



**Public Comments on MSHA's
Proposed Rule:**

**Lowering Miners' Exposure to
Respirable Coal Mine Dust,
Including Continuous Personal
Dust Monitors**

RIN 1219-AB64

**Specific Comments on: Quantitative
Risk Assessment**

Prepared for

Murray Energy Corporation
29325 Chagrin Boulevard, Suite 300
Pepper Pike, OH 44122

Prepared by

Richard Reiss, ScD, MS
Kenneth Bogen, DrPH, MPH, DABT
Exponent
1800 Diagonal Road, Suite 500
Alexandria, VA 22310

April 27, 2011

© Exponent, Inc.

QMS QA ID no. 1007321.000 D0T0 0411 RR27

AB64-COMM-92-2

Contents

	<u>Page</u>
List of Tables	iii
Qualifications	iv
Dr. Richard Reiss	iv
Dr. Kenneth Bogen	iv
Executive Summary	vi
Introduction	1
General Comments	2
Introduction	2
Number of Coal-Mine Dust Samples Used in the Analysis	2
Missing Entity Code	4
Temporal Trends	4
Analysis of Covariance Approach	6
Biased Data Adjustment Methodology	9
Challenges in Meeting the Proposed Standard	10
Introduction	10
Estimating the Reductions Needed to Meet the Standard	12
Lack of Quantitative Uncertainty Analysis	16
Feasibility of Meeting the Rule	17
Conclusions	19
Attachment A <i>Curriculum Vitae</i> for Dr. Richard Reiss	
Attachment B <i>Curriculum Vitae</i> for Dr. Kenneth Bogen	

List of Tables

	<u>Page</u>
Table 1. Summary of distributional analysis of log-transformed MSHA inspector data, by job category.	8
Table 2. Summary of changes in proposed rule that will affect compliance with the new standard	10
Table 3. Reductions required to meet proposed standard with a 95% annual compliance rate	13
Table 4. Reductions required to meet proposed standard with a 99% annual compliance rate	13

Qualifications

Dr. Richard Reiss

Dr. Richard Reiss is a Principal Scientist in Exponent's Health Sciences Center for Chemical Regulation and Food Safety. He is an experienced environmental health scientist with expertise in risk assessment, exposure assessment, environmental chemistry and fate, mathematical modeling, and applied statistics. He has conducted risk assessments, data analyses, probabilistic exposure modeling, and environmental exposure modeling for environmental agents, such as pesticides, industrial chemicals, consumer product chemicals, and asbestos. He has conducted risk assessments for new and existing products.

Dr. Reiss is actively involved in several scientific societies and is the Past President of the Society for Risk Analysis, the leading scientific society devoted to the field of risk assessment. Dr. Reiss was the Managing Editor of *Risk Analysis: An International Journal*, the leading scholarly journal for risk analysis, from 2001 through mid-2008. He was the winner of the 2001 Chauncey Starr award from the Society for Risk Analysis. This award recognizes a risk analyst younger than 40 who has made major contributions to the field of risk analysis. Dr. Reiss was also a councilor in the Society for Risk Analysis (term 2005-2008). In 2010, he was elected a Fellow of the Society for Risk Analysis.

A full *curriculum vitae* for Dr. Reiss is provided as Attachment A.

Dr. Kenneth Bogen

Dr. Kenneth T. Bogen is a Managing Scientist in Exponent's Health Sciences Center for Exposure Assessment and Dose Reconstruction. He has nationally recognized expertise in risk assessment for environmental carcinogens, and in related exposure, pharmacokinetic, dose-response, and uncertainty analysis. Before joining Exponent in 2007, he led experimental, epidemiological, and mathematical-modeling research on health risks posed by environmental

exposures to chemicals and ionizing radiation, as a University of California environmental scientist for 20 years at Lawrence Livermore National Laboratory.

Dr. Bogen consults as an expert on chemical-risk and statistical aspects of litigation involving environmental, occupational, dietary, and consumer-product exposures, as well as groundwater contaminants. He helped develop methods that are now widely used to quantitatively characterize uncertainty and variability in environmental exposure and risk, and to develop and apply physiologically based pharmacokinetic (PBPK) models, and biologically based, mechanistic dose-response models that are used to assess risks posed by exposures to volatile solvents, carcinogens, and cytotoxic chemicals.

Dr. Bogen served as a Member of the National Academy of Sciences/National Research Council (NRC) committees that issued *Science and Judgment in Risk Assessment* (1994) and *Review of the Army's Technical Guides on Assessing and Managing Chemical Hazards to Deployed Personnel* (2004); served as expert panelist at the NRC Standing Committee on Risk Analysis Issues and Reviews, Workshop on Uncertainty in Cancer Risk Based on Bioassay Data (2007); chaired the Metabolism and Mode of Action Panel, *Naphthalene State of the Science Symposium* (NS³), Monterey, CA (2006); and chaired the U.S. Consumer Product Safety Commission's Chronic Hazards Advisory Panel on Diisononyl Phthalate (DINP) (2000–2001). Dr. Bogen also wrote and continues to develop *RiskQ* computer software (a University of California–licensed *Mathematica*[®] package) for biostatistics, stochastic modeling, and uncertainty analysis. He also is the author of *Uncertainty in Environmental Health Risk Assessment* (Garland, New York, 1990), and is the author or coauthor of more than 100 reports and publications in peer-reviewed scientific journals. Dr. Bogen served as President (1995) and Councilor (2004–2006) of the Northern California Chapter of the Society for Risk Analysis.

A full *curriculum vitae* for Dr. Bogen is provided as Attachment B.

Executive Summary

MSHA's Quantitative Risk Assessment (QRA) provides two types of calculations: (1) an estimation of the mean respirable coal mine dust (RCMD) concentration that will be necessary to meet the proposed rule, and (2) an estimation of the potential reduced incidence of disease associated with meeting the RCMD reductions. The comments focus on the first set of calculations, while another Exponent report discusses the underlying epidemiologic studies that were used in the benefits assessment (Kelsh and Doemland, Exponent 2011).

MSHA provides a detailed statistical analysis of the RCMD concentration data for a data set from 2004–2008. However, the analysis is overly complicated and makes a number of questionable assumptions. A few of the key issues include:

- The QRA makes contradictory statements about the number of samples used in the analysis, which makes reproducing the MSHA analysis impossible.
- The QRA only includes operator data for 2008, based on the conclusion that a downward temporal trend exists. However, the trend can be also explained by the fact that there is increased sampling error associated with decreasing sample size for the right-skewed data. Therefore, it is very possible that there was no actual change in RCMD concentrations over time as MSHA has assumed.
- The Analysis of Covariance (ANOCOVA) model used by MSHA is overly complicated and relies on an unnecessary non-parametric distributional analysis. As demonstrated in these comments, the RCMD data are well described by a mixed log-normal distribution. We provide the fitted parameters of the distribution so that MSHA can use it to refine the analysis.

MSHA's analysis of the required RCMD reductions needed to meet the proposed standard is not adequate and substantially underestimates the necessary reductions. Three major changes need to be accounted for: (1) the change in the compliance level from 2 mg/m^3 to 1 mg/m^3 , (2) the

change in the compliance basis for a 5-shift average to a 1-shift exceedance, and (3) the substantially greater number of samples required to be collected. MSHA has fully accounted for only the RCMD compliance level. It has partially, but not fully, accounted for the change in the compliance basis. It has not made any attempt to account for the change in the number of samples required to be collected.

Calculations of required RCMD reductions are provided that account for all of the changes in the proposed rule. Data for longwall tailgate operators were used to demonstrate the method. To achieve an annual probability of 95% for going a year without a violation, the mean RCMD levels for longwall tailgate operators would need to be reduced to 0.14 mg/m^3 , or a 90% reduction. To achieve an annual probability of compliance of 99%, the mean RCMD levels for longwall tailgate operators would need to be reduced to 0.11 mg/m^3 , or a 92% reduction.

The QRA also lacks a quantitative uncertainty analysis, which is necessary for readers to understand the potential uncertainties in the benefits assessment.

MSHA devotes less than a full page to discussing the technological feasibility of the rule and argues that meeting the standard will not be too difficult, because many operations already have dust levels less than 1.0 mg/m^3 . However, the calculations in these comments showing the required RCMD reductions contradict MSHA's claim. The concentrations necessary to meet the proposed standard with a reasonable rate of compliance are extremely low, and mine operators have indicated that these levels are not feasible.

Introduction

The MSHA Quantitative Risk Assessment (QRA) provides two significant calculations:

- Estimate of the reduced coal-mine dust level required for compliance with the proposed rule.
- Estimate of the reduced incidence of respiratory disease, including coal worker pneumoconiosis, emphysema, and non-malignant respiratory mortality (NMRD), associated with achieving the estimated coal-mine dust reductions.

The most significant comments relate to the calculation of the reduced coal-mine dust level required to meet the standard. The analysis shows that MSHA has considerably underestimated the effect of the different elements of the rule changes. Before describing this analysis, we first provide some general comments on the QRA that address issues of transparency and data analysis.

The health effect incidence calculations rely on a series of epidemiologic models. Exponent has separately provided comments on those models (Kelsh and Doemland, Exponent 2011).

To perform this review, the 2004–2008 coal-mine dust data used by MSHA in the QRA analysis were requested and obtained, including both the inspector and operator data sets. The calculations in these comments are based on these data sets.

General Comments

Introduction

This section provides general comments about the calculations and statistical methods used in the QRA. Generally, the QRA is overly complicated and relies on more complex statistical methods than is necessary. This makes the document opaque and difficult to read. Some of the comments below contain suggestions for reducing the complexity to provide a more straightforward and accurate analysis. Other comments relate to inconsistencies and inaccuracies in the calculations.

