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[Technical Paper]

Application of MARSSIM for Final Status Survey of the Decommissioning Project

해체사업의 최종현황조사를 위한 MARSSIM 적용

Sang Bum Hong[1], Ki Won Lee, Jin Ho Park and Un Soo Chung

Korea Atomic Energy Resrarch Institute, 1045 Daedeokdaero, Yuseong-gu, Deajeon

홍상범[1], 이기원, 박진호, 정운수

한국원자력연구원, 대전시 유성구 덕진동 대덕대로 1045

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Abstract

The release of a site and building from regulatory control is the final stage of the decommissioning process. The MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual) provides overall framework for conducting data collection for a final status survey to demonstrate compliance with site closure requirements. The KAERI carried out establishing a final status survey by using the guidance provided in the MARSSIM for of a site and building of the Korea Research Reactor. The release criteria for a site and building were set up based on these results of the site specific release levels which were calculated by using RESRAD and RESRAD-Build codes. The survey design for a site and building was classified by using the survey dataset and potential contamination. The number of samples in each survey unit was calculated by through a statistical test using the collected data from a scoping and characterization survey. The results of the final status survey were satisfied the release criteria based on an evaluation of the measured data.

Key words : Decommissioning, Final Status Survey, MARSSIM, RESRAD, RESRAD-Build

요 약

해체의 최종단계는 대상 부지 및 건물을 규제로부터 제외하는 것이다. MARSSIM은 부지를 개방하기 위한 최종현황조사를 수행함에 있어 요구되는 자료의 수집 등의 다양한 요건을 만족키기 위한 총괄적인 지침을 제공한다. 연구로 해체 후 부지 및 건물의 최종현황조사를 위해 MARSSIM에서 제시하고 있는 방법을 적용하였다. 연구로 부지의 특성을 반영한 개방기준을 도출하기 위해 RESRAD 및 RESRAD-Build 전산코드를 이용하여 부지 및 건물에 대해서 계산하였다. 부지 및 건물의 조사설계(Survey Design)를 위해서 잠재적 오염도 및 측정 결과를 활용하여 조사구역을 구분하였고, 개략조사 및 특성조사를 통해 수집된 다양한 결과에 기초하여 통계학적 검사를 통해 조사구역 별로 요구되는 시료의 수를 산정하게 된다. 측정된 결과에 기초하여 연구로 최종현황조사는 개방기준에 만족하는 것으로 평가되었다.

중심단어 : 해체, 최종현황조사, MARSSIM, RESRAD, RESRAD-Build

1) Corresponding Author. E-mail : sbhong@kaeri.re.kr

I. Introduction

In 1996, it was concluded that the KRR-1(Korean Research Reactor #1) and KRR-2(Korean Research Reactor #2) would be shut down and dismantled. The main reason for decommissioning was to diminish utilities due to the start of a new research reactor, High-flux Advanced Neutron Application Reactor (HANARO). Another reason was the urbanization of the surrounding area of the reactors. A project was launched for the decommissioning of these reactors in January 1997 with the goal of completion by 2008. The total budget for the project was 20.0 million US dollars, including the cost for the waste disposal and for the development of required technologies. The work scope during the reactor decommissioning project was the dismantling of all the facilities and the removal of all the radioactive materials from the reactor site. After confirming the removal of all radioactive materials, the site and its buildings will be released for unrestricted use.

1. Final Status Survey

① Site conditions

The site of KRR-1 & 2 comprised about 30,000 m^2 and included various laboratory, office, warehouse and reactor buildings. The main contaminants at a site and buildings were ^{60}Co and ^{137}CS but all the detected radionuclides in decommissioning waste were considered during the final status survey[1]. For the surface soil and buildings, dose rates were measured with survey meters connected with a GPS(Global Positioning System) during the scoping and characterization survey, and the measured data were used for detecting the existence of hot spots and predicting the soil and building contamination levels. The results of the dose rates in the site are given in Figure 1. The level of contamination for most of the site was around the background level (blue zone in Figure 1), but that of the soil around natural evaporation facilities, which was used for treatment of the waste water during operation and dismantling duration, indicated that it could be expected to be contaminated. A detailed inspection for the identification of the radionuclide present was carried out around the

