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■ 論 文 ■

Establishment of Release Limits for Airborne Effluent into the Environment Based on ALARA Concept

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=**Abstract**=

A derivation of new release limit, named Derived Release Limit(DRL), into the atomsphere from a reference nuclear power plant has been performed on the basis of the new system of dose limitation recommended by the ICRP, instead of the (MPC)a limit which has been currently used until now as a general standard for radioactive effluents in Korea.

In DRL Calculation, a Concentration Factor Method was applied, in which the concentrations of long-term routinely released radionuclides were in equilibrium with dose in environment under the steady state condition. The analytical model used in the exposure pathway analysis was the one which has been suggested by the USNRC and the exposure limits applied in this analysis were those recommended by the USEPA lately. In the exposure pathway analysis, all of the pathways are not considered and some may be excluded either because they are not applicable or their contribution to the exposure is insignificant compared with other pathways.

In case, the environmental model developed in this study was applied to the Kori nuclear power plant as the reference power plant, the highest DRL value was calculated to be as 9.10×10^{6}Ci/yr for Kr-85 in external whole body exposure from the semi-infinite radioactive cloud, while the lowest DRL value was observed 3.64Ci/yr for Co-60 in external whole body exposure from the contaminated ground by the radioactive particulates. The most critical exposure pathway to an individual in the unrestricted area of interest (Kilchun-Ri, 1.3 km to the north of the release point) seems to be the exposure pathway from the contaminated ground and the most critical radionuclide in all pathways appears to be Co-60 in the same pathway.

When comparing the actual release rate from KNU-1 in 1982 with the DRL's obtained here the release of radionuclides from KNU-1 were much lower than the DRL's and it could be conclued that the exposure to an individual had been kept below the exposure limits recommended by the USEPA.

1. Introduction

In the fuel cycle of the nuclear power industry, gaseous and liquid radioactive wastes are produced during normal operation and are released into environment to a minor extent. As is well known, the release of radioactive wastes should be complied with the relevant national requirement in radiation safety and should be controlled properly to protect the environment from contamination and to protect the general public from the unnecessary exposure due to released radioactive wastes.

It has often considered sufficient to limit the release of radioactive wastes or materials to the environment by usually limiting the concentrations of the various radionuclides in air and water effluents as a fraction of the Maximum Permissible Concentration (MPC) concept based on the Critical Organ Concept1) recommended by the International Commission on Radiological Protection (ICRP) in 1959.

This system of release limitation by MPC concept has been used and observed so far without any modification as a standard in Korea, even in the regulation of the Atomic Act2). But if the release rates were high, such limits based on MPC concept obviously would not prevent substantial amounts of radioactive material from reaching the environment nor would they assure that the concentration process in environment might not cause high concentrations in certain environmental materials which result in unexpectedly high does in members of general public3).

In order to remove these eventualities and irrationalities the ICRP has introduced a new system of dose limitation which is based on the ALARA philosophy of Total Risk Concept in 1977 with the experiences and knowledges having been accumulated during past 20 years and recommended using a new release limit derived by the new system of dose limitation4). Therfore, new principles relating to the limitation of environmental releases and to the assessment of radiological significance of such releases have been, and continued to be, developed in the foreign advanced countries such as USA and Canada,

Likewise, in accordance with this trend of developing new principles, a new release limit based on the concept of dose limitation should be developed and determined to control the radiological safety for the currently opertaing facilities and to reduce the health detriment of the public due to the unexpected radiation exposure from released radionuclide in Korea as well.

With this necessity and demand, this research was initiated to derive the new release limit of the gaseous radioactive materials to the environment from a reference nuclear power plant complying with the newly recommended exposure limits by the USEPA5) as the environmental radiation protection standards for the nuclear power plant operation6) in early 1985.

This rsearch was the aim of deriving and calculating 'the release limits of the gaseous radioactive materials to the environment from a reference nuclear power plant complying with the newly recommended exposure limits by the Environmental Protection Agency (EPA), USA in early 1985[1]. The exposure limits recomended by the EPA are 25 mrem to the whole body and 75 mrem to the other body organ of an individual, and 3 times greater than those limits currently used by the United States Nuclear Regulatory Commission (USNRC) in 10 CFR 50, App. I[6] for the nuclear power industry.

To derive the release limits one should analyze the exposure pathways of released radionuclides in the environment by the relevant analytical model. In this research, the standard model of the USNRC in Regulatory Guide 1.109[7], which is adopting the Concentration Factor (CF) Method[3,8] that the long-term averaged concentration of released radionuclide is time-independent, was used as a standard model for the DRL calculation.

