

## Statistical Hypothesis Test for Decommissioning Site Release using Integrated Site Characterization Code: COSMOS

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### 1. Introduction

A statistical hypothesis test is a method of statistical inference used to decide whether the data at hand sufficiently support a particular hypothesis. And this test allows us to make probabilistic statements about population parameters. Formal use of this test concept is widespread in science, for example, astronomy, biology, and engineering.

In the decommissioning of NPPs (Nuclear Power Plants), it eventually has the final goal of returning site to its pre-construction state and it is accompanied by statistical hypothesis test to prove of site release. For this purpose, radiological surveys on the site called site characterization should be conducted during the entire decommissioning period. In the end, this site characterization must prove whether it is satisfied according to set criteria for how dangerous the impact on human is. For example, the IAEA (International Atomic Energy Agency) has set regulatory guidance of site release below 0.3 mSv/y, and the U.S.NRC (United States Nuclear Regulatory Commission) has stipulate that it is not exceed 0.25 mSv/y on an unlimited site release for total effective dose of the average determined group. Lastly in Korea, 0.1 mSv/y regulatory guidance is presented for both unrestricted and restricted site release in the Nuclear Safety and Security Commission Notice No. 2021-11.

As above, the regulatory guidance of site release for each country are stipulated differently, but there is a methodology that is typically referenced to perform site characterization to demonstrate safety for unrestricted or restricted site release. The site characterization during decommissioning of nuclear facilities generally follows a procedure called MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual) developed by DOE (Department of Energy), DOD (Department of Defense), EPA (Environmental Protection Agency) and NRC in the United States.

With reference to this manual, we have developed a integrated software called COSMOS (COde for Site characterization and Management of Overall Surveys) that can perform site characterization and manage survey data [1, 2]. As a final stage of the site characterization, a FSS (Final Status Survey) is performed to demonstrate that residual radioactivity in each survey unit satisfies the predetermined criteria for release for unrestricted use or, where appropriate, for

use with designated limitations. The survey provides data to demonstrate that all radiological parameters do not exceed the established DCGLs (Derived Concentration Guidance Levels). For the FSS, survey units represent the fundamental elements for compliance demonstration using the statistical tests [3].

For these purposes, this paper shows the process of statistical test using the COSMOS. And we have tested the performance on the configuration of survey units to facilitate survey design and ensure that the number of survey data points for a specific site is relatively uniformly distributed among areas of similar contamination potential.

### 2. Literature review

A number of software programs have been developed over the years to facilitate the design of surveys, for example, VSP (Visual Sample Plan), developed by the PNNL (Pacific Northwest National Laboratory). These software programs can perform calculations to determine the number of sampling locations.

#### 2.1. VSP

VSP is a software tool that supports the development of a defensible sampling plan based on statistical sampling theory and the statistical analysis of sample results to support confident decision making. VSP couples site, building, and sample location visualization capabilities with optimal sampling design and statistical analysis strategies. It can perform calculations to determine the number of locations where measurements should be made or where samples should be collected [4].

#### 2.2. COMPASS

ORAU (Oak Ridge Associated Universities) developed COMPASS software which is designed to facilitate the use of and guide the user into making informed decisions in designing final status radiological surveys. COMPASS also simplifies the application of the statistical tests by performing the statistical calculations and providing prospective power curves that help in determining what level of confidence the user is willing to accept for a particular number of measurements or samples for a survey unit. After

performing the final status survey, COMPASS assesses the data for comparison to the release criteria [5].

As such, there are several codes used for statistical test purposes for site release, but there is no program to manage all data from the beginning to the end of the survey and evaluate them according to the procedure. For solving this problem, the COSMOS ensures the reliability and quality of data management process by preventing risks such as data loss.

### 3. Statistical hypothesis test for site release

An evaluation to determine that the data are consistent with the underlying assumptions made for the statistical procedures helps to validate the use of a test. One may also determine that certain departures from these assumptions are acceptable when given the actual data and other information about the study [3].

In the MARSSIM, method of statistical test is differentiated by whether the survey unit is contaminated or not. In other words, if substance of contaminant presents in the background of the survey unit, it needs to select a background reference area. If a survey unit presents contaminant in the background, then comparison of measurements from the reference area and survey unit is made using the WRS (Wilcoxon Rank Sum) test which should be conducted for each survey unit. For this reason, the number of data points is calculated by equation (1) [3].

