Sampling Low-Level Waste – Building a Program – 16101

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ABSTRACT

Low level radioactive waste is routinely sampled and analyzed to demonstrate compliance with Title 10 Code of Federal Regulations Part 61. The sample results are frequently used to create scaling factors to relate the activity of hard to detect (HDT) radionuclides to gamma emitting activity if there is a correlation between the key and scaled radionuclide pair. The activity of gamma emitters can be used with these scaling factors to calculate activity of the low level waste generated in the plant. Another method is to use the sample results directly and scale the total activity to the volume or weight of the waste in the container. Either method assumes that the sample results are representative of the total waste in the container. This requires that the waste streams be accurately defined and that the samples contain radionuclides at ratios that are representative of the bulk waste. This is not always the case and deviations between the sample results and the actual radionuclide concentrations in the waste can lead to miss-classification of the waste resulting in regulatory non-compliance, increased waste disposal costs or both. A deliberate sampling methodology that considers the context of the waste generation and the inherent limitations in practical sampling methodologies will enhance the licensee's ability to demonstrate the analytical results from the sample are representative and defendable.

A good sampling program starts with the establishment of waste streams that are consistent with both production mechanisms and plant systems. Once waste streams have been established, data quality objectives can be determined and then the methods for obtaining an appropriate sample can be developed along with the identification of sample points and sample schedules. Sometimes it may not be practical or even possible to obtain a truly representative sample in which case the results from the measurement of the sample must be evaluated within the context of the expected values and the factors inhibiting the collection of a truly representative sample.

This paper will explore objectives of a sampling program in relation to the regulations and identify methods that can be used to obtain and evaluate sample data that can be defended as 'representative'.

INTRODUCTION

What is a sample and why do we need to take them? The Merriam-Webster Dictionary defines a sample as “a small amount or part of something that gives you information about the thing it was taken from”. [1] Samples are taken of low level radioactive waste (LLRW) so that we can determine the qualities of the whole. This may be a beaker, a liner / High Integrity Container (HIC), a storage tank or a process stream. A sample is taken because the whole quantity is too large, too radioactive or too expensive to measure in its entirety or the constituents to be measured require analysis techniques that preclude the evaluation of the whole. Most often, all of these are reasons to take a sample. The values of the measurements obtained from a sample must be relatable to the remainder of the waste to be useful in describing the material for the purposes of transportation or disposal.

PURPOSE OF WASTE SAMPLING

Low level radioactive waste is routinely sampled and analyzed to demonstrate compliance with Title 10 Code of Federal Regulations Part 61 (10 CFR 61). The sample results are then applied to the low level waste generated in the plant. Appropriate sampling techniques will ensure that the analytical results are representative of the waste.

The Nuclear Regulatory Commission (NRC) identifies 4 basic methods that can be used to comply with the disposal requirements in 10 CFR Part 61. These are described in their Branch Technical Position on Waste Classification (BTP 1983) [2]. They are:

- Source or Inventory Control/Process Knowledge.
- Direct measurement.
- Gross Radioactivity (dose to activity).
- Correlations – Scaling Factors (Derived from Direct Measurements).

Most characterization activities applied in nuclear power plants are some combination of these methods.

The NRC guidance in the BTP 1983 directs licensees with complicated waste generation processes (such as nuclear reactors) to use any and all methods necessary to determine accurate activity and waste classification. . The NRC recognized in the BTP, however, that accuracy in measuring and reporting activity may be difficult for some waste types and forms. Built into the guidance is an expectation of accuracy with the statement that licensees use “reasonable” efforts to ensure realistic representation of activity and defined a “reasonable target” for accuracy as within a factor of 10 of actual concentrations. [2]

Implicit in this expectation of accuracy is that the licensee has to have some knowledge of what the actual activity and concentrations are. Defining accuracy requires some knowledge of what result is expected so that bias can be established. Bias is essentially the difference between the expected result and the observed result. Therefore, without an expectation, you cannot establish bias. Some of the

radionuclides that the regulations require for tracking can't be reliably measured using standard radiochemistry. Some are vulnerable to sample handling. The overall process presents challenges to the use of measurement results without an appreciation of the bias involved in the process. The NRC recognized these problems and expected an effort to understand and explain process mechanisms as part of the demonstration of compliance.

