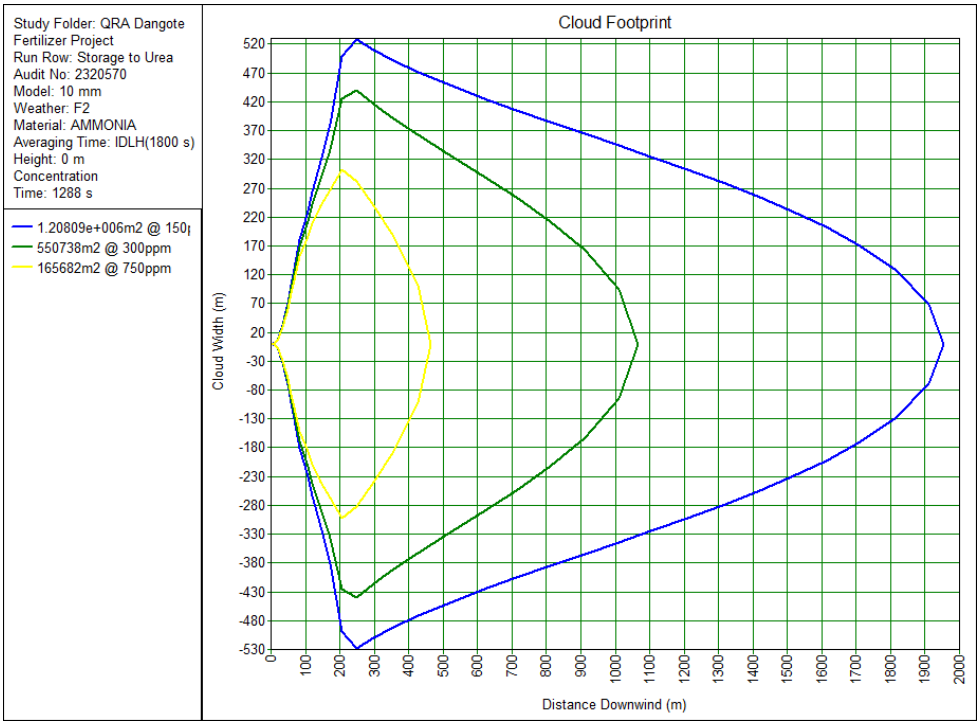
The concentration contours refer to the steady state of the plume. Distances are summarized in the table below.

Meteorological conditions	Distances to threshold concentrations (m)		
	ERPG-3	IDLH	ERPG-2
2/F	450	1080	1940
5/D	230	390	585









7.4 *Line downstream Ammonia Process Transfer Pump 30-P-01 to Urea Unit (10/20) - 50 mm*

In case of a 50 mm leakage from the 8" liquid ammonia piping, the initial ammonia flow-rate (80 kg/s) is greater than the pump flow rate (25 kg/s), and cannot be sustained. For the analysis, the discharge rate has been limited to 120% of the pump flow rate (30 kg/s), allowing for the shift of the pump working point.

The release has been assumed to last until, upon toxic gas detection or low flow / low pressure indications on the line, the pump is stopped by means of remote shutdown button, and the line isolated by the operator through the closure of manual valves (assumed intervention time: 20 minutes), after which the line continues to be emptied at a lower release rate.

The liquid ammonia flashed to atmosphere, partly rains out to ground forming a liquid pool. The ammonia vapour cloud developing in air is the result of two contributes: two-phase jet and evaporating pool. Once the leak is over, the pool could still be evaporating, then the contribution to the vapour cloud from the liquid pool could last for a period longer than the release duration (20 minutes).

Input data

Leak size : 50 mm;

Operating pressure : 26.9 bar;

Operating temperature : -33 °C;

Release height : 1m;

