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Comparative Study of Dose Evaluation of Liquid Effluent in Nuclear Power Plants for Radiological Impact on the Environment Review

Seokju Hwang*, Si-Young Kim, Deuk-Man Kim, Young Hwan Hwang, and Jungkwon Son
Central Research Institute, Korea Hydro & Nuclear Power Co., Ltd., 70, Yuseong-daero 1312beon-gil, Yuseong-gu, Daejeon 34101, Republic of Korea

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Currently, off-site dose calculations for nuclear power plants are conducted using a computer program (K-DOSE 60). The program is developed based on the regulatory guidelines of the Korea Institute of Nuclear Safety (KINS), which is a domestic nuclear regulatory agency. In this study, a domestic application of the International Atomic Energy Agency (IAEA) TRS (Technical Reports Series)-472 methodology for ^{3}H and ^{14}C in liquid effluents was studied. The dose-evaluation methods adopted and the program configuration for dose evaluation are described based on ^{3}H and ^{14}C in the liquid-effluent-evaluation module of the computer program. The accuracy of the program is verified by comparing the program-calculated results with hand calculation values. Furthermore, a comparative evaluation with LADTAP II, which is a liquid-effluent-evaluation methodology developed by the U.S. NRC (Nuclear Regulatory Commission), is performed. The result confirms that the program-calculated results for the IAEA TRS-472 methodology are consistent with the hand calculation values. Meanwhile, the result of comparative evaluation with LADTAP II indicates different results depending on the methodology used.

Keywords: Liquid effluent, IAEA TRS-472, Off-site dose calculation (ODC), Tritium, ^{14}C

*Corresponding Author.
Seokju Hwang, Central Research Institute, Korea Hydro & Nuclear Power Co., Ltd., E-mail: hsjhhhhh@khnp.co.kr, Tel: +82-42-870-5577

ORCID

Seokju Hwang	http://orcid.org/0000-0001-5428-6217	Si-Young Kim	http://orcid.org/0000-0001-9656-7172
Deuk-Man Kim	http://orcid.org/0009-0005-9144-2633	Young Hwan Hwang	http://orcid.org/0000-0002-6627-4763
Jungkwon Son	http://orcid.org/0009-0009-2058-692X		

1. Introduction

In 1990s, the International Commission on Radiological Protection (ICRP) provided radiation protection recommendations through ICRP Publication 60, and the International Atomic Energy Agency (IAEA) published the Basic Safety Standards (IAEA Safety Series 115), based on the content of ICRP-60 to be used as a foundation for radiation protection regulations in various countries [1]. Korea also enacted the ICRP-60 radiation protection standards through government notification [3]. As a follow-up measure, the Korea Institute of Nuclear Safety (KINS) has presented guidelines for the off-site dose calculation near nuclear facilities and modified certain parts of the dose calculation methodologies by considering the domestic environmental characteristics apart from ICRP-60 [4]. The IAEA published the "Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments (TRS-472)" in 2010, which provides evaluation models and input parameter values for ^{3}H and ^{14}C [2].

Dose evaluation due to liquid effluent is divided into external exposure, which includes activities such as swimming, activities on sea-shoreline and boating, and internal exposure through the ingestion of seafood. Both external exposure and internal exposure doses are calculated by multiplying the radioactive concentration in environmental media by the dose conversion factors specific to tissues and organs per each unit concentration. ICRP-60 suggests the guideline to evaluate the impact of radioactive material on 12 main organs and 10 other tissues. The organs are the gonads, bone marrow (red), colon, lung, stomach, bladder, breast, liver, oesophagus, thyroid, skin and bone surface. For these organs, the ICRP-60 adds weighting factors for individual tissues and organs [1]. For internal exposure, radioactive materials can accumulate in the body over a long time and continue to cause exposure even after one year has passed. Therefore, ICRP-60 stipulates assessing the committed dose up to the age of 70 for each age group. That means the evaluation period shall be 50 years for adults and 70 years for infants [1]. The behavior of radioactive nuclides in the human body varies depending on the chemical form. Therefore, different dose conversion factors are applied depending on the type of nuclide. In other words, even for the same nuclide, the dose conversion factors vary depending on the chemical form of the nuclide. For example, in the case of ^{3}H, the dose is evaluated by distinguishing its chemical forms as Tritiated Water (HTO) and Organically Bound Tritium (OBT) for ingestion cases [5].

