Risk Assessment of Radionuclides Releases during Extreme Low-Wind Atmospheric Conditions

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Reasons for development of specific local (national) codes:

- **To access the areas insufficiently covered by general complex codes:**
  - ***analysis of specific features of AD***
  - ***Implementation of the latest experience (e.g. based on Chernobyl data - long term activity deposition and resusp.,…)***
- **Adaptation on specific local features and governmental regulations in the field of radioactive releases risk assessment**
- **Special „worst case" activity release scenarios analysis**

The issues in atm. dispersion modeling remaining so far essentially unresolved:

- **Treatment of the missing data periods**
- **Dispersion of admixtures during extreme weather conditions:**
  - ***Intensive local precipitation***
  - ***Dispersion under low wind or calm situations***
  - ***Cumulation of conditions in the most adverse way with regard to risk ass.***
- **Trends in long-term changes of climate, potential synergistic effects among admixtures forms**

Dispersion of radionuclides during calm atmospheric conditions:

- **So far no strict definition exists**
- **Basic characteristics (common opinion of experts) of calms:**
  - ***Wind speed drops below a certain limit*** *(1 or even 0.5 m/s)*
  - ***Wind direction become undefined***
  - ***Puff can diffuse at the point of release without being advected***
- **Can lead to extremaly hazardous peak ground level activity concentrations** *(especially during stable atm. stratification)*

TWO SIMPLE NUMERICAL APPROACHES FOR CALM CONDITIONS ANALYSIS ARE PRESENTED HERE:

Superposition of 3-D Gaussian puffs

Ground level activity concentration of nuclide n in puff (born in time m, puff total activity Q^n_m [Bq], reached time interval i) :

$$C^n_{mi}(x,y,z=0\,;t_{mi}) = \frac{Q^n_m}{(2\pi)^{3/2}\cdot\sigma_x(t_{mi})\cdot\sigma_y(t_{mi})\cdot\sigma_z(t_{mi})}\cdot\exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2(t_{mi})}+\frac{y^2}{\sigma_y^2(t_{mi})}\right)\right]$$

$$\left\{\exp\left(-\frac{(z-h_{ef,m})^2}{2\cdot\sigma_z^2(t_{mi})}\right)+\Re^m_{refl}\right\}\cdot f_R^{\,n}(t_{mi})\cdot f_F^{\,n}(t_{mi})\cdot f_W^{\,n}(t_{mi})$$

Continuous release → equivalent discrete chain of M puffs duration of puff m (m=1,…,M) = Δt_m

Main driving output variables for radiological risk are:

TIC – Time Integrated activity Concentrations (Bq.s/m³)

DEPO – activity deposition on the ground (Bq/m²)

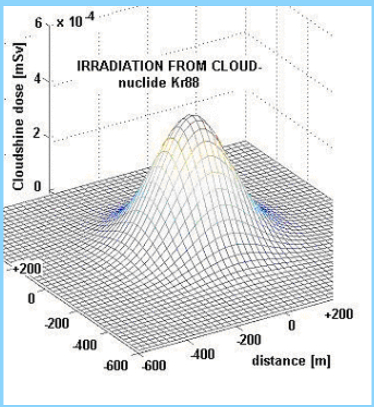
Total contribution to TIC for puff born at m during its propagation to i →

$$TIC^n_{mi} = \sum_{k=m}^{k=i}\left(C^n_{mk}\cdot\Delta t_k\right)$$

Vertical and horizontal dispersion coefficients: **time-dependant empirical formulas based on field measurements at low-wind conditions (*Okamoto, S., H.Onishi, Yamada T., et al.*, 1999) :**

$\sigma_x = \sigma_y = \alpha\,.\,t$; $\sigma_z = \gamma\,.\,t$; $u_s = 0$

α = 0.30 ~ 0.40 m/s a γ = 0.09 ~ 0.18 m/s



Multiple puff simulations: cloudshine dose (adults) in miliSieverts [mSv] from radionuclide Kr88

λ^{Kr88}=6.88·10^{-05} s^{-1}, conversion factor for semi-infinite cloud= 1.02·10^{-13}[Sv.s^{-1}.Bq^{-1}.m^3], stable atm. stratification, constant conditions in all time subintervals, release height =45m release duration : 2 hours calm duration : 2 hours total activity of Kr88 released during 2 hours : 8.80 · 10^{11} Bq

