Summary Report for "Accounting for Errors in Radiation Dose Estimates"

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Project Title: Accounting for Errors in Radiation Dose Estimates

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List of Publications

1. Gilbert ES, Fix JJ, Baumgartner WV: An Approach to Evaluating Bias and Uncertainty in Estimates of External Dose Obtained from Personal Dosimeters. Health Phys. 70:336-345, 1996.

2. Gilbert ES: Accounting for Uncertainty in Systematic Bias in Exposure Estimates Used in Relative Risk Regression. Richland, WA: Pacific Northwest Laboratory, PNL-10909, 1995.

3. Gilbert ES, Fix JJ: Laboratory Measurement Error in External Dose Estimates and Its Effects on Dose-Response Analyses of Hanford Worker Mortality Data. Richland, WA: Pacific Northwest Laboratory, PNL-11289, 1996.

4. Gilbert ES: Accounting for Dose Measurement Error in Analyses of Studies of Workers Exposed to External Radiation. Submitted to Health Physics.

Significant Findings

The research conducted under this project has led to analyses of data from the epidemiologic study of Hanford workers that account for errors in external radiation dose estimates that are used in this study. In these analyses, estimates of the excess relative risk were corrected for bias in recorded doses as estimates of organ dose, and confidence intervals reflected uncertainty in the correction factors. The approach developed for these analyses is applicable to other epidemiologic studies of nuclear workers exposed to external radiation including several studies in the United States and also an international collaborative study of nuclear workers in several countries. The analyses address both random and systematic errors in dose estimates, and provide confidence limits that reflect uncertainty resulting from such errors. In the case of combined analyses of data from several studies, the analytic approach could account for variation in the uncertainties in dose estimates in different studies. A major objective of these worker studies is to provide a direct evaluation, based on data at low doses and dose rates, of the health risk estimates that serve as the basis for radiation protection standards. The application of analytic methods that account for dose measurement error increases the appropriateness and validity of this evaluation. The analyses of the Hanford data and the overall approach used are described in the fourth publication listed above.

To account for external dose estimation errors in dose-response analyses, it is first necessary to quantify the biases and uncertainties in these estimates. Thus, the objective of Task 1 of this project was to prepare a journal article (publication 1 above) that described and illustrated an approach for doing so. This article made the material provided in a earlier technical report more accessible to scientists with an interest in a practical approach to specifying uncertainty in external dose estimates in a form that could be utilized in epidemiologic dose-response analyses. The approach described in this paper evaluates biases and uncertainties in external dose estimates from each of several sources, and combines them to obtain an overall assessment. The approach addresses the extent to which errors are correlated across workers and across different dosimeter readings for the same worker, since this information is needed for adjustment of epidemiologic analyses. The approach is applied to dose estimates for workers at the Hanford site, and provides quantitative estimates of both bias and uncertainty in recorded dose as estimates of deep dose, red bone marrow dose, and lung dose; separate estimates are given for each of four time periods in which different dosimetry systems were in use.

Second, it was necessary to develop and implement an approach for accounting for uncertainty in systematic bias in recorded external doses. This was addressed in Task 2 of the project with results described in publication 2. This publication addresses the situation in which systematic bias in exposure measurements is known to be present, but where there is uncertainty in the magnitude and nature of the bias. Two approaches that allow this uncertainty to be reflected in confidence limits and other statistical inferences were developed and applied to the Hanford worker data using the bias and uncertainty factors developed in Task 1 and provided in publication 1. For the Hanford data, sampling error was found to dominate and allowing for additional uncertainty did not greatly affect confidence limits. However, taking account of uncertainty in factors that correct for systematic bias will become more important as uncertainty resulting from sampling variation decreases as is likely in future combined analyses of data from several countries. In general, the approaches developed under Task 2 make it possible to account for a potentially important type of exposure uncertainty. The methods could be applied to any study where quantitative risk estimates (expressed per unit of exposure) are of interest.