In this investigation, the Kori Nuclear power Plant Unit No. 1 (in short, KNU-1) was selected as a reference power plant and the gaseous radioactive source terms considered were Noble Gases (Kr-87, Xe-133, Xe-133m, Xe-135), Iodines (I-131, I-133), Particulate (Co-60, Cs-137) and Tritium Gas (H-3) based on the actual release data in 1982[9]. The nearest permanent area, where the calculation of the DRL was performed, was assumed Kilchun-Ri locating at 1300 m to the north of the release point[10,14]. It is also assumed that the releases were carried out continuously on the routine basis throughout the year and the concentrations of released radionuclides were in equilibrium with the environment under steady state condition[3,8,9].

2. Derived Release Limit

The basic condition of radiation protection which the exposure to an individual in general public should be kept below the annual exposure limit recommended can be satisfied by introducing the derived limit for the annual discharge of radionuclides to the environment[7].

In the practical point of view, the DRL is the upper limit for the release rate of a single radionuclide from a single release point which is derived from the regulatory dose limits by analytical models of all significant environmental pathways to an individual in the critical group[8].

The actual release rates resulted from the operation of the facility should be controlled to be lower than the authorized limits[7] which are set by the relevant regulation authority as a fraction of DRL, and further reduced and maintained as the operational limits[7,8] by the managing or administrative side of the facility to optimize the releases as low as reasonably achievable (ALARA) through cost-benefit analysis.

In order to estimate the DRL's one has to know the relationship between the release rate and exposure dose to the critical group. If we set the release rate of radionuclide i as Q_i, the exposure dose to the individual in exposure group j by exposure pathway k can be expressed as following[7].

$$H_{ij}=f_{ijk}\cdot Q_i \text{ (mrem/yr)} \cdots\cdots\cdots\cdots\cdots (1)$$

where, Q_i: release rate of radionuclide i (Ci/yr).

f_{ijk}: conversion factor relating the release rate to exposure dose, ie, combination of relevant parameters (mrem/pCi).

After setting the H_{ij} equal to the annual dose limit recommended by the regulation, it is able to calculate the release rate Q_i which keeps the exposure complying with the annual dose limits (ADL) by substituting proper f_{ijk} value.

$$Q_i=\frac{\text{ADL}}{\sum\limits_i\sum\limits_j f_{ijk}} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

In the case of more than one organ related to exposure, the following equation should be satisfied for all the organ T.;

$$Q_{iT} \leq \frac{\text{ADL}}{\sum\limits_i\sum\limits_k\sum\limits_T f_{ijkT}} \cdots\cdots\cdots\cdots\cdots (3)$$

In Eq. (1), Q_i (Ci/yr) is the maximum permissible release rate of radionuclide i to the body organ T for all exposure pathway and becomes to be the DRL which this research aims to calculate.

The population group which is exposed to the radionuclide which is released by this release rate, Q_i is "critical group" and the exposure pathway which contribute most of exposure to this group is called "critical pathway" or "dominant pathway"[6].

3. Analysis of Exposure Pathway

Gaseous radioactive wastes released from nuclear facilities are transferred to the environmental material or ecosystem by the atmospheric disperson effect and dry or wet deposition process, and give radiation exposure to man who is the final trophic level of the terrestrial food chain.

The atomospheric transport of released radionuclide was mostly explained by the so-called Gaussian Plume Model which explains the dispersion of released materials or particulates by the statistical characteristics under the assumption that the concentrations of dispersing plume follow the Gaussian distribution. A simple Gaussion Plume Model for ground level release($z=0$, $H\leq 10$m) are expressed as following;

$$X(x,y,0)=\frac{Q}{\pi\sigma_y\sigma_z\bar{u}}\cdot\exp\left\{-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right\} \cdots\cdots\cdots\cdots (4)$$

From the assumption of routine and continuous releases for long period, the annual averaged concentrations in a sector of interest at a downwind distance x can be calculated after dividing the surrounding area of the release point with 16 directions by 22.5°. So, for the long-term averaged concentration Eq. (4) can be rewritten for the sector k of downwind distance as following;

$$\chi(x,\ k)=\frac{2.032Q}{x}\sum_{i,j}^{n,\tau}\frac{f_{ij}(k)}{\bar{U}_i\cdot\sigma_{zj}(x)} \quad (5)$$

The parameters in Eq. (4) and (5) are

designated as,

χ : concentration (Ci/m^3).

Q : release rate (Ci/sec, Ci/yr).

σ_y, σ_z : horizontal or vertical dispersion coefficient of the plume respectively (m).

k : sector to which the wind blows.

$f_{ij}(k)$: joint frequency of the wind speed i blowing into sector k under the atmospheric stability j.

$\bar{U}$: mean wind speed (m/sec).

i : 1−n, (wind speed group).

j : 1−τ, (atomospheric stability group, 1=A: most unstable to τ=G: calm).

Using Eq. (5), one can calculate the $\bar{\chi}/Q$ (x, k) after normalizing the release rate as 1 Ci/yr. This is the atomospheric dispersion coefficient which is most important input parameter in the exposure pathway analysis.

