CHLORINE CLOUD HEIGHT PREDICTIONS

This annex presents information on the height of a chlorine cloud which has been obtained from the wind tunnel testing, CFD modelling and DRIFT flat terrain dispersion modelling. This is important for determining the impact on populations within high rise buildings.

Wind tunnel testing has been used in this study to investigate a range of release scenarios, wind directions and wind speeds in near-neutral atmospheric conditions. CFD has been used to determine the influence of atmospheric stability on the dispersion of chlorine and provide a broad comparison against the wind tunnel results for neutral stability. Wind tunnel simulations were undertaken for all eight sites, whereas CFD modelling was undertaken for two sites representing the extremes of topography (Sha Tin WTW and Tai Po Tau WTW). Both the wind tunnel testing and CFD modelling have included off-site high rise buildings as well as on-site buildings, as these have a significant influence on the dispersion of the chlorine.

The role of the flat terrain dispersion modelling has been to provide the 'source term' for both the wind tunnel and CFD studies. The model used in this study was DRIFT (Webber et al, 1992). As DRIFT runs in a matter of minutes, it has also been possible to use the code to simulate the full range of chlorine release rates and weather conditions.

Table E1 below summarises the data obtained from the wind tunnel testing, CFD and DRIFT modelling on the chlorine cloud height.

Table E1 *Chlorine Cloud Height Predictions*

Release case	Chlorine cloud height (m) at LD03 distance[1]					
	Wind tunnel[2]		CFD[3]		DRIFT	
1.4 kg/s continuous	30[4]	(D2)	60/60	(D2)	7	(D2)
	-	(D5)	-	(D5)	5.5	(D5)
	-	(F2)	20/30	(F2)	-	(F2)
1 tonne instantaneous	4[5]	(D2)	20/30	(D2)	6.5	(D2)
	4[6]	(D5)	-	(D5)	8.5	(D5)
	-	(F2)	10/20	(F2)	4	(F2)
3 tonnes instantaneous	-		-		10[7]	(D2)
					12.5[8]	(D5)
					-	(F2)
10 tonnes instantaneous	-		-		12[9]	(D2)
					20[10]	(D5)
					-	(F2)

(1) The data given relates to the chlorine cloud height at the maximum horizontal distance to the LD03 (Lethal Dose - 3% fatality) concentration. 'Height' refers to the height at which the chlorine concentration falls to negligible levels, ie <5% of the ground level concentration (unless otherwise stated).

(2) Results are for Sha Tin WTW, measured at nearest block of Hin Keng Estate

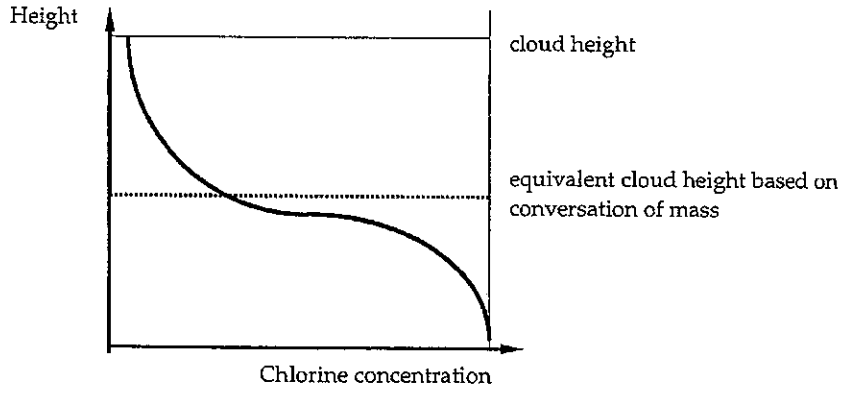
(3) Results are for Sha Tin WTW/Tai Po Tau WTW

(4) Estimate by RWDI for cloud height at LD03 distance based on conservation of mass
(5) Height at which concentration drops to 1/2 of ground level concentration
(6) Height at which concentration drops to 1/6th of ground level concentration
(7) Cloud height is 10 metres at LD03 distance and 6 metres at LD50 distance (D2)
(8) Cloud height is 12.5 metres at LD03 distance and 8 metres at LD50 distance (D5)
(9) Cloud height is 12 metres at LD03 distance and 9 metres at LD50 distance (D2)
(10) Cloud height is 20 metres at LD03 distance and 11 metres at LD50 distance (D5)

Continuous Releases

As detailed in *Section* 4.2.2 of the main report, the CFD modelling has been used to set the downwind extent of the chlorine hazard range for the 1.4 kg/s continuous release case. Therefore the corresponding value of the chlorine cloud height from the CFD modelling has also been used in the QRA. From *Table E1* it can be seen that the predicted cloud height is 60m, which is the height at which the chlorine concentration drops to negligible levels. However for the purposes of the QRA, the parameter required is the equivalent height of the chlorine cloud based on conservation of mass (to ensure a realistic assessment of fatalities in high rise buildings). The relationship between these two values is illustrated in *Figure E1* below. The equivalent chlorine cloud height is estimated conservatively as 30m, assuming that the chlorine concentration is inversely proportional to cloud height . (In reality the chlorine concentration drops off more rapidly with height and therefore the equivalent cloud height would be less than 30m).

Figure E1 Estimation of Equivalent Chlorine Cloud Height



Instantaneous Releases

For instantaneous releases the wind tunnel LD contours are used in the QRA. However only a limited number of measurements of chlorine cloud height are available from the wind tunnel simulations, indicating a cloud height of around 4m for a 1 tonne instantaneous release (*Table E1*). Consideration has therefore also been given to the cloud height predictions from the DRIFT simulations. These indicate a cloud height of 4 - 8.5m for a 1 tonne instantaneous release. Based on this data, a cloud height of 6m will be assumed for a 1 tonne instantaneous release.

For a 10 tonne instantaneous release a cloud height of 9m will be assumed based on the cloud height predicted by DRIFT at the LD50 distance for D2 weather conditions - see Note (9) to *Table E1*. This is considered to be more representative of the average height of the cloud over the range of chlorine concentrations of interest (LD03 - LD90) than taking the cloud height at LD03.

For instantaneous chlorine releases between 3 and 10 tonnes (or in excess of 10 tonnes), linear interpolation (or extrapolation) of the chlorine cloud height has been performed, but rounding the value thus obtained up to the nearest number of equivalent building storeys. The calculations assume 3m per storey.

Horizontal & Vertical Scaling Factors

For scenarios that were not modelled explicitly in the consequence assessment, scaling factors were used to relate the height, width and length of clouds, to the released mass.

The scaling factors for the horizontal and vertical direction were taken from the DRIFT modelling from which it was found that they varied approximately to the 1/2 power with release quantity. The same relationship could not be used in the vertical dimension because of the smaller extent of mixing in the z direction. Therefore as an approximation it was assumed that a 1/3 power law applies.

For example, a uniform cloud height of 9m for an 8 tonne release is estimated by interpolation from the results on *Table E1*. Thus, it is assumed that 3 floors could be affected by the cloud (each floor is of about 3m height).

Although conservation of mass is achieved within the DRIFT modelling (even though DRIFT adopts different scaling factors for horizontal and vertical components of cloud dispersion), the estimation of cloud height is conservative; so conservation of mass is not strictly achieved with the above approach.