The NRC's expectation of accuracy applies in both directions. Over-reporting of activity is discouraged as much as under-reporting. This is evident in the statements in Information Notice IE 86-20 'Low Level Radioactive Waste Scaling Factors, 10 CFR Part 61' [3]. In the IE notice NRC staff documented inspector's observations that utility waste programs showed poor correlation between generic radionuclide concentration data and actual radionuclide sample data. Discrepancies greater than a factor of 10 were noted and NRC concluded that the practices could lead to significant over estimates as well as under estimates of actual activity. [3] The IE Notice concluded with four major expectations of utility waste programs:

- Programs should be facility and waste stream specific,
- Method should not unduly over-estimate or under-estimate actual concentrations,
- Concentrations determined from scaling factors should be accurate to within a factor of 10 (also noting that factor of 10 variations are identified as significant and may indicate a possible change or non-compliance but not that they do represent non-compliance)
- Basing activity on a single sample is acceptable – if the sample is representative of the waste as a whole.

The last point is important to further clarify as many licensees rely on the last sample almost exclusively to evaluate a waste container. The text of the IE Notice states that "…as a sample analysis history of facility waste streams is compiled , licensees may choose to determine new scaling factors based on the most recent sample analysis results or combine the latest analysis with those previously obtained to refine the scaling factors currently in use." [3] This implies (rather strongly) that there is a context for making a choice that is based on operating history, sample history for the waste stream or any plant changes that may have occurred and that samples are actually representative of the waste. The preference for using site-specific data and building a history (or context) for evaluating samples is clear. Reliance on the most recent sample was identified as a choice or alternative from the primary expectation of gathering more detailed information over time.

REPRESENTATIVE SAMPLING ISSUES

The question of what constitutes a representative sample becomes the key issue that can be resolved only by building a context within which to evaluate the individual data points. The basic expectation of a representative sample is that it is a subset of all the contaminants represented in the same proportions as in the whole population. On the physical side, this requires a well-mixed source, defined and consistent inputs, meticulous sampling technique and statistically relevant

sample size. These conditions are almost never fully met in a normal operating environment. Most nuclear plant systems are not designed for good mixing and have multiple inputs to tanks or liners. [4] [5] Most samples consist of <1-10 grams of material used to represent 2,000 to 3,000 kilograms of waste.

Samples must also be representative of the operating period during which the waste was generated. Waste samples sent for laboratory analysis are typically taken at annual intervals. [2] Sometimes they consist of a number of other samples composited over the interval. Radioactive decay is not always accounted for in isotopic ratios. Tank design and operation do not always allow for a complete and even change of material. Therefore tanks may contain mixtures of old and new waste. These factors can significantly affect the distribution of activity from the sample results as compared to any other batch of the waste material.

Decisions for the classification and packaging of LLRW based on non-representative sample data can lead to errors. Under predicting the activity in the waste container can lead to selection of the wrong package for transportation resulting in increased risk to the public and emergency response personnel in case of an incident during transportation and place more activity into the disposal site than evaluated in the performance assessment. Over-predicting activity has the effect of wasting resources and increasing costs. [3] The use of more restrictive packaging for transportation can increase worker exposures to radiation (packaging and handling multiple containers to fit the smaller Type B packages), increase storage times (due to limited availability of Type B packages) and increase safety risks to workers (due to the need for multiple handling of containers and use of heavier equipment). Disposal site resources are wasted and the site may need to close earlier than intended as the reported activity reaches the performance assessment limits. While the risks of over-predicting seem more palatable from the perspective of public opinion, they may in fact create more problems for society as a whole.

Making the correct decision then requires that each piece of data available is properly evaluated and placed in the proper context so the true nature of the waste can be accurately determined. The results of individual samples are only pieces to be examined and not necessarily the true description of the waste. Data users often look at a concentration obtained from a laboratory as being ‘the concentration’, without realizing that the number generated by the laboratory is the end point of an entire process, extending from design of the sampling, through collecting, handling, processing, analysis, quality evaluation, and reporting. The U.S. Environmental Protection Agency (EPA) has done studies as part of Superfund clean-up work. In their Soil Sample User’s Guide, EPA states that “…data obtained from sampling and analyses are never perfectly representative and accurate, and that the cost of trying to achieve perfect results would be quite high. Consequently, EPA acknowledges that some uncertainty in data must be tolerated, and focuses on controlling the uncertainty which affects decisions based on those data”. [6] The recommended approach to evaluate individual sample data is to establish a statistical basis wherein the normal variance of the total population can be described and the results of any single sample can be declared to be representative with a designated degree of confidence. [7] [8]