This study compared and evaluated the doses of ^{3}H and ^{14}C in liquid effluent due to seafood ingestion through the domestic nuclear power plant (NPP) off-site dose calculation computer program (K-DOSE 60) applying the IAEA TRS-472 methodology. Furthermore, this study explained the dose calculation methodology and program configuration for the calculation of dose from seafood ingestion due to liquid effluent in the mentioned computer program. In addition, as the calculated results from the program were compared with hand calculation and the results from LADTAP II of the U.S. NRC. Also, the reliability of the program was demonstrated.

2. Off-site Dose Calculation Method Caused by Liquid Effluent

The main contents of the ICRP-60 radiation protection framework include the exposure age groups, the concept of dose, and the system of nuclides and dose conversion factors. This study describes the application of the KINS regulatory guidelines (KINS/RG-N02.02), which are used to evaluated off-site doses in existing domestic nuclear power plants and dose calculation formulas outlined in the IAEA TRS-472.

2.1 Exposure Age Groups

We applied the exposure age groups based on the six representative age groups presented in the IAEA Safety

Series 115 on radiation protection of the IAEA, as follows.

- 3 months: Population group consisting of newborns ~ less than 1 year old
- 1 year: Population group consisting of aged 1 ~ less than 2 years old
- 5 years: Population group consisting of aged 2 ~ less than 7 years old
- 10 years: Population group consisting of aged 7 ~ less than 12 years old
- 15 years: Population group consisting of aged 12~ less than 17 years old
- Adult: Population group consisting of aged 17 years and above

2.2 Ingestion Dose Conversion Factor

Dose conversion factors are broadly divided into external exposure dose conversion factor and internal exposure dose conversion factor. As ^{3}H and ^{14}C, which are the subject of verification in this study, influence on ingestion-related internal exposure, we applied the internal exposure dose conversion factor as follows.

We applied the dose conversion factors caused by intake according to the six age groups recommended in ICRP-67, 69 and ICRP-72. However, ICRP-67 and 69 presents dose conversion factors for only certain nuclides and ICRP-72 provides effective dose conversion factors only [9, 10, 11]. Therefore, we decided to use the values for other radionuclides and organs from database of dose coefficient of ICRP in 1999 [12].

2.3 Dose Evaluation Methodology

The existing code applied the liquid effluent evaluation methodology of the KINS regulatory guidelines based on the U.S. Reg. guide 1.109. The dose evaluation methodology is as shown in Eq. (1). Calculate the concentration in seawater through the emissions of nuclides, dilution water discharge rate, dilution factor, re-accumulation factor, and decay constant. The radioactivity concentration of seafood is calculated using the calculated seawater concentration and bioaccumulation factor. Finally, the dose from seafood ingestion is evaluated based on the radioactivity concentration of seafood and annual ingestion.

$$R_{apj} = 1.12\times10^{9}\,\frac{M_p\,U_{ap}}{Q_r}\sum_i q_i R_i B_{ip} D_{aipj}\exp(-\lambda_i t_p) \quad (1)$$

where, R_{apj} Exposure dose from ingestion of sea food ($\mu Sv\cdot y^{-1}$)

M_P Mixing factor at evaluation point (Reciprocal of dilution factor)

U_{ap} Seafood ingestion ($kg\cdot y^{-1}$)

Q_r Dilution water discharge rate ($ft^{3}\cdot sec^{-1}$)

q_i Emission rate of radionuclide i ($TBq\cdot y^{-1}$)

R_i Re-accumulation factor of radionuclide i

B_{ip} Bioaccumulation factor ($L\cdot kg^{-1}$)

D_{aipj} Ingestion dose conversion factor ($Sv\cdot Bq^{-1}$)

λ_i Decay constant of radionuclides (h^{-1})

t_p Radioactive material transport time (h)

The changed parts of ^{3}H and ^{14}C evaluation in this study are as follows.

2.3.1 Dose Evaluation by ^{3}H

For the dose evaluation by ^{3}H, the existing codes calculate the ^{3}H concentration by applying aquatic bioaccumulation factors based on the liquid effluent. However, the IAEA TRS-472 suggests assessing the concentration of tritiated water (HTO) in seafood using the moisture content of the products and assessing the organically bound tritium (OBT) by considering the water equivalent factor of the excluding moisture and partition factor.

