STUDY OF SAMPLING LOCATIONS FOR CLASSIFICATION OF LWR PROCESS WASTES

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ABSTRACT

A study was performed to identify the considerations arising in the selection of waste sampling locations for LWR process waste streams. The selection of sampling locations, either at points prior to treatment or at the points prior to packaging for off-site shipment, was assessed with respect to how reasonable and accurate these locations would be in determining waste classification. This waste classification is directed at implementing the recent 10CFR61 regulations pertaining to waste destined for near-surface land disposal.

SUMMARY

This study was a preliminary investigation into the influence of waste sampling locations on the ability to provide LWR process waste classification. The two general sampling locations considered were: (1) a point prior to treatment of a liquid waste stream, and (2) a point just prior to the final packaging of a particular process waste stream (e.g., spent resins, concentrates). A modeling study was conducted to determine if waste classification can be implemented by tracking radionuclides in radwaste systems. In general, it was found that due to the relative complexity in modeling some radwaste processing modules, waste classification based on sampling locations at the packaging point would be more desirable. For less complex processing modules, it was found that a waste classification program could be developed based on mathematical modeling of the process in conjunction with upstream sampling by inline flow and radiation monitoring instruments. The trade-off between the two approaches would be determined on a plant specific basis by evaluating if the establishment of an experimental modeling program for such components would be technically feasible and cost effective.

BACKGROUND

Low-level waste generators are required to develop and implement a waste classification program in order to comply with the requirements of 10CFR61 for near-surface land disposal of radioactive waste[1]. The program must provide sampling and analysis methods to identify waste radionuclide distributions so that wastes are classified within the limits upon which the disposal regulations are based. Because some of the radionuclides listed in the NRC Regulation (10CFR61.55) are difficult to measure on a routine basis, waste generators have been searching for alternative waste classification methods that can identify radionuclide concentrations, within the required accuracies, while avoiding extensive nuclide-by-nuclide measurement efforts. Recognizing this situation, the NRC staff has issued a Branch Technical Position (BTP) on waste classification[2]. The BTP states that the principal consideration for acceptability of a waste classification program will be whether a reasonable effort has been made to ensure that: (1) a realistic representation is obtained of the distribution of radionuclides within wastes; and (2) wastes are classified in a consistent manner. A description of a general program which would be acceptable to the NRC regulatory staff is included as Appendix A of the BTP.

While most waste generators have already selected a basic waste sampling approach for classification of their wastes, they are in the process of identifying and developing alternative techniques that can simplify the waste classification efforts and reduce exposures associated with sampling operations. Given the requirements imposed by the regulations and the recommendations of the BTP, various waste classification choices are available to light water reactor (LWR) plants. This paper presents a description of waste classification methodologies currently proposed for LWR plants, focusing on two different choices of plant waste sampling practices, and assesses possible solutions to problems that may be encountered during the implementation of the waste classification program.

BASIC APPROACH TO WASTE SAMPLING AND CLASSIFICATION

Packaged LWR wastes consist of process wastes (such as dewatered slurries and solidified liquids) and dry active wastes (such as discarded components and housekeeping trash). For each of the two waste types, there is a different set of classification methodology options.

This paper focuses on the options available for sampling and classification of process wastes. These waste streams ordinarily include such products as spent resins, evaporator concentrates, spent filters and filter sludges. The basic approach to classification of the LWR process wastes is the same for each of the various waste types. The difference lies in the choice of sampling locations and the hardware (manual or remote) used.