This is especially problematic in nuclear utility waste streams where on-site analysis capabilities are limited to gross counting and/or gamma spectroscopy. The remaining radionuclides important to classification must therefore be derived from scaling factors based on laboratory analysis of annual samples. Scaling factors thus derived are subject to statistical variances depending on operational issues and representativeness of the sample. [9] When scaling factors are based on the results from a single sample it becomes very difficult to establish the accuracy of the result.

Obtaining truly representative samples of utility waste streams is also problematic. [10] There are many barriers to obtaining a representative sample. Many system designs do not have the capability of sampling until multiple waste types have been transferred to a collection tank. Some systems do not have sampling capabilities until after the waste has been transferred to the disposal container. Mixing capabilities are varied with some sites having no mixing capability at all. Tank designs or operations may not allow complete removal of all material on discharge to a waste container resulting in a mixture of waste from different operating periods and with different radioactive decay periods. [4] The collection of multiple samples for a particular batch of waste is frequently not possible due to dose concerns for the workers and adherence to the regulatory principle of As Low As Reasonably Achievable (ALARA). [4]

Waste sample sizes are frequently limited to less than 500 grams. The sample size sent to an offsite laboratory may be limited by activity and license restrictions to less than 1 gram. [4] On-site samples used for gamma spectroscopy are sometimes less than 1 milligram. The results from such samples cannot be assumed to be truly representative based on size alone.

Many studies have been done to identify methods to determine if a sample is representative. Figure 1 shows the results of sample size on concentration. The study was performed by the U.S Department of Energy in the mid 1970's. The data was derived from 20 replicate aliquots of various mass of a single finely milled (homogenized) sample of 4 kg. The larger sample sizes results in a tighter distribution around the true concentration. The smaller samples result in a wider range of probable results. The data shows that even when you have made efforts to homogenize the sample, variability is inevitable at the laboratory level. [11] Therefore, any decision based on the data is uncertain unless you have some other context to know what the expected value should be.

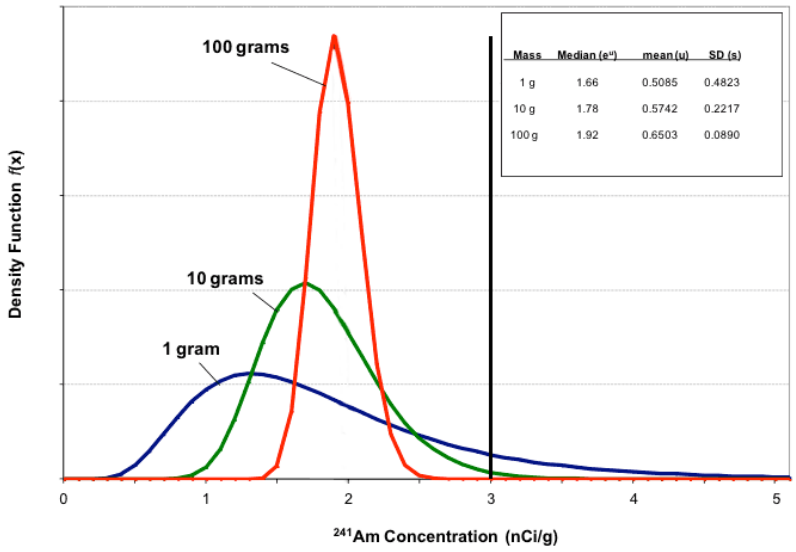

Figure 2-9. Smaller analytical masses contribute to high data variability.
Source: Data from an experimental study on radioactively contaminated soil (Gilbert and Doctor 1985).

(http://www.itrcweb.org/ism-1/2_4_1_3_The_effect_of_subsample_mass_on_data_variability.html)

Figure 1 Effect of Sample Size on Results

The lack of ability to obtain a truly representative sample from utility waste streams defines the issue with respect to characterizing waste. The results of any single sample analysis have very little meaning without some context within which to evaluate the data.

