A Nuclide Inventory Verification System for the Development of a Waste Certification Program

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1. Introduction

For the safe disposal of decommissioning wastes, they must be processed, managed, and transferred in accordance with waste acceptance criteria [1]. The waste certification programs (WCP) have been developed in many countries to resolving problems related to the management of radioactive wastes. To support the development of WCP, properties of radioactive wastes such as the inventory of each radionuclide in a drum must be evaluated and verified. Therefore, we developed a nuclide inventory verification system to support the development of a WCP for decommissioning wastes.

2. Methods and Results

In this section, the overall scheme of the nuclide inventory verification system and the example verification is described. The verification is made based on the specific activity of each radionuclide in the radionuclide inventory database.

2.1 Database for Radionuclide Inventories

We developed a radionuclide inventory database of radioactive wastes through the survey of reports and the calculation of them using ORIGEN [2] and PISFACT [3] program. The important fields of the database for the nuclide inventory verification are a reactor type, an isotope, a waste stream, and a specific activity as shown in in Fig. 1.

1	ID +1	Source *	Country *	Arising Date 💌	Reactor Type	 NPP Site + 	Waste Type 💌	Waste Stream *	Isotopes -	Specific Activity *
2	SN000001	Reference	Korea	01.12.2014	CANDU	묄성	단순저장	잡고체	H-3	1.69E+05
3	SN000002	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	C-14	1.66E+01
4	SN000003	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Fe-55	2.71E+02
5	SN000004	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Co-58	1.07E+00
6	SN000005	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Co+60	2.96E+01
7	SN000006	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Ni-59	3.76E+02
8	SN000007	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Ni-63	6.10E+00
9	SN000008	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Sr-90	3.46E-02
10	SN000009	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Nb-94	6.54E-01
11	SN000010	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Tc-99	2.83E-01
12	SN000011	Reference	Korea	01.12.2014	CANDU	묄성	단순저장	잡고체	1-129	1.36E-03
13	SN000012	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Cs-137	4.66E-01
14	SN000013	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Ce-144	8.81E-01
15	SN000014	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Alpha	2.32E-01
16	SN000015	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	H-3	5.88E+03
17	SN000016	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	C-14	5.75E-01
18	SN000017	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Fe-55	9.41E+00
19	SN000018	Reference	Korea	01.12.2014	CANDU	월성	단순저장	잡고체	Co-58	3.70E-02
20	SN000019	Reference	Korea	01.12.2014	CANDU	묄성	단순저장	잡고체	Co-60	1.03E+00

Fig. 1. Example of database for nuclide inventory.

2.2 Nuclide Inventory Verification System

The nuclide inventory verification system consists of following menus: a database for nuclide inventory, an analysis, a verification and assessment, and a change account as shown in Fig. 2. In the database menu, there are submenus such as search, add, delete, and modify to control the radionuclide inventory database. The analysis menu is a menu for identifying statistical trends by obtaining mean (m) and standard deviation (σ) of a specific activity of each nuclide. The example analysis result for H-3 in dry active wastes of all kinds of reactor types are shown in Fig.3. Based on the statistical analysis results, the user can obtain the mean and the standard deviation of a selected radionuclide and the log-normal probabilistic distribution function as shown in Fig.3. The verification and assessment menu is a menu for verifying radionuclide inventories in a waste drum by checking whether they are within an acceptable range or not. The change account menu is a menu for changing account from a general user to administrator.