In this research the annual averaged atmospheric dispersion coefficient corrected for radioactive decay and plume depletion, $(\bar{\chi}/Q)_D$ for the KNU-1 in 1982 was obtained from the data in Ref. 4 at Kilchun-Ri locating at 1.3 km to the north of the release point. In Table 1, $(\bar{\chi}/Q)_D$ for each direction is shown.

In Fig, 1 the environmental transfer pathway and exposure pathway for gaseous radionuclide to man are shown. In Fig. 1 pathway No. F and G (drawn by dotted line) considered to be negligible because the average annual ingestion of milk and meat by the residents are much lower than those by the American. The justification of this assumption can be verified from the Table 2 following.

In this research the exposure pathway was divided into following 4 modes as shown in Fig. 1

(1) Pathway A: external exposure from semi-infinite radioactive cloud of noble gases.

(2) Pathway B: external exposure from contaminated ground by radionuclide deposition.

(3) Pathway C: internal exposure due to inhalation of radionuclide.

Table 1. $(\bar{\chi}/Q)_D$ at area of interest, KNU-1, 1982
unit : sec/m^3

Direction (K)	$(\chi/Q)_D$(1300, K)	Remarks
E	8.40E−6	
ENE	8.10E−6	
NE	1.50E−6	
NNE	1.20E−6	
N	7.00E−6	Kilchun-Ri
NNW	3.15E−6	
NW	3.10E−6	
WNW	2.72E−6	
W	4.20E−6	

Remainder toward sea, no residence

Table 2. Annual average consumption of meat and milk by Korean and American

Classification	Korean (1983)*	American (1974)**
meat (kg/yr)	13.2	110
milk (l/yr)	11.9	310

Source: *From table of food supply and consumption, Ministry of Agriculture and Fishery, 1983
**From table of food consumption, demand and cost, Dept. of Agriculture, USA, 1974.

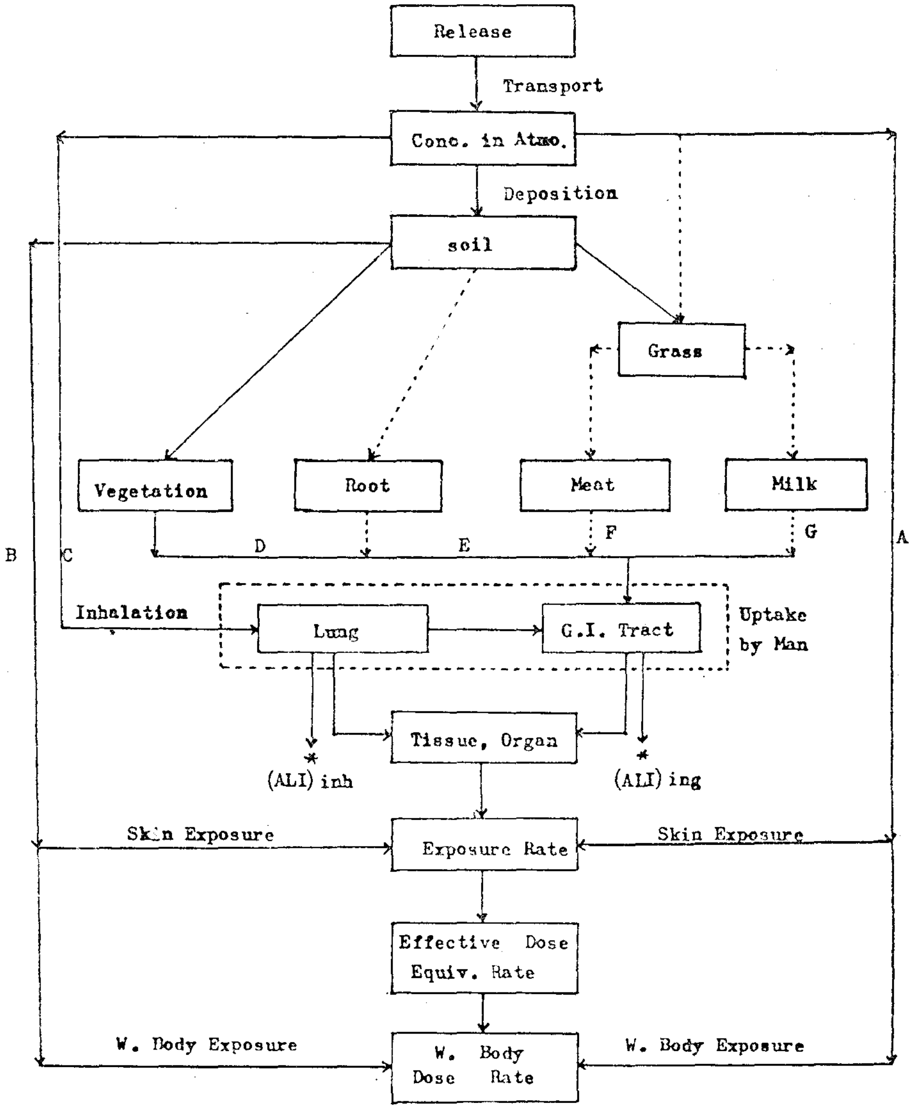


Fig. 1. Environmontal Transfer Pathways and Exposure Pathways for Gaseous Effluents.