Number of Coal-Mine Dust Samples Used in the Analysis

There are several inconsistent statements regarding the number of coal mine dust samples used in the analysis. MSHA employed a database of coal-mine dust samples collected in 2004–2008. On page 4, the QRA refers to a total of 181,767 valid (non-voided) samples and states:

Appendix B provides details on an additional 20,833 samples excluded from this QRA either because they could not be linked to an occupational exposure or because they were collected within 21 days of samples collected on a prior MSHA dust inspection day. The later samples were excluded because they were generally collected in response to excessively high dust concentration measurements on the first day of an inspection. [Samples collected more than 21 days apart may be considered to come from independent inspections.] Appendix C contains a statistical analysis of these samples and explains why retaining them would bias the occupational exposure estimates. The remaining 146,917 valid occupational ‘Day-1’ samples...

The total of 146,917 samples is quoted in Table 1 on page 6 as the total number of valid “Day-1” respirable coal-mine dust (RCMD) concentration samples collected by MSHA inspectors during 2004–2008, after excluding (a) intake air samples, (b) samples not associated with an occupation, and (c) samples collected within 21 days after “Day 1” of an MSHA dust

inspection. This same number is quoted on page 8 as the number of “valid occupational ‘Day-1’ samples by job category.” However, 181,767 minus 20,833 is 160,934, not 146,917. So it is not clear many samples were actually analyzed. MSHA should address this apparent discrepancy and, if necessary based on their review, should update these analyses with a consistent and well-documented explanation of the number of samples analyzed.

Furthermore, Table 34 (page 93) indicates that, of 181,767 valid (non-voided) samples, a total of 14,016 were excluded as non-Day-1 samples, leaving a total of 167,750 valid Day-1 samples. Also, the table indicates that 9,906 of these were Intake Air samples that are explained as having all been excluded from the quantitative risk analysis (QRA), as was one miscoded sample, leaving a total 157,844 samples potentially available for the QRA. It is then stated (on page 93, paragraphs 2-3), “In addition, 10,927 Day-1 samples were excluded because they could not be linked to an occupational exposure. ... Therefore, the QRA relies on a total of $167,751 - 1 - 10,927 = 146,917$ valid Day-1 MSHA inspector samples.” However, $167,751 - 1 - 10,927$ equals 156,823, not 146,917. Moreover, of the 157,844 samples potentially available for the QRA mentioned above, only 7,382 appear to be flawed in the sense that they either (a) have a job code that is missing or excluded (or equal to zero), (b) have a work location that is missing (or equal to zero), or (c) have a missing (non-numeric) Dust Concentration or ApplDustStand value, assuming that zero values of job code and/or work location are intended to be excluded. This leaves a total of $157,844 - 7,382 = 150,462$ apparently valid samples, which again is greater than 146,917.

An appendix needs to be added that explains the data files that were used. It should provide a clear, step-by-step explanation of exactly what criteria (in terms of variables defined in those data files) were used to define each final data set used in each analysis referred to in the QRA. Only with such an explanation could any reader repeat these analyses. The appendix should also include how job codes and/or work locations with a value of zero are intended to be interpreted. Such explanatory material is now either absent, or obfuscated by being dispersed in the report text, table footnotes, and appendices.

Missing Entity Code

On page 5, reference is made to “the 4-digit entity code” in the raw coal-mine dust data text file(s). However, in the ‘Inspector Samples.txt’ file, the Entity Code values, if present, were all integer values ranging from 0 to 9999, and were thus not character codes all containing 4 digits. The text needs to clarify whether the data files, which contain integer values for the Entity Code without any leading zeros, can be used to repeat the analysis performed, or instead whether any of the leading zeros are required for correct data interpretation.

Temporal Trends

Table 5 of the QRA tabulates the number of valid “Day-1” samples collected per work location. However, the QRA does not explain or comment on the unusual patterns in Table 5. First, within each occupation, the year-specific mean sampling rates, R , of the number of valid samples per work location (WL) are all substantially less than those corresponding to the entire 5-year period 2004–2008 (evidently due to substantial WL overlap across years). Second, for nearly all underground occupations, there are apparently significant negative linear trends in R over time (i.e., fewer samples taken per work location over time). Each of these factors can bias the statistical analysis.

The QRA concludes that “there is, in fact, a correlation between average dust concentration and the number of Day-1 samples at specific WLs” (i.e., between the coal-mine dust concentrations in a work location and the number of samples taken at the work location). For this reason, and because of potential temporal trends in WL-specific RCMD, the QRA (at p. 24-25) explains that all of its subsequent analysis considers only (Box-Cox transformed values of) WL-specific mean RCMD, independent of R . However, no consideration is given to the substantial skewing (approximate single-lognormal or mixed-lognormal distribution) of the RCMD data. From this skewing, it is expected that larger sample sizes will be associated with larger sample means, and thus (due to the temporal trends in underground sample size per WL evident from Table 5), the underground sample mean RCMD values should exhibit a downward temporal trend due (spuriously) to reductions over time that occurred in R (the number of samples taken per WL). This questions the validity of the statement made on page that “A negative value indicates a

decline (i.e., improvement) in median dust concentration. Measurements on underground laborers, for example, improved significantly over the 5-year period, at an annual rate averaging about 10 percent.”

The nested ANOCOVA model used in the QRA to analyze the inspectors’ data included data from all years 2004–2008; however, operator data were restricted to 2008 only. The logic for including the operator data in the analysis, and for restricting these data to 2008, is stated on p. 24:

Although improvements in average dust concentration over the period 2004–2008 were evident for several occupational categories ... Therefore, undue influence of measurements in earlier years constitutes one source of potential bias with respect to estimates of current exposure conditions. Second, there is evidence suggesting that dust concentrations are lower than average on shifts sampled by MSHA inspectors. [References footnote 24 – “See MSHA, 1993. Also, anecdotal evidence was presented in oral testimony at the public hearings on proposed coal mine dust regulations held in August, 2000 and May, 2003.”]

Thus, a study that pre-dates all of the 2004–2008 was used, together with anecdotal evidence, as the basis for justifying the calculation of “adjusted” data using an algorithm that combined inspector data for 2004–2008 together with operator data restricted to 2008 only. The conclusion that there were “improvements in average dust concentration over the period 2004–2008” is not established using the 2004-2008 inspector data, given that RCMD levels were skewed to the right in all years, and the number of underground measures per location declined significantly from year to year (see Table 6, page 18): Thus, a downward trend in the average level per WL is expected due to increasing sampling error associated with decreasing sample size for the right-skewed data, absent any real change in RCMD distributions over that period.

The QRA (2010, p. 3) notes that “sampling requirements for the operators’ program target those occupations and areas in a mine that MSHA considers most likely to experience the highest dust concentrations on a given shift [, which] sampling strategy is intended to protect all workers by monitoring the most highly exposed.” The countervailing claim (pp. 3-4) that “MSHA

inspectors' sampling data, on the other hand, include dust concentration measurements" that reflect "potential alterations of work practices in the presence of an inspector" is not supported by evidence from any specific data analysis, and in any event, such bias could be quantified easily by bounding typical location-specific temporal RCMD variability using sets of continuous-monitoring data.

An independent assessment of temporal trend by job category in the MSHA inspector Day-1 sample data shows no meaningful temporal trend in any category or for the aggregated data. While some such trends reach nominal statistical significance, they explain virtually zero percent of the variance of the natural-log-transformed RCMD data, and therefore have no practical significance.

Consequently, the decision in the QRA to exclude any pre-2008 data in the QRA, and/or to include time as a relevant factor in the analysis, is unjustified. MSHA should re-analyze a data set that includes the years 2004–2008 to obtain a better assessment of current dust levels in U.S. underground mines, and then should consider the feasibility of meeting the proposed rule's concentration level of 1.0 mg/m^3 (in the context of other proposed rule requirements).

Analysis of Covariance Approach

Appendix G of the QRA concludes that a substantial fraction of adjusted Day-1 WL-specific natural-log-transformed data exhibit non-normality. Thus, a Box-Cox data transformation was used, which greatly complicates the data analysis.

However, an independent analysis of the transformed inspector data by job category (excluding Part-90 miners, for whom there were very few data) shows that, when each MineID- and WL-specific set of untransformed data is normalized (divided) by its corresponding applicable dust standard (ApplicableDustStd) value, the resulting log-transformed data sets aggregated by job category are, in each, either approximately normally distributed (for 9 of 33 job categories), or otherwise approximately distributed as a mixture of two normal distributions for the remaining job categories (see Table 1). These approximations are all fairly or highly accurate.

Specifically, in each job category, the coefficients of determination (i.e., R^2 values) were all

≥ 0.998 , with most considerably closer to 1. The Kolmogorov one-sample goodness-of-fit test p-values were ≥ 0.3 for all job categories but one (S8), and for that one, the R^2 was 0.998 (with $n = 8,878$), indicating little practical importance of the minor, albeit statistically significant, lack of fit for this one category. For this analysis, a very small fraction (on average 0.031%) of all (149,899) data were pre-excluded as outliers, defined as any log-transformed, RCMD-standard-normalized RCMD concentration having a standard normal score (calculated using all corresponding MineID- and WL-specific data) indicating a likelihood ≤ 0.0001 . The final data set included a total of 149,852 measures.

The mixed lognormal distributions in Table 1 provide a more accurate and simpler basis for performing statistical analysis with the coal-mine dust data set.

