ASSESSMENT OF AIRBORNE RADIOACTIVE ROUTINE RELEASES IN THE NETHERLANDS

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INTRODUCTION

Airborne radioactive routine releases in the Netherlands are under regulatory control (licensed) or are exempted from a license. E.g., releases from installations of the nuclear fuel cycle like nuclear power plants and enrichment facilities are under regulatory control. The last ten years however, also routine releases from other, i.e. non-nuclear, installations have often been subject to regulatory control, for example the releases of Natural Occurring Radioactive Materials (NORM) from some ore-processing industries.

As part of this regulatory control an assessment of the airborne routine releases is required. The release characteristics of routine releases from nuclear fuel cycle installations in The Netherlands are relatively simple: the release can be described by a more or less continuous flow of contaminated air from a ventilation stack or duct. The temperature of the released air is in general low (room temperature). Non-nuclear fuel installations have often complex release characteristics such as surface sources and hot releases from high stacks. These release characteristics require an improved modelling of the dispersion. In addition to modelling of the dispersion also dose calculations for NORM activity are more complex due to the long decay chains of nuclides to account for.

NRG uses the computer program NUDOS (NUclide DOSes) for dose assessments of airborne radioactive routine releases. NUDOS can be used for both accidental and routine airborne releases of radioactive materials. The program has been parameterised in accordance with the regulatory requirements before the ratification of the Euratom Directive 96/29 ‘Basic Safety Standards’ in The Netherlands. This ratification has affected the Dutch regulatory requirements for the assessment of the radioactive routine releases. NRG has investigated the impact of the Euratom Directive 96/29 ratification on the modelling of routine radioactive releases as well as the effort needed for a radiological assessment of these releases.

DESCRIPTION OF NUDOS

The computer program NUDOS (Poley, 1996; Grupa, 1996) calculates the annual average concentrations of activity in air, the average deposition of activity and the annual doses due to exposure to contaminated air and external radiation from the contaminated soil. For routine releases accumulation of activity in the soil due to releases in previous years is taken into account. In addition the annual doses are calculated for ingestion of food products directly contaminated by deposition and root uptake from the contaminated soil. Activity of releases in previous years is taken into account.

Atmospheric dispersion

To calculate the average concentration in air, the horizontal and vertical dispersion have been modelled separately. The horizontal dispersion is calculated with a so-called 'sector model'. A polar calculation grid is used with rings in radial direction while the wind rose is divided in sectors. The width of a sector depends on the distance from the release point. It is assumed that the concentration is homogeneously mixed in all sectors downwind of the source. The influence of the actual plume width cancel out if the wind direction statistics are rather uniform, which is the case in The Netherlands. The long-term-average concentration in a sector is proportional to the probability of the sector being downwind of the source and is inversed proportional to the width of the sector. The model can be used in a range from 100 meters to 30 kilometres.

The vertical dispersion is calculated with a Gaussian plume model. The effect of the height of the mixing layer is accounted for by multiple reflections of the Gaussian plume shape. Fore each single weather type, the vertical dispersion coefficient, σ_z, characterises the height of the (vertical) Gaussian plume. The parameter depends on the roughness length z_0 of the surface, the distance from the point of release and a constant, which is determined by meteorological Pasquill stability. The meteorological data is arranged according to the Pasquill stability scheme with weather type A to F. According to this scheme, weather type A is very unstable, D is neutral and F is very stable. Each class is subdivided into 2 or 3 wind velocity classes. For each class representative parameter values have been determined that are used in the formula of the dispersion coefficient σ_z. This formula gives σ_z as a function of distance from the source and the surface roughness.