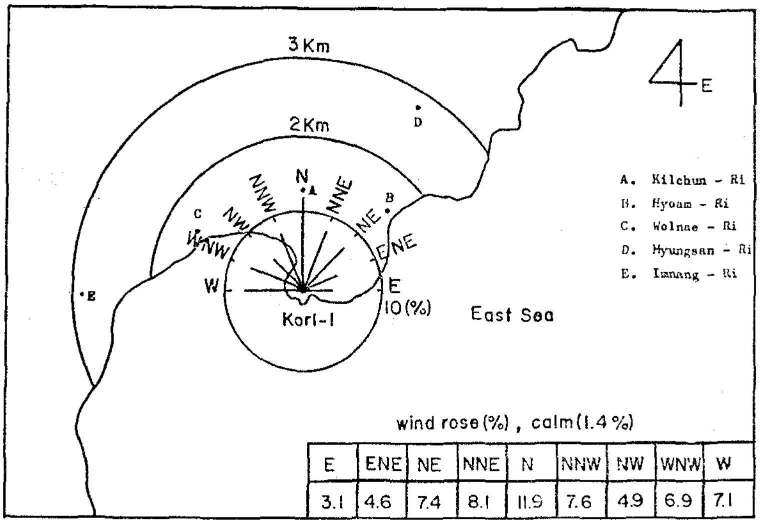
(4) Pathway D: internal exposure due to ingestion of contaminated vegetations by radionuclide deposition

In Fig. 3 the geography and wind rose for KNU-1 site, the reference nuclear power plant in this research, in 1982 are shown.

4. DRL calculation and the Result

4.1 Pathway A: external exposure from radioactive cloud

In this pathway the main exposure mode is an external exposure to whold body and skin from the radioactive cloud of noble gases such as Kr, Xe.



E	ENE	NE	NNE	N	NNW	NW	WNW	W
3.1	4.6	7.4	8.1	11.9	7.6	4.9	6.9	7.1

Fig. 2. KNU No.1: Geography and Annual Wind Rose, 1982

The annual exposure dose rate to an individual in the area of interest, D (1300, N), can be written as following.

a. whole body exposure

$$D^T_\infty(1300,\mathrm{N})=1.11\times 3.17\times 10^4\cdot S_F\cdot Q_i\cdot(\bar{\chi}/Q)_D\ (1300,\mathrm{N})\cdot DFB_i\cdots\cdots(5)$$

where, $D^T_\infty(1300,\ \mathrm{N})$: mrem/yr

1.11 : (μ/g) tissue/(μ/g)air

3.17×10^4 : pCi−sec/Ci-yr

S_F : shielding factor due to building, house, etc.

Q_i : annual release rate of radionuclide i (Ci/yr).

$(\bar{\chi}/Q)_D(1300,\mathrm{N})$: annual averaged atmospheric dispersion coefficient at the area of interest, L(1300, N), (sec/m³).

DFB_i : whole body dose conversion factor for radionuclide i, (mrem-m³/pCi-yr).

b. skin exposure

$$D^R_\infty(1300,\mathrm{N})=Q_i\cdot(\bar{\chi}/Q)_D\cdot(1.11\times3.17\times10^4 S_F\cdot DF_i^r+DFS_i)\ \cdots(6)$$

Where, $D^S_\infty(1300,\mathrm{N})$: mrem/yr

DF_i^r : gamma dose conversion factor for radionuclide N, (mrad-m³/pCi-yr).

DFS_i : beta dose conversion factor for radionuclide i, considered for the attenuation by the dead layer of the skin (ρ=7mg/cm²) (mrem-m³/pCi-yr).

From these Eq. (5) and (6), the maximum permissible release rate of radionuclide i, Q_i can be calculated if the $D_\infty{}^T$ and $D_\infty{}^S$ are set as the exposure limit given by the EPA and the values of various parameters, S_F, $(\bar{\chi}/Q)_D$, DFB_i etc are given.

