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Derived Limits for Radiological Protection Against Ionizing Radiation Based on ICRP-60 Recommendations

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Abstract

In Korea, the dose limits are reduced and are set at the ICRP-60 limits. However, derived limits tabulated as MPC in air and water are still specified in Notice No. 98-12. There are some discrepancies between the primary dose limits and MPCs in air and water. Therefore, in order to accept ICRP-60 recommendations fully, derived limits such as ALI, DAC, ECL for radiological protection against ionizing radiation based on ICRP-60 recommendations were calculated using modified methods of those of 10 CFR part 20, dose limits and committed effective dose coefficients of the Basic Safety Standards of the IAEA. The derived limits in this study were also compared with those prescribed in 10 CFR part 20 as well as MPCs of Notice No. 98-12 in order to analyze the impact of implementing derived limits on nuclear facilities. ECLs in air and water for the control of radioactive discharge into the environment in this study are shown to have lower values (i.e. more conservative), for most part, than those in Notice No. 98-12. Especially, for uranium elements, ECLs in water are approximately a magnitude in the order of two lower than those in Notice No. 98-12.

Key Words : ICRP-60, derived limits, ALI, DAC, effluent concentration limits

1. Introduction

The radiation exposure to individuals resulting from the combination of all of the relevant practices should be subject to dose limits. Dose limits are required as a part of the control of radiation exposure. The protection of workers and general members of the public against taking radioactive materials into the body, however, is accomplished through the use of regulations based on derived limits expressed in terms of quantities or concentrations of radionuclides. These derived limits are applied to the design and operation related to the radiation protection such as radiation monitoring, ventilation systems, and control of radioactive discharge into the environment.

In Korea, the dose limits are specified in the Enforcement Decree Article 2 of the Korean Atomic Energy Law promulgated on 31 August

1999 [1]. In the Article 2, the dose limits are reduced according to the International Commission on Radiological Protection (ICRP-60) recommendations [2]. However, a preparation period is necessary to accommodate and to minimize the possible impact of the lower occupational dose limit. Therefore, as an interim measure, the dose limit for the worker is applied at twice the ICRP-60 limit for a 5-year period in effective dose, until the end of 2002. With regard to the dose limit for the public in Korea, the Article 2 specifies the effective dose limit at 1mSv in a year.

However, derived limits of ICRP-2 [3] and ICRP-6 [4] tabulated as the Maximum Permissible Concentration (MPC) in air and water are still specified in Notice No. 98-12. Since these derived limits are based on dose limits of ICRP-9 [5], there are some discrepancies between the dose limits stated in the Article 2 as primary limits and the dose limits applied in deriving MPCs in air and water. Therefore, in order to fully accept ICRP-60 recommendations, it is necessary to reflect derived limits such as the Annual Limit on Intake (ALI), the Derived Air Concentration (DAC) and the Effluent Concentration Limit (ECL) in air and water based on dose limits of ICRP-60 into Notice No. 98-12 [6].

In this study, derived limits such as ALI, DAC and ECL for radiological protection against ionizing radiation based on ICRP-60 recommendations were calculated using modified methods of those of 10 CFR part 20, dose limits in the Article 2 and committed effective dose coefficients of the Basic Safety Standards of the International Atomic Energy Agency (IAEA BSS-96) [7]. The derived limits calculated from this study were, in addition, compared with those prescribed in 10 CFR part 20 [8][9] as well as MPCs of Notice No. 98-12 in order to analyze the impact of their applications on nuclear facilities.

2. Calculation Method

2.1. Derived Limits for the Worker

ALIs and DACs, which are applicable to occupational exposure to radioactive material, were derived using dose coefficients in BSS-96, methodologies of the ICRP-61 report [10] and dose limit stated in the ICRP-60 report. The age group considered in this study is "Reference Man", which is stated in ICRP-23 report [11] for the occupational exposure. The ALI is the annual limit of intake of a given radionuclide by "Reference Man", which would result in a committed effective dose of 20mSv/yr. Spending 40 hours a week for 50 weeks a year in an atmosphere with 1 DAC, the DAC leads to a committed effective dose of 20mSv/yr.