WASTE STREAMS

LLRW sampling should reflect the bulk waste that will be generated in the plant. Typical waste streams for BWRs include dry active waste (DAW), reactor clean up resin, radwaste resin, radwaste filters, condensate resin, spent fuel pool resin and waste oil. Typical waste streams for PWRs include DAW, primary resin, primary filters, secondary resin, evaporator concentrates and spent fuel pool resin. For multiple unit sites, these waste streams may be unit specific. Although waste may be generated as distinct components from each of these systems from a practical standpoint waste may not be traceable to individual plant systems. For example, DAW may not be segregated and tracked to each unit and spent resin may be generated from individual resin beds but comingled in a single resin storage tank.

The NRC in IE Information Notice 86-20 identifies a representative set of wastes streams that could be targeted for routine sampling. Separate lists are provided for BWRs and PWRs. Inherent in the discussion in 86-20, is a continuing process of developing scaling factors to develop a basis for demonstrating compliance with 10 CFR 61. The list provided for broad coverage of streams and waste types to envelop an expected range of conditions and establish more accurate reporting. [3]

While establishing specific waste streams by system may not always be practical, the waste characteristics should be accounted for in the LLW sampling program. An example would be primary system and fuel pool clean-up resins collected in the same tank. Primary system resins will have isotopes and activity consistent with recent production. There will be isotopes with relatively short half-lives and the measured ratios between short and long-lived species will be consistent with production mechanisms. Fuel pool resins will (or should) not contain short-lived isotopes and the measured ratios between short and long-lived isotopes will change according to the decay constants. Sampling a tank with a mixture of these waste streams will yield different measurement values depending on the time of sampling relative to the input of waste and the relative abundance of the two different streams.

SAMPLING TERMS AND METHODS

Terms

The confidence in the results of any series of measurements can be expressed in terms of accuracy and precision. The two terms define the system used to obtain the data and can be used to adjust the plan for obtaining samples. The purpose of samples is to provide good measurements. A good sampling program is both accurate and precise and can then be representative of the whole. If results are either not accurate, not precise or neither, then the sampling program has some kind of systemic error that should be corrected. Statistical methods should be applied to analyze multiple samples over time to develop confidence.

Accuracy.

Sampling accuracy is the closeness of the measured value from the sample to the true value. Sample accuracy cannot be determined without some knowledge of what the true value is. Lacking an absolute standard, this is usually determined by taking multiple samples under controlled conditions and performing some type of statistical analysis on the measurements as a population. Sample accuracy can generally be improved by increasing the number of samples. [12] The true value can also be established using calculations based on production mechanisms and process knowledge or in the case of LLRW from nuclear power plants, measurements of the waste source (coolant) and tracking to the waste stream collections.

Precision.

The sampling precision is the closeness or repeatability of results. When data from repeated samples returns nearly the same result, then the data can be said to be precise. Precision can be improved by increasing the size of the sample. [12] Precision in samples from LLW can be difficult to achieve due to many factors. Precision relies on the stability of conditions. Stability in reactor systems is relative due to the complexity and interaction of the systems, the ability of filter material to extract and hold on to radionuclides and the distribution of flow within filtration systems. Precision in nuclear power plant waste stream measurements may be expressed in orders of magnitude.

Methods

Random Sampling.

Random sampling is usually desirable where the waste to be sampled is well mixed and the activity uniformly distributed. Any location of the material of interest can be sampled with the expectation that the sample is representative of the material. For homogenous material or randomly heterogeneous material, simple random sampling should result in a reasonably representative sample. When little is known about the material random sampling is the typical method to start with until enough data is collected to develop another sampling strategy.

Stratified Sampling.

For materials that are known to be stratified but otherwise homogeneous, a random sample can be taken from each stratum. The stratification of the material can be in space or time. The results of the samples can be combined as an average or in relative proportion to the quantities of the layers if that is known. If the stratification is not well known, this approach may not be appropriate.

Systematic Sampling.

In this approach an initial sampling decision is made randomly followed by sampling at specified intervals. The most common approach is to combine the intervals into one combined sample for analysis. Systematic random sampling is similar to random sampling in that the waste is expected to be homogeneous or uniformly distributed. Systematic sampling can be misleading in cases where the waste is not well mixed and contains quantities of varying activity.

Authoritative Sampling.