Table 1. Summary of distributional analysis of log-transformed MSHA inspector data, by job category.

ob Code ^a	N	Mixed normal model parameters: Prob(X≤x) = (1-p)Φ[(x-μ1)/σ1] + p Φ[(x-μ2)/σ2]					Shapiro-Wilk test*	R ²	Kolmogorov 1- sample test	Pr(Ratio>1) ^a
		μ1	σ1	μ2	σ2	P	P-value		P-value	
U1	118	-0.870647	0.245379	-1.15593	0.772498	0.617598	0.016571	0.997833	0.998	0.042
U2	16981	-1.00577	0.716085	-0.492163	0.564833	0.220868	10 ⁻⁹	0.99997	0.955	0.11
U3	567	-1.23124	0.924781	-0.461161	0.54055	0.312152	0.00021	0.999274	0.940	0.12
U4	636	-1.46212	0.930144	-1.21549	0.530642	0.378101	0.028	0.999637	0.997	0.040
U5	2409	-1.73119	0.778026	-1.73119	0.778026	0	0.091	0.999512	0.743	0.013
U6	995	-1.12149	0.428353	-1.84694	1.05052	0.861761	0.010	0.999856	0.99999	0.035
U7	598	-2.11789	0.487236	-1.55838	0.600508	0.377188	0.022	0.999725	0.9992	0.0018
U8	1936	-2.03668	0.344063	-0.848808	0.576299	0.922634	0.00045	0.999849	0.995	0.065
U9	2000	-0.670991	0.496959	-0.670991	0.496959	0	0.034	0.999265	0.33	0.089
U10	1028	-0.502403	0.584618	-0.473415	0.322903	0.366929	0.0045	0.99974	0.9881	0.15
U11	963	-1.51909	0.763103	-1.51909	0.763103	0	0.70213	0.999578	0.990	0.023
U12	3384	-1.14696	0.619672	-1.44168	0.981394	0.175428	8 × 10 ⁻⁷	0.99992	0.993	0.039
U13	33369	-2.70846	0.495417	-1.13292	0.710631	0.956481	0	0.999988	0.82	0.053
U14	8641	-1.53771	0.916098	-1.24275	0.65615	0.57182	<10 ⁻¹⁰	0.999972	0.96	0.0367
U15	1149	-1.23088	0.65677	-2.68699	0.276245	0.0589964	0.00031	0.999646	0.975	0.029
U16	26679	-2.0323	0.567823	-1.01169	0.606551	0.694099	<10 ⁻¹⁴	0.999977	0.72	0.033
U17	820	-1.71247	0.795146	-1.71247	0.795146	0	0.39	0.999173	0.94	0.016
U18	1984	-0.825375	0.191948	-1.35519	0.739529	0.950241	0.0015	0.999792	0.91	0.032
U19	3182	-1.35878	1.16058	-1.02544	0.644356	0.548448	<10 ⁻¹⁰	0.999894	0.993	0.085
S1	667	-2.54988	0.950523	-2.54988	0.950523	0	0.40	0.997779	0.42	0.0037
S2	1702	-1.38985	0.509661	-3.14123	0.809767	0.826015	2 × 10 ⁻⁶	0.999638	0.82	0.00060
S3	7886	-2.88871	0.949271	-1.47411	0.81183	0.250768	0.00064	0.999867	0.76	0.0096
S4	1593	-1.43004	0.75065	-2.9242	0.753699	0.333379	2 × 10 ⁻⁷	0.99978	0.979	0.019
S5	463	-3.05337	0.792309	-0.839522	0.481682	0.0521871	0.00014	0.999451	0.997	0.0022
S6	2801	-2.92774	0.84	-1.8	1.18	0.6	8 × 10 ⁻⁸	0.999514	0.65	0.038
S7	642	-2.18401	0.860443	-2.18401	0.860443	0	0.33	0.997599	0.25	0.0056
S8	8778	-3.04322	1.08802	-4.68664	0.291702	0	2 × 10 ⁻¹⁰	0.998066	3 × 10 ⁻⁶	0.0026
S9	1115	-2.36596	1.07291	-1.22973	0.528432	0.129181	5 × 10 ⁻⁵	0.999498	0.90	0.013
S10	1545	-2.43122	1.11153	-2.43122	1.11153	0	0.057	0.999299	0.70	0.014
S11	717	-2.39337	1.01377	-2.39337	1.01377	0	0.15	0.998039	0.70	0.0092
S12	5949	-3.11459	0.88	-2.14	0.8	0.5	0.000056	0.999851	0.92	0.0019
S13	1941	-2.13944	1.01664	-2.13944	1.01664	0	0.10	0.999073	0.37	0.018
S14	6614	-2.76875	0.917687	-1.47079	0.785824	0.268954	0.0034	0.999927	0.84	0.0092

^a Job codes are listed for underground (U) and surface (S) mining occupational categories in the order these appear in Table 34 on page 91 of the MSHA (2010) report. Part 90 workers, for whom relatively few inspector data are available, were excluded from this analysis. "Log" here denotes the natural logarithm.

Biased Data Adjustment Methodology

The QRA uses the MSHA inspector RCMD data as the basis for its ANOCOVA model, because it alleges that it is less biased. However, MSHA then introduces a biased method to upwardly adjust the inspector data:

- When the estimate of samples exceeding the standard was greater for the operator samples compared to the combined inspector and operator samples, an upward adjustment was made to the dust concentrations.
- When the inspector samples are higher, no adjustment was made.

This approach was motivated by the concern that dust levels are temporarily lowered when MSHA inspectors are present; thus, MSHA wants to adjust the inspector data upward to account for this factor. However, when the operator data are higher than the inspector data, MSHA has no real evidence that this is because of extra control efforts during the inspector sampling.

This adjustment method defeats the substantial efforts that MSHA makes to adjust the RCMD for bias. MSHA should decide which data set it believes is superior and use it, rather than mixing and matching the data sets to get the highest value.

Challenges in Meeting the Proposed Standard

Introduction

The QRA devotes a considerable amount of time and analysis to estimating the potential levels of RCMD in the mines after complying with the new standard. Three separate changes are included that will affect the dust concentrations required to comply with the proposed standard as summarized in Table 2.

Table 2. Summary of changes in proposed rule that will affect compliance with the new standard

Factor	Current Standard	Proposed Rule	Accounted for in QRA
Compliance level	2 mg/m ³	1 mg/m ³	Yes
Compliance basis	5-shift average	1-shift exceedance	Partially, but underestimates
Number of required samples	Maximum of 5-shift average per 2-month period	Maximum of 3 shifts/day and 90 days/quarter = 270 samples/quarter	No

^aTo address measurement error associated with RCMD measurements, the Excessive Concentration Value (ECV) for determining compliance with an RCMD standard equal to 2 or to 1 mg/m³ is taken to be 2.33 or 1.13 mg/m³, respectively, in accordance with U.S. Department of Labor, Mine Safety and Health Administration. Lowering Miners' Exposure to Respirable Coal Mine Dust, Including Continuous Personal Dust Monitors; Proposed Rules. XIII. Appendix A—Excessive Concentration Values, Fed Register 2010; 75(201 [Tues. Oct 19, 2010]):64412–64506, at pp. 64483–64484.

MSHA estimated the reduction in concentrations required to meet the standard in two steps. First, it compared concentrations within work locations currently under a 1-mg/m³ standard (e.g., a Part 90 miner) with its ANOCOVA model and estimated an expected reduction factor (ERF) that applies to any measurement less than 1 mg/m³. This first part is designed to estimate the effect of changing the compliance level from 2 to 1 mg/m³. In the second step, it adjusted any measurement above the proposed standard to 1 mg/m³. This was designed to account for the change from the current 5-shift average compliance basis to a 1-shift exceedance compliance basis. Regarding the latter methodology, the QRA states:

MSHA recognizes that under successful implementation of the proposed rule, average dust concentrations on those shifts corresponding to the portion

currently exceeding the FEL [Federal Exposure Level] would almost certainly fall somewhere below the FEL. However, MSHA knows of no valid theoretical or empirical basis for estimating the degree by which 'single-sample single-shift' enforcement would reduce exposures on these shifts below the FEL.

We strongly disagree with MSHA's contention that valid methods do not exist for estimating the effect of changing from a five-shift average to a single-shift exceedance. Standard statistical theory provides a method for estimating the change, and we demonstrate its application later in these comments. In fact, standard statistical theory shows that changing from a five-shift average to a one-shift exceedance represents a substantial change. MSHA needs to acknowledge that the impact of one shift exceedance can be assessed using standard statistical methods similar to what we present in these comments. MSHA would then need to comment on the impacts of such an analysis on their discussions of feasibility and compliance strategies.

MSHA also failed to consider the substantial changes being required in sampling frequency. At present, MSHA requires that Designated Operators (DOs) be sampled for five consecutive days bimonthly. The proposed rule requires that the continuous monitors be employed "during each production shift, seven days per week (Sunday through Saturday), 52 weeks per year." Thus, over a given two-month period, the current standard requires five samples, while the proposed rule would require 180 samples, for a total of 1,080 samples per year. This represents a 36-fold increase in the number of samples.

A large increase in the number of samples will lead to significantly greater chances of sampling during an exceedance event, without any change in the average concentrations that exist at the mine. Consider an analogy. If one is looking for four-leaf clovers (a relatively rare thing), one is much more likely to find a four-leaf clover if one looks for 36 hours than if one looks for 1 hour. However, by looking for longer, the number of four-leaf clovers that exist has not changed. In the same way, dramatically increasing the number of samples will increase the probability of finding an exceedance, even if the concentrations in the mine do not change.

Mine operators will need to substantially lower coal-mine dust concentrations to account for the increased sampling regime, to maintain the current situation of exceedances being rare. Below, we provide some quantitative estimates of the reductions that will be required.

Estimating the Reductions Needed to Meet the Standard

To estimate the reductions needed to meet the standard, a statistical sampling method was used with the mixed lognormal distribution fits presented above. To demonstrate the method, we used the distribution of measured RCMD concentrations, C_{LT} , experienced by longwall tailgate operators, which had the highest mean RCMD level of 1.39 mg/m^3 (Table 1). The estimated parameters for the corresponding mixed-normal distribution in log-space are $\mu_1 = -0.502$, $\sigma_1 = 0.585$, $\mu_2 = -0.473$, $\sigma_2 = 0.323$ (Table 1). The steps used to do this calculation were:

1. Draw samples from the mixed log-normal model of C_{LT} , with sample sizes generated to parallel the expected number of samples to be collected under the current and proposed standard.
2. Simulate five-shift average and single-shift RCMD levels
3. Estimate the reduction necessary obtain different levels of compliance. Specifically, we considered 95% or 99% criteria to specify the level of confidence for not having a single exceedance over a year. These confidence criteria mean that the operator would reduce their likelihood of having an exceedance for the longwall tailgate operator over a period of one year to 5% or 1%, respectively.