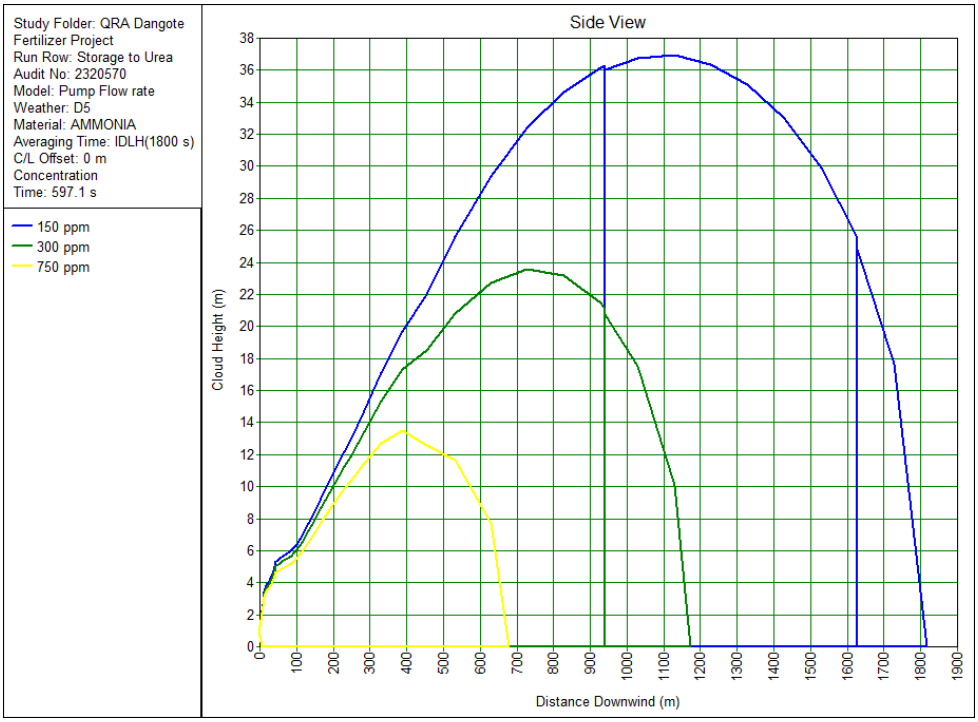
Meteorological conditions :Pasquill F & 2m/s ; Pasquill D & 5 m/s.