Another type of sampling is authoritative sampling, which is performed without regard to randomness. This approach is used where the origination of the waste, either by system, time of generation or both, is known and the objective is to ensure the sample contains the appropriate proportions of each group. The results of this type of sampling should be the most accurate but a significant amount of process knowledge is required to implement the strategy.

Composite Sampling.

Composite samples are multiple individual samples that are combined for analysis. The component samples are usually well separated by location and/or time of generation. This type of sampling is typically used where the source of activity in the waste is derived from multiple and distributed areas and it is not practical to analyze individual samples of each area.

Waste Stream Sampling

Sampling techniques should be designed to collect radionuclides in the waste stream in the same concentrations that they are present in the bulk waste; that is, representative. The sampling techniques may be specific to the waste stream. In all cases, it is important to ensure that the data collected can be related to the final waste product. The sample may need to be processed, dewatered or otherwise altered in a way that the activity can be related to the final waste form. In the case of smears, some quantification of the area or mass of the sample is necessary if the

data is to be used in a quantitative manner. Not all radionuclides will be adequately detected in every sample. The data should be analyzed using appropriate statistical methods to develop meaningful relationships.

Homogeneous Wastes

Resin.

For resin waste streams manual grab samples or a column sample can be taken following transfer to a disposal container. In line samplers are also widely used. [4] Although taking random aliquots is common, using a sample plan may be necessary to ensure representativeness. The nuclide content is likely to be heterogeneous in samples of small volume or weight due to layering or channeling within the demineralizer bed, ion mixture or inadequate tank mixing. Collection of the sample to include all media types that are present in the resin bed is desired. The ratio of anion and cation resin (or other media types) in the sample should match the bulk waste. Failure to take this into account can result in over (or under) reporting of radionuclides. Cs-137 is particularly vulnerable due to ionic specificity.

For resin samples dose rate constraints and analytical laboratory activity license limits may result in bulk waste on the order of several tons being characterized with samples of less-than-one to ten grams. The bulk waste may also include waste of different ages particularly if the resin storage tank has not been completely emptied during processing campaigns. The bulk waste will also contain varying levels of particulate waste.

Concentrates.

Concentrates are typically sampled as grab samples unless in line sampling capability is available in the system. An alternative is coring of waste from the disposal container. [4] Concentrates may be variable over time and subject to layering from successive process batches. Multiple grab samples can be composited and sub sampling performed if necessary due to activity levels.

Oil.

Grab samples may be appropriate for waste oil, however, waste oil is typically a low volume and low activity waste stream. This results in the activity level problems as discussed in the DAW section. This makes it less practical to sample waste oil directly and implies that it may be appropriate to establish a surrogate waste stream. This is discussed further below.

Dry Active Waste

Obtaining representative samples of DAW is challenging due to the large activity variation and low activity concentration. A composite sample of DAW can be collected by taking items of trash from bagged DAW until the desired sample size is achieved. [4] For low activity DAW, sample results are often reported at below analytical minimum detectable activity (MDA) for hard to detect (HTD) radionuclides. This can result in data that is not correlated and not suitable for developing scaling factors. Using scaling factors developed in this manner has the potential over reporting of waste activity levels. Surrogate samples as discussed below are often taken for DAW. An alternative is to select higher activity level DAW

materials for sampling and analysis. This will make it more likely that the analytical results will include detectable levels for HTD radionuclides from which actual correlations can be established.

Discrete Items

Filters

Sampling of filter wastes may be complicated by high activity and variability among individual mechanical filter elements. Smears may be taken of filter housings, filter transfer shields or filter elements however this may not be truly representative and may result in excessive personnel radiation exposure. [4] Smears may also absorb liquid differently resulting in over reporting of H-3 or Cs-137 compared to the filter material. More reproducible results may be achieved by taking cuttings or coring of the filter material however this is physically difficult and may also result in excessive personnel radiation exposure. [4] In some cases high activity smears may be smeared again to achieve a lower dose rate sample but this can lead to loss of material or non-representative proportioning. Segmenting of the initial smear may be a more effective method to reduce total activity in the sample sent to the laboratory for analysis.

A preferable method to sampling of the filters is to perform parallel filtration of the liquid waste or system with a laboratory scale filtration rig or other suitable alternative. [4] This is most applicable for the reactor coolant system (RCS) or in the case of maintenance work in the spent fuel pool (SFP).