Since dose coefficients in BSS-96 are presented for radionuclides inhaled in particulate, gas and vapor form, these physico-chemical forms were considered to calculate derived limits for the radionuclides. For radionuclides in particulate form, it is assumed that the default value of particle size is 5μm Activity Median Aerodynamic Diameter (AMAD), which is considered to be more representative of workplace aerosols than 1 μm default value adopted in ICRP-30 [12] and 10 CFR part 20. In this study, ALI and DAC are calculated using methods recommended in ICRP-61 as:

- ALI (inhalation and oral ingestion respectively)

$$ALI(Bq) = \frac{E(0.02Sv)}{e_{worker}(Sv/Bq)} \tag{1}$$

- DAC

$$DAC(Bq/m^3) = \frac{ALI(Bq)}{R(1.2m^3/hr) \times 2000hr} \tag{2}$$

where E is the committed effective dose limit,

e_{worker} is the dose coefficient for the worker given in BSS-96, R is the volume of air breathed per hour at work by Reference Man under light-work condition, and 2000hr is working hours per year.

Especially, it is known that H-3 in tritiated water form is absorbed into the body through inhalation and skin absorption, in the case of an exposure to the atmosphere contaminated by H-3 [8]. The absorption through intact skin, in this study, was considered in the calculation of DAC for H-3 in tritated water form.

For decay products of radon (Rn-222, Rn-220), dose calculation is particularly difficult. As this reason, a separate limit expressed in terms of Working-Level Month (WLM) is usually recommended by the ICRP and IAEA. Primary limits are 4 WLM for Rn-222 and 12 WLM for Rn-220, which are recommended by ICRP-65 [13] and BSS-96. Although derived limits for radon and its decay products are calculated using methodologies of ICRP-32 [14], their potential α-energy intakes in this study were replaced with values of BSS-96 rather than those of ICRP-32 to incorporate the updated IAEA recommendations on the radon matters.

2.2. Derived Limits for the Public

Dose limit, dose coefficients for the public stated in BSS-96, and age-dependent inhalation and water-intake rates recommended by the ICRP were considered in deriving ECLs in air and water for the control of radioactive discharge into the environment. Three cases of methodologies for deriving ECL were considered.

- **Case 1**

Age-dependent concentration limits in air and water were derived by using age-dependent inhalation and water-intake rates, and dose coefficients for the public stated in ICRP reports and BSS-96 respectively. After that, the most conservative value of age-dependent concentration limits was taken as ECL in air and water.

- **Case 2**

Concentration limit for the adult in case 1 was temporarily selected as an occupational derived limit. After that, ECL was derived by dividing it by a factor of 2. The factor of 2 adjusts the occupational value so that it is applicable to other age groups.

- **Case 3**

Methodologies used in this case are similar to those in 10 CFR part 20. In this study, ECL in air, however, was derived by calculating occupational DAC (based on 1μm and 5μm AMAD for particulate form) temporarily and dividing it by a factor of 20, factor of 3, and factor of 2 adopted in 10 CFR part 20. The factor of 20 relates the 20mSv/yr annual occupational dose limit to the 1mSv/yr limit for members of the public, the factor of 3 adjusts for the difference in exposure time and the inhalation rate between workers and members of the public, and the factor of 2 adjusts the occupational values so that ECLs are applicable to other age groups.

ECL in water was derived by taking occupational oral ingestion ALI and dividing it by a factor of 20, factor of 2, and annual water-intake of Reference Man (i.e. 0.73 m^3/yr). The factors of 20 and 2 are explained above.

For those radionuclides (i.e. noble gases) for which submersion is limiting, ECL was derived by taking the occupational DAC and dividing it by a factor of 20 and a factor of 4.38. The factor of 20 is explained above and the factor of 4.38 relates occupational exposure for 2000 hours per year to 8760 hours per year.