The dose evaluation methodology proposed by the KINS and LADTAP II dose evaluation methodology provides calculation methods for HTO only, but IAEA TRS-472 was reflected in the program so that OBT generated in seafood could also be evaluated.

2.3.1.1 Evaluation of HTO Concentration From Ingestion of Seafood

The dose evaluation methodology in this program utilizes the fractional water content of animals and plants (WC_f) for HTO evaluation.

$$C_{ffw}^{HTO} = WC_f C_w \tag{2}$$

where, C_{ffw}^{HTO} HTO concentration in the fresh weight aquatic animals and plants (Bq·kg-fresh weight^{-1})
WC_f fractional water content of the aquatic animals and plants (L·kg-fresh^{-1})
C_w HTO concentration in the water (Bq·L^{-1})

2.3.1.2 Evaluation of OBT Concentration From Ingestion of Seafood

The dose evaluates OBT by considering the dry weight (excluding moisture) using the water equivalent factor of animals and plants (WEQ_f) and the partition factor (R_f).

$$C_{ffw}^{OBT} = (1 - WC_f) WEQ_f R_f C_w \tag{3}$$

where, C_{ffw}^{OBT} OBT concentration in the fresh weight aquatic animals and plants (Bq·kg-fresh weight^{-1})
WEQ_f water equivalent factor of the aquatic animals and plants (L·kg-dry weight^{-1})
R_f partition factor

2.3.1.3 Evaluation of ^{3}H Concentration From Ingestion of Seafood

The dose evaluation due to ^{3}H is evaluated by summing the contributions from HTO and OBT according to Eq. (4).

$$C_{ffw}^{Total} = C_{ffw}^{HTO} + C_{ffw}^{OBT} \tag{4}$$

2.3.2 Dose Evaluation by ^{14}C

The existing program calculates ^{14}C concentration by applying aquatic bioaccumulation factors for each seafood based on liquid effluents like the dose calculation methodology presented in the regulatory guidelines of the KINS. However, the IAEA TRS-472 assumes that the concentration of ^{14}C in seafood is in equilibrium with the concentration in the seawater.

2.3.2.1 Evaluation of ^{14}C Concentration From Ingestion of Seafood

They present a ratio-radioactivity model, presents in Eqs. (5) and (6), to evaluate the ^{14}C concentration in the seafood from the stable carbon concentration in the products, using the ratio of ^{14}C concentration in seawater and the stable carbon concentration.

$$C_{ffw} = C_{DIC} S_f \tag{5}$$

where, C_{ffw} ^{14}C concentration in fresh weight aquatic animals and plants (Bq·kg-fresh^{-1})
C_{DIC} ^{14}C concentration in dissolved inorganic carbon in the water (Bq·gC^{-1})
S_f the concentration of stable carbon in the aquatic animals and plants (gC·kg-fresh^{-1})

$$C_{DIC} = C_w / C_s \tag{6}$$

where, C_w ^{14}C concentration in the water (Bq·L^{-1})
C_s Stable carbon in the water (gC·L^{-1})

2.4 Exposure Pathway of Liquid Effluent

In the liquid effluent evaluation program, developed based on the U.S. NRC Reg. guide 1.109, the pathway of exposure through the ingestion of agricultural and livestock products is considered, specifically concerning the use of contaminated water for irrigation [7]. However, as seawater is not used as irrigation water in Korea, this pathway is excluded from consideration.

Domestic nuclear power plants follow regulatory guidelines and NRC Reg. guide 1.109 to evaluate liquid effluents through the ingestion pathway of four seafood groups (fish,

Table 1. Nuclide recognition system

#	Nuclide	Remark
1	^{3}H (Particle)	Chemical form of nuclide
2	^{3}H (HTO)	
3	^{3}H (OBT)	
4	^{3}H (HT)	
5	^{3}H (Tritiated methane)	
6	^{7}Be (Particle)	Isotope number
7	^{10}Be (Particle)	
~	~	~
12	^{14}C (Particle)	Chemical form of nuclide
13	^{14}C (Vapor)	
14	^{14}C (Dioxide)	
15	^{14}C (Monoxide)	

mollusc, crustacea and algae). In this study, the same four seafood groups were used to evaluate liquid effluents. As the IAEA TRS-472 provides data only for fish, its utility is limited. Data for fish, mollusc, crustacea and algae were obtained from the CSA N288.1:20 [14]. We applied data such as seafood ingestion rates from the guidelines of the KINS [4].