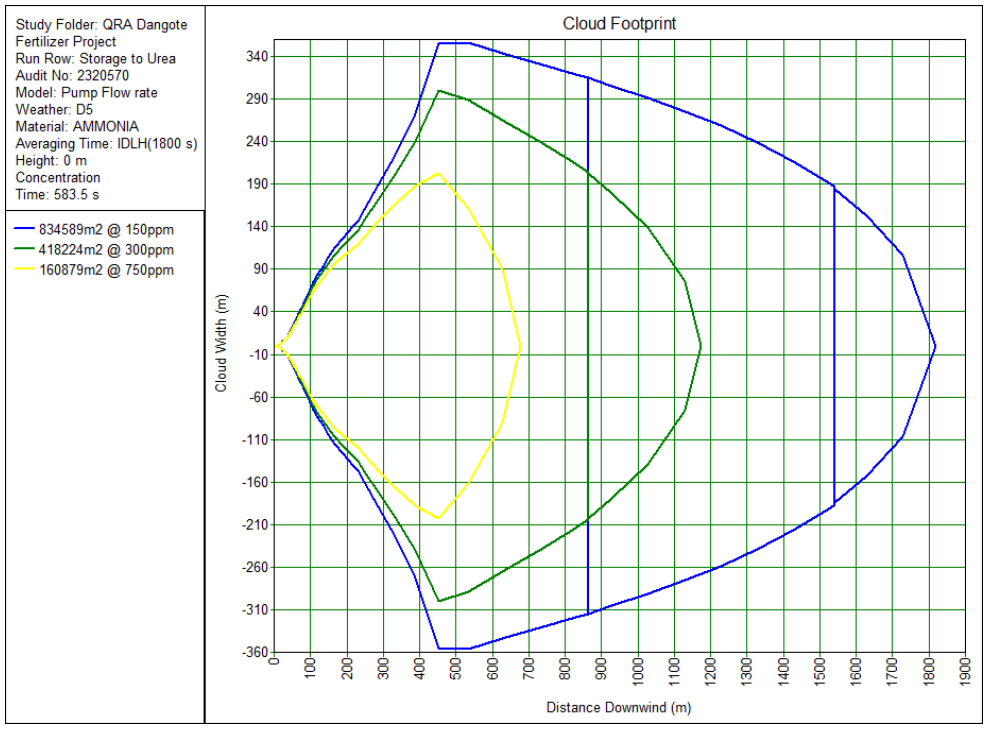
Results

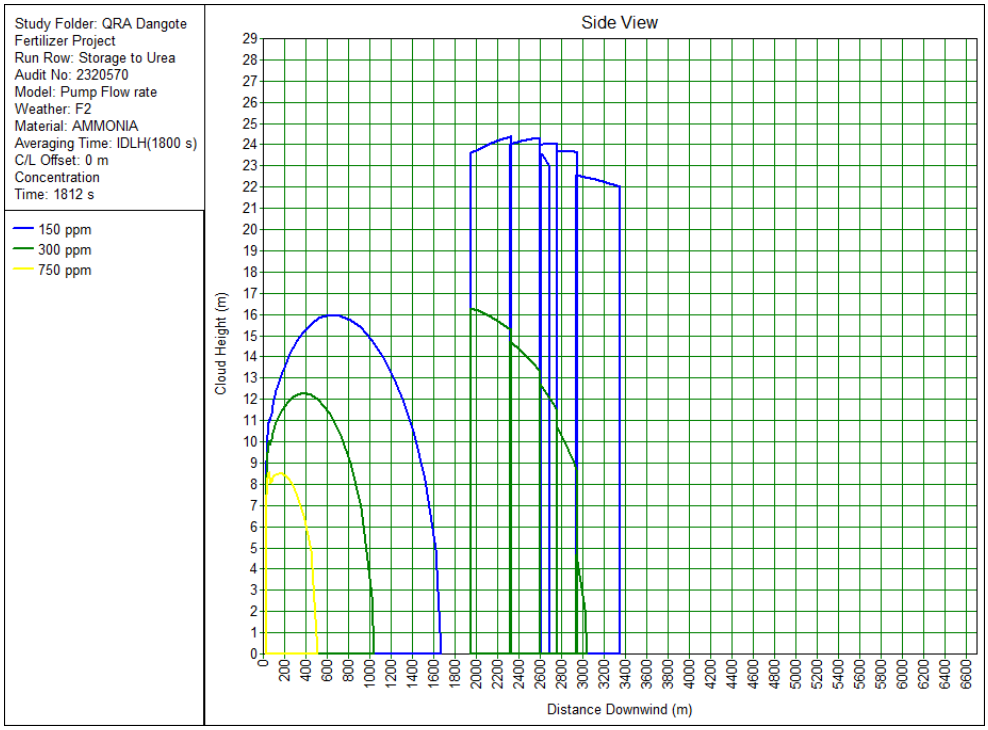
The following figures show the toxic cloud contours at three threshold concentrations: 150ppm (ERPG-2); 300ppm (IDLH); 750ppm (ERPG-3), for both meteorological conditions considered. Both side view and footprint view are shown in the figures.

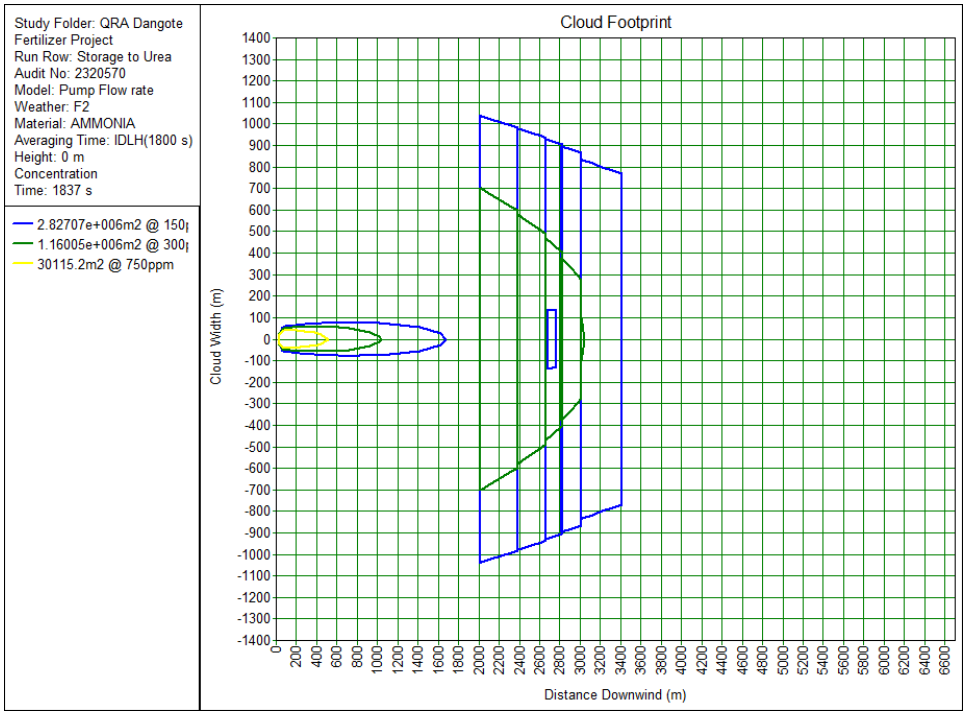
Due to the short duration of the release, and the formation of an evaporating pool, the dispersion contours do not reach a steady state, so the graph refer to representative instant time, generally selected in correspondence of the maximum overall extension of the cloud. Maximum distances reached by the unsteady dispersion are summarized in the table below.