Contaminated Items

Sampling of contaminated items is contingent on determining when they are different from DAW and must be considered individually. Contaminated items that must be evaluated as discrete must be both durable (during handling and disposal) and contain significant levels of activity. [13] In most cases the activity in the contaminate item will be from process liquids or other sources that are already defined by other waste streams. Smears may be taken of the contaminated item to verify the waste stream of origin or simply use sample data from the DAW waste stream.

Activated Metals

Direct sampling of activated metal items is not recommended. The total activity of these items, typically originating from the reactor vessel internal components results in dose rates that prohibit physical handling. Analytical methods based on the irradiation history, materials specifications and activation potential of base elements is preferred.

Surrogate Samples

Surrogate sampling can result in more accurate waste characterization than performing direct sampling for some waste streams. The technique is appropriate for low activity wastes such as DAW, waste forms that are difficult to directly sample such as cartridge filters and can also be applied for specific radionuclides. An example of surrogate sampling would be to take a reactor coolant system (RCS) filtrate sample and use the results for the DAW waste stream correcting for waste form and total activity in batches of DAW. Another common practice is to use the

RCS H-3 concentrations and apply that value with an assumed liquid content to calculate H-3 content in other waste streams. A conservative fraction for liquid content can be used such as fifty percent for resin, twenty five percent for concentrates and two to five percent for DAW. [4]

Smears of filter housings, transfer shields or fuel pool wall contamination are often used as surrogates for cartridge filters. Care needs to be taken to ensure these samples are reasonably representative of the material on the filters themselves. One waste stream that can be directly sampled can also be used as a surrogate for another waste stream as long as other data or process knowledge can be used to establish an appropriate relationship.

Indirect Sampling

Indirect sample methods determine concentrations of isotopes in waste though means other than measurement of the waste itself. Indirect methods can be the development of scaling factors from waste or process stream samples, samples of process streams, mass-balance from measurements before and after a filtration mechanism or computer codes that model the process and predict activity. All of these methods are acceptable to the NRC as a method to determine isotopic activity in waste as long as the license can demonstrate the applicability of the method to their waste generation process. [14]

INTERPRETATION OF SAMPLE RESULTS

Samples, once taken, are typically sent to independent laboratories for analysis and quantification. In-house gamma spectroscopy is frequently performed prior to sending the sample to the laboratory in order to establish comparative data to validate both the laboratory and in-house analysis methods. How these results are interpreted affects how the data may be used and the precision of the waste quantification.

It is extremely difficult to validate the results of a single waste sample as representative of the entire collection of waste or the waste stream over time. Single sample results are data points that must be evaluated in the context of the processes that generate the waste and the method(s) of sampling and measurement.

DATA QUALITY OBJECTIVES APPROACH

The Data Quality Objectives (DQO) process is a systematic approach to a data collection project. It was developed by the US Environmental Protection Agency (EPA) as part of project planning for collecting environmental samples. [7] The DQO process is used with a project plan, a sample plan and quality assurance program to ensure that any EPA project involving data collection is successful. A Data Quality Assessment (DQA) is used to verify and validate that the project data objectives have been met. A systematic method of data collection that incorporates the DQO process can be adapted to other types of data collection projects such as collection

of 10 CFR 61 data. The steps of the DQO process are discussed and an example applicable to a 10 CFR 61 data collection project is presented.

The DQO process includes seven steps that can be used in an iterative fashion to ensure collected data is robust. The DQO process is designed to support a decision or estimate a value. The 10 CFR 61 data is used for both purposes; to answer a question regarding the classification of waste and also to estimate the concentration of radionuclides in wastes. This investigation will consider an example for estimation of a concentration. The seven steps of the DQO process are: [7]

1. State the Problem
2. Identify the Goal of the Study
3. Identify Information Inputs
4. Define the Boundaries of the Study
5. Develop the Analytical Approach
6. Specify Performance or Acceptance Criteria
7. Develop the Plan for Obtaining Data

Once the DQO portion of the project is complete and the samples are collected, the Data Quality Assessment (DQA) phase is entered. The DQO process can be used iteratively for complex decisions or parameter estimates. If the data collection process is controlled and the data meet statistical requirements, statistical tools can be used to perform tests and draw quantitative conclusions. In cases where data is less robust, qualitative statistical methods can be used in the data evaluation.