Table 1. Comparison of Results by Application of Different Methodologies for ECL_{air}

(unit : Bq/m^3)

Radionuclide	Absorption Class	Case 1	Case 2	Case 3	
				1㎛	5㎛
Co-60	F	4[1)] 2×10^{1}	1×10^{1}	-	-
	M	5 1×10^{1}	6×10^{0}	7×10^{0}	1×10^{1}
	S	6 4×10^{0}	2×10^{0}	2×10^{0}	4×10^{0}
I-131	F	2 7×10^{0}	8×10^{0}	9×10^{0}	6×10^{0}
	M	2 4×10^{1}	3×10^{1}	-	-
	S	5 7×10^{1}	4×10^{1}	-	-
	Elemental	2 3×10^{0}	3×10^{0}	3×10^{0}	3×10^{0}
	Methyl	2 4×10^{0}	4×10^{0}	5×10^{0}	5×10^{0}
Cs-137	F	6 3×10^{1}	1×10^{1}	1×10^{1}	1×10^{1}
	M	5 1×10^{1}	6×10^{0}	-	-
	S	6 3×10^{0}	2×10^{0}	-	-
U-235	F	5 2×10^{-1}	1×10^{-1}	1×10^{-1}	1×10^{-1}
	M	5 4×10^{-2}	2×10^{-2}	2×10^{-2}	4×10^{-1}
	S	6 1×10^{-2}	7×10^{-3}	9×10^{-3}	1×10^{-2}

Note 1:denote the age group, which has the lowest ECL_{air}
age group 1: 3 month, age group 2: 1 year, age group 3: 5 years
age group 4: 10 years, age group 5: 15 years, age group 6: adult

2.3. Selection of Methodologies of the Derived Limits for the Public

With regard to ECLs for all mentioned cases above, there are no general trends in magnitude, which can be generally applicable to 764 radionuclides considered in this study. These arise from the dependencies of ECLs on chemical forms of compounds and age-dependent dose coefficients.

ECL_{air} values of three cases considered in this study are shown in Table 1. In case 1, since dose coefficients for 6 age groups are stated in BSS-96, inhalation and water-intake rates for each age group are required to calculate age-dependent concentration limits. It is possible to derive age-dependent concentration limits in air using inhalation rates for 6 age groups stated in ICRP-66 [15], while concentration limits in water are limited to values for 10 years old and adult because ICRP-23 provides water-intake rates only for both age groups.

Although ECLs of case 1 can be appropriate in the viewpoint of conceptual affinity to the public and have less restrictive values in magnitude than those of case 2 and case 3, ECLs in water are limited to values for 10 years old and adult as explained above and there is no detailed information on the chemical forms related to each absorption class of radionuclide. Furthermore, absorption classes of a given radionuclide for a worker are, in general, not identical to those for the public so that it is difficult to incorporate all data into the same table as shown in MPC tables of the Notice No. 98-12 of MOST. Case 2 also has the same limitations as case 1 in terms of chemical forms and absorption classes.

Thus, case 3 based on particle size of 1㎛

AMAD was selected in this study to calculate ECLs in air and water because this is already applied for deriving ECLs in other countries and can compensate the uncertainties in parameters by reflecting an additional factor for age-dependency. For radionuclides in particulate form, 1μm AMAD was considered for calculating ECLs, since this is more representative of environmental aerosols than 5μm AMAD and is recommended by ICRP-66. It is also possible to incorporate all data for derived limits of the worker and the public into the same table.

ECLs in air and water in this study are calculated using case 3 method as:

- ECL in air (ECL_{air}; excluding noble gases)

$$ECL_{air}(Bq/m^3) = \frac{DAC(Bq/m^3)}{20\times 3\times 2} \quad (3)$$

where DAC is the derived limit (based on 1μm AMAD for particulate form) intended to control occupational exposure, a factor of 20 relates the 20 mSv annual occupational dose limit to the 1 mSv limit for members of the public, a factor of 3 adjusts for the difference in exposure time and the inhalation rate for a worker and that for members of the public, and a factor of 2 adjusts the occupational values so that they are applicable to other age groups.