Meteorological conditions	Distances to threshold concentrations (m)		
	ERPG-3	IDLH	ERPG-2
2/F	1250	3010	6600
5/D	660	1.170	1.810









8 RISK RESULTS

In order to assess the impact of the evaluated ammonia release scenarios on the off-site area, the Local Specific Individual Risk (LSIR) have been estimated

Individual Risk is defined as the frequency with which, at a given location, conditions for lethality may exist, considering all the accident scenarios evaluated. In particular, LSIR (Local Specific Individual Risk) is defined as the frequency with which a hypothetical individual, permanently present at a specific location with no possibility of protecting himself, is expected to sustain a given level of harm (in this case fatality) from the realization of all the specified hazards. By its definition, the LSIR may be viewed as a theoretical upper bound of the risk actually experienced by a specific individual.

The LSIR takes into account:

- the frequency of the release events;
- the likelihood of specific conditions determining the final accidental outcomes (e.g. wind direction probabilities, etc.);
- the vulnerability (i.e. the fatality probability related to physical effects such as heat radiation, overpressure or toxic concentration).

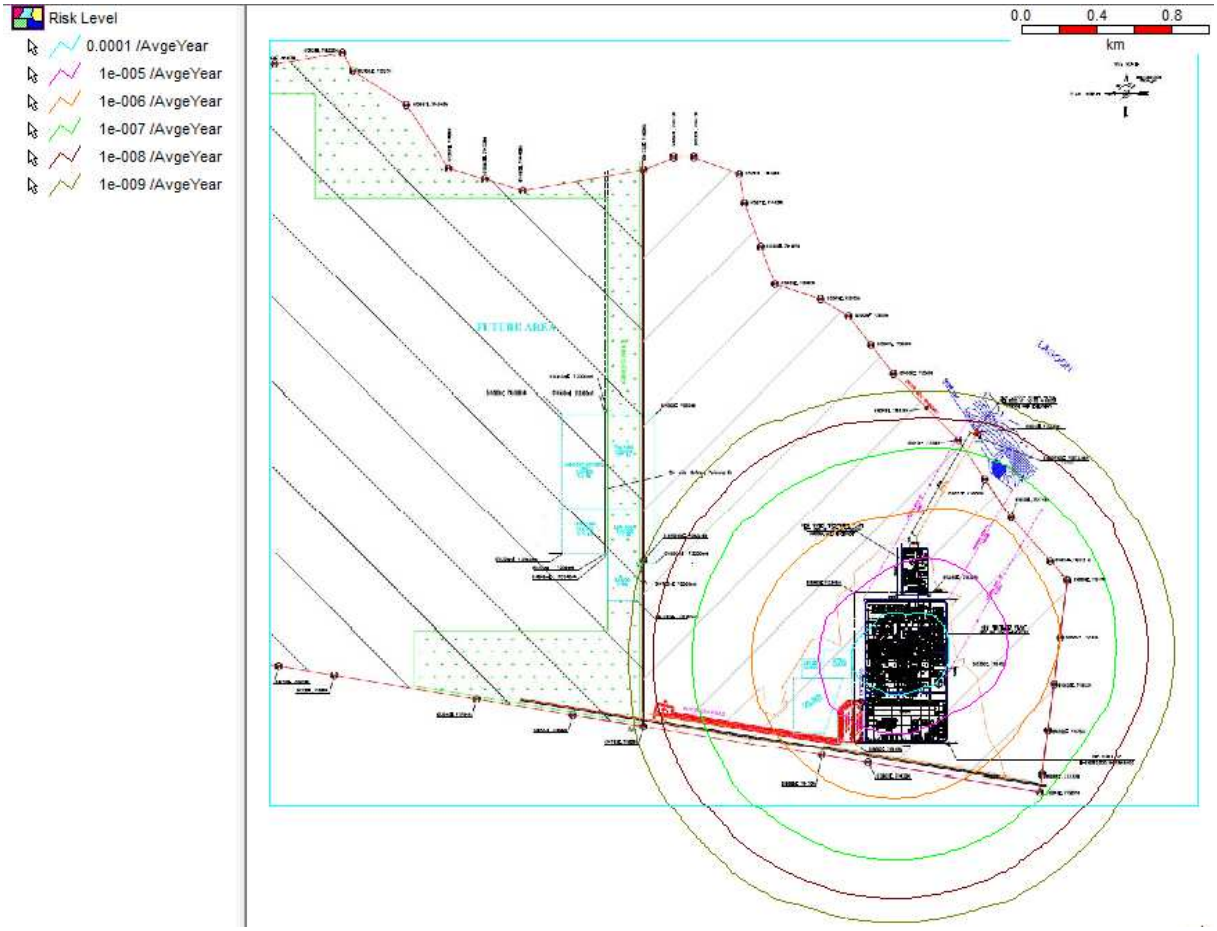
The LSIR at a given location T is calculated as follows:

$$LSIR(T) = \sum_l \lambda_l \sum_s P_{scen_{s,l}} \sum_w P_{wind_{l,s,w}} V(T)_{l,s,w} \quad (1)$$

Where:

λ = release frequency (summation is over all releases); P_{scen} = probability of the scenarios, given the release (summation is over all scenarios for each release); P_{wind} = wind direction probability (summation is over all the wind conditions for each scenario and each release); V(T) = vulnerability at point T.