State the Problem

As the initial step in a project the problem must be stated, resources identified and a budget established. Alternative approaches can be identified and constraints and deadlines can be established. [7]

For the 10 CFR 61 case, the problem is to establish content and distribution of radionuclides in identified waste streams. Budgets may be established as part of a routine sampling program and can be reviewed for adequacy. The cost in both financial and personnel radiation exposure may affect the number and types of samples that are reasonable. Alternatives may include validation of existing waste streams or establishing a unique waste stream with specific waste characteristics for a non-routine project. Finally deadlines may be established for the procedurally specified sampling interval (e.g. the current fuel cycle).

Identify the Goal of the Study

The goal of the study is identified in the principal study question. For an estimation problem the expected outcome should be identified that being in most cases determining the feasibility of alternative modes of disposition based on radioactivity content. The effects of various outcomes should be considered. [7]

For the 10 CFR 61 case, the study question may be, for various waste streams, what is the expected radionuclide concentration? This may be in the form of a table of historical reported radionuclide concentrations by waste stream. Because these data are often used as a ratio between a nuclide of interest and a gamma emitting reference nuclide, the expected value of this ratio should be identified.

Identify Information Inputs
Information inputs include the sampling methodology, required analytical methods and the use of existing information to establish the answer to the study question. Detailed consideration of sample location, tooling and sample handling are appropriate. The historical sampling methods and results may be reviewed and validated. [7]

For the 10 CFR 61 case, the information inputs include identifying the waste streams, identifying system properties that affect obtaining representative samples, identifying the most appropriate sampling method and sampling location and identifying an appropriate analytical vendor, ensuring that their techniques are acceptable to stakeholders and their stated analytical capability is sufficiently sensitive. The analytical capability could be compared to applicable detection level requirements to ensure that the study question can be answered. Review of historical data will ensure that any historical data that will be used in the study are robust and appropriate.

Define the Boundaries of the Study
The boundaries of the study are defined by the target population including the temporal and spatial boundaries. Data collection constraints are identified and the scale of the sample and the estimate are selected. Most broadly speaking the population is all that could be sampled. The sample scale is defined from this wider possible unit based on practical limits in time and location. Finally the inference scale is defined (in this case of estimation). [7]

For the 10 CFR 61 case, the population is all the plant radwaste materials that could be sampled. The sample scale can be defined based on practical considerations of waste streams of interest and the timeliness of the sampling effort. Some waste streams may be unavailable and excluded from a specific sampling project. Sample scale issues may result from the inherent level of radioactivity in a specific waste stream. Control of any effects on the study results from this sample scale limitation should be considered and factored into the sample methodology. This will help minimize the effect from the sample on the scale of the inference (estimate).

Develop the Analytical Approach
The analytical approach allows you to analyze the study results and specify the estimator used to create the estimate. The population parameter is selected and used with the boundaries and the scale of the estimate. Population parameters include the mean or median. There may be a level of the estimator that exceeds a critical value of the parameter. [7]

For the 10 CFR 61 case, the study results are typically used as an estimate of the mean value of the activity concentration. These study results are often used for pairs of radionuclides to estimate a radio of radionuclides. The scale will be used (at a later time) to determine an activity content of a specific waste container. It should be noted that use of less than values (non-detects) from analytical results can lead to incorrect application of statistical tools and inaccurate estimates. The effect of the estimate on waste classification should be considered.

Specify Performance or Acceptance Criteria

The estimated value of the parameter will be different than the true value in the population. The variability in the estimate can be expressed in absolute terms or relative to the value of the estimate. It may be appropriate to identify a maximum level of variability that is acceptable. The sources of error can be systematic or random and should be identified. Sampling error includes failure of the sample to represent the population. Measurement errors occur from sample handling, analysis and calculation. [7]

For the 10 CFR 61 case, the estimated value is used as a true value, often as paired values to establish a ratio between two radionuclides. This means it is assumed to be precise. The measurement error is often a large fraction of the estimated value and the sampling error is expected to exceed the measurement error. In addition, non-detects are common in 10 CFR 61 data. The accurate determination of waste activity is the goal of the 10 CFR 61 sample program so the use of an upper confidence level approach is not recommended. Estimates of total study variance can be used to identify the sources of error and that information can aid in designing approaches for further sample collection. Collection of higher activity samples may be desirable to minimize non-detect sample results.