- ECL in air (ECL_{air}; for noble gases)

$$ECL_{air}(Bq/m^3) = \frac{DAC(Bq/m^3)}{20\times 4.38} \quad (4)$$

where DAC and a factor of 20 are explained above, and a factor of 4.38 relates occupational exposure for 2000 hours per year to 8760 hours per year.

- ECL in water (ECL_{water})

$$ECL_{water}(Bq/m^3) = \frac{ALI(Bq)}{R(0.73m^3/yr)\times 20\times 2} \quad (5)$$

where ALI is for occupational oral ingestion, the factors of 20 and 2 are explained above, and R is the annual water-intake of Reference Man.

3. Results and Discussion

The derived limits obtained from this study were compared with those prescribed in 10 CFR part 20 as well as MPCs of Notice No. 98-12 in order to analyze the impact of implementing derived limits on nuclear facilities. Systematic comparisons are not made easily because the chemical forms of inhaled compounds used in this study (i.e. F: Fast, M: Moderate, S: Slow; based on the ICRP-66 and classified by the absorption rate of the radioactive material deposited in lung into the blood) are characterized in a different manner than those used in MPCs (i.e. soluble, insoluble) and 10 CFR part 20 (i.e. D: Day, W: Week, Y: Year; based on the ICRP-30 and classified by the clearance rate of the radioactive material deposited in lung into the blood and the gastro-intestine). Thus, for making these comparisons, the following was considered:

- The derived limits of Notice No. 98-12 based on ICRP-2 and ICRP-6 are tabulated as MPCs in air and water. The derived limits of 10 CFR part 20 and this study, which are based on ICRP-30 and ICRP-66 respectively, are tabulated as ALIs, DACs, and ECLs in air and water. In this study, DACs were compared with MPCs in air, although there are some differences in concept.
- For the inhalation exposure, the MPCs in air for soluble forms were compared with the DACs for compounds of clearance class "D" or "F". In the cases where no DAC was calculated for class "D" or "F", then the comparison was made with the DAC of class "W" or "M". It is considered inappropriate to compare soluble forms with class "Y" or "S" compounds because the MPCs for the insoluble forms were

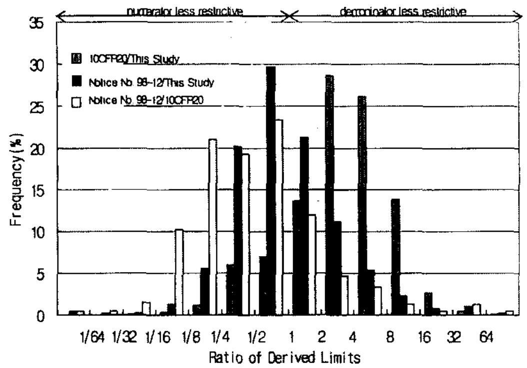

Fig. 1. Comparisons of DACs for Occupational Exposure Through Inhalation

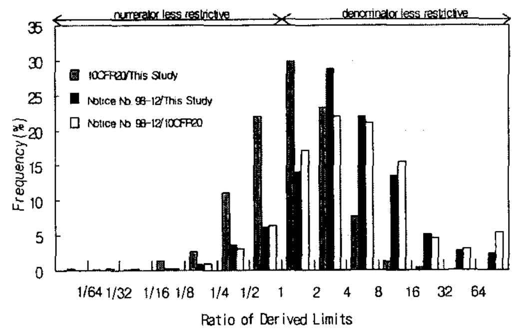

Fig. 2. Comparisons of ECLs (5μm AMAD for Particulate From) Through Inhalation

compared with the DACs of class "Y" or "S" compounds. If no DAC was calculated for class "Y" or "S" compounds, then the comparison was made with the DAC of class "W" or "M" compounds, unless a class "W" or "M" compound had already been compared to the soluble compound.