Finally, the formula of the air concentration for a nuclide is given in equation 1. The parameters in equation 1 are defined in Table 1. In NUDOS, equation 1 has been corrected with two factors, one for the penetration of the mixing layer and the other for the influence of the mixing height (relevant for very hot releases).

$$C_{\mathrm{sec}tor}^{continous}(x,H,i) = Q(x)\,\frac{p(i)N}{\pi x}\,\frac{1}{\sqrt{2\pi}u\sigma_z}\exp\left(-\frac{H^2}{2\sigma_z^2}\right) \qquad (1)$$

Table 1. Parameters in equation 1

Parameter	Description	unit	Parameter	Description	unit
C	Concentration	[Bq/m^3]	x	Longitudinal direction	[m]
Q	Release rate	[Bq/s]	σ_z	Vertical dispersion coefficient	[m]
p(i)	Probability of sector i being downwind of the source	[-]	i	Number of sector	[-]
N	Number of sectors	[-]	H	Emission height	[m]
u	Windspeed	[m/s]			

Further, the effect of wet and dry deposition has been implemented in equation 1 by applying a so-called source depletion model. The release rate Q is the 'source' that is depleted by deposition: e.g. if at distance 1 km 10% of the plume inventory has deposited, the source Q is multiplied by 0.90 for the calculation of C at distances larger than 1 km. This method is applied continuously along the X-axis of the plume. The source depletion model overestimates the dry deposition rate. This overestimation is smaller than the uncertainty in modelling the dry deposition.

Dry deposition is due to absorption of material to surfaces and wet deposition is due to rain. Both dry and wet deposition are taken into account by defining two nuclide-specific constants. For dry deposition, the deposition rate [Bq/(s.m^2)] is about 10^{-4} to 10^{-2} [s^{-1}] times the concentration [Bq/m^3] at ground level. For wet deposition the deposition rate [Bq/(s.m^2)] is roughly 10^{-4} [s^{-1}] times the average concentration [Bq/m^3] along the path of the raindrop through the plume. These values correspond with 2 mm rain per hour for particles with a size of 1micrometer.

Radiological modelling

The dispersion module of NUDOS results in both air- and groundconcentration at different locations on a polar grid around the source object. From the concentrations on the ground and in the air the dose can be calculated as a consequence of respectively ground and cloud shine after a multiplication with the corresponding dose coefficients (DC).

The other exposure pathways are exposure via inhalation of radioactive material and exposure via ingestion of contaminated food. First, the intake of radionuclides is determined via an averaged breath volume and food pattern respectively. Thereafter, the dose is calculated with a multiplication of the activity intake and the dose coefficient per exposure pathway.

Finally, the total dose is the sum of the dose received per exposure pathway. Normally the Effective Dose is calculated, although it is also possible to calculate specific organ doses by applying organ-specific Dose Coefficients. The Effective Dose is defined by the ICRP in such a manner that the exposure of different organs will result in the same value of the Effective Dose if they cause about the same level of health detriment.

RATIFICATION OF EURATOM DIRECTIVE 96/29 IN THE NETHERLANDS

The ratification of the Euratom Directive 96/29 'Basic Safety Standards' has affected the regulatory requirements for the assessment of the radioactive routine releases. The ratification affects primarily the radiological modelling. At the same time, the required atmospheric modelling has been changed because of new meteorological knowledge and improved computing possibilities. Fortunately, NUDOS is a modular computer model, which means that both aspects can be dealt with (more or less) separately.

Atmospheric modelling

For the atmospheric dispersion model a new model is required for the assessment of the release of airborne radio-toxic materials as well as other toxic materials. This model is the so called the New National Model (NNM) (NNM, 1998) and has specifically been developed to cope with dispersion of 'hot' releases from high stacks, which are typical for the process industry.

The NNM is still a gaussian plume model, however with a more sophisticated modelling of the vertical and lateral dispersion coefficients. In the NNM the dispersion is calculated for each hour of five to ten years of recorded meteorological data. The previous national model uses only the statistics of the occurrence of about 17 weather types, defined by Pasquill category, wind velocity, wind direction and rain intensity (40 year statistics).

The changes introduced with the NNM are particularly useful for a more reliable calculation of the probability of exceeding given concentration levels, which is very relevant for smell and toxic effects that (often) only occur if a concentration threshold is exceeded. For radiological assessment of routine releases, the long term average concentration is relevant. The long term average is much less affected by the changes introduced with the NNM.

