This *Annex* describes the methodology to derive a indoor fatality probability factor based on the results from DRIFT runs and the cumulative dosage model.

K1 METHODOLOGY

Based on the results from DRIFT runs (see *Annex A*) , the time from release (T), downwind distance (X_g) and downwind radius (R_1) can be determined when the centre of the cloud is diluted to the desired concentration (C). The corresponding cloud passage time (t_p) is given by:

$$t_p = 2\,R_1 / (X_g/T) \qquad \textit{Equation K1}$$

where:

t_p = cloud passage time (s)
R_1 = downwind distance (m)
X_g = downwind radius (m)
T = time from release (s)

The cumulative dosage (D) experienced by a person staying indoors is detailed in ERM (1997), and re-stated in *Equation K2*.

$$D = \int_0^{t_p} [C_0(1-\exp(-\lambda t))]^n dt + \int_0^{t_e} [C_0(1-\exp(-\lambda t_p))\cdot \exp(-\lambda t)]^n dt \qquad \textit{Equation K2}$$

where

D = cumulative dosage ($(mg/m^3)^n$ min)
C_0 = outdoor concentration (mg/m^3)
λ = building air exchange rate (per min)
t_e = escape time (taken as 15 min *after* the cloud has passed)
n = the power in the probit equation (n=2.3 for TNO probit)

The TNO probit based on the above dosage is given in *Equation K3*.

$$Y = -14.3 + \ln(D) \qquad \textit{Equation K3}$$

and the corresponding indoor fatality probability can be checked from standard table on transformation of probits to percentages. A more precise method, however, is to use *Equation K4*.

$$P = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Y-5} \exp\left(-\frac{u^2}{2}\right) du \qquad \textit{Equation K4}$$

The results of *Equation K4* are to be compared with the outdoor fatality probability governed by the outdoor probit described by *Equation K5*.

$Y' = -14.3 + \ln(C_0^n \, t_p)$ *Equation K5*

K2 SAMPLE CALCULATION

For the marker concentration of LD90, the parameters determined from the DRIFT runs for 10 tonnes instantaneous release at D2 weather conditions are obtained as follows. It is noted that interpolation of parameters is needed when the exact figure is not available.

Using *Equation K1*, and inserting the following data;

$T = 650.2$ s;
$X_g = 786.4$ m; and
$R_1 = 497.8$ m,

$t_p = 2 \times 497.8 \times 650.2 / 786.4$

$= 823.2$ s, or **14 min**

Equation K2 may now be utilised in order to obtain the cumulative dosage, ie

λ = air exchange rate = 0.017 air changes /min (1ach)
C_0 = 2828 mg/m^3 (975 ppm)
t_p = 14 minutes

$$D = \int_0^{t_p} [C_0(1-\exp(-\lambda t))]^{2.3} dt + \int_0^{t_c} [C_0(1-\exp(-\lambda t))\exp(-\lambda t)]^{2.3} dt = 3.76E+7$$

Therefore, the probit may now be calculated using *Equation K3*:

$Y = -14.3 + \ln(3.76E+7)$

$Y = 3.143$

and then, the probability of fatality for indoor population using *Equation K4*.

$$P = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Y-5} \exp\left(-\frac{u^2}{2}\right) du = 0.032$$

The indoor fatality probability is thus calculated to be 3.2%

The corresponding outdoor fatality probability may now be calculated by application of *Equation K5* in order to compare the two and derive a ratio of the indoor to outdoor values.

$Y' = -14.3 + \ln(2828^{2.3} \times 14) = 6.618$; and

$$P = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Y'-5} \exp\left(-\frac{u^2}{2}\right) du = 0.947$$

The outdoor fatality probability is thus calculated to be 94.7%
The indoor fatality probability is 0.032/0.947 or 3.3% of that of outdoor.

The ratios of indoor fatality probability to that of outdoor and the associated calculations are tabulated in *Table K1* based on different LD concentrations, weather conditions, release quantities and air exchange rates.