The LSIR contours are reported, overlaid on the overall plot plan of the installation, in the following figure.



For the evaluated ammonia release scenarios a 10^{-4} LSIR level may be expected on the internal fence. Off-site (off- "entire site boundary") the expected LSIR level is lower than 10^{-6}

9 ACCEPTANCE CRITERIA OF RISK

Acceptance Criteria of Risk for Dangote Fertilizer Project are taken from the following authoritative international guidelines:

- Center for Chemical Process Safety (CCPS), "Guidelines for Developing Quantitative Safety Risk Criteria", American Institute of Chemical Engineers (AIChE), 2009.

Sect. 3.4.2 of the above mentioned guidelines give Acceptance Criteria for the Individual Risk induced by existing or new establishments: these acceptance criteria are given in the below table.

Individual Risk Limit	**Public [fatality/year]**	**Workers [fatality/year]**	**Establishment**
Maximum Tolerable Risk	10^{-4}	10^{-3}	Existing Establishment
	10^{-6}	10^{-3}	New Estrablishment
Negligible Risk	10^{-6}	10^{-6}	All Establishment

10 CONCLUSIONS

Results of this Quantitative Risk Analysis (QRA) Report in terms of Individual Risk contours map relevant to the selected worst case scenarios for Dangote Fertilizer Poject are evaluated in this section based on the “acceptance criteria of risk”.

Individual Risk contours map relevant to Dangote Fertilizer Project shows that Individual Risk to the Public is lower than 10^{-6}.

According to the acceptance criteria of risk, Individual Risk to the Public is lower both than the maximum tolerable risk (10^{-4} in United Kingdom and 10^{-6} in the Netherlands, for new installations) or than the negligible risk (10^{-6} in UK) and, therefore, can be considered ‘acceptable’.

Moreover, Individual Risk contours map relevant to Dangote Fertilizer Project shows LSIR inside the Plant lower than 10^{-3}.

The Individual Risk to worker is lower than the maximum tolerable risk (10^{-3} in United Kingdom) but higher than the negligible risk (10^{-6} in United Kingand) and, therefore, can be considered “Tolerable” taking into account that a generic worker is exposed for not more than 8 hrs/day.

Mitigation measures should be aimed at avoiding degradation through inspection and maintenance and providing the field personnel with relevant personal protective equipment (e.g. escape masks).

APPENDIX 1 – MSDS AMMONIA

MATERIAL SAFETY DATA SHEET

SECTION 1. PRODUCT IDENTIFICATION

PRODUCT NAME: Ammonia
CHEMICAL NAME: Ammonia **FORMULA:** NH_3
SYNONYMS: Ammonia, Anhydrous

SECTION 2. COMPOSITION / INFORMATION ON INGREDIENTS

Ammonia is sold as pure product (>99%).

CAS NUMBER: 7664-41-7
EXPOSURE LIMITS:
OSHA: PEL = 50 ppm **ACGIH:** TLV/TWA = 25 ppm TLV-STEL = 35 ppm **NIOSH:** IDLH = 300 ppm

SECTION 3. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW

Anhydrous Ammonia is an irritating, flammable, and colorless liquefied compressed gas packaged in cylinders under its own vapor pressure of 114 psig at 70 °F. Ammonia can cause severe eye, skin and respiratory tract burns. It poses an immediate fire and explosion hazard when concentrations exceed 15%; therefore, area must be ventilated before entering. Wear self-contained breathing apparatus (SCBA) when entering release area if concentrations exceed allowable exposure limits. Fully protective suits are required in large releases. Always be aware of fire and explosion potential in the case of large releases.

ACUTE POTENTIAL HEALTH EFFECTS:

ROUTES OF EXPOSURE:

EYE CONTACT: Exposure to Ammonia can cause moderate to severe eye irritation.

INGESTION: Ingestion is not a likely route of exposure for Ammonia.

INHALATION: Ammonia is severely irritating to nose, throat, and lungs. Symptoms may include burning sensations, coughing, wheezing, shortness of breath, headache and nausea. Overexposure may also cause central nervous system effects including unconsciousness and convulsions. Upper airway damage is more likely and can result in bronchospasm (closing of the airway). Vocal chords are particularly vulnerable to corrosive effects of high concentrations. Lower airway damage may result in fluid build up and hemorrhage. Death has occurred following a 5 minute exposure to 5000 ppm.