Develop the Plan for Obtaining Data

The seventh step uses the data and information from the first six steps to complete an efficient sample collection plan. This will include developing the plan for the use of existing data, determining what additional data is needed and how samples will be collected and how the results will be validated. Regulatory requirements and knowledge of the population boundaries are factored into the extent of applying judgmental information in the sampling plan. To ensure representativeness of the collected samples, consider the intended use of the results. The final sample plan should be documented including: [7]

1. Number of samples
2. Sample type
3. Collection techniques
4. Sample size
5. Sample support (what the sample will represent)
6. Sample location
7. Sample handling requirements
8. Analytical methods
9. Statistical considerations

For the 10 CFR 61 case, the sample timing and analytical sensitivity is based on regulatory requirements. Practical budget constraints may dictate the amount of sampling. The sample plan typically incorporates sampling of the established waste streams for the site. Sample analytical techniques are often part of an analysis vendor's program, however, the licensee should ensure the vendor's program meets the analytical requirements for regulatory compliance and the vendor should be routinely audited. Sample size is often dictated by practical considerations such as vendor radioactive material license limits and sample shipping requirements. The effect of the sample size on the measurement results should be considered in the plan. Finally, validation of sample results should be planned including the use of

historical information and any statistical analysis of the data to identify measurements that are not consistent with the rest of the data. The data validation should also address the degree to which non-detect results occur, the effects of non-detect results on statistical analysis and strategies to minimize non-detect results.

Project Planning

The DQO process covers the seven steps discussed above; however, the project management process is not limited to these considerations. In a comprehensive programmatic approach the DQO process should be incorporated with the QA project plan and the data analysis process. The project cycle includes three steps: [7]

1. Planning
2. Implementation and Oversite
3. Assessment

The DQO process is a systematic approach to planning. This process is iterative where accumulation of information through the project can improve aspects of the project and the resulting estimate (or decision). [7]

For the 10 CFR 61 case, the DQO process can be used as a systematic planning tool. The results of the DQO plan are incorporated into the project QA plan and used for sample identification and collection. The sample analysis results are then assessed and validated resulting in a final estimate for the nuclide concentration.

Data Evaluation

Assessment of the data is the last phase of the sampling effort and is used to validate the results. Using an iterative approach with the DQO process the sampling project is improved over time. A systematic review of data involves five steps: [7]

1. Review the objectives and sampling design
2. Conduct a preliminary data review
3. Select a statistical method
4. Verify the assumptions of the statistical method
5. Perform calculations and complete the estimate

The assessment process ensures that the sampling has been performed appropriately and that the results are as expected. The data are then tested using an appropriate statistical test. Finally the data are used to complete the estimate.

For the 10 CFR 61 case the objectives of the sampling program and applicable regulations are already established. Data must be evaluated to ensure the objective has been achieved. This can include compiling historical data if this has not already been completed. The preliminary data review can include ensuring that the appropriate detection sensitivity has been achieved and that the analysis uncertainty is as expected. One appropriate statistical method involves taking the current sample result with the historical sample data and computing the dispersion for the data set. This can be validating by comparing to previous usage of this method. Finally the results can be used to compute a final scaling factor for the nuclide pair of interest.

CONCLUSION

Low level radioactive waste is routinely sampled and analyzed to demonstrate compliance with 10 CFR 61. An effective sampling program provides analytical results that are accurate, reproducible and representative of the final waste product. Due to the practical limitations of LLW sampling, sampling strategy needs to be developed and the data analyzed to ensure the regulatory objectives of the program are met. A good sampling program starts with the establishment of waste streams that are representative of varying activity levels, production mechanisms, and plant systems. Once waste streams have been established, the methods for obtaining a representative sample can be developed, sample points identified and sample schedules established. Additional sampling of less important waste streams can be avoided by using one of the sampled streams as a surrogate. It is generally not be possible to obtain a truly representative sample in which case the results from the measurement of the sample must be evaluated within the context of the expected values and the factors inhibiting the collection of a truly representative sample. The results from individual samples rarely provide an accurate description of the waste. A statistical analysis of multiple samples over time is more likely to be representative of the bulk radioactive waste generated in the plant.

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