3. Off-site Dose Calculation Program for Liquid Effluent

The computational program currently being used in domestic nuclear power plants (K-DOSE 60) considers various input data such as the nuclide recognition system, age group, tissues and organs, and dose conversion factor database. In addition, the program takes into various chemical forms of the same nuclide, such as dose calculation units requested by ICRP-60 radiation protection standards.

In this study, the nuclide recognition system using the currently used element symbol, mass number, radioactive decay constant, and chemical form of the nuclide is used, and the nuclide recognition system used in the program is listed in Table 1. The nuclide recognition system was used the same as before.

The program has been coded two programming languages. The dose calculation program was based on FORTRAN 77 and enforced a program that performed the entire process of program execution, such as data input, program execution, and result output. The GUI support system was coded using Visual C++. The main functions of this program are listed below [5].

- Maximum individual/collective dose evaluation (within 80 km)
- Calculation of emission sources per each unit of up to 10 and aggregation of them
- Evaluation period: Annual, quarterly, semi-annual, monthly, and specific periods
- Evaluation of effective and equivalent doses for 22 organs/tissues
- Age groups: 6 age groups
- Select liquid effluent exposure pathways for each nuclide
- Consideration of the following exposure pathway (liquid effluent)
  - External exposure by sea-shoreline activities
  - External exposure by swimming activity

Table 2. Input data for release amounts, half-life, and chemical forms for each nuclide

Nuclide	Release amount ($Bq \cdot y^{-1}$)	Half-life (s)	Chemical form
^{3}H	1.00×10^{12}	3.895×10^{8}	HTO
^{14}C	1.00×10^{12}	1.807×10^{11}	Dioxide

Table 3. Input data for seafood ingestion for liquid effluent evaluation [4]

Category	3 months	1 year	5 years	10 years	15 years	Adult
Fish ($kg \cdot y^{-1}$)	3.10	11.56	10.26	11.32	15.99	32.41
Crustacea ($kg \cdot y^{-1}$)	0.44	2.13	4.49	6.10	6.10	8.83
Molluscs ($kg \cdot y^{-1}$)	0.00	0.19	3.83	5.18	6.50	6.53
Algae ($kg \cdot y^{-1}$)	2.26	2.78	2.52	2.56	3.61	6.57

Table 4. Input data for seafood ingestion for liquid effluent evaluation [14]

Category (unit)	Value
Contamination ratio (Fish/molluscs/crustacea/algae)	0.9/0.9/0.9/1.0
Harvest to ingestion time (h) (Fish/molluscs/crustacea/algae)	24
Dilution water discharge rate ($m^3 \cdot s^{-1}$)	45.3
Dilution factor at exclusion area boundary	2
Re-accumulation factor	1
Radioactive material transport time (h)	1

- External exposure by boating activities
- Internal exposure by intake of seafood: fish, mollusc, crustacea and algae

4. Verification of Off-site Calculation Program for Liquid Effluent

Domestic nuclear power plants are conducting resident dose evaluation through the maximum individual dose at the exclusion area boundary (EAB). To evaluate the reliability of the calculated results of the dose evaluation program for liquid effluent, considering the evaluation methodology of ^{3}H and ^{14}C of IAEA TRS-472, the results of the evaluation of maximum individual dose for ^{3}H and ^{14}C nuclides were compared and evaluated with the LADTAP II methodology of the U.S. NRC.

The dilution factor and social environment factor applied to the comparative evaluation are presented in Tables 2, 3, 4, 5 [14, 15]. In Table 2, the emission amount of ^{3}H and ^{14}C was assumed to 1 TBq per year for comparison of calculated values, and the chemical forms were HTO and Dioxide forms considered in domestic nuclear power plants respectively. Input data such as seafood ingestion in Tables 3 and 4 were applied from the research report used in domestic nuclear power plants [6]. The input data for ^{3}H and ^{14}C in Table 5 was applied from CSA N288.1:20 [13]. The aquatic bioaccumulation factor in Table 6 used the applied values from the regulatory agency manual. The dose evaluation equations for ^{3}H and ^{14}C based on seafood ingestion followed the formulas specified in the IAEA TRS-472. The dose evaluation of ^{3}H includes OBT in this