- For the ingestion exposure, comparison of MPC in water with oral ingestion ALI can not made directly, so that MPC in water was converted into an ALI-equivalent quantity using the annual water-intake rate of Reference Man. It was assumed that a worker ingests 1.1 liters of contaminated water each day. Thus, the oral ingestion ALI was made equal to an intake of : 50weeks/year $\times$ 5days/week $\times$ 1100cm^3/day $\times$ MPC. If a radionuclide is assigned to a single gut-transfer factor (f1), then the ALI in 10 CFR part 20 and this study was compared with the MPC for soluble compounds. If a radionuclide is assigned to two gut-transfer factors (f1), then the ALI for the higher value of f1 was compared with the MPC for the soluble and insoluble form, respectively.

3.1. Comparison Results of Inhalation Pathway

Comparisons were made of derived limits of this study and 10 CFR part 20 as well as those of Notice No. 98-12 for 764 radionuclides. The solid histograms as shown in Figures 1, 2 and 3 show the relative numbers of cases in which the derived limits obtained from this study are different from those of 10 CFR part 20 and Notice No. 98-12.

With regard to occupational exposure, DACs in this study show lower values (i.e. more conservative) for about 80 % of the cases than those in 10 CFR part 20. It is attributable primarily to the reduction of dose limit from 50mSv/yr to 20mSv/yr (ICRP-26 vs. ICRP-60), and secondarily to improved respiratory-tract and metabolic modeling, and physiologic data (ICRP-30 vs. ICRP-66). DACs in this study are, however, shown to have larger values (i.e. less conservative) for about 55 % of the cases than MPCs in Notice No. 98-12. In spite of the reduction of dose limit, DACs in this study are higher than those in the Notice No. 98-12. These are because the reduced dose limit from 50mSv/yr to 20mSv/yr is compensated by the improved respiratory-tract and metabolic modeling, and physiologic data (ICRP-2 vs. ICRP-66).

ECLs of this study based on 5μm AMAD are shown to have lower values (i.e. more conservative) for about 60 % of the cases than those in 10 CFR part 20. There are not large differences between this study and 10 CFR part

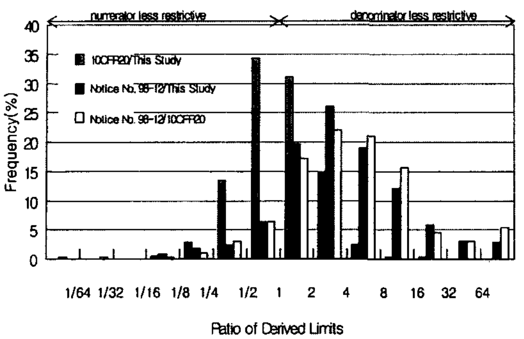

Fig. 3. Comparisons of ECLs (1μm AMAD for Particulate From) Through Inhalation

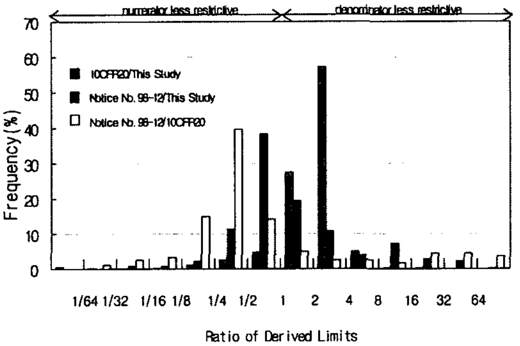

Fig. 4. Comparisons of ALIs for Occupational Exposure Through Ingestion

20. ECLs in this study, however, are shown to have lower values (i.e. more conservative) for about 90 % of the cases than MPCs in Notice No. 98-12. In comparison of this study and Notice No. 98-12, these differences are attributable primarily to the adoption of a weighting factor (i.e. factor of 2) for age-dependency in dose coefficients. ECLs based on particle size of 5μm AMAD are more restrictive than those of 1μm AMAD because particle size of 5μm AMAD results in higher lung retention of inhaled radionuclides than that of 1μm AMAD. Thus, as shown in Figure 3, solid histograms based on 1μm AMAD are shown to be more shifted to the left side (i.e. less conservative) for the most part than those based on 5μm AMAD.