★ +	4 🛄 🔛 😑	Ab .							
김석 추가 4	정 삭제 역할 역할:	225 3	25 25	20					
	내보내기 업어이	=D	84.58	59					
4	물 데이터테이즈- 	54	1923.84	A REPORT					
10	Source	Country	Arising Date	Reactor Type	NPP Site	Waste Type	Waste Stream	2sotopes	Specific Activ
SN625163	Origen Calculation	Korea	01.04.2021	PVIR	고리	단순지장	참고 제	Cs-137	883.0
5N625162	Origen Calculation	Korea	01.04.2021	PVR	28	단순적장	잡고제	1-129	0.000255
\$1625161	Origen Calculation	Korea	01.04.2021	PVR	고리	단순지장	224	Tc-99	1.2
SN625160	Origen Calculation	Korea	01.04.2021	PVR	2.8	100 HORE	관고제	10-94	8.83
SN625159	Origen Calculation	Korea	01.04.2021	PVR	28	단순적장	참고제	52-90	52.7
5%625158	Origen Calculation	Korea	01.04.2021	PVR	고리	단순적장	잡고체	NI-63	89100.0
SN625157	Origen Calculation	Koree	01.04.2021	PVR	28	단순적장	224	N-59	8.52
\$14525156	Origen Calculation	Korea	01.04.2021	PVIR	22	단순적장	잡고체	Co-60	9950000.0
SN625155	Origen Calculation	Korea	01.04.2021	PVR	28	단순적장	잡고제	C-14	15 1000.0
SN625154	Origen Calculation	Korea	01.04.2021	PVR	고리	단순적장	224	H-3	1220000.0
5N625153	Origen Calculation	Korea	01.04.2021	PVR	2.81	단순적장	잡고제	Y-90	52.7
SN625152	Origen Calculation	Korea	01.04.2021	PVR	그리	단순적장	월 <u>고</u> 북	Tm-171	1.04
SN625151	Origen Calculation	Korea	01.04.2021	PVR	2.4	단순적장	잡고제	Te-127	8.4%-17
SN625150	Origen Calculation	Korea	01.04.2021	PVIR	고리	단순적잡	잡고제	Te-125m	11.5
5N625149	Origen Calculation	Korea	01.04.2021	PVIR	고리	단순적장	집교체	Sm-151	4.98
5N625148	Drigen Calculation	Korea	01.04.2021	PVIR	그리	단순적장	잡고제	Pm-147	12.9
SN625147	Origen Calculation	Korea	01.04.2021	PVIR	고리	단순적장	잡고체	P-32	772.0
SN625146	Origen Calculation	Korea	01.04.2021	PVIR	2.8	단순적장	잡고제	Fe-55	422000.0
SN625145	Origen Calculation	Korea	01.04.2021	PWR	그리	단순자장	잡고체	Tm-170	4.39e-14
5N625144	Origen Calculation	Korea	01.04.2021	PVR	2.81	탄순저장	잡고제	\$-35	5.83e-18
SN625143	Origen Calculation	Korea	01.04.2021	PVIR	고리	단순적장	잡고제	N-63	89100.0
5N625142	Origen Calculation	Korea	01.04.2021	PVR	2.81	단순적장	잡고채	NE-59	8.59
SN625141	Origen Calculation	Korea	01.04.2021	PVIR	2.8	단순적잡	참고제	Lu-177	5.21e-14
SN625140	Origen Calculation	Korea	01.04.2021	PVIR	고리	단순적장	잡고체	K-42	121.0
SN625139	Origen Calculation	Korea	01.04.2021	PVIR	28	단순적잡	잡고제	2-194	1.22
SN625138	Origen Calculation	Korea	01.04.2021	PWR	고리	단순적장	잡고체	H-3	1220000.0
5N625137	Origen Calculation	Korea	01.04.2021	PVR	2.8	단순적장	잡고제	Cs-135	0.0172
SN625136	Origen Calculation	Korea	01.04.2021	PVIR	그리	단순적장	참고체	Ca-45	4.49e-06
5N625135	Origen Calculation	Korea	01.04.2021	PVR	2.81	탄순적장	접고체	2-93	0.641
SN625134	Origen Calculation	Korea	01.04.2021	PVR	2.2	단순적장	참고제	W-151	2.12e-19
5N625133	Origen Calculation	Korea	01.04.2021	PVIR	2.81	단순적장	잡고체	Te-127m	8.62e-17
SN625132	Origen Calculation	Koren	01.04.2021	PVIR	28	단순적장	참고제	Tc-97	1.3e-09
SN625131	Origen Calculation	Korea	01.04.2021	PVIR	고리	단순저장	잡고채	Nb-93m	2050.0
00110100	Origen Calculation	Krrea	01.04.2021	200	7.81	\$14 3KD	89 T 10	Ma 07	35.1

Fig. 2. Main screen and menus of the nuclide inventory verification system.