A basic approach employs a two-step classification program. In the first step, a detailed nuclide-by-nuclide measurement of liquid and/or solid samples, drawn from strategic points in the process, is conducted in order to establish constant scaling factors (f_{ik}) that can relate the readily measurable nuclides ("key" nuclides) to those nuclides listed in the regulation (Tables 1 and 2 of

10CFR61) that are not so readily measured. The key nuclides' concentrations (C_{ku}) multiplied by the scaling factors gives the nuclide concentrations at the sampling point location. This relationship and factors involved are as follows:

$$C_{iu} = f_{ik} \times C_{ku} \quad (1)$$

where:

C_{iu} = concentration of nuclide "i" ($\frac{Ci}{cc}$) at an upstream processing location "u"

f_{ik} = scaling factor relating "key" nuclide to nuclide "i"

C_{ku} = concentration ($\frac{Ci}{cc}$) of "key" radionuclide at upstream processing location "u"

The upstream location is defined as a sampling point prior to the treatment of a liquid waste through a reprocessing module which affects the stream's composition (see Fig. 1). This module may be one of the components commonly used to decontaminate liquid waste streams in a nuclear plant such as a demineralizer, filter, evaporator or precipitator (clarifier). Or, it may be some other component such as a waste holdup tank where the effect on the process stream is to allow for radionuclide decay. In general, the processing of the liquid stream will result in a concentration of contamination in a byproduct waste in a location downstream from the process module. The cleaned (decontaminated) liquid is the effluent stream from the module. The stream of interest for waste classification is the byproduct in the downstream locations, as this flow eventually will be that which is packaged for shipment offsite and ultimate disposal.

Once a measurement program specific to a given facility has established the nuclide scaling factor, a routine sampling operation would involve analysis only for the "key" radionuclide concentrations (C_{ku}). The "key" nuclide concentrations would then be used in conjunction with the equation above, applying the scaling factors f_{ik} to obtain C_{iu}.

The second step in the waste classification for packaged process waste would involve determining C_{ic}. In order to convert the radionuclide concentration at the sample point, C_{iu}, to the concentration in the container, C_{ic}, a second conversion factor, f_{ip}, must be developed to account for the process changes between the upstream sample point and the container. Using this conversion factor, the nuclide concentration in the container can be developed using the following equation.

$$C_{ic} = f_{ip} \times C_{iu} \quad (2)$$

where:

C_{ic} = concentration of radionuclide "i" in the waste container "c" ($\frac{Ci}{cc}$)

f_{ip} = process factor (or decontamination factor) relating concentration of radionuclide "i" in upstream process point to radionuclide concentration in the packaged waste.

C_{iu} = concentration of nuclide "i" at upstream processing location "u" ($\frac{Ci}{cc}$)

IMPACT OF SAMPLING LOCATION ON WASTE CLASSIFICATION

An important consideration in development of a waste classification program is selection of strategic sample points so that reasonably accurate conversion factors (f_{ik} and f_{ip}) can be established. Two basic sampling point choices are available. The first choice is sampling points at the waste process module influent line near the primary system discharge points. The second location is at the waste process module byproduct line just before it is discharged into the final waste package.

The scaling factor, f_{ik}, is a function of the fission and activation products released to the primary coolant and spent fuel pool, physical properties of the nuclides, and correlations between different nuclides. This factor is best determined if the sampling point is at the waste processing module influent line. This is due to the fact that the physical and chemical properties of the primary coolant change very little during normal plant operation. Hence, the accuracy of determining this scaling factor is expected to increase as the sampling point gets closer to the processing systems receiving wastes directly from the primary coolant.

In the first choice, however, a mathematical model must be developed for the process module to allow the process conversion factor f_{ip} to be determined . Therefore, the accuracy of f_{ip} will depend to how close the process module can be represented by a mathematical model. An investigation was conducted to determine processing module modeling feasibility. The results are discussed later in this paper.

The second sampling location choice (i.e. points closer to final waste packaging station) would require a very simplified mathematical model for determining the process factor f_{ip}. However, the level of confidence on the repeatability of the scaling factors, f_{ik}, would be less than that for the first sampling location choice. This is due to constant changing of the parameters that affect the ratio of the key nuclides to other, difficult to measure nuclides.