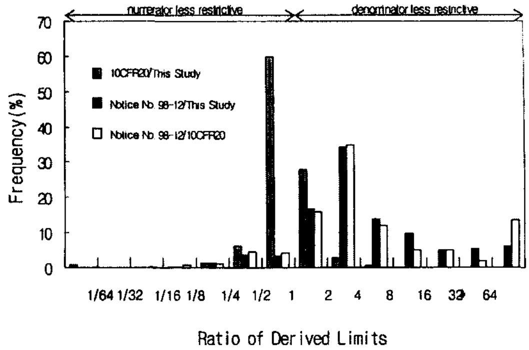

Fig. 5. Comparisons of ECLs Through Ingestion

3.2. Comparison of Ingestion Pathway

Comparisons were made of derived limits in water of this study and 10 CFR part 20 as well as those of Notice No. 98-12 for 764 radionuclides. Figures 4 and 5 show the relative numbers of cases in which the derived limits obtained from this study are different from those of 10 CFR part 20 and Notice No. 98-12.

With regard to occupational exposure, ALIs in this study are shown to have lower values (i.e. more conservative) for about 80 % of the cases than those in 10 CFR part 20. These differences are originated from the reduction of dose limit from 50mSv/yr to 20mSv/yr since the gastro-intestinal model recommended by ICRP-30 is applied to both this study and 10 CFR part 20. ALIs in this study are shown to have lower values (i.e. more conservative) for about 40 % of the cases than ALI-equivalent quantities based on Notice No. 98-12. These differences are attributable primarily to the reduction of dose limit from 50 mSv to 20mSv and secondarily to improved metabolic modeling and physiologic data (ICRP-2 vs. ICRP-30).

ECLs in this study are shown to have similar values (the both values differ by a factor of 2) for

Table 2. Comparison of Derived Limits for Important Radionuclides Through Inhalation

Nuclide	This Study				10 CFR part 20				NOTICE No. 98-12			Ratio in Occupational Exposure			Ratio in ECLs in Air		
	Chemical Form	ALI (μCi)	DAC (μCi/cc)	ECL in Air (μCi/cc)	Chemical Form	ALI (μCi)	DAC (μCi/cc)	ECL in Air (μCi/cc)	Chemical Form	MPC for Worker (μCi/cc)	MPC for Public (μCi/cc)	10CFR20 /This Study	NOTICE No.98-12/This Study	NOTICE No.98-12/10CFR20	10CFR20 /This Study	NOTICE No.98-12/This Study	NOTICE No.98-12/10CFR20
H-3	G, HTO	3E+04	8E-06	7E-08	G, HTO	8E+04	2E-05	1E-07	S	1E-05	4E-07	2.5	1.3	0.5	1.3	5.0	4.0
	G, OBT	1E+04	5E-06	5E-08	-	-	-	-	-	-	-	-	-	-	-	-	-
	G, Elemental	3E+08	1E-01	1E-03	-	-	-	-	-	-	-	-	-	-	-	-	-
	G, Methane	3E+06	1E-03	1E-05	-	-	-	-	-	-	-	-	-	-	-	-	-
C-14	G, Vapor	9E+02	4E-07	3E-09	-	-	-	-	S	4E-06	1E-07	-	10.0	-	-	33.0	-
	G, CO_2	9E+04	4E-05	3E-07	G, CO_2	2E+05	9E-05	3E-07	Submersion	5E-05	1E-06	2.3	1.3	0.6	1.0	3.3	3.3
	G, CO	7E+05	3E-04	2E-06	G, CO	2E+06	7E-04	2E-06	-	-	-	2.3	-	-	1.0	-	-
Fe-59	F	2E+02	8E-08	9E-10	D	3E+02	1E-07	5E-10	S	1E-07	5E-09	1.3	1.3	1.0	0.6	5.6	10.0
	M	2E+02	7E-08	5E-10	W	5E+02	2E-07	7E-10	I	5E-08	2E-09	2.9	0.7	0.3	1.4	4.0	2.9
Co-60	M	8E+01	3E-08	2E-10	W	2E+02	7E-08	2E-10	S	3E-07	1E-08	2.3	10.0	4.3	1.0	50.0	50.0
	S	3E+01	1E-08	6E-11	Y	3E+01	1E-08	5E-11	I	9E-09	3E-10	1.0	0.9	0.9	0.8	5.0	6.0
Xe-133	Noble Gas	-	5E-05	6E-07	Noble Gas	-	1E-04	5E-07	Noble Gas	1E-05	3E-07	2.0	0.2	0.1	0.8	0.5	0.6
I-131	F	5E+01	2E-08	2E-10	D	5E+01	2E-08	2E-10	S	9E-09	1E-10	1.0	0.5	0.5	1.0	0.5	0.5
	G, Elemental	3E+01	1E-08	9E-11	-	-	-	-	-	-	-	-	-	-	-	-	-
	G, Methyl	4E+01	2E-08	1E-10	-	-	-	-	-	-	-	-	-	-	-	-	-
U-235	F	9E-01	4E-10	4E-12	D	1E+00	6E-10	3E-12	S	5E-10	2E-11	1.5	1.3	0.8	0.8	5.0	6.7
	M	3E-01	1E-10	7E-13	W	8E-01	3E-10	1E-12	-	-	-	3.0	-	-	1.4	-	-
	S	9E-02	4E-11	2E-13	Y	4E-02	2E-11	6E-14	I	1E-10	4E-12	0.5	2.5	5.0	0.3	20.0	67.0
U-238	F	9E-01	4E-10	4E-12	D	1E+00	6E-10	3E-12	S	7E-11	3E-12	1.5	0.2	0.1	0.8	0.8	1.0
	M	3E-01	1E-10	7E-13	W	8E-01	3E-10	1E-12	-	-	-	3.0	-	-	1.4	-	-
	S	9E-02	4E-11	3E-13	Y	4E-02	2E-11	6E-14	I	1E-10	5E-12	0.5	2.5	5.0	0.2	17.0	83.0