Segmented Gaussian plume model modified to low-wind speed conditions

$$C^n(x,y,z) = \frac{S^n}{2\pi\cdot\sigma_y(x)\cdot\sigma_z(x)\cdot U}\cdot\exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2(x)}\right)\times\left\{\exp\left(-\frac{(z-h_{ef})^2}{2\cdot\sigma_z^2(x)}\right)+\Re^{GAUSS}_{refl}(x)\right\}\cdot f_R^{\,n}(x)\cdot f_F^{\,n}(x)\cdot f_W^{\,n}(x)$$

$\Re_{refl}$ …. *contribution of puff reflection from ground plane and from top of the boundary layer*

f_R , f_F , f_W …. *depletion factors of radionuclide concentration in the puff due to radioactive decay, dry activity deposition and washout of activity induced by possible atmospheric precipitation*

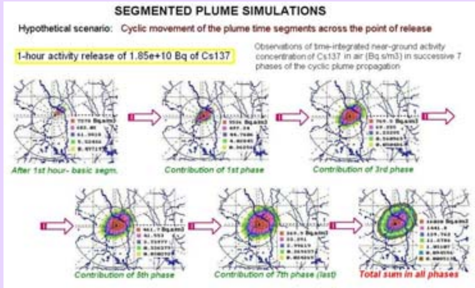
AVOIDANCE OF POSSIBLE PITFALLS OF UNQUALIFIED PLUME MODEL APPLICATIONS:

-Selection of a certain low limit for wind speed U_{lim} (singularity when wind speed U → 0)

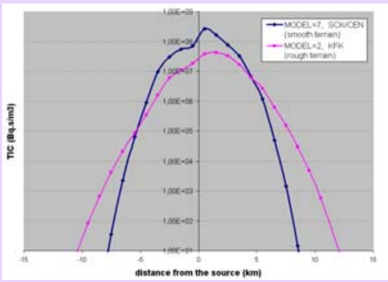
-Stable atmospheric conditions are assumed

- Modification of plume rise and dispersion according to expert recommendations for the calm situations

- Cyclic periodical movement of the plume time segments across the source of pollution, each segment can account for stepwise changes of meteorological and release dynamics characteristics



Dependence of near ground time integrated activity concentration (TIC) of Xe-133 on the model of dispersion category F, release height 45 m

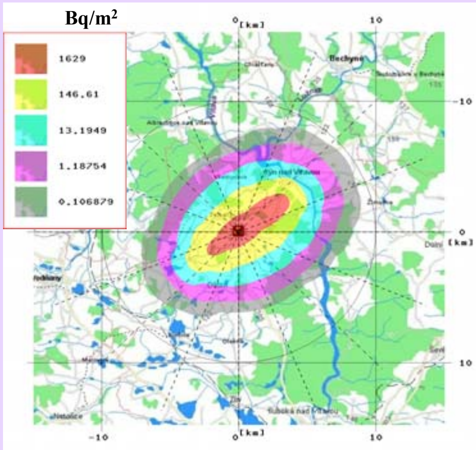


SENSITIVITY OF THE PLUME SPREAD ON DISPERSION MODEL USED:

SCK/CEN … power-low expressions for dispersion parameters for smooth terrain (MOL - Belgium)

KFK … power-low expressions for dispersion parameters for rough terrain (Karlsruhe- Jülich, Germany)

DETAILED TOPOGRAPHICAL BACKGROUND FOR NUCLEAR EMERGENCY DECISION SUPPORT



I131 ACTIVITY DEPOSITION ON THE TERRAIN

Scenario : 1– hour I131 activity release in direction North-East, total release of 1.28·10^{11} Bq; successive cyclic movement of the plume across the source in consecutive 7 phases (each 1-hour duration); U=1m/s, stability category F

Results:

For radiological risk assessment due to radioactive releses into the atmosphere during low-wind / calm conditions are presented two methods. The approximation of continuous release by discrete 3-D puffs gives obviously conservative Results. Modified Gaussian segmented plume method afford flexible tool for estimation of various postulated scenarios.

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