Including Below Detection Limit Samples in Decommissioning Soil Sample Analyses

Jung Hwan Kim and Man-Sung Yim*
Korea Advanced Institute of Science and Technology, 291, Daehak-ro, Yuseong-gu, Daejeon 34141
*msyim@kaist.ac.kr

1. Introduction

Decommissioning is an emerging international issue in the nuclear industry. Termination of the decommissioning authorization involves releasing the facility from the regulatory control for restricted or unrestricted use in the future.

Prior to releasing the facility from regulatory control, it must be shown that the site has been sufficiently cleaned up to meet either restricted or unrestricted use in the future. To meet the required standards the site owner has to show that the soil at the facility has been sufficiently cleaned up. To do this one must know the contamination of the soil at the site prior to clean up. This involves sampling that soil to identify the degree of contamination. However there is a technical difficulty in determining how much decontamination should be done. The problem arises when measured samples are below the detection limit. Regulatory guidelines for site reuse after decommissioning are commonly challenged because the majority of the activity in the soil at or below the limit of detection.

RESRAD is a computer model designed to estimate radiation doses and risks from RESidual RADioactive materials.

Using additional statistical analyses of contaminated soil after decommissioning is expected to have the following advantages: a better and more reliable probabilistic exposure assessment, better economics (lower project costs) and improved communication with the public. This research will develop an approach that defines an acceptable method for demonstrating compliance of decommissioned NPP sites and validates that compliance.

2. Methods and Results

2.1 Conventional Methods used to analyze Environmental Censored Data Sets

Censored values are reported as less than or greater than some value, or as an interval between some values. Left censored values are known to be less than some values. By definition, environmental data with below the detection limit observations are an example of left censored data.

The main approaches for handling censored data are simple replacement and extrapolation. The most common and easiest strategy is simple replacement, where censored values are replaced with zero, or some fraction of the detection limit (usually 1/2 of the detection limit), or the detection limit itself. The extrapolation strategies, on the other hand, use regression or probability plotting techniques to calculate the mean and standard deviation based on the regression line of the observed values that are, above limit of detection values. Commonly used methods for dealing with environmental data sets that contain the detection limits are statistically biased and limited in their usefulness.

According to National Human Exposure Assessment Survey (NHEXAS) database, 30 to 70% of the observations are below the detection limits for many pollutants. There is an impact on society due to uncertainties in technical factors. Costs for decommissioning are based on decommissioning strategies and final disposition of the site. Therefore, these biased results use of the detection limits in the analysis can affect public communication and economics which directly impact the nuclear industry.

2.2 Proposed Methods and Results

After decommissioning soil samples, representative radioactivity is determined by sampling analysis and the properties of residues or suspicious material from a monazite manufacturing factory. From Grid box No.1 and Grid box No.2, it is possible to get data points of U-238 and K-40, with data points below the detection limits.

Implementing goodness of fit tests demonstrate all nuclides in each Grid box follow both normal distribution and lognormal distribution.

Conventional methods, replacing censored values with zero, or 1/2 of the detection limit, or the detection limit, used to analyze censored data sets.

By applying additional methods, maximum likelihood estimation (MLE), Kaplan-Meier, and regression on order statistics (ROS), censored data sets are analyzed more accurately using Nondetects And Data Analysis (NADA) for R package and MATLAB [1,2].

Table 1. Summary statistics using several estimation methods – U-238 in Grid box No.1

	Mean	STD DEV	Pct25	Median	Pct75
Ignoring	0.339	0.212	0.123	0.351	0.534
zero	0.249	0.236	0.012	0.148	0.460
1/2 DL	0.261	0.223	0.048	0.148	0.460
DL	0.274	0.211	0.095	0.148	0.460
MLE(ln)	0.263	0.221	0.065	0.148	0.486
ROS(ln)	0.267	0.218	0.085	0.148	0.460
K-M	0.263	0.221	0.051	0.148	0.486

Table 2. Confidence intervals for the mean using MLE/Bootstrap

Cases	90% CI for the mea	95% CI for the mea
U-238 in Grid box No.1	[0.106, 0.336]	[0.068, 0.348]
U-238 in Grid box No.2	[0.140, 0.448]	[0.086, 0.465]

2.3 RESRAD Results

Radiation doses, risks, and cover thickness is calculated to show the difference between the each method using RESRAD code. Input data for radiological safety assessment landfill dsiposal using international and domestic references.

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Table 3. Maximum total dose and maximum excess cancer risk for the estimation methods in Grid box No.1

	Maximum Total Dose (mrem/yr)	Maximum Excess Cancer Risk
Ignoring	29.11	1.13E-3
zero	13.09	4.99E-4
1/2 DL	14.15	5.40E-4
DL	15.99	6.11E-4
MLE	14.13	5.39E-4

Table 4. Cover thickness calculated to show the difference between the each method

Cases	Cover thickness
Ignoring->MLE	more than 3m
DL->MLE	more than 3m
1.2 DL->MLE	13.5cm

3. Conclusions

Summary statistic and confidence intervals were compared to conventional methods. Proposed methods were performed using the soil samples from the monazite powder manufacturing plant. The preliminary evaluation shows that the proposed method can be effectively used to provide: the best estimate radioactivity levels at decommissioned NPP site and estimates of uncertainty in the mean value.

RESRAD is used to estimate radiation doses and risks in each case. Cover thickness is calculated to show the difference between the each method.

Using additional statistical analyses of contaminated soil before or after decommissioning is expected to have a better and more reliable probabilistic exposure assessment, better economics and improved communication with the public.

4. References

[1] Zhao, Y., and H.C. Frey, “Quantification of Uncertainty and Variability for Air Toxic Emission Factor Data Sets Containing Non-Detects,” Annual Meeting of the Air & Waste Management Association, Pittsburgh, PA, June 2003.

[2] Dennis R. Helsel (2005), Nondetects And Data Analysis: Statistics for censored environmental data, John Wiley & Sons, Inc., Hoboken, New Jersey.