Table K1 *Comparison of Indoor to Outdoor Fatality Probability*

LD Level	Conc of Chlorine (ppm)	Weather Condition	Release Quantity (te)	Cloud Passage Time (min)	Exchange Rate (/min)	Time of Escape after Cloud Passage (min)	Max Conc Attained (ppm)	Total Dose $(mg/m^3)^{[illegible]}$min	Indoor Fatality Probability	Outdoor Fatality Probability	Fatality Probability Ratio Indoor/Outdoor
Building Air Exchange Rate: 1 ach											
LD03	247	D2	1	7.9	0.017	15	32.6	4.20E+05	0.000	0.017	0.00%
LD50	560	D2	1	7.4	0.017	15	65.2	2.36E+06	0.000	0.335	0.00%
LD90	975	D2	1	7.1	0.017	15	108.6	7.58E+06	0.000	0.825	0.03%
LD03	247	D2	3	11.5	0.017	15	42.9	9.92E+05	0.000	0.041	0.00%
LD50	560	D2	3	10.5	0.017	15	90.0	5.34E+06	0.000	0.522	0.01%
LD90	975	D2	3	9.9	0.017	15	147.9	1.65E+07	0.004	0.898	0.41%
LD03	247	D2	8	15.8	0.017	15	67.2	2.11E+06	0.000	0.078	0.00%
LD50	560	D2	8	14.2	0.017	15	118.3	1.09E+07	0.001	0.640	0.15%
LD90	975	D2	8	13.2	0.017	15	191.9	3.23E+07	0.022	0.940	2.35%
LD03	247	D2	10	17.0	0.017	15	60.9	2.50E+06	0.000	0.089	0.00%
LD50	560	D2	10	15.2	0.017	15	125.7	1.27E+07	0.002	0.665	0.25%
LD90	975	D2	10	14.0	0.017	15	203.4	3.76E+07	0.032	0.947	3.34%
Building Air Exchange Rate: 3 ach											
LD03	247	D5	1	2.3	0.050	15	26.4	1.89E+05	0.000	0.000	0.00%
LD50	560	D5	1	1.9	0.050	15	51.7	7.82E+05	0.000	0.051	0.00%
LD90	975	D5	1	1.8	0.050	15	82.4	2.27E+06	0.000	0.325	0.03%
LD03	247	D5	3	3.1	0.050	15	35.5	3.46E+05	0.000	0.001	0.00%
LD50	560	D5	3	2.7	0.050	15	59.7	1.60E+06	0.000	0.093	0.00%
LD90	975	D5	3	2.4	0.050	15	111.4	4.05E+06	0.000	0.446	0.01%
LD03	247	D5	8	4.1	0.050	15	45.2	5.60E+05	0.000	0.003	0.00%
LD50	560	D5	8	3.6	0.050	15	81.2	3.09E+06	0.000	0.152	0.00%
LD90	975	D5	8	3.3	0.050	15	146.8	9.10E+06	0.001	0.564	0.09%
LD03	247	D5	10	4.4	0.050	15	49.0	7.64E+05	0.000	0.004	0.00%
LD50	560	D5	10	3.8	0.050	15	96.9	3.55E+06	0.000	0.168	0.01%
LD90	975	D5	10	3.5	0.050	15	156.2	1.05E+07	0.001	0.590	0.15%
Building Air Exchange Rate: 5 ach											
LD03	247	D5	1	2.3	0.083	15	42.4	3.62E+05	0.000	0.000	0.00%
LD50	560	D5	1	1.9	0.083	15	63.5	1.68E+06	0.000	0.051	0.00%
LD90	975	D5	1	1.8	0.083	15	133.5	4.50E+06	0.000	0.325	0.02%
LD03	247	D5	3	3.1	0.083	15	56.3	7.23E+05	0.000	0.001	0.00%
LD50	560	D5	3	2.7	0.083	15	111.2	3.39E+06	0.000	0.093	0.01%
LD90	975	D5	3	2.4	0.083	15	178.5	9.94E+06	0.001	0.446	0.16%
LD03	247	D5	8	4.1	0.083	15	72.1	1.36E+06	0.000	0.003	0.00%
LD50	560	D5	8	3.6	0.083	15	143.6	6.44E+06	0.000	0.152	0.10%
LD90	975	D5	8	3.3	0.083	15	232.1	1.91E+07	0.005	0.564	1.00%
LD03	247	D5	10	4.4	0.083	15	70.1	1.57E+06	0.000	0.004	0.01%
LD50	560	D5	10	3.8	0.083	15	152.0	7.44E+06	0.000	0.168	0.15%
LD90	975	D5	10	3.5	0.083	15	246.1	2.22E+07	0.009	0.590	1.44%

K3 *CONCLUSION*

The indoor fatality probability determined from *Table K1* can be up to 3.3% of the outdoor fatality probability. The previous assumption of 10% indoor fatality (ie 10% of the outdoor fatality probability) is judged to be conservative based on the above calculations.

It is proposed to adopt the indoor fatality probability to 5% in the study methodology. Further reduction below 5% could not be justified without significant additional work. This is due to factors such as air exchange rates for buildings which may be very variable, with open windows and air-conditioning being significant factors.

As a cautionary, the HSE in the UK have recently increased the equivalent factor from 10% to 30% for indoor ***injuries***. However, the UK approach is based on a more conservative toxic criteria of "dangerous dose" and not lethality.