4.2 Pathway B: External exposure from contaminated ground.

The dose rate to individual standing on the ground which is contaminated by the radioactive iodines and particulates through the dry or wet deposition pocesses during the transport of radioactive plume over the area of interest can be obtained from the following equation;

$$D_i^G(1300, \mathrm{N}) = 8760 \cdot S_F \cdot C_i(1300, \mathrm{N}) \cdot DFG_i$$

$$C_i(1300, \mathrm{N}) = \frac{1.0 \times 10^{12} \delta_i(1300, \mathrm{N})}{\lambda_i} \cdot$$

$$Q_i \cdot \{1 - \exp(-\lambda_i \cdot t_b)\} \cdots\cdots\cdots\cdots\cdots\cdots\cdots (8)$$

where, $D_i^G(1300, \mathrm{N})$: mrem/yr.

DFG_i : whole body or skin dose conversion factor of radionuclide i at the 1 m height above the ground (mrem-m^2/pCi-hr)

8760 : hr/yr.

$C_i(1300, \mathrm{N})$: the activity of radionuclide i deposited on the ground of unit area at the area of interest, $L(1300, \mathrm{N})$, (pCi/m^2).

$\delta_i(1300, \mathrm{N})$: annual average relative deposition of radionuclide i at the area of interest (m^{-2}).

λ_i : radioactive decay constant of radionuclide i (yr^{-1}).

t_b : the time duration of exposure of ground to deposited radionuclide i (yr)

1.0×10^{12} : pCi/Ci.

The value of $\delta_i(1300, \mathrm{N})$ is calculated by the method described by the Regulatory Guide 1.109 of USNRC.

$$\delta_i(1300, \mathrm{N}) = \frac{f_d \cdot f_{xk}}{y_{xk}} \cdots\cdots\cdots\cdots\cdots\cdots\cdots (9)$$

where, f_d : relative deposition rate of the plume (m^2)

f_{xk} : the fraction of plume transported over the area of interest (1300, N).

y_{xk} : the area length of the sector of interest (m).

From Eq. (7), (8) and (9) the value of Q_i in pathway B can be calculated as the same method described in pathway A.

4.3 Pathway C: internal exposure due to inhalation of radionuclide

The interal exposure dose rate $D_{ija}(1300, \mathrm{N})$ to the body organ j of age group a in exposure group due to inhalation of radionuclide i can be calculated by using the following equation.

$$D_{ija}(1300, \mathrm{N}) = 3.17 \times 10^4 \mathrm{Ra}.Q_i$$

$$(\bar{\chi}/Q_D(x, k)).\ DFI_{ija} \quad \cdots\cdots\cdots\cdots\cdots\cdots (10)$$

where, Ra : annual respiration rate of age group, a (m^3/yr).

DFI_{ija} : dose conversion factor for body organ j of age group, a, due to inhalation of radionuclide i, (mrem/pCi-inhaled).

The important radionuclides considered in this pathway are radioiodines, tritium gas, particulates and in this research the whole body and thyroid are considered as the body organ exposed to inhaled radionuclide i.

The exposure dose rate to the other organs except whole body and thyroid can be also estimated after knowing the relevant dose conversion factors to those organs.

The method of calculating the Q_i for pathway C is the same as described earlier.

4.4 Pathway D : Internal exposure due to ingestion of contaminated vegetations by radionuclide deposition

The annual dose rate to the body organ, j of an individual of age group, a in an area of interest through the ingestion of contaminated vegetables grown in this area by radionuclide i, can be calculated by following equation.

$$D_{ija}(1300, \mathrm{N}) = DFI_{ija} \cdot \{U_a^v \cdot f_g \cdot C^v_i (1300, \mathrm{N}) + U_a^l \cdot f_l \cdot C_i^l (1300, \mathrm{N})\} \quad \cdots (11)$$

where, $D_{ija}(1300, \mathrm{N})$: mrem/yr

DFI_{ija} : dose conversion factor for body organ i of age group a, due to ingestion of radionuclide i (mrem/pCi-ingested).

U_a^v, U_a^l : annual average consumption of vegetables and leafy vegetables of age group a, respectively (kg/yr).

C_i^v, C_i^l : concentration of radionuclide i in vegetables and leafy vegetables by ground deposition of radionuclide, respectively (pCi/kg).

f_g, f_l : fraction of consumption of vegetables and leafy vegetables grown in the area of interest, (1300, N), respectively.

In eq. (11) the C_i^v and C_i^l are calculated by following equation.

$$C_i(1300, \mathrm{N}) = d_i \cdot \left[\frac{r\{1-\exp\{-(\lambda_{ei}\cdot t_e)\}}{Yv.\lambda_{ei}} + \frac{Biv\{1-\exp(-\lambda_i \cdot t_b)}{P\cdot\lambda} \right] \cdot \exp(-\lambda_i \cdot t_h) \quad \cdots\cdots (12)$$

$$d_i(1300, \mathrm{N}) = 1.1\times 10^8 \delta_i \cdot Q_i \; \text{(particulates)}$$

$$5.5\times 10^7 \delta_i \cdot Q_i \; \text{(iodines)} \cdots\cdots (13)$$

where, $C_i(1300, \mathrm{N})$: pCi/kg.

d_i : ground deposition rate of radionuclide i (pCi/m^2-hr).

r : retention fraction of radionuclide in vegetation.