Table 3. Comparison of Derived Limits for Important Radionuclides through Ingestion

Nuclide	This Study			10 CFR part 20			NOTICE No. 98-12				Ratio in Occupational Exposure			Ratio in ECLs in Water		
	Chemical Form	ALI (μCi)	ECL in Water (μCi/cc)	Chemical Form	ALI (μCi)	ECL in Water (μCi/cc)	Chemical Form	MPC for Worker (μCi/cc)	MPC for Public (μCi/cc)	ALI-Equivalent (μCi)	10CFR20 /This Study	NOTICE No.98-12/This Study	NOTICE No.98-12/10CFR20	10CFR 20/This Study	NOTICE No.98-12/This Study	NOTICE No.98-12/10CFR20
H-3	HTO	3E+04	1E-03	HTO	8E+04	1E-03	S	2E-01	6E-03	6E+04	2.7	2.0	0.8	1.0	6.0	6.0
	OBT	1E+04	4E-04	-	-	-	-	-	-	-	-	-	-	-	-	-
C-14	Organic Compound	9E+02	3E-05	Organic Compound	2E+03	3E-05	S	2E-02	8E-04	6E+03	2.2	6.7	3.0	1.0	26.7	26.7
Fe-59	All Compounds	3E+02	1E-05	D	8E+02	1E-05	I	2E-03	5E-05	6E+02	2.7	2.0	0.8	1.0	5.0	5.0
Co-60	Other Compounds	2E+02	5E-06	W	5E+02	3E-06	S	1E-03	5E-05	3E+02	2.5	1.5	0.6	0.6	10.0	16.6
	Oxide Hydroxide, Inorganic Compounds	2E+02	7E-06	Y	2E+02	3E-06	I	1E-03	3E-05	3E+02	1.0	1.5	1.5	0.4	4.3	10.0
I-131	All Compounds	2E+01	8E-07	D	3E+01	1E-06	S	6E-05	3E-07	2E+01	1.5	1.0	0.7	1.3	0.4	0.3
U-235	Other Compounds	1E+01	4E-07	D	1E+01	3E-07	S	8E-04	3E-05	2E+02	1.0	20.0	20.0	0.8	75.0	100.0
	Tetravalent Compounds	7E+01	2E-06	-	-	-	I	8E-04	3E-05	2E+02	-	2.9	-	-	15.0	-
U-238	Other Compounds	1E+01	4E-07	D	1E+01	3E-07	S	1E-03	4E-05	3E+02	1.0	30.0	30.0	0.8	100.0	133.3
	Tetravalent Compounds	7E+01	2E-06	W	-	-	I	1E-03	4E-05	3E+02	-	4.3	-	-	20.0	-