The method assumes that the shape of the RCMD distribution (i.e., the relative variance) remains unchanged (see discussion below).

The results for a 95% confidence criterion for non-exceedance are summarized in Table 3, and the results for a 99% confidence criterion for non-exceedance are summarized in Table 4.

Table 3. Reductions required to meet proposed standard with a 95% annual compliance rate

RCMD for Standard ^a (mg/m ³)	Compliance Method	Annual Non-Compliance Rate at Current Levels	% RCMD Reduction	Mean RCMD Concentration (mg/m ³)
1 (proposed)	Current	99.99%	54% ^b	0.85 ^b
2 (current)	Proposed	100%	79%	0.29
1 (proposed)	Proposed	100%	90%	0.14

^a See Table 2, note a.

^b Under the current compliance method, to ensure annual compliance, the RCMD concentration C* to be compared to the 1.13-mg/m³ ECV criterion associated with a 1-mg/m³ standard (see note a) is the maximum RCMD concentration among six bi-monthly maxima of two sample mean RCMD concentrations, with each mean based on a sample size of 5 RCMD measures each sampled randomly from the modeled C_{LT} distribution. The expected (i.e., population mean) and 95th percentile values of the distribution characterizing sampling error in C* are 1.86 and 2.47 mg/m³, respectively, and the latter value exceeds 1.13 mg/m³ by a factor of 2.19. Efforts to comply with the new 1-mg/m³ standard are thus assumed to induce a downward, 2.19-fold multiplicative shift in C_{LT} and hence also in C*. Therefore, the resulting mean RCMD concentration is (1.86 mg/m³)/2.19 = 0.85 mg/m³, which represents a relative reduction equal to 100% × (1 - 1/2.19) = 54%.

Table 4. Reductions required to meet proposed standard with a 99% annual compliance rate

RCMD for Standard ^a (mg/m ³)	Compliance Method	Annual Non-Compliance Rate at Current Levels	% RCMD Reduction	Mean RCMD Concentration (mg/m ³)
1 (proposed)	Current	99.98%	60% ^b	0.55 ^b
2 (current)	Proposed	100%	83%	0.23
1 (proposed)	Proposed	100%	92%	0.11

^a See Table 2, note a.

^b Under the current compliance method, to ensure annual compliance, the RCMD concentration C* to be compared to the 1.13-mg/m³ ECV criterion associated with a 1-mg/m³ standard (see note a) is the maximum RCMD concentration among six bi-monthly maxima of two sample mean RCMD concentrations, with each mean based on a sample size of 5 RCMD measures each sampled randomly from the modeled C_{LT} distribution. The expected (i.e., population mean) and 99th percentile values of the distribution characterizing sampling error in C* are 1.86 and 2.85 mg/m³, respectively, and the latter value exceeds 1.13 mg/m³ by a factor of 2.52. Efforts to comply with the new 1-mg/m³ standard are thus assumed to induce a downward, 2.52-fold multiplicative shift in C_{LT} and hence also in C*. Therefore, the resulting mean RCMD concentration is (1.86 mg/m³)/2.52 = 0.55 mg/m³, which represents a relative reduction equal to 100% × (1 - 1/2.52) = 60%.

The results in Tables 3 and 4 show the effect of separately changing the compliance method (i.e., five-shift average to one-shift exceedance, and added number of required samples) and the RCMD level. If only the RCMD level is changed from 2 to 1 mg/m³, the analysis shows that operators would need to reduce levels by 54% for a 95% annual compliance rate, and 60% for a 99% compliance rate. The respective mean RCMD concentrations would need to be less than

0.85 mg/m³ for a 95% compliance rate and 0.55 mg/m³ for a 99% compliance rate. This would represent a very substantial reduction in concentrations over the current regime.

However, changing the compliance method has a larger effect. Even if the RCMD level were still 2 mg/m³ but the compliance method was changed as outlined in the proposed rule, operators would need to reduce concentrations by 79% for a 95% annual compliance rate, and 83% for a 99% annual compliance rate. The mean RCMD concentrations would need to be less than 0.29 mg/m³ for a 95% compliance rate and 0.23 mg/m³ for a 99% compliance rate.

If both the RCMD level changes to 1 mg/m³ and the compliance method is changed as outlined in the proposed rule, the RCMD levels would need to be reduced by 90% for a 95% compliance rate, and 92% for a 99% compliance rate. The mean RCMD concentrations would need to be lower than 0.14 mg/m³ for a 95% compliance rate, and 0.11 mg/m³ for a 99% compliance rate.

Clearly, the RCMD reductions required to meet the proposed rule with reasonable rates of compliance are substantial. The mining companies have indicated that meeting average RCMD levels as low as 0.1 mg/m³ is impossible for longwall operators. Only through significant analysis of the information in the proposed rule is it possible to perform calculations such as those presented above. In other words, the rule is not transparent about the actual RCMD reductions that will be required. If MSHA's true intent is to force concentrations to these levels, it should forthrightly say so. Obviously, MSHA needs to conduct further analysis of all aspects ([1] concentration level, [2] frequency of sampling, [3] rules for non-compliance) of the feasibility of the proposed rule.

When these analyses were presented at a public hearing at MSHA in Arlington, Virginia, MSHA questioned the assumption that the shape of the log-normal distribution would remain the same following reductions mandated by the rule. In fact, the assumption made in this analysis is that the effect of applying job-type-specific control measures to comply with new regulations will be to induce a leftward (downward) multiplicative shift in the mixed log-normal distribution that we estimated to be consistent with empirical data for that job category. Such an expectation is reasonable, because (1) empirical evidence was already shown to be entirely consistent with contributing log-normal components, and (2) that evidence was based on an

analysis of data that was performed only after the normalization (i.e., dividing) of the measured concentrations by compliance level specific to each job location and job category, as described above. Table 1 presents compelling evidence that such underlying pre-normalized data, combined within each job category, exhibit mixed log-normal distributions, which demonstrates that compliance resulted in job-category-specific multiplicative shifts of the type assumed in the subsequent analysis of compliance implications. If this were not the case, and more complex types of shifts had, in fact, arisen due to compliance, then the data that had been pre-normalized by corresponding standards would not be expected to exhibit the degree of consistency with mixed log-normal distributions that is summarized in Table 1. Downward multiplicative shifts of all concentrations within each job category, in response to compliance with more stringent standards, provide the simplest explanation of the distribution characterization summarized in Table 1.

Lack of Quantitative Uncertainty Analysis

The QRA provides the reader little basis for assessing the uncertainty of its estimates. It provides only a brief qualitative discussion and provides no quantitative estimates of uncertainty.

The National Research Council (NRC) of the National Academy of Sciences has long recommended that quantitative uncertainty analyses be provided for air pollution health effects benefits analysis. The NRC stated in its 2004 *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*:

Other NRC reports addressed the issue of uncertainty in risk assessment and benefits estimation (NAE 1972; NRC 1975, 1982, 1983, 1994, 1996; Presidential Commission 1997). Without exception, they found that proper characterization of uncertainty is essential” (emphasis added).

The NRC specifically recommends a quantitative uncertainty assessment, when possible. From the data presented in the QRA, a quantitative uncertainty analysis is easily possible. Both the key inputs of the benefits assessment have uncertainty bounds. The RCMD data can be characterized by statistical distributions with uncertainties around the mean. The epidemiologic models include regression coefficients with associated uncertainty bounds. Therefore, a quantitative assessment of uncertainty could be performed easily.

However, such Monte Carlo-type analysis has the potential to underestimate uncertainty due to its lack of incorporation of model uncertainty. The major potential source of model uncertainty in the QRA is the potential non-linearity of the concentration-response function and, in particular, the potential for a threshold. MSHA acknowledges this, stating on p. 59 that peaks in concentrations “may overload the respiratory system’s clearance mechanisms.” The potential for a threshold could be a significant issue for the benefits. For these situations, the NRC recommends expert judgment methods or a qualitative discussion. We recommend that MSHA conduct the needed uncertainty analyses that NRC has developed.

Feasibility of Meeting the Rule

MSHA devotes less than a full page to discussion of the technological feasibility of meeting the new rule. It is worth quoting the first paragraph of this brief, four-paragraph discussion:

Based on both Agency and mine operator data, MSHA believes that this proposed rule is technologically feasible. Data show that not only are mine operators keeping miners' exposures at or below the levels required under the existing standards, but dust exposures at most operations average less than 1.0 mg/m³. Based on these data, the majority of miners' exposures are at or below the limits in the proposed rule. MSHA understands that these data reflect measurements under the existing sampling program and that requirements under the proposed rule (*e.g.*, use of single fullshift samples to determine noncompliance, change in the definition of normal production shift) would result in higher measured exposures compared to the existing sampling program. However, existing engineering controls including ventilation, sprays, and environmentally controlled cabs along with changes in work practices can be used to further reduce dust levels. To facilitate operator implementation of the requirements in the proposed rule related to the lower exposure limits, MSHA has included a 24-month phase-in period to allow mine operators time to come into compliance. During this phase-in period, MSHA will work with the mining industry to help them identify, develop, and implement feasible engineering controls, and train miners and supervisors in new technology.

Essentially, MSHA argues that, since many work locations already have exposures less than 1 mg/m³, meeting the new rule will not be difficult. Such a facile analysis is wholly inadequate for such a large and economically significant change in the coal mining industry.

MSHA adds that its analysis does not consider some aspects of the proposed changes, but does not mention the increased sampling requirements. It then makes a simple declarative statement

that “existing” methods are available to meet the standard without any justification for its conclusion.