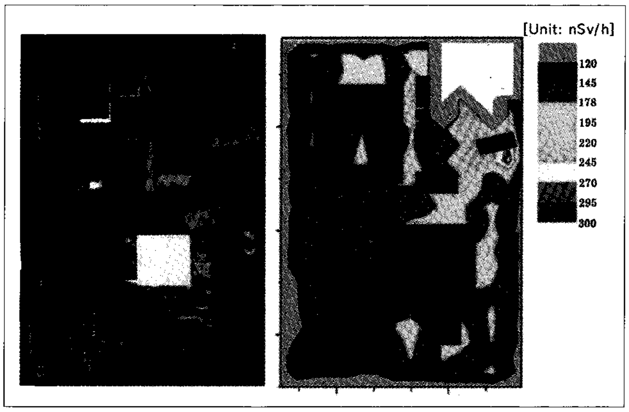

Fig. 1. Surface dose rate on the KRR-1&2

area. Remedial action to remove the contaminated soil was carried by using an excavator at the area, which was classified into Class 1 during final status survey.

The final status of the contamination level of the site was less than 0.02 Bq/g and 0.03 Bq/g of ^{60}Co and ^{137}CS, respectively. The total amount of the removed waste during remedial action was about 16m^3, which was temporally stored in the reactor building.

② Release criteria of the site and building

The objective of the assessment of the residual radioactivities is to demonstrate a satisfactory residual contamination level in accordance with the established release criteria. Therefore, one of the most important aspects of the final status survey planning was a clear understanding of the criteria will be applied to a particular decommissioning project. A dose modeling and setting of the release criteria was performed to evaluate the future radiological impacts on the individuals at the site or surrounding area, and to assure a compliance with regulatory cleanup requirements. The release dose criteria recommended by the IAEA are between the dose constraint (300 μSv/y; a portion of dose limit) and a trivial dose range (~10 μSv/y)[2,3]. The release criteria hasn't been established in Korea, but KAERI has proposed the release criteria (100 μSv/y) for considering the future unrestricted use of the site and the urbanization of the surrounding area. The regulatory body also recommended the same value of criteria. The site specific DCGL (Derived Concentration Guideline Level) was calculated for the KRR-1&2 site and buildings by using RESRAD and RESRAD-Build codes separately[4,5,6]. The calculated results by adopting the site specific parameters of the site are shown in Table 1.

③ Survey design and result of final status survey

The purpose of the final status survey was to demonstrate that the residual radioactivity in each survey unit would satisfy the release criteria. The final radiological conditions of a site and building must satisfy the DCGL. In order to reach the final status survey, it was very useful to follow a radiation survey and site investigation process which is a series of surveys designed to demonstrate compliance with dose or risk based regulation for radioactive site contaminations, which includes HAS (Historical Site Assessment), SS (Scoping Survey) and CS (Characterization Survey). For the MARSSIM survey design, the contaminants and their levels were identified, and it was determined whether the concern radionuclides exist in the background. The site was divided into Class 1, Class 2, and Class 3 according to the potential contamination[7].

• Class 1 : The area around natural evaporation facilities is most likely to be contaminated, and the contamination levels are expected to exceed the DCGLw(average concentration over a wide area). The designation to Class 1 implied that the highest level of effort (100% scanning survey, area limit up to 2,000 m^2) required.

• Class 2 : Most of the site and building interiors are expected to have a residual radioactivity level greater than the background, but not exceeding the DCGLw.

• Class 3 : Contamination levels of the outside area and building exteriors are expected to be quite similar to the background. While contaminations are identified, their levels are a small fraction of the DCGLw.

The statistical parameters for a survey design at the Class 1 area are shown in Table 2. The numbers and locations of the sampling points used to demonstrate compliance with the release criteria.