ASSESSMENT OF PROCESS MODELING FOR WASTE CLASSIFICATION

Investigations were conducted to assess process modeling to allow determination of waste package radionuclide inventory by sampling the waste at the process influent by remote inline instruments. Techniques that can be used in the development of a mathematical model for a typical waste processing module can be demonstrated by considering the simplified model shown in Fig. 1. Typically, the operation of a waste processing system involves pumping input waste to a process module where radionuclides, and other impurities, are removed and concentrated in the byproduct. The clean liquid is discharged as the effluent. A process module could be an evaporator, demineralizer, filter, or a

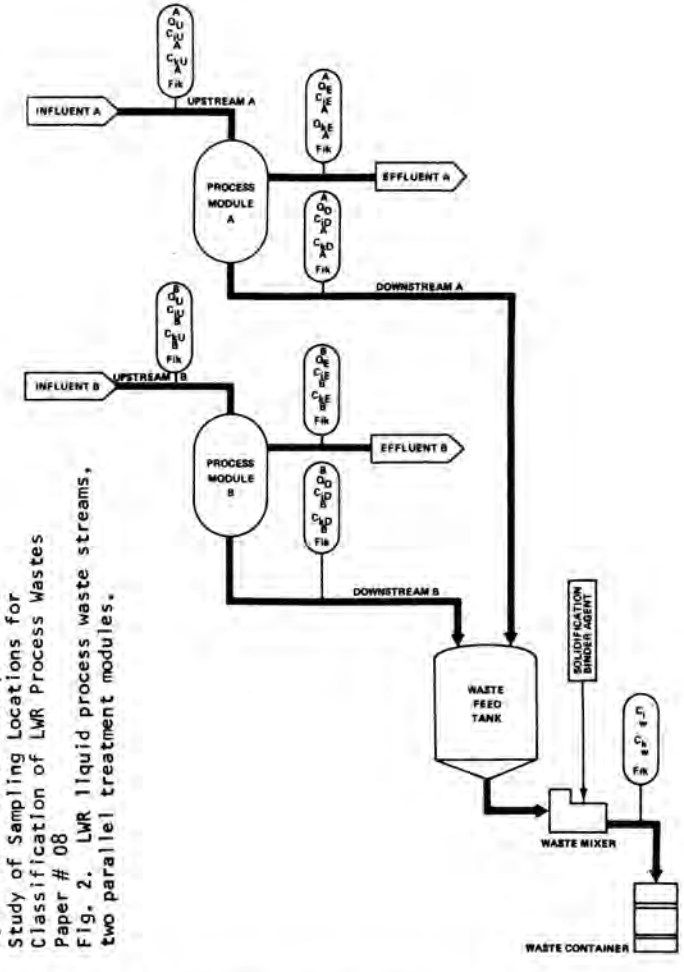

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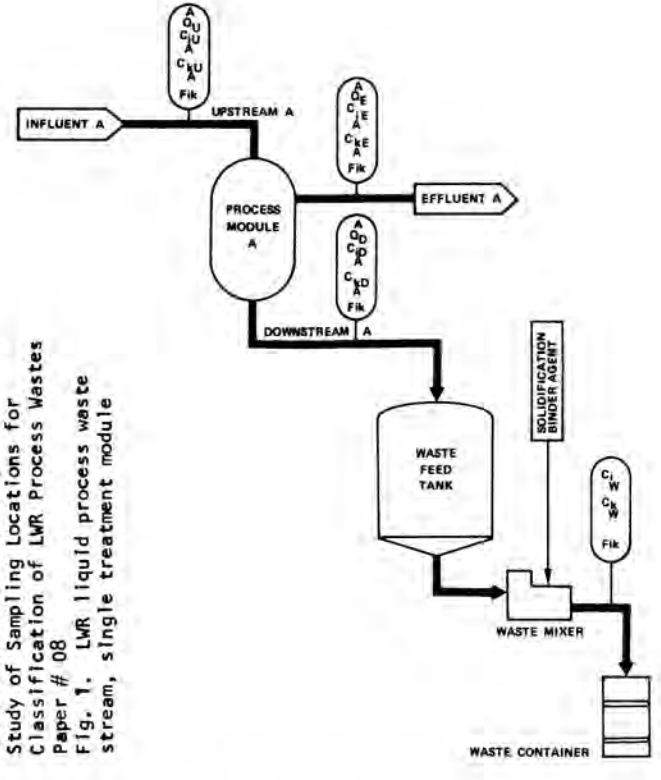
Fig. 2. LWR liquid process waste streams,
two parallel treatment modules.