MSHA is making a hand-waving argument: the change in the standard is relatively small, and technology exists to meet the new levels, even if we are not sure what they are. However, it is not possible to reach a valid conclusion regarding the technological feasibility of meeting the proposed rule without a valid and complete analysis of the changes in dust concentrations that would be required. MSHA did not conduct such an analysis; thus, it cannot reliably assess the technological feasibility of meeting the proposed rule.

Conclusions

From this review of the QRA, we have concluded:

- MSHA's statistical analysis of RCMD concentration data is overly complex, and the discussion includes inconsistencies (e.g., the number of samples).
- MSHA's RCMD concentration analysis could be refined by using the mixed log-normal distributions derived in these comments, and by using a more parsimonious model.
- MSHA has substantially underestimated the reductions in RCMD concentrations that would be needed to meet the proposed standard. In particular, they failed to account for the increased number of samples that the rule requires.
- The QRA lacks a quantitative uncertainty analysis.
- Without an adequate analysis of the reductions required to comply with the proposed standard, the technological feasibility analysis is inadequate.

Attachment A

***Curriculum Vitae* for
Dr. Richard Reiss**



Exponent
1800 Diagonal Road
Suite 500
Alexandria, VA 22314

telephone 571-227-7200
facsimile 571-227-7299
www.exponent.com

Richard Reiss, Sc.D.
Principal Scientist

Professional Profile

Dr. Richard Reiss is a Principal Scientist in Exponent's Health Sciences Center for Chemical Regulation and Food Safety. He is an experienced environmental health scientist with expertise in risk assessment, exposure assessment, environmental chemistry and fate, mathematical modeling, and applied statistics. He provides consulting services related to scientific issues associated with numerous environmental statutes, and has expertise in both air quality and chemical risk assessment. He has conducted risk assessments, data analyses, probabilistic exposure modeling and environmental exposure modeling for environmental agents, such as pesticides, industrial chemicals, consumer product chemicals, and asbestos. He has conducted risk assessments for new and existing products.

Dr. Reiss is very active in the application and development of quantitative methods in risk assessment. He is the developer of the Probabilistic Exposure and Risk assessment model for FUMigants (PERFUM), which is an air dispersion model designed to evaluate bystander inhalation exposure following fumigant applications. PERFUM was favorably evaluated by a multidisciplinary expert panel assembled by Environmental Protection Agency (EPA), and is being used by EPA to evaluate the registration of new fumigant active ingredients and the re-registration of existing fumigant products. Generally, he has used a variety of mathematical models in conducting occupational and ecological risk assessments for pesticides and industrial chemicals; and performed statistical analyses, including dose-response modeling to evaluate chemical toxicity.

Dr. Reiss is actively involved in several scientific societies and he is the Past-President of the Society for Risk Analysis, the leading scientific society devoted to the field of risk assessment. Dr. Reiss was the Managing Editor of *Risk Analysis: An International Journal*, the leading scholarly journal for risk analysis, from 2001 through mid-2008. He was the winner of the 2001 Chauncey Starr award from the Society for Risk Analysis. This award recognizes a risk analyst less than 40 years of age that has made major contributions to the field of risk analysis. Dr. Reiss was also a councilor in the Society for Risk Analysis (term 2005-2008). In 2010, he was elected a Fellow of the Society for Risk Analysis.

Academic Credentials and Professional Honors

Sc.D., Environmental Health, Harvard University, School of Public Health, 1994
M.S., Environmental Engineering, Northwestern University, 1991
B.S., Chemical Engineering, University of California, Santa Barbara, 1989

Chauncey Starr Award from the Society for Risk Analysis, 2001, recognizing a scientist under 40 years of age who has made significant contributions to risk analysis; Outstanding Service

Award, Society for Risk Analysis, 2009; Leslie Silverman Scholarship, Harvard University, 1991; Walter P. Murphy University Fellowship, Northwestern University, 1989–1990

Publications

Cantor R, Lyman M, Reiss R. Asbestos claims and litigation. *The John Liner Review* 2009; 23:28–38.

Reiss R, Lewis G, Griffin J. An ecological risk assessment for triclosan in the terrestrial environment. *Environ Toxicol Chem* 2009, 21:2483–2492.

Levy J, Reiss R. The importance of modeling in exposure and risk assessments. *Environmental Manager* 2008; 14–17, June.

Reiss R, Anderson EL, Cross CE, Hidy G, Hoel D, McClellan R, Moolgavkar S. Evidence of health impacts of sulfate and nitrate containing particles in ambient air. *Inhalat Toxicol* 2007; 19:419–449.

Reiss R. Temporal trends and weekend–weekday differences for benzene and 1,3-butadiene in Houston, Texas. *Atmos Environ* 2006; 40:4711–4724.

Reiss R, Griffin J. A probabilistic model for acute bystander exposure and risk assessment for soil fumigants. *Atmos Environ* 2006; 40:3548–3560.

Reiss R, Schoenig GP, Wright, GA. Development of factors for estimating swimmer exposures to chemicals in swimming pools. *Hum Ecol Risk Assess* 2006; 12:139–156.

Reiss R, Gaylor D. Use of benchmark dose and meta-analysis to determine the most sensitive endpoint for risk assessment for dimethoate. *Regul Toxicol Pharmacol* 2005; 43:55–56.

Reiss R, Anderson EL, Lape J. A framework and case study for exposure assessment in the Voluntary Children’s Chemical Evaluation Program. *Risk Anal* 2003; 23:1069–1084.

Reiss R, MacKay N, Habig C, Griffin, J. An ecological risk assessment for triclosan in lotic systems following discharge from wastewater treatment plants in the U.S. *Environ Toxicol Chem* 2002; 21:2483–2492.

Wilkinson CF, Christoph GR, Julien E, Kelley JM, Kronenberg J, McCarthy J, Reiss R. Assessing the risks of exposures to multiple chemicals with a common mechanism of toxicity: How to cumulate? *Regul Toxicol Pharmacol* 2000; 31:30–43.

Allen G, Sioutas C, Koutrakis P, Reiss R, Lurmann FW, Roberts PT, Burton RM. Evaluation of the TEOM method for measurement of ambient particulate mass in urban areas. *J Air Waste Manage Assoc* 1997; 47:682–689.

Reiss R, Ryan PB, Koutrakis P, Tibbetts S. Ozone reactive chemistry on interior latex paint. *Environ Sci Technol* 1995; 29:1906–1912.

Reiss R, Ryan PB, Tibbetts S, Koutrakis P. Measurement of organic acids, aldehydes, and ketones in residential environments and their relation to ozone. *J Air Waste Manage Assoc* 1995; 45:811–822.

Reiss R, Ryan PB, Koutrakis P. Modeling ozone deposition onto indoor residential surfaces, *Environ Sci Technol* 1994; 28:504–513.

Selected Presentations and Conference Proceedings

Reiss R. Atmospheric modeling of fumigants. Workshop on methyl bromide alternatives, Kansas State University, Manhattan, KS, May, 2010.

Reiss R. Health risk assessment for fumigants. Keynote address to the annual meeting of the Australia-New Zealand Chapter of the Society for Risk Analysis, Sydney, Australia, September 2010.

Reiss R. Evaluation of water contamination from consumer product uses. Invited presentation to the National Capitol Area Chapter of the Society for Toxicology, Washington, DC, April, 2010.

Reiss R. The evolution of health risk assessment in the United States. Keynote address to the first annual Society for Risk Analysis meeting of the Taiwan SRA chapter, Taichung, Taiwan, January, 2010.

Reiss R. Risk analysis: The evolution of a science. Invited presentation to the Joint IRAC-SRA-CBER-JIFSAN Symposium on New Tools, Methods and Approaches for Risk Assessment, Baltimore, MD, December, 2009.

Reiss R. Exposure analysis: Pathways to refining regulatory risk assessments. Midwest States Risk Assessment Symposium, Indianapolis, IN, November 2009.

Williams P, Reiss R. Modeling the variability in consumer product use patterns. International Society for Exposure Analysis annual meeting, Minneapolis, MN, November 2009.

Cramer S, Poletika N, Everich R, Schocken M, Habig C, Reiss R. Framework for estimating exposure to ESA-listed salmon to pesticides. American Chemical Society semiannual meeting, Washington, DC, August 2009.

Reiss R, Edwards M. Analysis of cholinesterase variability in animals and implications for risk assessment. Society for Risk Analysis Annual Meeting, Boston, MA, December 2008.

Reiss R, Lewis G, Griffin J, Inauen J, Navarro L. Terrestrial risk assessment for triclosan. Poster presentation, Pacific Northwest Organic Residuals Symposium, Davis, CA, October 2008.

Reiss R, Chan R. Estimation of emission rates for building fumigations. Methyl Bromide Alternative Outreach conference, San Diego, CA, October 2007.

Reiss R, Chan R. Impact of estimation methods and tarping methods on flux rates. Methyl Bromide Alternative Outreach conference, San Diego, CA, October 2007.

Reiss R, Anderson E, Turnham P. Exposure and risk assessment for residents and contractors associated with vermiculite attic insulation. International Society for Exposure Analysis. Durham, North Carolina, October 2007.

Reiss R. A critical evaluation of the National Ambient Air Toxics Assessment (NATA) program for benzene. Society for Risk Analysis Annual Meeting, Baltimore, MD, December 2006.

Reiss R, Inauen J, Hoffman-Kamensky M, Capdevielle M. Terrestrial risk assessment for triclosan. Society of Environmental Toxicology and Chemistry Meeting, Montreal, Canada, November 2006.

Reiss R. Near-field air quality impacts from fumigant applications. American Chemical Society Meeting, San Francisco, CA, September 2006.

Reiss R. A probabilistic model for estimating bystander inhalation risks following fumigant applications. American Chemical Society Meeting, San Francisco, CA, September 2006.

Reiss R, Gaylor D. Statistical evaluation to determine the most appropriate endpoint for dimethoate risk assessment. Society for Risk Analysis Annual Meeting, Orlando, FL, December 2005.

Reiss R. Bystander risk assessment for fumigant: an evaluation of current regulatory activity. Society for Risk Analysis Annual Meeting, Orlando, FL, December 2005.