Table 5. Input data for ^{3}H and ^{14}C [2, 13]

Category	Value	Remark
WC_f	0.75	Fish
	0.8	Crustacea
	0.8	Mollusc
	0.9	Algae
WEQ_f	0.7	Fish
	0.6	Crustacea
	0.6	Mollusc
	0.56	Algae
R_f	0.8	Fish
	0.8	Crustacea
	0.8	Mollusc
	0.8	Algae
S_f	127.44	Fish
	110.76	Crustacea
	87.96	Mollusc
	50	Algae
Stable carbon in the water	0.026	Fish
	0.026	Crustacea
	0.026	Mollusc
	0.026	Algae

Table 6. Aquatic bioaccumulation factors [8]

	Saltwater parameter			
	Fish	Mollusc	Crustacea	Algae
H	9.0×10^{-1}	9.3×10^{-1}	9.3×10^{-1}	9.3×10^{-1}
C	1.8×10^{3}	1.4×10^{3}	1.4×10^{3}	1.8×10^{3}

study. The aquatic bioaccumulation factors used for the comparison evaluation with the LADTAP II methodology are presented in Table 6 [8]. The same value was applied to all exposure paths for the dilution factor. The computational program can calculate separate pathways by classifying fish, mollusc, crustacea, and algae.

The calculated values of the computer code changed in this study, the results of hand calculations, and the evaluation results of LADTAP II are compared and presented in Tables 7, 8, 9, 10. Since ^{3}H and ^{14}C only affect internal exposure through ingestion, it was confirmed that the results obtained by applying the IAEA TRS-472 methodology to the evaluation of internal exposure were matched with the hand calculations. In the comparison with LADTAP II results, it was observed that the evaluations for ^{3}H were generally similar, but for ^{14}C, the modified evaluation method

Table 7. Comparison of internal exposure dose by fish ingestion (unit: $mSv \cdot y^{-1}$)

Category / Nuclide	Effective dose			Equivalent dose (skin)			Equivalent dose (Thyroid)		
	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II
HTO	1.433×10^{-7}	1.433×10^{-7}	1.837×10^{-7}	1.433×10^{-7}	1.433×10^{-7}	1.837×10^{-7}	1.433×10^{-7}	1.433×10^{-7}	1.837×10^{-7}
OBT	4.046×10^{-8}	4.046×10^{-8}	-	3.950×10^{-8}	3.950×10^{-8}	-	3.950×10^{-8}	3.950×10^{-8}	-
^{3}H (HTO+OBT)	1.838×10^{-7}	1.838×10^{-7}	1.837×10^{-7}	1.828×10^{-7}	1.828×10^{-7}	1.837×10^{-7}	1.828×10^{-7}	1.828×10^{-7}	1.837×10^{-7}
^{14}C	2.665×10^{-2}	2.665×10^{-2}	1.066×10^{-2}	2.617×10^{-2}	2.617×10^{-2}	1.164×10^{-2}	2.619×10^{-2}	2.619×10^{-2}	1.164×10^{-2}

Table 8. Comparison of internal exposure dose by mollusc ingestion (unit: $mSv \cdot y^{-1}$)

Category / Nuclide	Effective dose			Equivalent dose (skin)			Equivalent dose (Thyroid)		
	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II
HTO	3.002×10^{-8}	3.002×10^{-8}	3.877×10^{-8}	3.002×10^{-8}	3.002×10^{-8}	3.877×10^{-8}	3.002×10^{-8}	3.002×10^{-8}	3.877×10^{-8}
OBT	8.927×10^{-9}	8.927×10^{-9}	-	8.614×10^{-9}	8.614×10^{-9}	-	8.614×10^{-9}	8.614×10^{-9}	-
^{3}H (HTO+OBT)	3.895×10^{-8}	3.895×10^{-8}	3.877×10^{-8}	3.863×10^{-8}	3.863×10^{-8}	3.877×10^{-8}	3.863×10^{-8}	3.863×10^{-8}	3.877×10^{-8}
^{14}C	4.416×10^{-3}	4.416×10^{-3}	2.031×10^{-3}	4.306×10^{-3}	4.306×10^{-3}	1.980×10^{-3}	4.306×10^{-3}	4.306×10^{-3}	1.980×10^{-3}