The expected contamination level based on the characterization data is the lower boundary of the gray region, which calculated by using the Equation 1. The characterization survey of 10 samples of contamination level of ^{60}Co is 0.0084 ± 0.0062 (1σ) Bq/g and ^{137}Cs is 0.0178 ± 0.0143 (1σ) Bq/g in the Class 1 area. The relative shift was also calculated based on the measured results, but MARSSIM recommend from 1 to 3. The survey design for final status survey adopted the relative shift as 3 in the class 1 site. Type I and type II decision error which is typical value chosen for many statistical analyses and is associated with a 95% level of confidence in the final results.

Table 1. The DCGL of the KRR site and Buildings

Radionuclides	Site (Bq/g)	Building (Bq/cm^2)
^{60}Co	6.50E-02	5.18E+03
^{134}Cs	1.11E-01	7.75E+03
^{137}Cs	2.50E-01	1.18E+04
^{152}Eu	1.42E-01	1.02E+04
^{154}Eu	1.32E-01	8.70E+03

Table 2. Statistical parameter of the survey design.

Item	Value
LBGR (Lower Bound of Gray Region)	0.2
Sigam(σ)	0.1
Relative Shift(Δ/σ)	7.27
Type I and type II decision error	0.05

$$LBGR = \frac{Con._{Co}}{DCGL_{Co}} + \frac{Con._{Cs}}{DCGL_{Cs}} \quad (1)$$

$$\sigma = \sqrt{\left(\frac{\sigma_{Co}}{DCGL_{Co}}\right)^2 + \left(\frac{\sigma_{Cs}}{DCGL_{Cs}}\right)^2} \quad (2)$$

In this case, the contaminant of the KRR site and building was not in background, the Sign test was used for the survey design. The required sample size was 14 samples in each survey unit. The number of data sets necessary to satisfy these non-parametric tests was determined on the basis of the DCGL of contaminants. The MARSSIM also requires a reasonable level of assurance that any hot spots that could have a significantly higher radioactivity than regulatory limits should not be missed during the final status survey[8]. To determine additional samples, the required scan MDC (Minimum Detectable Concentration) was calculated and compared with the actual scan MDC. The required scan MDC was calculated as 0.17 based on the product of the area factor and DCGLw. The RESRAD code was used to generate the area factors and the resulting area factors, are shown in Fig. 2.

For scanning the surface soil of KRR-1 and KRR-2, an

InSpector-1000 with a 2 ×2 inch NaI detector was used and actual scan MDC was reported in NUREG-1507 as 0.185 [9]. Because the actual scan MDC was larger than required scan MDC for the Class 1 area of the KRR site, it was necessary to calculate a new area factor that corresponds to the actual scan MDC by using a RESRAD code (1.43 = 50 m^2). The new sample size was determined by dividing the area into the survey unit. The required number of samples was 24 samples, which mean that 10 additional samples were needed. The sampling locations in each survey unit ware established by using a random start triangular grid pattern because the site contains many facilities. The soil samples measured for their radioactivity by using the HPGe detector. The summarized final status survey results are given in Table 3 and Figure 3 show detail residual contamination level in Class 1. The results of the final status survey are sufficiently lower than the release criteria.

The survey design of the building, the laboratory used or contaminated a radioactive material were classified as Class 2 and offices were classified as Class 3. Most of the rooms smaller than limitation size (100 to 1,000 m^2) of the Class 2 strictures could be divided one survey unit. Survey design of the laboratory shows in the Figure 4. The DCGL of the building was calculating by using a detector efficiency, surface efficiency and detector area. The calculated DCGLw of the building is 27.7 cps for gross beta. The results of the survey units also satisfied the DCGLw, and Table 4 show the detail results of the laboratory in Class 2.