Gibb HJ, Kozlov K, Centeno J, Kolker A, Conko K, Reiss R. Potential health risks from long term mercury exposure in Gorlovka, Ukraine. Society for Risk Analysis Annual Meeting, Orlando, FL, December 2005.

Reiss R. Development of risk-based buffer zones for a fumigant application. Society for Risk Analysis Annual Meeting, Palm Springs, CA, December 2004.

Reiss R. Estimating fumigant buffer zones by air dispersion modeling. Methyl Bromide Alternatives Outreach Conference, Orlando, FL, October 2004.

Reiss R. Air exposure following a fumigant application. International Society of Exposure Analysis Meeting, Philadelphia, PA, October 2004.

Reiss R. Analysis of benzene and 1,3-butadiene emissions in the Houston Ship Channel. Presented at API/EPA Conference on Emissions Uncertainties, Houston, TX, 2003.

Reiss R, Anderson EL. A framework and case study for the Voluntary Children's Chemical Evaluation Program. Presented at the Society for Risk Analysis Annual Meeting, New Orleans, December 2002.

Reiss R. Emerging issues in environmental health for children. Invited lecture given at the Air and Waste Management Association meeting in Baltimore, MD, June 2002.

Reiss R, Griffin, J. A critical review of the National Emissions Inventory for Air Toxics. Presented at the Coordinating Research Council conference on Air Toxics Modeling, Houston, TX, February 2002.

Reiss R, MacKay N, Habig C, Griffin J. A probabilistic ecological risk assessment for Triclosan in lotic systems following discharge from wastewater treatment systems. Presented at the Society of Environmental Toxicology and Chemistry meeting, Baltimore, MD, November 2001.

Reiss R. A review of the National Air Toxics Assessment. Presented at the Mid-Atlantic Section Meeting of the Air and Waste Management Association, Baltimore, MD, December 11, 2000.

Reiss R, Wilkinson CW. Exposure to chemicals with same mechanism of action: How to add the risk? Presented at the Annual Meeting of the American College of Toxicology, McLean, VA, November 9, 1999.

Lurmann FW, Reiss R. Analysis of the first three years of PM_{2.5} data collected in the Southern California Children's Health Study. Presented at PM_{2.5} A Fine Particle Standard, Long Beach, CA, sponsored by A&WMA, U.S. Environmental Protection Agency, and the U.S. Department of Energy, January 28–30, 1998.

Reiss R, Chinkin L. Ozone exceedance data analysis: representativeness of the 1995 summer ozone season in the Northeast. Paper presented at the 1st NARSTO Northeast Data Analysis Symposium and Workshop, Norfolk, VA, December 10–12, 1996.

Coe D, Chinkin L, Reiss R, DiSogra C, Hammerstrom K. An emission inventory of agricultural internal combustion engines for California's San Joaquin Valley. Paper presented at the Air & Waste Management Association Emission Inventory: Key to Planning, Permits, Compliance & Reporting Conference, New Orleans, LA, September 4–6, 1996.

Main HH, Roberts PT, Kore ME, Coe DS, Dye TS, Lindsey CG, Reiss R. Analysis of PAMS and NARSTO-Northeast data—Supporting evaluation and design of ozone control strategies: A

workshop. Presented at U.S. Environmental Protection Agency, Research Triangle Park, NC by Sonoma Technology, Inc., Santa Rosa, CA, December 11–12, 1995.

Chinkin LR, Ryan PA, Reiss R. A critical evaluation of biogenic emission systems for photochemical grid modeling in California. Paper presented at the Air & Waste Management Association and U.S. Environmental Protection Agency Emissions Inventory Conference, Research Triangle Park, NC, October 11–13, 1995.

Main HH, Roberts PT, Lurmann FW, Wright DB, Reiss R, Hering SV. Measurement of acid gases and PM_{2.5} in 12 Southern California communities for use in an epidemiologic study. Paper presented at the Air & Waste Management Association and U.S. Environmental Protection Agency Conference on Measurement of Toxic and Related Air Pollutants, Research Triangle Park, NC, May 16–18, 1995.

Reiss R, Lurmann FW, Roberts PT, Schoell BM, Geyh AS, Koutrakis P. A pilot personal ozone study in Southern California for validation of a microenvironmental model. Paper presented at the Air & Waste Management Association and U.S. Environmental Protection Agency Conference on Measurement of Toxic and Related Air Pollutants, Research Triangle Park, NC, May 16–18, 1995.

Allen G, Koutrakis P, Reiss R, Lurmann F, Roberts PT, Burton R, Wilson W. Evaluation of the TEOM method for measurement of ambient particle mass in urban areas. In: Transactions of the Air & Waste Management Association Conference on Particle Matter: Health and Regulatory Issues, Pittsburgh, PA. Air & Waste Management Association, Pittsburgh, PA, April 4–6, 1995.

Reiss R, Ryan PB, Tibbetts S, Koutrakis P. Ozone reactive chemistry in residential environments. Presented at Air & Waste Management Association Conference, Measurement of Toxic and Related Air Pollutants, Durham, NC, May 1994.

Reiss R, Ryan PB, Koutrakis P, Bamford S. Modeling ozone deposition onto indoor surfaces. Presented at an Air & Waste Management Association Conference, Measurement of Toxic and Related Air Pollutants, Durham, NC, May 1993.

Book Chapters

Cantor R, Lyman M, Reiss R. Asbestos claims and litigation. In: Product Liability, 2011.

Reiss R. Ozone reactive chemistry on interior surfaces of buildings. In: Encyclopedia of Environmental Analysis and Remediation, 1998.

Prior Experience

Vice President, Sciences International, 2000–2006

Senior Scientist, Quantitative Risk Assessment Expert, Jellinek, Schwartz & Connolly, Inc., 1998–2000

Senior Air Quality Analyst, Sonoma Technology, Inc., 1994–1998

Engineer, Environmental Solutions, Inc., 1990–1991

Editorships

- Managing Editor, *Risk Analysis: An International Journal*, 2000–2008
- Editorial Board, *Risk Analysis: An International Journal*, 2008–Present

Advisory Panels

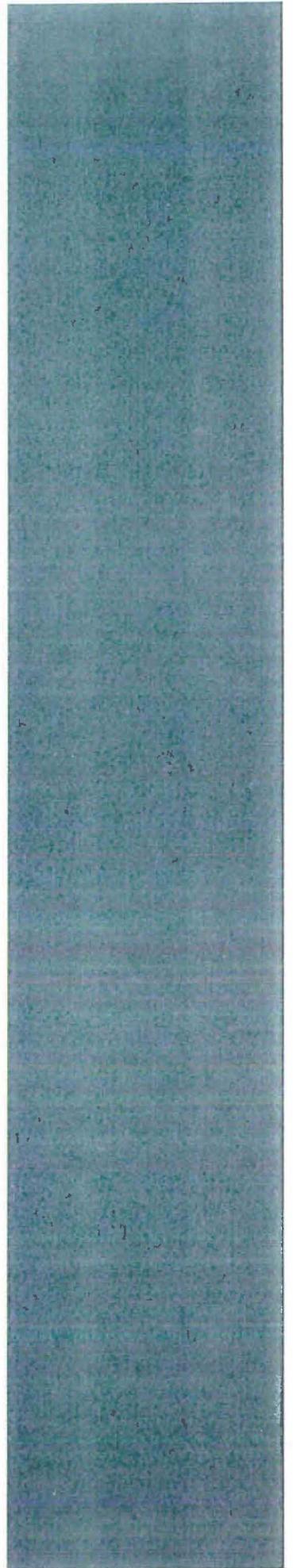
- Air Quality Public Advisory Panel (AQPAC) for the Metropolitan Washington Council of Governments, Appointment for 2009–2011

Peer Reviewer

- *Risk Analysis: An International Journal*
- *Atmospheric Environment*
- *Environmental Science & Technology*
- *Journal of the Air & Waste Management Association*
- *Journal of Environmental Quality*
- *Regulatory Toxicology and Pharmacology*
- *Ecotoxicology and Environmental Safety*
- *Integrated Environmental Assessment and Management*

Attachment B

***Curriculum Vitae* for
Dr. Kenneth Bogen**



Kenneth T. Bogen, DrPH, DABT
Managing Scientist**Professional Profile**

Dr. Kenneth T. Bogen, a Managing Scientist in Exponent's Health Sciences Center for Exposure Assessment and Dose Reconstruction, has nationally recognized expertise in risk assessment for environmental carcinogens and in related exposure, pharmacokinetic, dose-response and uncertainty analysis. Before joining Exponent in 2007, he led experimental, epidemiological and mathematical-modeling research on health risks posed by environmental exposures to chemicals and ionizing radiation, as a University of California environmental scientist for 20 years at Lawrence Livermore National Laboratory.

Dr. Bogen consults as an expert on chemical-risk and statistical aspects of litigation involving environmental, occupational, dietary and consumer-product exposures, as well as groundwater contaminants. He helped develop methods now widely used to quantitatively characterize uncertainty and variability in environmental exposure and risk, and to develop and apply physiologically based pharmacokinetic (PBPK) models, and biologically based, mechanistic dose-response models to assess risks posed by exposures to volatile solvents, carcinogens and cytotoxic chemicals.

Dr. Bogen served as a Member of the National Academy of Sciences/National Research Council (NRC) committees that issued *Science and Judgment in Risk Assessment* (1994) and *Review of the Army's Technical Guides on Assessing and Managing Chemical Hazards to Deployed Personnel* (2004); served as expert panelist at the NRC Standing Committee on Risk Analysis Issues and Reviews, Workshop on Uncertainty in Cancer Risk Based on Bioassay Data (2007); chaired the Metabolism and Mode of Action Panel, *Naphthalene State of the Science Symposium* (NS³), Monterey, CA (2006); and chaired the U.S. Consumer Product Safety Commission's Chronic Hazards Advisory Panel on Diisononyl Phthalate (DINP) (2000–2001). Dr. Bogen also authored and continues to develop *RiskQ* computer software (a University of California-licensed *Mathematica*[®] package) for biostatistics, stochastic modeling, and uncertainty analysis, authored *Uncertainty in Environmental Health Risk Assessment* (Garland, New York, 1990), and has authored or coauthored more than 100 reports and publications in peer-reviewed scientific journals. Dr. Bogen served as President (1995) and Councilor (2004–2006) of the Northern California Chapter of the Society for Risk Analysis.