The implementation of the NNM will still be interesting, because of the ratification of the legislation the releases of NORM are licensed too. These releases will mostly occur in a more complex situation including high stacks and hot releases.

At this moment the implementation of NNM in NUDOS has still to be performed. The most effective and less time-consuming way will be chosen. Probably the implementation can be reduced to some relevant steps, because of the above mentioned differences between the exposure limits for the licence application in the toxic and nuclear industry.

Radiological modelling

The radiological models are changed with respect to the values of the Dose Coefficients (DC). The weight factors to calculate the effective dose by weighted summing of the different organ doses and the formula to calculate the dose received by the lungs are changed.

The influence of the new radiological models has been assessed in particular for the doses due to inhaled radioactive material (J.F.A. van Hienen, 2001). This is demonstrated for a release with a spectrum of radionuclides where the Dose Coefficients (DC) -for adults -for the exposure pathway inhalation are given in Table 2. The nuclides, which are presented in the first column, are a typical example of a release with Natural Occurring Radioactive Material (NORM) in the ore-processing industry. The assessment has shown that the total effective dose will decrease if the new DC's are applied. The reason is that these nuclides accumulate at the bone surfaces, and the new weight factor for the contribution of the bone surface to the effective dose is decreased from 0.03 to 0.01.

The other nuclides (column four of Table 2) are often relevant for nuclear practises. For these nuclides a decrease of the dose is expected too if the new DC's are applied. The reason is that the most important exposure pathway for these nuclides is inhalation, and that the use of the new lung model results in lower DC values.

Table 2. A spectrum of nuclides with old and new Dose Coefficients

Nuclides	ICRP-26 before 1990	Euratom Directive 96/29	Nuclides	ICRP-26 before 1990	Euratom Directive 96/29
U-232	$3.4\ 10^{-06}$	$4.0\ 10^{-06}$	I-129	$6.7\ 10^{-08}$	$3.6\ 10^{-08}$
Th-228	$6.9\ 10^{-05}$	$3.2\ 10^{-05}$	I-130	$1.0\ 10^{-09}$	$6.7\ 10^{-10}$
U-234	$7.4\ 10^{-07}$	$5.6\ 10^{-07}$	I-131	$1.4\ 10^{-08}$	$7.4\ 10^{-09}$
U-235	$6.9\ 10^{-07}$	$5.2\ 10^{-07}$	I-132	$1.3\ 10^{-10}$	$9.4\ 10^{-11}$
Th-231	$2.3\ 10^{-10}$	$3.1\ 10^{-10}$	I-133	$2.3\ 10^{-09}$	$1.5\ 10^{-09}$
U-236	$7.0\ 10^{-07}$	$5.3\ 10^{-07}$	I-134	$4.3\ 10^{-11}$	$4.5\ 10^{-11}$
U-238	$6.6\ 10^{-07}$	$5.0\ 10^{-07}$	I-135	$4.6\ 10^{-10}$	$3.2\ 10^{-10}$
Th-234	$8.0\ 10^{-09}$	$6.6\ 10^{-09}$			
Np-237	$9.6\ 10^{-05}$	$2.3\ 10^{-05}$			
Pa-233	$2.2\ 10^{-09}$	$3.3\ 10^{-09}$			
Tc-99	$2.3\ 10^{-09}$	$1.9\ 10^{-11}$			
Ru-106	$3.2\ 10^{-08}$	$2.8\ 10^{-08}$			

CONCLUSION

The ratification of the Euratom Directive 96/29 ‘Basic Safety Standards’ in the Netherlands has affected the regulatory requirements for the assessment of the radioactive routine releases. The ratification affects primarily the radiological modelling. At the same time, the required atmospheric modelling has been changed.

The atmospheric dispersion will especially be improved with respect to the dispersion of 'hot' releases from high stacks, which are typical for the process industry. The new requirements for the atmospheric modelling will become more time-consuming, but can probably be reduced to some relevant steps.

In radiological aspect the changes are small. The calculated dose will probably decrease, because of the new Dose Coefficients. The update of this part of the local model NUDOS by NRG has been performed already.

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