Table 9. Comparison of internal exposure dose by crustacea ingestion (unit: $mSv \cdot y^{-1}$)

Category / Nuclide	Effective dose			Equivalent dose (skin)			Equivalent dose (Thyroid)		
	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II
HTO	4.005×10^{-8}	4.005×10^{-8}	5.173×10^{-8}	4.005×10^{-8}	4.005×10^{-8}	5.173×10^{-8}	4.005×10^{-8}	4.005×10^{-8}	5.173×10^{-8}
OBT	1.121×10^{-8}	1.121×10^{-8}	-	1.095×10^{-8}	1.095×10^{-8}	-	1.095×10^{-8}	1.095×10^{-8}	-
^{3}H (HTO+OBT)	5.126×10^{-8}	5.126×10^{-8}	5.173×10^{-8}	5.099×10^{-8}	5.099×10^{-8}	5.173×10^{-8}	5.099×10^{-8}	5.099×10^{-8}	5.173×10^{-8}
^{14}C	6.872×10^{-3}	6.872×10^{-3}	2.509×10^{-3}	6.754×10^{-3}	6.754×10^{-3}	2.466×10^{-3}	6.754×10^{-3}	6.754×10^{-3}	2.466×10^{-3}

Table 10. Comparison of internal exposure dose by algae ingestion (unit: $mSv \cdot y^{-1}$)

Category / Nuclide	Effective dose			Equivalent dose (skin)			Equivalent dose (Thyroid)		
	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II	K-DOSE 60	Hand calculation	LADTAP II
HTO	4.555×10^{-8}	4.555×10^{-8}	4.707×10^{-8}	4.555×10^{-8}	4.555×10^{-8}	4.707×10^{-8}	4.555×10^{-8}	4.555×10^{-8}	4.707×10^{-8}
OBT	4.252×10^{-9}	4.252×10^{-9}	-	3.897×10^{-9}	3.897×10^{-9}	-	3.897×10^{-9}	3.897×10^{-9}	-
^{3}H (HTO+OBT)	4.981×10^{-8}	4.981×10^{-8}	4.707×10^{-8}	4.945×10^{-8}	4.945×10^{-8}	4.707×10^{-8}	4.945×10^{-8}	4.945×10^{-8}	4.707×10^{-8}
^{14}C	2.994×10^{-3}	2.994×10^{-3}	2.802×10^{-3}	2.994×10^{-3}	2.994×10^{-3}	2.802×10^{-3}	2.994×10^{-3}	2.994×10^{-3}	2.802×10^{-3}

incorporating the IAEA TRS-472 approach was more conservative (106.8% to 273.9% higher). For ^{3}H, the fractional water content of the seafood (WC_f) of the IAEA TRS-472, which is similar to the aquatic bioaccumulation factors of LADTAP II, along with the contamination ratio of seafood, a site characteristic data. As a result, the dose calculation outcomes showed similar even when the OBT dose was added to the HTO dose. For ^{14}C, LADTAP II calculated the concentration of ^{14}C in seafood using aquatic bioaccumulation factors, while IAEA TRS-472 used a ratio-radioactivity model to calculate the ^{14}C concentration of seafood. Therefore, there was a difference in exposure dose according to the concentration calculation methodology.

Ultimately, it was confirmed that the hand calculated values and aquatic dose evaluation results from the computational program were consistent and aligned well, while the differences in evaluation were observed based on the methodology when comparing with the U.S. NRC LADTAP II methodology.

5. Conclusion

In this study, we validated a liquid effluent evaluation program that integrates the evaluation methodology of the IAEA TRS-472 into the existing K-DOSE 60 program, which is an off-site dose calculation software based on the ICRP-60 radiation protection system and the regulatory guideline of the KINS. To assess the reliability of the calculation results of the ^{3}H and ^{14}C through the improved program for the dose evaluation of liquid effluent, we compared the results with the hand calculated values and the results obtained using the U.S. NRC LADTAP II methodology. The comparative evaluation indicated that the calculated values from the computer program and the results from the hand calculation matched well, and the origin of dissimilarity between the improved methodology and the NRC's LADTAP II methodology was studied. Therefore, we can establish a comprehensive framework for evaluating liquid effluent by enforcing the latest methodology into the existing evaluation system. It is expected that this research contributes the advancement of radiation environment system and enhance trust in the local residents.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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