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Fast Dose Assessment Models, Parameters and Code under Accident Conditions for Qinshan Nuclear Power Plant+

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Abstract: In this paper, fast dose assessment models, parameters and code were described concisely. According to requirment of accident emergency plan for Qinshan Nuclear Power Plant, a Gaussian straight—line model was adopted for estimating radionuclide concentration in surface air. In addition, the effects of mountain body on atmospheric dispersion was considered. By combination of field atmospheric dispersion experiment and wind tunnel modeling test, necessary modifications have been done for some models and parameters. A computer code for assessment was written in Quick BASIC(V4.5) language. The radius of assessment region is 10km and the code is applicable to early accident assessment.

I. Introduction

Qinshan nuclear power plant (QNPP) is located at the north side of Hangzhou bay, 80 km to Shanghai and 60 km to Hangzhou. The reactor is PWR, and the specified output power is 300MWe.

Based on the needs of health and safety, an accident emergency plan and preparation was made before the reactor into operation. The fast dose assessment system as an important part was included in it. For the region within 10km radius from reactor, a stright—line Gaussian plume model was adopted and some necessary modefications have been done for the models and parameters, such as atmospheric diffusion parameters, lateral plume deviation, vertical plume slant and effective height of plume that effected by the mountain bodies. These modefications are based on the results of field atmospheric dispersion experiment and wind tunnel modeling test for QNPP. The computer program was designed according to the models and parameters and it could be easily used to other nuclear power stations if some reletive site—specific parameters was inputed.

II. Source terms

The source terms under accident release condition are based on UANRC standard 9 accident categories of PWR that described in WASH—1400 reports[1] and 14 accident categories of DBA (designed basis accident) which was given by Qinshan nuclear power plant. 21 main radionuclides were selected for dose evaluating. Considering the radioactive decay during the period, t_r, that from accident occurrence to the environment, the quantity of radioactive arrived for the envirement, Q_i, can be calculated by the formula: $Q_i = Q_{0i} e^{-0.693 t_r / T_i}$, where the subscript i refers to the ith nuclide and it has the same meaning below. Q_{0i}(Bq) is the radioactive quatity of nuclide i which will be released from the containment vessel. t_r(hour) is the period length that noted above. T_i(hour) is the half—life of ith nuclide.

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3. Models and parameters

3.1 Atmospheric dispersion factors

For computing radionuclide concentration, the atmospheric dispersion factor equations were selected respectively according to both states of elevated and ground level release. Depend on the terrain of Qinshan and the results of environmental wind tunnel modeling test, the elevated release is determined as the effective release is higher than 100 meters. For lower that, it is to be called ground level release.

The longest duration of accident release among 9 categories of PWR accident is 10 hours, and it is considered short term release. For longer than that, it should be called long term release.

(1) Dispersion factor for short term release accident

For elevated point source release, the dispersion factor is given as follows.

$$(\frac{\chi}{Q})_H = \frac{1}{\pi U \sigma_y \sigma_z} \cdot exp(-\frac{y^2}{2\sigma_y^2}) \cdot exp(-\frac{H^2}{2\sigma_z^2}) \quad (1)$$

where:

$(\chi/Q)_H$=average effluent concentration χ, normalized by source strength, Q, for elevated release (S/Bq m)

U=the mean windspeed at the time of release (m)

σ_y, σ_z=the horizontal and vertical disffusion parameters respectively

H =the height differential between receptor and effective plume height(m)

Dispersion factor of ground level release is given below:

$$(\frac{\chi}{Q})_G = \frac{1}{\pi U \Sigma_y \Sigma_z} \cdot exp(-\frac{y^2}{2\Sigma_y^2}) \quad (2)$$

where:

$\Sigma_y=(\sigma_y^2+CA/\pi)^{1/2}$, $\Sigma_z=(\sigma_z^2+CA/\pi)^{1/2}\leqslant\sqrt{3}\sigma_z$

and where C is building—wake constant (C=0.5), A is minimum cross—section area of the reactor building, m^2.

If the time—intergrated concentration and accumulative doses need to be predicated during all accident time, the models assume that the wind direction, windspeed and weather stability are same as those at the time of computation.

(2) For long term accident release

The lasting time of long term accident release is up to 30 days, therefore the dispersion factors should be given separately for several periods of release.

If t is assumed as the time from accident release to the moment of computing, then for the time of $0<t\leqslant2$ hours or $2<t\leqslant8$ hours, the formula of dispersion factor is same as equation (2). As the time, t, is in the period of $8<t\leqslant24$ hours, and the wind direction in one sector is considered not to be changed, then:

$$(\frac{\chi}{Q}) = \frac{2.032}{x\sigma_{zF}U_F} \quad (3)$$

where x (m) is the distance from release point to receptor. U_F is the typical windspeed under the F—stability condition. σ_{ZF} is vertical diffusion parameter under the F—stability. For ground level calculation, Σ_{ZF} was used instead of σ_{ZF}.

3.2 Horizontal and vertical diffusion parameters

Since Qinshan topography is comparetive complex, the diffusion parameters in the area are different with the different direction sectors. Meanwhile, the diffusion parameters will be effected by weather stabitlity, wind direction, wind speed and effective release height. Based on the results of field atmospheric tracer experimant and wind tunnel modeling test, we obtained the anisotropic antomspheric diffusion parameters listed in table 1.

