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The Use of Data from Other Facilities in the Completion of Dose Reconstructions Under the Energy Employees Occupational Illness Compensation Program Act		Page 1 of 11
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1.0 INTRODUCTION

The basic principle of dose reconstruction is to characterize the radiation environments to which workers were exposed and then place each worker in time and space within this exposure environment. Methods are then applied to translate exposure to radiation into quantified radiation doses at the specific organs or tissues relevant to the types of cancer occurring among the workers.

To ensure accuracy and completeness, a dose reconstruction should consider all relevant monitoring data in the evaluation of exposure. Because personnel monitoring data is specific for an individual, it should be given the most weight in retrospectively evaluating exposure. This assumes, of course, that the data have been determined to provide an accurate characterization of the exposure environment. That is, the data have been reviewed for the following: 1) the validity of the measurement method for the workplace exposure condition being evaluated; 2) the detection limit of the process used; and, 3) the representativeness of the data to the segment of the workforce to which it is applied.

When personnel monitoring data are unavailable or limited in number as to be unrepresentative, workplace measurements, such as air samples or area measurements of external dose may be used. Lacking the above, information about the sources and types of radiation present at a facility and the process operations involving the radioactive materials may be used to construct a model to estimate worker exposure. Table 1 provides a listing of the hierarchical approach to data source usage that is prescribed in NIOSH's dose reconstruction regulation (USHHS 2002).

Table 1: Hierarchy of data sources used in the reconstruction of doses[1]

Hierarchy	Data source	Examples
1	Individual monitoring data	In-vivo analyses, in-vitro analyses, breathing zone air samples, external dosimeters
2	Individual monitoring data of coworkers[2]	Information based on in vitro bioassays or film badge measurements of coworkers
3	Workplace monitoring data	General work area air samples or area themoluminescent dosimeters
4	Source term data and process information	Identification of radionuclides and quantities available for dispersal, along with knowledge of process information

[1] As described in 42 C.F.R. 82.2

[2] Coworkers are considered to be workers at a site (potentially grouped by work location, job description, or other appropriate category) whose radiation monitoring measurements are considered to be representative of those received by one or more workers with no individual monitoring data.

When the source term and process information (hierarchy #4) for a particular facility need to be supplemented to adequately characterize the workplace exposure conditions, it may be necessary to rely on data from another facility to completely develop an exposure model. The data, which could be obtained from any of the first three sources listed in Table 1, are referred to as surrogate data in this implementation guide[3]. These data can be used in the reconstruction of either internal or external dose, providing that the criteria described in this document have been met. In instances, where facility-specific monitoring data are sparse, surrogate data can also be used to support the characterization of the radiation exposure environment at a facility.

In practice, surrogate data are most often used by NIOSH in the reconstruction of internal doses. This is because a complete exposure model for internal dose must not only consider the quantity and composition of the source term, but must also predict the plausible levels of airborne contamination that are generated from the variety of work processes that occurred at a facility. Later in this document, examples of the application of surrogate data to the reconstruction of an internal and an external exposure scenario are provided.

To use surrogate data in the development of an exposure model, certain conditions must be met to ensure that the established exposure values accurately estimate (or plausibly bound) the exposure conditions at a facility. The purpose of this document is to: 1) review the past practices reported in the open literature on the use of surrogate data; 2) describe the conditions under which surrogate data can be used for conducting dose reconstructions under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA); and 3) provide examples of the use of such data.

2.0 PRECEDENCE FOR THE USE OF SURROGATE DATA

2.1 Epidemiologic Studies

Surrogate data has been used in epidemiological studies to estimate exposure to individuals in the workplace. Two previously published review papers provide a good summary of the various methods that have been used in reconstructing exposures for epidemiological study cohorts (Kauppinen et. al 1994 and Seixas et. al 1996). Because the information available for reconstructing chemical and physical agent exposures in the workplace has historically been incomplete, a number of papers have been published that report on the use of surrogate data

[3] Traditionally, the term "surrogate data" refers to the use of any data that is not a direct measure of the individual worker's exposure conditions (e.g., general air samples or coworker models). In this document, however, "surrogate data" is only considered in the context of the use of data from another facility.

in reconstructing these types of exposures. For example, Hornung, et al. (1994) developed a statistical model for the prediction of ethylene oxide exposure that was applied to reconstruct exposure in an occupational mortality study. The data used in the development of the model were obtained from measurements made at 20 different facilities and walk through observations at 36 different plants. Another study reported on the development of a model to estimate chemical exposures to funeral embalmers using measurements taken at a surrogate test facility in which the various parameters that affect exposure could be controlled (Stewart et. al 1992).

Other studies that specifically report on the use of surrogate data for reconstructing occupational radiation exposures have been published. In the study by Eheman and Tolbert (1999), a job exposure matrix was developed for a wide variety of occupations that are potentially externally exposed to radiation. For each occupation, a time-dependent log normal probability distribution (characterized by a geometric mean and geometric standard deviation) was developed that could be used in the reconstruction of individual dose.