Academic Credentials and Professional Honors

Dr.P.H., Environmental Health Science, University of California, Berkeley, 1986
M.P.H., Environmental Health Science, University of California, Berkeley, 1982
M.A., Science, Technology, and Public Policy, George Washington University, 1979
A.B., Biology, Princeton University, 1978

Patents

Patent 6,270,972: Kit for detecting nucleic acid sequences using competitive hybridization probes, August 7, 2001 (with J.N. Lucas and T. Straume).

Patent 6,027,879: Detection and isolation of nucleic acid sequences using a bifunctional hybridization probe, February 22, 2000 (with J.N. Lucas and T. Straume).

Patent 5,783,387: Method for identifying and quantifying nucleic acid sequence aberrations, July 21, 1998 (with J.N. Lucas and T. Straume).

Patent 5,731,153: Identification of random nucleic acid sequence aberrations using dual capture probes which hybridize to different chromosome regions, March 24, 1998 (with J.N. Lucas and T. Straume).

Patent 5,616,465: Detection and isolation of nucleic acid sequences using competitive hybridization probes, April 1, 1997 (with J.N. Lucas and T. Straume).

Publications

Bogen KT, Brorby G, Berman DW, Sheehan P, Floyd M. Measuring mixed cellulose ester (MCE) filter mass under variable humidity conditions. *Ann Occup Hyg* 2011, in press. DOI:10.1093/annhyg/mer003.

Brorby GP, Sheehan P, Berman DW, Bogen KT, Holm SE. Potential artifacts associated with historical preparation of joint compound samples and reported airborne asbestos concentrations. *J Occup Environ Hygiene* 2011, in press.

Bogen KT. Generic Hockey-Stick model for estimating benchmark dose and potency: performance relative to BMDS and application to anthraquinone. *Dose-Response* 2011, in press. Published online 21 Oct 2010, DOI: 10.2203/dose-response.10-018.Bogen.

Sheehan P, Bogen KT, Hicks J, Goswami E, Brorby G, Lau EC, Ott B. Benzene inhalation by parts washers: new estimates based on measures of occupational exposure to solvent coaromatics. *Risk Anal* 2010; 30(8):1249–1267.

Bogen KT, Goswami E. Screening-level hazard assessment for six phthalates under A.B. 1108 and Proposition 65 (Rev. 1). Technical Report prepared by Exponent, Inc., for the Environment Section, Office of the Attorney General, California Department of Justice (CalDOJ), May 2009 (made public by CalDOJ, August 2009). Exponent Doc. no. 0800736.000 0601 0509 KB01. Exponent, Inc., Oakland, CA, 97 pp.

Bogen KT, Cullen AC, Frey HC, Price PS. Probabilistic exposure analysis for chemical risk characterization. *Toxicol Sci* 2009; 109(1):4–17.

Bogen K. An adjustment factor for mode of action uncertainty with dual-mode carcinogens: The case of naphthalene-induced nasal tumors in rats. *Risk Anal* 2008; 28(4):1033-1051.

Louis ED, Keating GA, Bogen KT, Rios E, Pellegrino KM, Factor-Litvak P. Dietary epidemiology of essential tremor: Meat consumption and meat cooking practices. *Neuroepidemiol* 2008; 30:161-166.

Bogen KT, Benson JM, Yost GS, Morris JB, Dahl AR, Clewell HJ, Krishnan K, Omiecinski CJ. Naphthalene metabolism in relation to target tissue anatomy, physiology, cytotoxicity and tumorigenic mechanism of action. *Regul Toxicol Pharmacol* 2008; 51(2 Suppl 1):S27-S36.

Griego FY, Bogen KT, Price PS, Weed DL. Exposure, epidemiology and human cancer incidence of naphthalene. *Regul Toxicol Pharmacol* 2008; 51(2 Suppl 1):S22-S26.

Bogen KT, Gouveia FJ. Impact of spatiotemporal fluctuations in airborne chemical concentration on toxic hazard assessment. *J Hazard Mater A* 2008; 152(1):228-240.

Robison WL, Hamilton TF, Bogen KT, Conrado CL, Kehl SR. ¹³⁷Cs inter-plant concentration ratios provide a predictive tool for coral atolls with distinct benefits over transfer factors. *J Environ Radioact* 2008; 99:181-189.

Bogen KT, Jones ED, Fischer LE. Hurricane destructive power predictions based on historical storm and sea surface temperature data. *Risk Anal* 2007; 27(6):1497-1517.

Bogen KT, Keating II GA, Chan JM, Paine LJ, Simms EL, Nelson DO, Holly EA. Highly elevated PSA and dietary PhIP intake in a prospective clinic-based study among African Americans. *Prostate Cancer Prostatic Dis* 2007; 10(3):261-269.

Keating GA, Bogen K, Chan J. Development of a meat frequency questionnaire for use in diet and cancer studies. *J Am Dietetic Assoc* 2007; 107(8):1356-1362.

Louis ED, Zheng W, Jiang W, Bogen KT, Keating GA. Quantification of the neurotoxic β -carboline harmine in barbecued/grilled meat samples and correlation with level of doneness. *J Toxicol Environ Health A* 2007; 70(12):1014-1019.

Bogen KT. Comment on "Steady state solutions to PBPK models and their applications to risk assessment I: Route to route extrapolation of volatile chemicals." *Risk Anal* 2006; 26(6):1415.

Bogen KT, Jones ED. Risks of mortality and morbidity from worldwide terrorism: 1968-2004. *Risk Anal* 2006; 26:45-59.

Bogen KT. Risk analysis for environmental health triage. *Risk Anal* 2005; 25:1085-1095.

Keating GA, Bogen KT. Estimates of heterocyclic amine intake in the U.S. population. *J Chromatogr B* 2004; 802:127-133.

Bogen KT, Marchetti A, Brown TA. Use of a correlated compound-binomial model to assess absence of non-counting noise in Pu-isotope ratios measured by AMS at LLNL. *Nucl Instr Meth Phys Res B* 2004; 223:209–215.

Enns L, Bogen KT, Wizniak J, Murtha AD, Weinfeld M. Low dose radiation hypersensitivity is associated with p53-dependent apoptosis. *Molec Cancer Res* 2004; 2:557–566.

Raber MS, Carlsen TM, Folks KJ, Kirvel RD, Daniels JI, Bogen KT. How clean is clean enough? Recent developments in response to threats posed by chemical and biological warfare agents. *Int J Health Res* 2004; 14:31–41.

Robison WL, Conrado CL, Bogen KT, Stoker AC. The effective and environmental half-life of ¹³⁷Cs at coral islands at the former U.S. nuclear test site. *J Environ Radioact* 2003; 69:207–223.

Bogen KT, Cullen J. Residential radon in U.S. counties vs. lung cancer in women who predominantly never smoked. *Environ Geochem Health* 2002; 24:229–247.

Bogen KT, Witschi HP. Lung tumors in A/J mice exposed to environmental tobacco smoke: estimated potency and implied human risk. *Carcinogenesis* 2002; 23:511–519.

Bogen KT. Biologically based prediction of empirical nonlinearity in lung cancer risk vs. residential/occupational radon exposure. *Hum Ecol Risk Assess* 2001; 7:811–827.

Bogen KT, Keating GA. U.S. dietary exposures to heterocyclic amines. *J Expos Anal Environ Epidemiol* 2001; 11:155–168.

Cullen J, Bogen KT. Historical residential coal use and female lung cancer mortality. *Hum Ecol Risk Assess* 2001; 7:369–385.

Keating GA, Bogen KT. Methods to estimate heterocyclic amine concentrations in cooked meats in the U.S. diet. *Food Chem Toxicol* 2001; 39:29–43.

Bogen KT, Enns L, Hall LC, Keating GA, Weinfeld M, Murphy G, Wu RW, and Panteleakos FN. Gel microdrop flow cytometry assay for low-dose studies of chemical and radiation cytotoxicity. *Toxicol* 2001; 160:5–10.

Daniels JI, Bogen KT, Hall LC. Analysis of uncertainty and variability in exposure to characterize risk: Case study involving trichloroethylene groundwater contamination at Beale Air Force Base in California. *Water Air Soil Pollut* 2000; 123:273–298.

Keating GA, Sinha R, Layton D, Salmon CP, Knize MG, Bogen KT, Lynch CF, Alavanja M. Comparison of heterocyclic amine levels in home-cooked meats with exposure indicators. *Cancer Causes Control* 2000; 11:731–739.

Bogen KT. Comments on papers by Andersen and Conolly and by Downs and Franowski. *Hum Exper Toxicol* 1998; 17:711–712.

Bogen KT. Mechanistic model predicts a U-shaped relation of radon exposure to lung cancer risk reflected in combined occupational and U.S. residential data. *Hum Exper Toxicol* 1998; 17:691–696.

Bogen KT. Response to reviewer comments. *Hum Exper Toxicol* 1998; 17:716–718.

Bogen KT, Layton DW. Risk management for plausibly hormetic environmental carcinogens: the case of radon. *Hum Exper Toxicol* 1998; 17:463–467.

Bogen KT, Keating GA, Meissner S, Vogel JS. Initial uptake kinetics in human skin exposed to dilute aqueous trichloroethylene *in vitro*. *J Expos Anal Environ Epidemiol* 1998; 8:253–271.

Bogen KT. Do U.S. county data disprove linear no-threshold predictions of lung cancer risk for residential radon?—A preliminary assessment of biological plausibility. *Hum Ecol Risk Assess* 1997; 3:157–186.