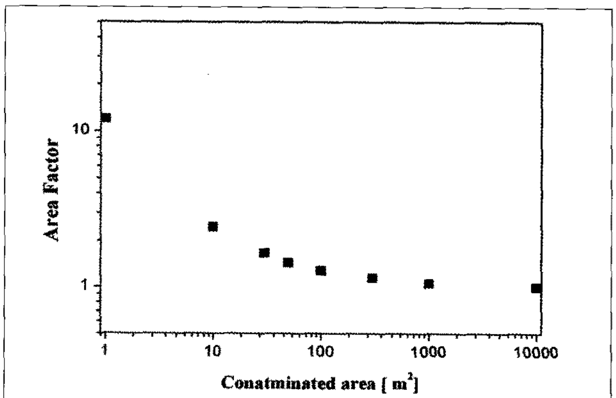

Fig. 2. Area factor in Class 1 area.

Table 3. The summarized final status survey results of the site.

	Class 1	Class 2	Class 3
Number of survey unit	1	3	1
Total number of samples	24	42	14
Average contamination levels (Bq/g)	^{60}Co : 6.26E-3	^{60}Co : 2.63E-3	^{60}Co : 1.49E-3
	^{137}Cs : 1.20E-2	^{137}Cs : 8.72E-3	^{137}Cs : 5.00E-3
Maximum contamination levels (Bq/g)	^{60}Co : 3.89E-2	^{60}Co : 9.71E-3	^{60}Co : 2.25E-3
	^{137}Cs : 3.59E-2	^{137}Cs : 7.25E-2	^{137}Cs : 9.02E-3

Table 4. The summarized final status survey results of the building.

	Lab. 1	Lab. 2	Lab. 3
Number of survey unit	1	1	1
Total number of samples	15	15	15
Average contamination levels (cps)	19.1	18.7	19.4
Maximum contamination levels (cps)	20.3	19.4	20.3

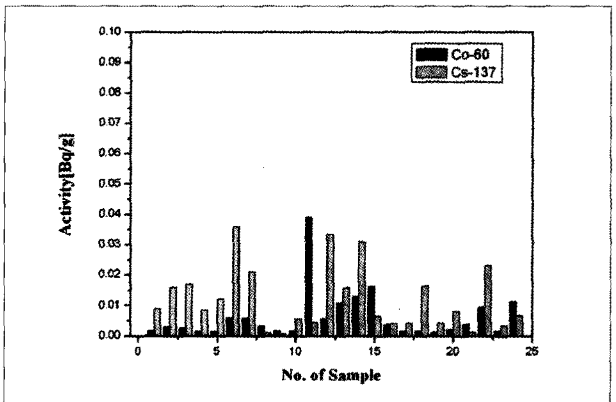

Fig. 3. Final status survey results in Class 1 area.

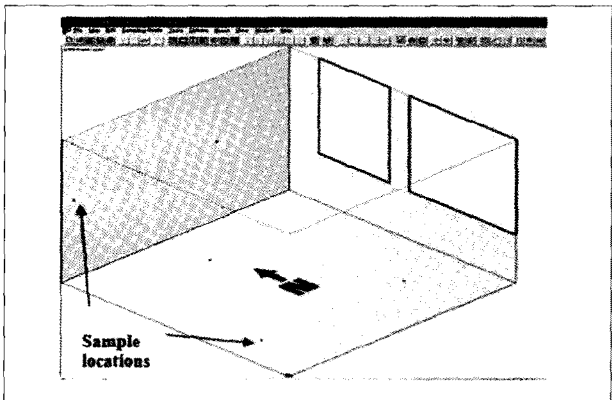

Fig. 4. Survey design in the Class 2 Building

II. Conclusions

In this study, plan for the final status survey and release criteria for a site release were established by applying the MARSSIM procedure. The survey design for the final status survey of the KRR site and buildings was carried out. A site and buildings were classified into Class 1, Class 2, and Class 3 based on the potential contamination by using the measured and calculated results. The MARSSIM procedure was proved to be flexible, scientifically rigorous and cost-effective for a final status survey of decommissioning a site and building. For the effective plan for the final status survey of the KRR site and its implementation, KAERI and regulation body are in ongoing discussions way to ensure the validation of the final status survey after decommissioning.

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