In another publication, involving a comprehensive study of historical exposures to radiologic technologists, Simon et al. (2006) used published data from a number of medical facilities to establish the distribution of exposures to unmonitored technologists. The exposure models developed using these data were used to estimate the risk of contracting cancer after exposure to ionizing radiation in the workplace.

2.2 Compensation Programs

<u>The Radiation Exposure Compensation Act</u>

The use of surrogate data has also been employed in the evaluation of exposure in U.S. compensation programs. For example, the evaluation of certain claims under the Radiation Exposure Compensation Act (RECA) requires proof of a total radon exposure of greater than 40 working level months. If actual radon measurements in the mine where a claimant worked are unavailable, RECA specifies the following graded approach for evaluating exposure (USDOJ 2004):

- *(i) If actual measurements from three or more mines of the same or similar type, ventilation, and ore composition are available from the mines in the same locality as the mine in which the claimant was employed, the average of the exposure levels from mines in the same locality will be used.*
- *(ii) If there are insufficient actual measurements from mines in the same locality…an average of the exposure levels in the same mining district will be used.*

(iii) If there is no average of exposure levels from mines in the same mining district, the average of exposure levels in the same state will be used.

The Nuclear Test Personnel Review

Another example of the use of surrogate data in a U.S. radiation exposure compensation program can be found in the Nuclear Test Personnel Program (NTPR) that is administered by the U.S. Department of Veterans Affairs. This program covers military personnel who participated in the U.S. nuclear atmospheric weapons tests that were conducted from 1945 to 1962. Also covered are members of the U.S. military forces who occupied Hiroshima and Nagasaki, Japan, after the atomic bombs were dropped in 1945.

Part of the dose reconstruction for this military cohort requires the reconstruction of internal dose due to the inhalation of radioactive particulate. In many instances, there are no available bioassay samples or measurements of the concentration of radioactivity in air. To reconstruct the inhalation intake of radioactive material that deposited on the surface of ships, the NTPR relies on the use of resuspension factors that were derived from surrogate data. That is, the resuspension factors were developed at a site that performed similar operations to those being evaluated under NTPR.

2.3 General Exposure Modeling

Knowledge of the extent to which physical parameters and processes affect the level of airborne radioactive material in buildings has been used by the U.S. Department of Energy to develop exposure models for occupants of a building. For example, the RESRAD-BUILD[4] program provides a framework for evaluating the dose to an individual who works in a building that is contaminated with radioactive material. It allows for the prediction of airborne contamination using model input parameters, such as surface contamination levels, building air exchanges rates, and resuspension fractions. The bases for many of the exposure scenario values used in this program are taken from those reported in the literature. Thus, this model relies to a large extent on the use of surrogate data.

3.0 CRITERIA FOR THE USE OF SURROGATE DATA

3.1 Introduction

In situations where NIOSH lacks personal and/or area monitoring data, the dose reconstruction regulation (USHHS 2002, 42 C.F.R. § 82.14 (h)(1) thru (5))

[4] RESRAD-BUILD – residual radioactivity in a building.

provides for the use of source-term and process data to complete reconstructions. Specifically, in section 82.2(c), it states:

> *If neither adequate worker nor workplace monitoring data are available, the dose reconstruction may rely substantially on process description information to analytically develop an exposure model.*

Because NIOSH has encountered a number of facilities where radiation monitoring data are sparse, models that incorporate non-facility-specific data to provide actual or bounding estimates of exposure are necessary to complete some dose reconstructions. These models may be needed to reconstruct dose for each type of exposure that is evaluated under EEOICPA (i.e., internal, external, environmental, and medical). To the extent possible, facility-specific data should be used in any dose reconstruction, however, data from other facilities should be used when necessary, according to the criteria outlined in this Implementation Guide.

3.2 Source Term

To model the exposure for a specific process, NIOSH must have, at a minimum, knowledge of the types and general quantities of material being processed at the facility for which a model is being developed. That is, to some extent the source term must be known (USHHS 2002; 42 C.F.R. § 82.14 (h)(1) thru (5)). Section 83.13 of the Special Exposure Cohort (SEC) rule requires that a dose reconstruction must, as a starting point, be based on some information from the site where the employee worked (USHHS 2004). For reconstructing exposures, this means that some information must be available to identify the radionuclide(s) or radiation generating equipment that were present at the facility.

At Atomic Weapons Employer facilities, where it is more likely that surrogate data might be used, the radionuclide dose being reconstructed is most often uranium and/or thorium. Thus, if it can be established that the facility processed uranium or thorium, the criterion of section 83.13 has been met. Although for practical purposes, additional process information would be needed as well. Care must be taken, however, to ensure that any disequilibrium in the uranium or thorium decay series that is created as a result of chemical processing is taken into account in the model.