Finally, it was necessary to develop an approach for addressing random errors in dose estimates. This first required developing models for describing laboratory measurement errors in cumulative doses of workers, and this was accomplished under Task 3 by reviewing historical materials relevant to determining the likely magnitude and nature of errors for Hanford workers. As an alternative to taking account of these errors (which would be complicated), calculations were made that demonstrate that, in general, the distorting effects of laboratory measurement errors in dose-response analyses of Hanford worker data are likely to be trivial. This occurs because the larger cumulative doses that are the most influential in dose-response analyses are almost always the sum of a large number of independent dosimeter readings over time, and thus the relative laboratory errors in such doses are small. These calculations, as well as the development of the Task 3 models, are described in publication 3. In addition, it is argued in publication 4 that aside from taking account of uncertainty in correction factors (Task 2), no additional corrections are needed to address random errors resulting from variation in exposure energies and geometries.

Usefulness of Findings

A major objective of epidemiologic studies of nuclear workers is to provide a direct evaluation, based on data at low doses and dose rates, of the health risk estimates that serve as the basis for radiation protection standards. The results of these studies are considered by groups that set radiation protection standards, which are of benefit to workers employed in the nuclear industry. The research conducted under this grant will lead to analyses of data from epidemiologic studies of nuclear workers that account for errors in external radiation dose estimates, and thus increase the appropriateness and validity of this direct evaluation.

How the Aims of the Project are Addressed in the Publications.

The aims of this project are best summarized in terms of the four tasks proposed in the original proposal. These are repeated below followed by an indication of the publication that addresses the task.

Task 1. Describe a recently developed approach for quantifying biases and uncertainties in external dose measurements in a journal article that focuses on the kind of information needed for adjustment of epidemiologic dose-response analyses. This article will make methodology currently described in an extensive draft technical report accessible to a wider audience.

This is addressed in publication 1: Gilbert ES, Fix JJ, Baumgartner WV: An Approach to Evaluating Bias and Uncertainty in Estimates of External Dose Obtained from Personal Dosimeters. Health Phys. 70:336-345, 1996.

Task 2. Develop and implement an approach for accounting for uncertainty in systematic bias in recorded external doses. Apply this approach to dose-response analyses based on Hanford worker data, and to analyses of combined data from Hanford, Oak Ridge National Laboratory, and Rocky Flats.

This is addressed in publication 2: Gilbert ES: Accounting for Uncertainty in Systematic Bias in Exposure Estimates Used in Relative Risk Regression. Richland, WA: Pacific Northwest Laboratory, PNL-10909, 1995.

Task 3. Develop a model for uncertainties resulting from random variation in laboratory measurements, taking account of the dependence of these uncertainties on the number of readings and the magnitude of the dose.

This is addressed in publication 3: Gilbert ES, Fix JJ: Laboratory Measurement Error in External Dose Estimates and Its Effects on Dose-Response Analyses of Hanford Worker Mortality Data. Richland, WA: Pacific Northwest Laboratory, PNL-11289, 1996.

Task 4. Develop and implement an approach for accounting for random uncertainties in estimates of cumulative external dose used in nuclear worker studies. Apply this approach to dose-response analyses based on Hanford worker data.

As an alternative to developing an approach for accounting for random uncertainties in estimates of cumulative external doses, it was demonstrated in publication 3 (Gilbert ES, Fix JJ: Laboratory Measurement Error in External Dose Estimates and Its Effects on Dose-Response Analyses of Hanford Worker Mortality Data. Richland, WA: Pacific Northwest Laboratory, PNL-11289, 1996) that the effects of laboratory errors on dose-response analyses were negligible. It was argued in publication 4 (Gilbert ES: Accounting for Dose Measurement Error in Analyses of Studies of Workers Exposed to External Radiation. Submitted to Health Physics) that no further adjustments were needed for random errors resulting for other reasons.