SKIN CONTACT: Vapor contact may cause irritation and burns. Contact with liquid may cause freezing of the tissue accompanied by corrosive caustic action and dehydration.

POTENTIAL HEALTH EFFECTS OF REPEATED EXPOSURE:
ROUTE OF ENTRY: Inhalation, eye or skin contact
SYMPTOMS: Repeated or prolonged skin exposure may cause dermatitis.

TARGET ORGANS: Eyes, skin, central nervous and respiratory systems.
MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE: Conditions generally aggravated by exposure include asthma, chronic respiratory disease (e.g., emphysema), dermatitis and eye disease.
CARCINOGENICITY: Ammonia is not listed as a carcinogen or potential carcinogen by NTP, IARC, or OSHA.

SECTION 4. FIRST AID MEASURES

EYE CONTACT: Flush eyes with large quantities of water. Seek medical attention immediately.
INGESTION: Ingestion is not a likely route of exposure for Ammonia.
INHALATION: Remove person to fresh air. If not breathing, administer artificial respiration. If breathing is difficult, administer oxygen. Obtain prompt medical attention.
SKIN CONTACT: Flush affected area with large quantities of water. Remove contaminated clothing immediately. If liquid comes in contact with skin, remove contaminated clothing and flush with plenty of lukewarm water for several minutes. Seek medical attention immediately.
NOTE TO PHYSICIAN: Bronchospasm may be treated with the use of a bronchodialator such as albuterol and an anticholinergic inhalant such as Atrovent.

SECTION 5. FIRE FIGHTING MEASURES

FLASH POINT:	AUTOIGNITION:	FLAMMABLE RANGE:
Not applicable	1204 °F (651 °C)	16% - 25%

EXTINGUISHING MEDIA: Dry chemical, carbon dioxide or water.
SPECIAL FIRE FIGHTING INSTRUCTIONS: Evacuate all personnel from area. If possible without risk, stop the flow of Ammonia, then fight fire according to types of materials that are burning. Extinguish fire only if gas flow can be stopped. This will avoid possible accumulation and re-ignition of a flammable gas mixture. If possible, move adjacent cylinders away from fire area. Keep adjacent cylinders cool by spraying with large amounts of water until the fire burns itself out. Self-contained breathing apparatus (SCBA) may be required.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Most cylinders are designed to vent contents when exposed to elevated temperatures. Pressure in a cylinder can build up due to heat and it may rupture if pressure relief devices should fail to function. Runoff from firefighting may be contaminated; check pH. Ammonia can form explosive compounds when combined with mercury.
HAZARDOUS COMBUSTION PRODUCTS: Oxides of nitrogen

SECTION 6. ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Evacuate immediate area. Eliminate any possible sources of ignition, and provide maximum explosion-proof ventilation. Shut off source of leak if possible. Isolate any leaking cylinder. If leak is from container, pressure relief device or its valve, contact your supplier. If the leak is in the user's system, close the cylinder valve, safely vent the pressure, and purge with an inert gas before attempting repairs. Ammonia vapors can be controlled with water spray, however; runoff may be contaminated. Releases that exceed 100 lbs (45.4 kgs) during a 24-hour period must be reported. (See Section 15).

All responders must be adequately protected from exposure. Levels of Ammonia should be below levels listed in Section 2 (Composition / Information on Ingredients) and the atmosphere must have at least 19.5% oxygen before personnel can be allowed in the area without self-contained breathing apparatus (SCBA).

SECTION 7. HANDLING AND STORAGE

STORAGE: Store cylinders in a well-ventilated, secure area, protected from the weather. Cylinders should be stored upright with valve outlet seals and valve protection caps in place. There should be no sources of ignition. All electrical equipment should be explosion-proof in the storage areas. Storage areas must meet National Electrical Codes for class 1 hazardous areas. Flammable storage areas should be separated from oxygen and other oxidizers by a minimum distance of 20 ft. or by a barrier of non-combustible material at least 5 ft. high having a fire resistance rating of at least ½ hour. Ammonia cylinders should not be stored near acids or acid-forming gases. Post "No Smoking or Open Flames" signs in the storage or use areas. Do not allow storage temperature to exceed 125 °F (52 °C). Storage should be away from heavily traveled areas and emergency exits. Full and empty cylinders should be segregated. Use a first-in first-out inventory system to prevent full containers from being stored for long periods of time.

Caution: Ammonia cylinders are subject to theft and misuse. Cylinders should be stored and used in controlled areas.