λ_{ei} : effective removal constant of radionuclide i in vegetation (hr^{-1}),

$\lambda_{ei} = \lambda_i + \lambda_w$

λ_w : removal constant by weathering effect.

t_e : period of vegetation exposure during growing time (hr).

Y_v : agricultural productivity in unit area (kg/m^2).

B_{iv} : transfer coefficient of stable isotope i to vegetation from soil by the metabolism of vegetation, concentration factor.

P : effective surface density of soil (assuming 15cm deep plow layer) (kg/m^2).

t_b : period of long-term buildup and retention of radionuclide in soil (hr) (normaly half of the plant life).

t_h : time delay between harvest of vegetation and ingestion (hr).

δ_i : relative deposition (m^{-2}).

1.1×10^8 : 10^{12}pCi/Ci/8760hr/yr.

Using Eq. (11), (12) and (13) the value of Q_i for each radionuclide in Pathway D can be calculated after setting the D_{ija} value as the exposure limit to each body organ of an individual in the area of interest.

The value of every parameter used in this research is presented in Table 3. The authors tried to use a proper value for each parameter if it was available to obtain in Korea[10] as possible, but in case of no data at all the values in Reg. Guide 1.109[3] or other results[12] were used unavoidably with conservative consideration of the safety margin.

The values of various dose conversion factors used in this research are tabulated in Table 4.

4.5 Result of DRL calculation

By using the various equations above in

Table 3. Value of Each Parameter used

Symbol	Unit	Value		Ref(s)
S_v	—		0.7	3
Ra	m^3/yr	adult	6,200	11
		child	2,900	11
r	—	Iodines	1.0	3
		particulates	0.2	3
λ_w	hr^{-1}		0.0021	3
t_b	hr	(15yr)	131,400	3
t_e	hr	(90d)	2,160	3
t_h	hr	(14d)	336	3
Y_v	kg/m^2	—	2.0	3
P	kg/m^2	—	240	3
B_{iv}	Veg./soil	I	2.0E−2	3, 11
		Co	9.4E−3	3, 11
		Cs	2.0E−3	3, 11
U_a^v	kg/yr	adult	646.4	11
		child	336.2	11
U_a^l	kg/yr	adult	73.9	11
		child	41.9	11
f_g	—	—	0.76	3
f_l	—	—	1.0	3
f_d	m^{-1}	—	4.3E-5	3
f_{xk}	—	—	0.119	Fig. 3
y_{xk}	m	—	510.25	Fig. 3

Table 4. Various Dose Conversion Factors(1)

Nuclide	DF_i^γ	DFB_i-γ	$DFS_{i-\beta}$	DFG_i	
				W. body	Skin
Kr—85	1.72E−5	1.61E−5	1.34E−3	·	·
Kr—87	6.17E−3	5.92E−3	9.73E−3	·	·
Xe—133	3.53E−4	2.94E−4	3.06E−4	·	·
Xe—133m	3.27E−4	2.51E−4	9.94E−4	·	·
Xe—135	1.92E−3	1.81E−3	1.86E−3	·	·
I—131	·	·	·	2.89E−9	3.40E−9
I—133	·	·	·	3.70E−9	4.50E−9
Co—60	·	·	·	1.70E−8	2.00E−8
Cs—137	·	·	·	4.20E−9	4.90E−9

Source: Ref. 3, Ref. 12
Unit : DF_i^γ ($mrad\text{-}m^3/pCi\text{-}yr$)
DFB_i, DFS_i ($mrem\text{-}m^3/pCi\text{-}yr$)
DFG_γ ($mrem\text{-}m^2/pCi\text{-}hr$)

Table 4. Various dose conversion factors (2)

Nuclide	Exposed Group	DFI-inhaled		DFI-ingested	
		W. Body	Thyroid	W. Body	Thyroid
I-131	adult	2.56E-6	1.49E-3	3.41E-6	1.95E-3
	child	7.37E-6	4.39E-3	9.83E-6	5.72E-3
I-133	adult	5.65E-7	2.69E-4	7.53E~7	3.67E-4
	child	2.08E-6	1.04E-5	2.77E-6	1.36E-3
Co-60	adult	1.85E-6	—	4.72E-6	—
	child	6.12E-6	—	1.56E-6	—
Cs-137	adult	5.36E-5	—	7.14E-5	—
	child	6.12E-6	—	1.56E-5	—
H-3	adult	1.58E-7	1.58E-7	1.05E-7	1.05E~7
	child	3.04E~7	3.04E~7	2.03E-7	2.03E-7

Source: Ref. 3, Ref. 12
Unit : mrem/pCi-inhaled(or ingested)