Fig. 1. LWR liquid process waste stream, single treatment moduel.



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combination of all three. The objectives are to determine the inventory of the radionuclides that are concentrated in the byproduct. This byproduct can be in the form of concentrated liquid, slurry, sludge, or spent ion exchange resin. Normally, this byproduct is discharged into a feed tank where it is conditioned prior to final packaging.

From the standpoint of process modeling considerations, a more complicated case such as that shown in Fig. 2 could exist. In this case, two parallel process modules discharge their byproduct to a common feed tank. A third case involving two process modules installed in series could also exist (see Fig. 3).

Theory

The radionuclide inventory in the waste byproduct from a simplified single unit process module (shown in Fig. 1) can be expressed by an activity balance equation which accounts for the nuclides entering the system, those leaving the system, those retained in the system components, and those lost due to decay. Using a series of composite parameters, the activity balance equation can be represented as follows:

$$\frac{dF}{dt} = A - B - C - D \qquad (3)$$

Where:

F = nuclide inventory in the byproduct

A = nuclide influent rate

B = nuclide effluent rate

C = nuclide deposition rate in the system

D = nuclide loss due to decay.

The composite parameter "A" consists of two subparameters; flow and radionuclide concentration of the influent waste. These two parameters can be accurately determined with inline devices. Hence, using the signal from these instruments processed through an integrator, one can accurately determine the radionuclide inventory entering the process module.

The composite parameter "B" in Eq. (3) above represents the radionuclide content in the effluent. This composite factor can also be determined in the same manner as the parameter "A". It should be noted that in many cases this parameter is already being measured by the plants to account for effluent release quantities. An interesting case arises when the assumption is made that the radionuclide concentration in the effluent is negligible. With the exception of the volatile and hard to remove ions, such an assumption is valid for a majority of the cases involving ion exchange and evaporation processes. Whether completely valid or not, this assumption will result in a conservative estimation of the radionuclide inventory in the favor of the regulator. Therefore, a waste classification program based on this assumption should be acceptable to the NRC and would simplify the overall system model.

The composite parameter "C" accounts for radionuclide loss due to deposition in the system. The mechanisms affecting this loss are too complex to be accurately modeled. However, the impact can be estimated by using a simple reduction factor based on experimental results. Again, underestimating this factor will result in a conservative estimate of the nuclide inventory in the byproduct.

The composite parameter "D" in Eq. (3) is a time dependent exponential relationship for determining radionuclide loss due to decay. The decay time is a function of the system processing time which is dependent on the system mass flow rates and the system volume. The system volume is a known constant but the system mass flow rates must be measured at the influent and effluent points. For system processing periods less than 2 days the composite parameter "D" may not have a major impact on the overall accuracy of the nuclide inventory in the byproduct.

Equation (3) addresses cases involving only a single process unit in a module. For two process modules in parallel (Fig. 2), models of each process module can be determined as discussed above. Then, the process factor for the two process modules can be multiplied by the byproduct feed ratio from each module. This is a simple mathematical equation and can be easily incorporated in the overall model. Accurate results can be generated if the feed rate of the byproduct entering the feed tank can be accurately measured.

For cases involving two process modules in series, a monitoring point between the two modules must be established. This will result in two separate, single module models similar to the one discussed above.