HANDLING: Do not drag, roll, slide or drop cylinder. Use a suitable hand truck designed for cylinder movement. Never attempt to lift a cylinder by its cap. Secure cylinders at all times while in use. Use a pressure reducing regulator or separate control valve to safely discharge gas from cylinder. Use a check valve to prevent reverse flow into cylinder. Never apply flame or localized heat directly to any part of the cylinder. Do not allow any part of the cylinder to exceed 125 °F (52 °C). Once cylinder has been connected to properly purged and inerted process, open cylinder valve slowly and carefully. If user experiences any difficulty operating cylinder valve, discontinue use and contact supplier. Never insert an object (e.g., wrench, screwdriver, etc.) into valve cap openings. Doing so may damage valve causing a leak to occur. Use an adjustable strap-wrench to remove over-tight or rusted caps. All piped systems and associated equipment must be grounded. Electrical equipment should be non-sparking or explosion-proof.

Only a recommended CGA connection should be used. Adapters should not be used. Use piping and equipment adequately designed to withstand pressures to be encountered. If liquid product is being used, ensure steps have been taken to prevent entrapment of liquid in closed systems. The use of pressure relief devices may be necessary. Dedicated inert gas cylinders with in line back-flow protection should be used for purging.

SPECIAL REQUIREMENTS: Always store and handle compressed gases in accordance with Compressed Gas Association, Inc. (ph.703-979-0900) pamphlet CGA P-1, *Safe Handling of Compressed Gases in Containers*. Local regulations may require specific equipment for storage or use.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS:

VENTILATION: Provide adequate natural or mechanical ventilation to maintain Ammonia concentrations below exposure limits.

RESPIRATORY PROTECTION:

Emergency Use: Self-contained breathing apparatus (SCBA) or positive pressure airline with full face mask with escape pack should be worn in areas of a large release or unknown concentration.

EYE PROTECTION: Safety glasses for handling cylinders. Chemical goggles with full faceshield for connecting, disconnecting or opening cylinders.

SKIN PROTECTION: Leather gloves for handling cylinders. Rubber or Neoprene gloves, and chemical resistant outergarment should be worn when connecting or disconnecting cylinders. Total encapsulating chemical suit may be necessary in large release area. Fire resistant suit and gloves in emergency situations.

OTHER PROTECTIVE EQUIPMENT: Safety shoes are recommended when handling cylinders. Safety shower and eyewash fountain should be readily available.

CAUTION: Contact with cold, evaporating liquid on gloves or clothing may cause cryogenic burns or frostbite. Cold temperatures may also cause embrittlement of PPE material resulting in breakage and exposure.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE, ODOR AND STATE: Colorless gas with a sharp, strong odor similar to "smelling salts" which is readily detectable at 20 ppm
MOLECULAR WEIGHT: 17.0
BOILING POINT (1 atm): -28.1 °F (-33.4 °C)
SPECIFIC GRAVITY (air=1): 0.59
FREEZING POINT / MELTING POINT: -107.9 °F (-77.7 °C)
VAPOR PRESSURE (At 70 °F (21.1 °C)): 114.4 psig
GAS DENSITY (At 70 °F (21.1 °C) and 1 atm): 0.045 lb/ft^3
SOLUBILITY IN WATER (vol./vol. at 68 °F): 0.848

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY: Stable
CONDITIONS TO AVOID: High temperatures (greater than 800 °F (426 °C)). Cylinders should not be exposed to temperatures in excess of 125 °F (52 °C).
INCOMPATIBILITY (Materials to Avoid): Copper, silver, cadmium and zinc and their alloys; mercury, tin, acids, alcohols, aldehydes, halogens and oxidizers.
REACTIVITY:

A) **HAZARDOUS DECOMPOSITION PRODUCTS:** Hydrogen at high temperatures.
B) **HAZARDOUS POLYMERIZATION:** Will not occur

SECTION 11. TOXICOLOGICAL INFORMATION

LC_{50} (Inhalation): 7338 - 11590 ppm (rat, 1 hour); 2000 ppm (rat, 4 hours)
LD_{50} (Oral): Not applicable
LD_{50} (Dermal): Not applicable
SKIN CORROSIVITY: Ammonia is corrosive to the skin.
ADDITIONAL NOTES: Rats exposed continuously to 180 ppm Ammonia for 90 days did not show any abnormalities of organs or tissues. Mild nasal irritation was observed in 12 out of 49 rats exposed to 380 ppm Ammonia. At 655 ppm Ammonia, 32 out of 51 rats died by day 25 of exposure and 50 out of 51 rats had died after 65 days of exposure.