Table 5. Maximum permissible release rate, Q_i and DRL in KNU-1, 1982

Nuclide	Pathway	Q_i(C_i/yr)	DRL(C_i/yr)
Kr-85	A	9.01E+6	9.01E+6
Kr-87	A	2.45E+4	2.45E+4
Xe-133	A	4.93E+5	4.93E+5
Xe-133m	A	5.78E+5	5.78E+5
Xe-135	A	8.01E+4	8.01E+4
I-131	B	4.57E+3	—
	C	26.5	26.5
	D	3.94E+3	—
I-133	B	3.19E+4	—
	C	203	203
	D	1.66E+4	—
Co-60	B	3.64	—
	C	1.90E+4	3.64
	D	1.44E+6	—
Cs-137	B	7.62	—
	C	1.02E+3	7.62
	D	11.79E+5	—
H-3	C	3.45E+5	1.66E+4
	D	1.66E+4	—

exposure pathway analysis, the maximum permissible release rate of radionuclide *i*, Q_i for each pathway was calculated and listed in Table 5. The Derived Release Limit for each radionuclide which keeps the exposure to an indidual in the critical group in the area of interest (Kilchun-Ri) complying with the exposure limit of the EPA, was selected from this result as the minimum Q_i value in all pathways, because if the release of a radionuclide is controlled to be this minimum Q_i, the release larger than this value would be controlled automatically.

The Derived Release Limit's which are selected by this method are also listed in Table 5.

In Table 6 the DRL's obtained in this research are compared with the actual release rates from KNU-1 in 1982[5)] and the critical pathway to man and the critical group are

Table 6. Comparison of DRL with actual release rate in KNU-1, 1982.

Nuclide	Critical Pathway	DRL	DRL$_0$ 1)	Actual 2) Release	Critical Group	2)/1) (%)
Kr−85	ext. exposure	9.01E+6	9.01E+4	—	adult, (1300, N)	—
Kr−87	ext. exposure	2.45E+4	2.45E+2	0.077	adult, (1300, N)	0.031
Xe−133	ext. exposure	4.93E+5	4.93E+3	1722.79	adult, (1300, N)	34.94
Xe−133m	ext. exposure	5.78E+5	5.78E+3	8.87	adult, (1300, N)	0.153
Xe−135	ext. exposure	8.01E+4	8.01E+2	1.076	adult, (1300, N)	0.134
I−131	inhalation	26.5	0.265	2.255×10^{-3}	child, (1300, N)	0.850
I−133	inhalation	203	2.03	6.222×10^{-5}	child, (1300, N)	3.06×10^{-3}
Co−60	cont. ground	3.64	0.0364	0.033	adult, (1300, N)	90.65
Cs−137	cont. ground	7.62	0.0762	—	adult, (1300, N)	—
H−3	ingestion	1.66E+4	1.66E+2	0.116	child, (1300, N)	0.070

1) DRL$_0$: Optimum DRL, assumed 1% of DRL here, it must be determined through Cost-Benefit Analysis with ALARA concept.

also explained.

5. Discussion and Conclusions

Derived Release Limits (DRL's) for gaseous effluents released to the atmosphere from the KNU-1 were calculated after assuming the KNU-1 is the reference nuclear power plant.

The area of interest where the DRL's were calculated was considered to be Kilchum-Ri locating at 1.3km to the north of the release point and considered to be the nearest permanent residence area around the KNU-1.

The exposure limits applied in the DRL's calculation was those newly recommended by the USEPA in early 1985.

The analytical model for the exposure pathway analysis which is currently suggested by the USNRC in Reg. Guide 1.109 was used as the standard model in the calculation of the DRL's, but the milk and meat ingestion pathways were neglected because of the much low consumption rates by the Korean, especially by the residents in the area of interest, comparing with those by the American. It seemed to be plausible that the milk and meat pathways can be considered negligible in current sitution.

The annual averaged atmospheric coefficient corrected for radioactive decay and plume deppletion, $(\overline{\chi}/Q)_D$ was obtained from the assumption that the terrain surrounding the nuclear power plant is flat as in the USA. But in Korea where the terrain is rather complex, the $(\overline{\chi}/Q)_D$ would be less than the value in flat terrain. So, the $(\overline{\chi}/Q)_D$ should be modified properly for real geographical condition. This would be an interesting subject to be considered in the future.

The Optimum Derived Release Limits (DRLo) which can be used as an operational limit by the facility was assumed to be 1% of the DRL in this research. But the DRLo must be determined carefully through the justification by dose limitation and optimization by the adequate Cost-Benefit Analysis with the ALARA philosophy taking into considerations of socio-economic factors. This research shall be continued to determine the Optimum Derived Release Limit in the near future.

From this research it could be concluded that:

1) The actual release rates of the gaseous radionuclides from the KNU-1 in 1982 were much below the Derived Release Limits newly calculated and still below the Optimum Derived Release Limit which is assumed to be 1% the DRL as operating limits except Co-60 radionuclide which gets closer to the Optimum DRL by 90%.