FEASIBILITY OF UPSTREAM SAMPLING

In considering whether this method of sampling upstream of the treatment components is desirable, the difficulties in providing realistic modeling for the process must be thoroughly evaluated for each individual plant case. For some types of treatment components, the modeling studies discussed above indicate that a reasonably accurate mathematical model can be devised without major difficulties. The use of such models in conjunction with inline flow and radiation monitoring instruments located in process upstream points can lead to a reasonably accurate radionuclide inventory determination by remote means. For more complex components, such as the demineralizers and evaporators in series, whose overall performances are functions of many combined parameters which are difficult to measure, the use of models to determine the process factors appears to be less desirable. In these cases, the recommended waste sampling location is at the point prior to packaging of the final waste product.

CONCLUSIONS

This study serves to identify some of the considerations in the selection of waste sampling locations. For waste streams originating from relatively simple to model components such as demineralizers and evaporators, the use of process factors to determine their downstream concentration may be practical. For other processing modules consisting of a combination of components, such as filters, reverse osmosis, clarifier and decay tanks, modeling to determine downstream concentrations of waste may be impractical. In the past, the decision for selection of sampling points has been made based on the assumption that system modeling is impractical. This paper concludes that in certain cases, remote upstream sampling in conjunction with process modeling has a potential for providing an acceptably accurate waste classification program and

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Fig. 3. LWR liquid process waste streams,
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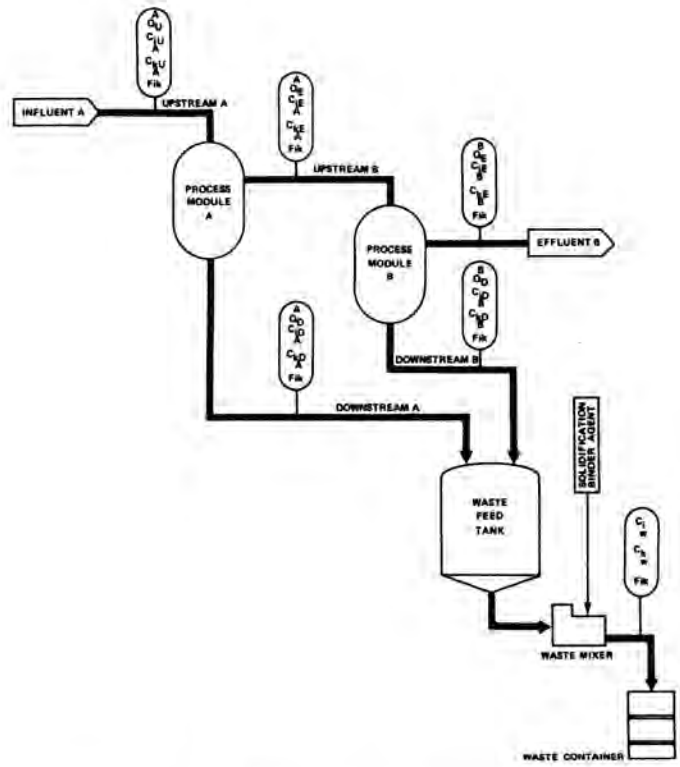

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should be further investigated by actual inplant tests.

REFERENCES

1. CODE OF FEDERAL REGULATIONS, Title 10 - Part 61 "Licensing Requirements For Land Disposal of Radioactive Waste", (1982).

2. U.S. NUCLEAR REGULATORY COMMISSION, "Low-Level Waste Licensing Branch Technical Position on Radioactive Waste Classification", Rev. 0, (1983).

3. W.E. CLARK, "The Use of Ion Exchange to Treat Radioactive Liquids in Light Water Cooled Nuclear Power Reactor Power Plants" Addendum to ORNL-4792, (1978).

4. H. GODBEE and A. KIBBEY, "The Use of Evaporation to Treat Radioactive Liquids in Light-Water-Cooled Nuclear Reactor Power Plants "ORNL-4790, (1978).