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{3(P_r - 0.5)^2} \quad (1)$$

where,

N: Number of sampling data points

$Z_{1-\alpha, \beta}$ : Decision error percentiles by the selected decision error levels  $\alpha$  and  $\beta$

$P_r$ : probability that a random measurement from the survey unit exceeds a random measurement from the background reference area

Conversely, if it is not contaminated in the survey unit, a background reference area is not necessary. It means that the survey unit can be evaluated using the sign test that compares directly with the DCGLs. For performing the sign test, the number of data points is calculated by equation (2) [3].

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(\text{Sign}_p - 0.5)^2} \quad (2)$$

where,

$\text{Sign}_p$ : Probability that a random measurement from the survey unit will be less than the DCGLs

Established hypothesis are verified with the number of points calculated as above, and the assumptions used to select the statistical test are examined to determine

whether the conditions are met for the test. All of these processes can be performed through the COSMOS.

### 4. Test results

In this study, we performed statistical hypothesis test using the COSMOS. The NPPs have room numbering drawings which is marked mainly in two categories. One is inherent number given to each room, and the other is a name that can figure out the meaning of the room. We use open room drawing. However, since this drawing is not available for security reason, therefore we evaluated using easily opened drawing

First, we selected interested nuclides (i.e. Co-60 and Cs-137) and assumed DCGLs of them. After that, the COSMOS calculated sampling data points to perform the selected statistical test and presented the points on the drawing as shown in Fig. 1.

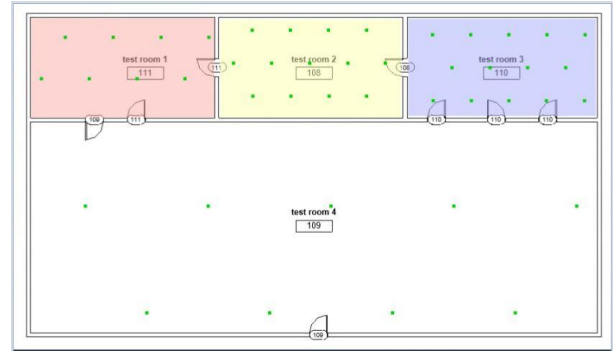


Fig. 1 Sampling data point marking on example drawing

Each of the survey units calculated by COSMOS then has a, b, c, and d sampling points, where radioactivity concentration values are entered. Finally, the COSMOS performs statistical test regarding survey unit by comparing the radioactivity concentration entered with DCGLs, and the results of test show whether the site release are satisfied as shown in Table I.

Table I: Statistical test results for site release by the COSMOS

Survey unit ID (room name/number)	Class	# of Data point	Statistical test result
SU_001 (test room 1/111)	1	9	WRS test (accept)
SU_002 (test room 2/108)	2	14	Sign test (reject)
SU_003 (test room 3/110)	3	14	Sign test (reject)
SU_004 (test room 4/109)	uncontaminate d	9	WRS test (accept)

The result of the Sign test or the WRS test is the decision to reject or not to reject the null hypothesis that the survey unit is contaminated above the DCGL. Therefore, statistical test conducted through the COSMOS shows that SU\_001 and SU\_004 cannot be released because the contamination level is higher than

the DCGL, on the contrary, SU\_002 and SU\_003 are shown that they are satisfied with the site release criteria.

## **5. Conclusion**

We developed integrated software for site characterization called COSMOS to perform statistical hypothesis test for decommissioning site release. In this study, the contamination level was set for each room shown in the drawing and survey units were formed, then the statistical test accordingly was determined by COSMOS. And the COSMOS calculated the number of sampling data points in the survey unit according to the set specific parameters of statistical test and presented them on the drawing. Next, statistical test will be performed according to the result of entering the radioactivity concentration for each nuclide, finally the COSMOS will be shown the results whether the site is satisfied with decommissioning site release.

The COSMOS is derived that the results of site characterization are evaluated using statistical tests to determine if they exceed the release criteria. If the release criteria have been exceeded or if results indicate the need for additional data points, appropriate further actions will be determined by the site management and the regulatory agency. Lastly, we expected that the COSMOS can be utilized to provide information for radioactive waste management during decommissioning and for preparation of FDP (Final Decommissioning Plan) and FSS report in the decommissioning project.

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