2) Radiation exposures to the residents in the area of interest (Kilchun-Ri, 1.3km to the north of the release point of the KNU-1) were not likely to be occurred in excess of the exposure limits of the EPA applied in this research.

3) The most critical exposure pathway to man seemed to be an external exposure pathway to whole body from the contaminated ground by the radioactive particulates depositing from the plume, and the most critical radionuclide seemed to be Co-60 particle because of its relatively long half-life (271 yr) and high penetrating gamma energies.

4) The order of most to least critical pathway seemed to be the following order.

Pathway B>Pathway D> Pathway C> Pathway A

5) For the released radionuclides the order of most to least critical radionuclides seemed to be the the following order.

Co-60> Cs-137> I-131> I-133> H-3> Kr-87> Xe-135> Xe-133> Xe-133m> Kr-85

REFERENCES

1) News reported in 'Atomic Industry Newspaper', "Atmospheric Releases of Radionuclides," Japanese Atomic Industry Committee (Feb. 7, 1985)
2) 10CFR 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion, As Low As is Reasonably Achievable" for Radioactive Materials in Light-Water-Cooled Power Reactor Effluents," Code of Federal Regulation, USNRC (1975)
3) USNRC Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Release of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50 App. I", USNRC (1977)
4) ICRP publication No. 29, "Radionuclide Release into the Environment: Assessment of Doses to Man," Pergamon Press (1978)
5) J. H. Lee et al., "Studies on the Standardization of the Environmental Monitoring of Nuclear Facilities," KAERI/RR-423/83, Ministry of Science and Technology (1984)
6) Korea Electric Co., "Final Safety Analysis Report for Kori Nuclear Power Plant Unit No. 1," Vol. 1(1975)
7) IAEA Safety Ser., No., 45, "Principles for Establishing Limits for the Releases of Radioactive Materials into the Environments," IAEA, Vienna (1978)
8) J. E. Palmer, "Derived Release Limits for Airborne and Liquid Effluents from the Chalk River Nuclear Laboratories during Normal Operations," AECL-7243, CRNL (1981)
9) D. H. Slade (Ed.), "Meteorology and Atomic Energy," TID-24190, USAEC (1968)

10) J. F. Sagendorf et al., "XOQDOQ: A computer Program for Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations," NUREG/CR-2919, USNRC (1982)

11) Korea Electric Co., "Grand Evaluation of Environmental Radioactivity around Kori Nuclear Power Plant Unit No. 1," KAERI (1980)

12) M. Mills et al., "Parameters and Variables Appearing in Radiological Assessment Codes," Final Report, NUREG/CR-3160, USNRC(1983)

ALARA 槪念에 의한 氣體狀放射性物質의 環境放出限度 設定

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=要約=

濃縮因子法(Concentration Factor Method)을 利用하여 決定被曝經路를 分析한 後 標準原電의 氣體狀放射性大氣放出物에 대한 誘導放出限度(Derived Release Limits, DRL's)를 計算하였다. 이 放出限度는 核施設 周邊의 決定群構成個人에 對한 放射線 被曝을 關聯被曝限度以下로 維持시키는 量이다. 本 研究에서는 1985年 初 美國의 環境保護廳(EPA)에서 새로 勸告한 被曝限度를 採擇하여 計算을 遂行하였다.

誘導放出限度(DRL)의 計算은 美國의 原子力 規制委員會(USNRC)가 規制指針(Reg. Guide) 1.109에서 提示하고 있는 線量評價모델을 標準모델로 使用하여 遂行하였으나, 同 모델의 被曝經路分析에서 牛乳 및 肉類의 攝取經路는 國內의 現實狀 無視可能한 것으로 考慮하여 本 研究에서 除外시켰다.

計算에서 考慮한 放出線源項은 稀有氣體, 요오드, 粒子狀元素 및 三重水素氣體였으며, 放出源에서 北쪽으로 1.3 km 거리에 位置하고 있는 住民永久居住地域을 對象으로 計算을 遂行하였다.

本 研究에서는 標準原電의 對象으로 古里原電 1號機를 選定하여 同原電의 年間放出에 對한 誘導限度를 計算하였으며, 1982年度의 實放出率과 比較・檢討하였다.

檢討結果, 古里原電 1號機의 1982年度의 實放出率은 本 研究에서 求해진 誘導放出限度보다 낮았으며, 放出物에 의한 施設周邊 個人의 年間被曝線量은 EPA에서 勸告하는 被曝限度以下로 維持되었음을 알 수 있었다. 또한 本 研究에서 가장 決定的인 被曝經路는 Co-60와 Cs-137과 같은 粒子狀沈積放射核種으로 汚染된 土壤에 의한 全身外部 被曝經路였다.