Fig. 3. A display screen for the distribution of specific activity of a radionuclide (H-3).

2.3 Example Verification of Nuclide Inventories

The example verification of nuclide inventories in a waste drum is made through the verification and assessment menu using the characteristics data of each waste drum and statistical values of each radionuclide in the radionuclide inventory database. It is made based on the information of the waste drum given by the waste generator. The screen for the selection of verification data is shown in Fig. 3. First of all, if a user clicks the get waste drum information button in the upper part of Fig. 3, a user can import the information of waste drums to be verified and then they are displayed in the box in the upper part of Fig. 3. And then a user can choose a waste drum to be verified, and the drum number and related information are displayed in the boxes of lefthand side of Fig. 3. The distribution of each radionuclide with mean and standard deviation are plotted in the right-hand side of Fig. 3. The minimum and maximum value of specific activity are also displayed in red color.

For the verification, a user can modify the number of n in $m\pm n\sigma$, which is the acceptable range of the specific activity of each radionuclide. The default value of n is 3. The minimum and maximum value of a specific activity of each radionuclide are also displayed based on the statistical analysis results of data in the nuclide inventory database.



Fig. 3. Screen for the selection of verification data

With this information, the verification result of a waste drum is displayed if a user clicks the verification button. The example verification results are shown in Fig. 4. As shown in Fig. 4, the color of verification result is green if the verification result is acceptable. If the value of specific activity of a radionuclide is beyond the acceptable range, the color of verification result of each radionuclide changes to red. After the verification for each waste drum is finished, the verification result can be output as a report in the PDF format by clicking the report generation button. The example verification report in the PDF format is shown in Fig. 5. As shown in this figure, the identification number of a waste drum and the verification result for each radionuclide in a waste drum are displayed.



Fig. 4. Screen for the example verification result

	Radioactivity	Permitted o-Level	Permitted R	Dicision		
액송	(Bq/g)		Min_Value	Max_Value	Result	
н-з	2.76e+03	3,00	1.09e-09	6.63e+10	만족	
C-14	8.90e+00	3,00	2,29e-11	4.40e+09	만족	
Fe-55	1.15e+01	3.00	1,85e-08	7.44e+11	만족	
Co-58	5.02e-02	3,00	1,27e-31	7,42e+13	[만족	
Co-60	2.75e+01	3,00	1.12e-09	8.81e+12	만족	
Ni-59	1.44e+01	3,00	4.35e-12	2,23e+09	만족	
Ni-63	8.77e+02	3,00	1.46e-10	7.73e+11	만족	
Sr-90	1.58e+00	3,00	1.07e-32	1.92e+11	만족	
Nb-94	2.66e-01	3.00	5,13e-13	1.91e+07	(만족)	
Tc-99	3,21e-01	3,00	8,40e-16	1.06e+07	만족	
-129	8.94e-03	3.00	3.94e-42	9.55e+07	만족	
Cs-137	1.66e+01	3,00	1.03e-35	8.81e+16	만족	
Ce-144	1.14e+00	3,00	2.82e-35	5.70e+11	만족	
Alpha	3.26e+00	3.00	5.05e-05	3.10e+03	만족	
종합결과						

Fig. 5. Screen for the example verification result

3. Conclusions

The verification of nuclide inventories in waste drums is a fundamental task for securing the safe disposal of radioactive wastes. Therefore, we developed a nuclide inventory verification system to support the development of a waste acceptance program. The verification is made based on the statistical analyses of specific activity of radionuclides in the database of radionuclide inventory. We checked the applicability of nuclide inventory verification system by applying it to the radionuclide inventory data of the operational wastes. This radionuclide inventory verification system can be a useful tool to support the development of WCP.

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