the most part than those in 10 CFR part 20 since the same dose limit and gastro-intestinal model are applied to this study and 10 CFR part 20. ECLs in this study are shown to have lower values (i.e. more conservative) for the most part than MPCs in Notice No. 98-12. Since the reduction of dose limit from 5mSv/yr to 1mSy/yr compensates the improved metabolic modeling and physiologic data (ICRP-2 vs. ICRP-30), these differences are primarily attributable to the adoption of a weighting factor (factor of 2) for age-dependency.

3.3. Comparisons for Some Important Radionuclides

Derived limits for commonly encountered radionuclides in nuclear facilities are shown in Tables 2 and 3. ECLs in water for uranium elements (i.e., ^{235}U, ^{238}U, etc.), which are governing ones in the nuclear fuel industries, are approximately a magnitude in the order of two lower than those in Notice No. 98-12. It is originated from the adoption of a weighting factor (factor of 2) for age-dependency in dose coefficients, newly recommended dose coefficients (ICRP-2 vs. ICRP-30) for ingestion pathway and reduction of dose limit from 5mSv/yr to 1mSv/yr. It was found out that the differences in ECLs in water for uranium elements originate mostly from ingestion dose coefficients recommended by BSS-96. If derived limits obtained from this study are implemented into regulations, then nuclear facilities, especially nuclear fuel-cycle facilities, should be controlled more tightly radioactive discharge into the environment. Accordingly, alarm-set level for the effluent monitor should be reduced to comply with ECLs in this study.

For the occupational exposure, derived limits obtained from this study are shown to be lower values (i.e., more conservative) for the most part than those in 10 CFR part 20. These differences are attributable primarily to the reduction of the dose limit from 50mSv/yr to 20mSv/yr. However, DACs in this study are shown to be comparable to MPCs in Notice No. 98-12. Thus, additional cost for maintaining occupational exposure as low as reasonably achievable (ALARA) is not necessary.

4. Conclusions

Derived limits for radiological protection against ionizing radiation based on ICRP-60 recommendations were derived. The derived limits calculated from this study were compared with those prescribed in 10 CFR part 20 as well as MPCs of Notice No. 98-12 in order to analyze the impact of implementing derived limits on nuclear facilities. According to the comparison results, ECLs in air and water for the effluent control to the environment in this study are shown to have lower values (i.e. more conservative) for the most part than those in Notice No. 98-12. These differences are mainly due to the adoption of a weighting factor (factor of 2) for age-dependency in dose coefficients since the new respiratory tract model and bio-kinetic model compensate the reduction of dose limit from 5mSv/yr to 1mSv/yr. Especially, for uranium elements (i.e., ^{235}U, ^{238}U, etc.), which are governing ones in the nuclear fuel industries, ECLs in water are approximately a magnitude in the order of two lower than those in Notice No. 98-12. Thus, if derived limits calculated from this study are implemented into regulations, then nuclear facilities, especially nuclear fuel-cycle facilities, should be controlled more tightly radioactive discharge into the environment. Accordingly, alarm-set level for the effluent monitor should be reduced to comply with ECLs in this study. For the occupational exposure, derived limits calculated from this study are shown to be comparable to MPCs in Notice No. 98-12.

Therefore, additional cost for maintaining occupational exposure ALARA is not necessary.

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