Table 1. Several diffusion parameters

weather stability	wind direction	He(m)	σ_y	σ_z	distance to source x(m)
A—B	all directions	not limit	0.16x	$0.139(x-27.5)^{[illegible]}$	
C—D	E, ESE, SW, WSW, W, WNW	≤100	$16.932x^{[illegible]}$	$4.027x^{[illegible]}$	x<800
			$11.36x^{[illegible]}$	$4.027x^{[illegible]}$	x≥800
		>100	$0.4972x^{0.7771}$	$2.082x^{0.4885}$	
E—F	all directions	not limit	$1.67x^{[illegible]}$	$2.157(x-90.5)^{[illegible]}$	

3.3 Herizontal deviation and vertical slant modifications *

Because the mountain body effects on the pathway of airborn effluents transport, the lateral removal and vertical slant occure obviously in some wind direction sectors, and it should be considered in doses assessment. For modifications of the lateral removal and vertical slant, some correcting founctions have be drawn, but do not be given in this paper.

3.4 Concentration calculation

For concentration calculation, it is assumed that the beginning time of accident release to environment is zero (t=0). The time intervals of release periods are Δt_1, Δt_2, …, Δt_n respectively. The endtime correlation to various periods are t_1, t_2, …, t_n and the release amount of nuclide i in various intervals are Q_{i1}, Q_{i2}, …, Q_{in}. At the time of computing, $t_{n-1}<t<t_n$, the time—intergrated concentration $\psi_i(t)$ (B_q/m^3) can be given by the formula below:

$$\psi_i(t) = \{\sum_{k=1}^{n-1} Q_{ik} (\frac{\chi}{Q})_K \frac{1-e^{-\lambda_i \Delta t_k}}{\lambda_i \Delta t_k}\} e^{-\lambda_i (t-t_k)} + Q_{in} (\frac{\chi}{Q})_n \frac{1-e^{-\lambda_i (t-t_{n-1})}}{\lambda_i \Delta t_n} \quad (4)$$

where $(\frac{\chi}{Q})_k$ is the atmospheric dispersion factor in k period. λ_i is the radioactive decay constant of ith nuclide.

Ⅵ. Deposition during an accident

4.1 Quantity of dry deposition $W_{Di}(t)$ (Bq/m^2)

Dry deposition of elemental radionuclides and other particulates should be considered for all release. The dry deposition quantity of the ith radionuclide on ground level in the time interval from accident occurrence to computing moment is given by following formula:

$$W_{Di}(t) = V_{di} \psi_i(t) \quad (5)$$

where V_{di} is the dry deposition velocity of ith radionuclide, (m/s).

4.2 Quantity of wet deposition $W_{Wi}(t)$ (Bq/m^2)

The effects of wet deposition and attendant plume depletion must be considered in the assessment. For computing the quantity of wet deposition, it is assumed that the rainfall rate is a constant from the beginning of accident occurrence to computing moment. The formula is then given below:

$$W_{wi}(t) = \{\sum_{k=1}^{n-1} Q_{ik} W_{ik} \frac{1-e^{-\lambda_i \Delta t_k}}{\lambda_i \Delta t_k} e^{-\lambda_i (t-t_k)}\} e^{-\lambda_i x/u} + Q_{in} W_{in} \frac{1-e^{\lambda_i (t-t_{n-1})}}{\lambda_i \Delta t_n} e^{-\lambda_i x/U} \quad (6)$$

where W_{ik} (s/m^2) refers to wet depsition factor in k period. Correspending to various periods, W_{ik} can be expressed respectively as following:

when $0<t\leq 2$ hours or $2<t\leq 8$ hours,

$$W_{i1}=W_{i2}=\frac{\sqrt{2}\Lambda_i}{\sqrt{\pi}U\sigma_y}e^{-y^2/(2\sigma_y^2)}e^{-\Lambda_i x/U} \qquad (7)$$

when $8<t\leqslant 24$ hours,

$$W_{i3}=\frac{2.032\sqrt{2\pi}\Lambda_i}{xU_F}e^{-\Lambda_i x/U_F} \qquad (8)$$

where Λ_i is washout factor of ith nuclide.

V. Doses calculation

For doses calaulation in the assessment, three pathways of exposure were considered.

(1)External dose from immersion, $D_{Ei}(t)$ (Sv)

$$D_{Ei}(t)=g_{Ei}\phi_i(t) \qquad (9)$$

where g_{Ei} is dose conversion factor, $Sv/(S\cdot Bq/m^3)$. $\phi_i(t)$ is the concentration at the time t.

(2) Internal dose from inhalation, $D_{ai}(t)$ (Sv)

$$D_{ai}(t)=R_a g_{ai}\phi_i(t) \qquad (10)$$

where R_a is breath rate of ath age group, m^3/s. g_{ai} is inhalation dose conversion factor, Sv/Bq. For lung and thyriod dose, the estimation is similar as the inhalation dose computation.

(3) External dose due to deposition, $D_{Gi}(t)$ (Sv)

$$D_{Gi}(t)=[W_{Di}(t)+W_{wi}(t)]g_{Gi} \qquad (11)$$

where g_{Gi} is deposition dose conversion factor, $Sv/(S\cdot Bq/m^2)$.

VI. Doses assessment code

A Quick BASIC (V4.5) computer code system "QSFACS" has been designed for purpose of fast dose assessment. It was developed on IBM−286/386 microcomputer or other compatible computers that had better equipped a math co−processor for speeding computation. The code system includes six files and is constructed in modules. It can be carried out in computer DOS state when it was compiled into an executive file as well as in Quick BASIC (V4.5) environment. The results of the code computation can be output on printer or plotter as well as on CRT with an VGA card. The specification of the code design was given in special papers.

References

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