SECTION 12. ECOLOGICAL INFORMATION

AQUATIC TOXICITY: Currently, the following aquatic toxicity data are available for Ammonia:

Daphnia magna (48 hour) LC_{50} = 189 mg/l

Rainbow trout (24 hour) LC_{50} = 0.97 mg/l

Fathead minnow (96 hour) LC_{50} = 8.2 mg/l

MOBILITY: Not available
PERSISTENCE AND BIODEGRADABILITY: Not available
POTENTIAL TO BIOACCUMULATE: Not available
REMARKS: Do not release large amounts of Ammonia to the atmosphere. It does not contain any Class I or Class II ozone depleting chemicals.

SECTION 13. DISPOSAL CONSIDERATIONS

UNUSED PRODUCT / EMPTY CYLINDER: Return cylinder and unused product to supplier. Do not attempt to dispose of unused product.

DISPOSAL: Small amounts of Ammonia may be disposed of by discharge into water. A ratio of ten parts water to one part Ammonia should be sufficient for disposal. The subsequent solution of ammonium hydroxide can be neutralized and should be properly disposed of in accordance with regulations.

SECTION 14. TRANSPORT INFORMATION

DOT SHIPPING NAME: Ammonia, Anhydrous
HAZARD CLASS: 2.2
IDENTIFICATION NUMBER: UN1005
ADDITIONAL DESCRIPTION: Inhalation Hazard
SHIPPING LABEL(s): Nonflammable gas
PLACARD (When required): Nonflammable gas

ADDITIONAL MARKING: Ammonia is also a hazardous substance regulated by the EPA. When shipping quantities of 100 lbs. or more in one cylinder, add the prefix "RQ" to the DOT shipping name on the documentation and clearly mark "RQ" on the cylinder near the label.

SPECIAL SHIPPING INFORMATION: Cylinders should be transported in a secure upright position in a well-ventilated truck. Never transport in passenger compartment of a vehicle. Ensure cylinder valve is properly closed, valve outlet cap has been reinstalled, and valve protection cap is secured before shipping cylinder.

CAUTION: Compressed gas cylinders shall not be refilled except by qualified producers of compressed gases. Shipment of a compressed gas cylinder which has not been filled by the owner or with the owner's written consent is a violation of Federal law (49 CFR 173.301).

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SECTION 15. REGULATORY INFORMATION

U.S. FEDERAL REGULATIONS:

EPA - ENVIRONMENTAL PROTECTION AGENCY

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (40 CFR Parts 117 and 302)

Reportable Quantity (RQ): 100 lbs (45.4 kgs)

SARA TITLE III: Superfund Amendment and Reauthorization Act

SECTIONS 302/304: Emergency Planning and Notification (40 CFR Part 355)

Extremely Hazardous Substances: Ammonia is listed.
Threshold Planning Quantity (TPQ): 500 lbs (227 kgs)
Reportable Quantity (RQ): 100 lbs (45.4 kgs)

SECTIONS 311/312: Hazardous Chemical Reporting (40 CFR Part 370)

IMMEDIATE HEALTH:	Yes	PRESSURE:	Yes
DELAYED HEALTH:	No	REACTIVITY:	No
		FIRE:	No

SECTION 313: Toxic Chemical Release Reporting (40 CFR Part 372)

Ammonia is on the list of chemicals which may require reporting under Section 313.

CLEAN AIR ACT:

SECTION 112 (r): Risk Management Programs for Chemical Accidental Release (40 CFR PART 68)

Ammonia is listed as a regulated substance.
Threshold Quantity (TQ): 10,000 lbs (4535 kgs)

TSCA: Toxic Substance Control Act
Ammonia is listed on the TSCA inventory.

OSHA - OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION:
29 CFR Part 1910.119: Process Safety Management of Highly Hazardous Chemicals
Ammonia is listed as a highly hazardous chemical.
Threshold Quantity (TQ): 10,000 lbs (4535 kgs)

STATE REGULATIONS:
CALIFORNIA:
Accidental Release Prevention Program: Threshold Quantity (TQ): 100 lbs (45.4 kgs)
Proposition 65: This product is not a listed substance which the State of California requires warning under this statute.

NEW JERSEY:
Toxic Catastrophe Prevention Act: Registration Quantity (RQ): 5200 lbs (2358 kgs)

SECTION 16. OTHER INFORMATION

NFPA RATINGS:		HMIS RATINGS:	
HEALTH:	= 3	HEALTH:	= 3
FLAMMABILITY:	= 1*	FLAMMABILITY:	= 1
REACTIVITY:	= 0	REACTIVITY:	= 0
SPECIAL:			

* NFPA rates this gas a 1 as opposed to a 4 because it is "difficult to burn".