3.3 Facility and Process Similarities

For an exposure model to be sufficiently accurate, it must be based on a process that is substantially similar to the one being reconstructed. For example, operations that involve grinding, welding, or cutting have a high potential for generating airborne particulate and would be inappropriately modeled using data from a facility that performed solvent extraction operations. For process-specific models, breathing zone air samples are considered the most representative sources of data for modeling inhalation intakes. If breathing zone samples are not available, general area air samples may be used, but corrections must be made to account for the potential negative bias associated with these types of samples. When resuspension models are being developed, it is appropriate to rely on general air sample measurements. This is because general area samples are less affected by the airborne particulate generated by workplace production activities (e.g., grinding, welding, rolling, etc.)

The physical parameters (e.g., size and ventilation) of the surrogate work area must also be considered. How closely the surrogate work area and the area for which reconstructions are being performed must match depends to a large extent on the types of exposures being evaluated. When attempting to model ambient airborne levels in a plant (for example radon levels), care must be taken to relate the facilities on size and ventilation rates. This is somewhat less important when one is evaluating process-specific breathing zone samples. These samples tend to be taken very near the source and are less affected by the facility size and general ventilation patterns. These types of samples may, however, be influenced by the existence of local capture exhaust ventilation, so care must be taken to consider this in model development.

3.4 Temporal Considerations

Because building design and processes change over time, it is important to consider matching the surrogate facility time period of operation with the facility being modeled. If the era of operation of the surrogate facility differs substantially from the time period of operation for the facility being modeled, the appropriateness of the use of such data should be justified. To the extent possible this should be based on the actual recorded conditions at the facilities, but input from site subject matter experts can also be used when such information are lacking.

3.5 Data Evaluation

As with any data used in reconstructing doses, it is important to evaluate the quality of the data used in the development of an exposure model. For internal exposure models, the methods employed to measure bioassay samples or generate air sample results must be evaluated to determine if they were capable of detecting the radionuclide being assayed. In addition, the detection limits of the method should be considered in the development of the model. If data have been censored due to the use of recording or reporting practices (e.g., the reporting of zero values or use of less than values that reflect regulatory limits), the effect of this practice on the overall usefulness of the data should also be evaluated. The overall uncertainty of the model should reflect the uncertainty of that data used in its generation.

3.6 Review of Bounding Exposure Models

When a bounding exposure model is developed using surrogate data, the upper bound must be plausible. That is, it must be realistically possible given the nature of operations at the facility being modeled and other relevant factors. While it is not possible to provide fixed criteria for evaluating plausibility, certain reasonableness tests can be applied. For example, internal exposures should not predict dust loading that would result in asphyxiating conditions, nor should external exposure rates produce conditions that would result in acute radiation syndrome (unless a criticality event were being modeled or employees experienced acute radiation syndrome). Each model should be evaluated for plausibility in light of the known conditions in existence at the facility.

Another test for plausibility might be to compare the exposure values estimated by the surrogate model to any facility-specific values that exist for other time periods of operation. After taking into consideration differences in plant conditions, the predicted values should be evaluated to see if they vary substantially (e.g., differences of an order of magnitude or more) from the plant-specific measurements. If large differences are found to exist, efforts should be made to determine why the model may or may not be representative of the true exposure conditions.

4.0 EXAMPLES

4.1 Internal Dose

A common use of surrogate data in the reconstruction of internal dose is the evaluation of bounding air concentration values at a facility that worked with uranium metal. During the early years of the Atomic Energy Commission's (AEC's) operations, there were a number of AWE facilities that had contractual agreements to conduct forming or shaping work on pieces of uranium metal. Because the contracts with a number of these facilities involved short duration projects, AEC did not attempt to establish routine radiological monitoring programs.

There exists, however, a significant amount of monitoring data from the uranium metal working operations that were engaged in longer-term production activities. Further, the equipment at these facilities (e.g., rolling mills, automatic grinding machines, lathes, etc.) was substantially similar. If care is exercised in the interpretation of the monitoring data available from these facilities, using the criteria described in section 3 of this implementation guide, it should be possible to develop ranges of air concentrations to which workers were exposed.

4.2 External Dose

When a source term and its geometric configuration is known, it is possible to model external exposure rates from first principles using knowledge of the inherent radiological properties associated with specific radioactive materials or radiation generating devices. Based on this, the external radiation exposure rates for various source-terms can be developed using standard Monte Carlo based computer codes such as the Los Alamos Monte Carlo N-Particle (MCNP) transport code. In certain situations, however, the source terms are not present in configurations that easily lend themselves to modeling. This is especially true for chemical processing facilities where the radioactive material moves through the plant in various chemical forms and degrees of radioactive equilibrium. For these types of facilities, it is sometimes possible to bound external exposures using the distribution of external doses observed at a facility where a personnel monitoring program was in place. In keeping with the requirements of section 3, care must be used to ensure that the source term, production rates, and processing operations are substantially similar.

An example where this type of analysis could be employed is in the reconstruction of external doses for workers in the phosphate ore processing industry. A review of the literature indicates that a fairly extensive evaluation of film badge measurements of workers at phosphate plants has been compiled by the Florida Institute of Phosphate Research (FIPR). Given that many phosphate plants use similar chemical separation processes and equipment, it could be possible to bound external exposures at phosphate plants using the distribution of data developed by the FIPR.

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