Bogen KT, Swirsky Gold L. Trichloroethylene cancer risk: simplified calculation of PBPK-based MCLs for cytotoxic endpoints. *Regul Toxicol Pharmacol* 1997; 25:26–42.

Robison WL, Bogen KT, Conrado CL. An updated dose assessment for a U.S. nuclear test site—Bikini Atoll. *Health Phys* 1997; 73:100–114.

Bogen KT, Conrado CL, Robison WL. Uncertainty and variability in updated estimates of potential dose and risk at a U.S. nuclear test site—Bikini Atoll. *Health Phys* 1997; 73:115–126.

Bogen KT. Improved prediction of carcinogenic from mutagenic potencies for chemicals positive in rodents and the Ames test. *Molec Environ Mutagen* 1995; 25:37–49.

Bogen KT. Methods to approximate joint uncertainty and variability in risk. *Risk Anal* 1995; 15(3):411–419.

Layton DW, Bogen KT, Knize MG, Hatch FT, Johnson VM, Felton J. Cancer risk assessment of heterocyclic amines in cooked foods: An analysis and implications for research. *Carcinogenesis* 1995; 16:39–52.

Bogen KT. Applicability of alternative models of variance in replicate Ames-revertants measured for 121 mutagenic rodent carcinogens. *Mutat Res* 1994; 322:265–273.

Bogen KT. Cancer potencies of heterocyclic amines found in cooked foods. *Food Chem Toxicol* 1994; 32:505–515.

Bogen KT. Models based on steady-state *in vitro* dermal permeability data underestimate short-term *in vivo* exposures to organic chemicals in water. *J Expos Anal Environ Epidemiol* 1994; 4:457-476.

Bogen KT. A note on compounded conservatism. *Risk Anal* 1994; 14(4):379-381.

Hamilton LD, Holtzman S, Meinhold AF, Morris SC, Pardi R, Rowe MD, Sun C, Anspaugh LR, Bogen KT, Layton DW, McKone TE, Straume T, Andricevic R, Jacobson RL. Pilot study risk assessment for selected problems at three U.S. Department of Energy facilities. *Environ Int* 1994; 20:585-604.

Bogen KT. An intermediate-precision approximation of the inverse cumulative normal distribution. *Commun Statist Simulat* 1993; 22:797-801.

Bogen KT. Reassessment of human peripheral T-lymphocyte lifespan deduced from cytogenetic and cytotoxic effects of radiation. *Int J Radiat Biol* 1993; 64:195-204.

McKone TE, Bogen KT. Uncertainties in health-risk assessment: An integrated case study based on tetrachloroethylene in California groundwater. *Regul Toxicol Pharmacol* 1992; 15:86-103.

Bogen KT, Colston BW, Machicao LK. Dermal absorption of dilute aqueous chloroform, trichloroethylene and tetrachloroethylene in hairless guinea pigs. *Fund Appl Toxicol* 1992; 18:30-39.

McKone TE, Bogen KT. Predicting the uncertainties in risk assessment. *Environ Sci Technol* 1991; 25:1674-1681.

Bogen KT. CKM carcinogenesis models: Response. *J Natl Cancer Inst* 1990; 82:1723-1724.

Bogen KT. Of apples, alcohol, and unacceptable risk [guest editorial]. *Risk Anal* 1990; 10:199-200.

Bogen KT. Risk extrapolation for chlorinated methanes as promoters vs. initiators of multistage carcinogenesis. *Fund Appl Toxicol* 1990; 15, 536-557.

Bogen KT. Cell proliferation kinetics and multistage cancer risk models. *J Natl Cancer Inst* 1989; 81:267-277.

Bogen KT. Letter to the editor. *J Natl Cancer Inst* 1989; 82:320.

Bogen KT, Hall LC. Pharmacokinetics for regulatory risk analysis: The case of 1,1,1-trichloroethane (methyl chloroform). *Regul Toxicol Pharmacol* 1989; 10:26-50.

Lichtenberg E, Zilberman D, Bogen K. Regulating environmental health risks under uncertainty: Groundwater contamination in California. *J Environ Econ Management* 1989; 17:22–34.

Bogen KT. Pharmacokinetics for regulatory risk analysis: The case of trichloroethylene. *Regul Toxicol Pharmacol* 1988; 8:447–466.

Bogen KT, McKone TE. Linking indoor air and pharmacokinetic models to assess tetrachloroethylene risk. *Risk Anal* 1988; 8:509–520.

Bogen KT, Spear RC. Integrating uncertainty and inter-individual variability in environmental risk assessment. *Risk Anal* 1987; 7:427–436.

Zweig G, Gao R, Witt JM, Poppendorf W, Bogen KT. Dermal exposure to carbaryl by strawberry harvesters. *J Agric Food Chem* 1984; 32:1232–1236.

Bogen KT. Quantitative risk-benefit analysis in regulatory decision-making: A fundamental problem and an alternative proposal. *J Health Politics Policy Law* 1983; 8:120–143.

Bogen KT. Coordination of regulatory risk analysis: Current framework and legislative proposals. *Environ Econ J* 1982; 1:53–84.

Bogen KT. Public policy and technological risk. *IDEA: J Law Technol* 1980; 21:37–74.

Bogen KT. Managing technical dissent in private industry. *Indust Labor Relations Forum* 1979; 13:3–32.

Books and Monographs

Bogen KT. *Uncertainty in environmental health risk assessment*. Garland, New York, 1990.

Bogen KT. *Uncertainty in environmental health risk assessment: A framework for analysis and an application to a chronic exposure situation involving a chemical carcinogen*. Doctoral Dissertation, University of California Berkeley, School of Public Health, Berkeley, CA, 1986.

Book Chapters

Bogen KT, LE Fischer, ED Jones. 2011. Hurricane intensity, sea surface temperature, and stochastic variation. In: *Hurricane Research*, InTech (www.intechweb.org/books.html), Vienna, Austria (in press).

Bogen KT, Homann SG, Gouveia FJ, Neher LA. 2009. A prototype near-field GIS model to characterize acute risks of sequestered CO₂ release through orphan wells. In: *Carbon Dioxide Sequestration in Geological Media—State of the Science*. Grobe M, Pashin J, Dodge R (eds), Am Assoc Petroleum Geologists (AAPG) Studies in Geology 59, pp. 587–593.

Keating GA, Bogen KT, Vogel JS. Measurement of short-term dermal uptake *in vitro* using accelerator mass spectrometry. pp. 475–486. In: Percutaneous Absorption: Drugs, Cosmetics, Mechanisms, Methodology, Third Edition. R.L. Bronaugh and H.I. Maiback (eds), Marcel Dekker, Inc., New York (Drugs Pharmaceutical Sci 97), 1999.

Bogen KT, Keating GA, Vogel JS. Chloroform and trichloroethylene uptake from water into human skin *in vitro*: Kinetics and risk assessment. pp. 195–198. In: Prediction of Percutaneous Penetration, Volume 4b. V.J. Brain, V.J. James, K.A. Walters (eds), STS Publishing Ltd., Cardiff, UK, 1996.

Bogen KT, Colston BW, Machicao LK. Percutaneous absorption of dilute aqueous chlorinated organic solvents in the hairless guinea pig. pp. 321–345. In: Drinking Water Contamination and Health. R. Wang (ed), Marcel Dekker, Inc., New York, NY, 1994.

Daniels JI, McKone TE, Hall LC, Layton DW, Bogen KT. Remedial investigation of a Superfund site. pp. 67–82. In: Effective and Safe Waste Management: Interfacing Sciences and Engineering with Monitoring and Risk Analysis. R.L. Jolley, R.G. Wang (eds), Lewis Publishers, Boca Raton, FL, 1993.

Bogen KT. Cancer-risk prediction for carbon tetrachloride using pharmacokinetic and cell-kinetic multistage models. pp. 445–470. In: Risk Analysis: Prospects and Opportunities. Plenum Press, New York, NY, 1991.

Bogen KT, McKone TE. Tetrachloroethylene metabolism resulting from domestic respiratory exposure: Pharmacokinetic considerations relevant to risk assessment. pp. 593–608. In: Risk Assessment in Setting National Priorities. J.J. Bonin and D.E. Stevenson (eds), Plenum, New York, NY, 1989.

Zweig G, Gao R, Witt JM, Poppendorf W, Bogen KT. Exposure of strawberry harvesters to carbaryl. pp. 123–138. In: Dermal Exposure Related to Pesticide Use: Discussion of Risk Assessment. N.N. Ragsdale (ed), American Chemical Society, Washington, DC, 1985.

Technical Reports

Bogen KT, Goswami E. Screening-Level Hazard Assessment for Six Phthalates Under A.B. 1108 and Proposition 65 (Rev. 1). Doc. no. 0800736.000 0601 0509 KB01 (May 9, 2009). Technical Report prepared for the Office of the Attorney General, California Department of Justice. Exponent, Inc., Oakland, CA, 97 pp., 2009.

Bogen KT. Mode-of-action uncertainty for dual-mode carcinogens: Lower bounds for naphthalene-induced nasal tumors in rats implied by PBPK and 2-stage stochastic cancer risk models. Report to DOE-Oak Ridge Associated Universities. UCRL-TR-227766-Rev-1. Lawrence Livermore National Laboratory, Livermore, CA, 2007.

Bogen KT, Hamilton TF, Brown TA, Martinelli RE, Marchetti AA, Kehl SR, Langston RG. Statistical basis for interpreting urinary excretion of plutonium based on accelerator mass spectrometry (AMS) data from the Marshall Islands. Technical Basis Document UCRL-TR-230705. Lawrence Livermore National Laboratory, Livermore, CA, 2007.

Bogen KT. RiskQ 5.0: Summary of updates to RiskQ computer software. UCRL-SM-205904. Lawrence Livermore National Laboratory, Livermore, CA, 2004.

Bogen KT, Daniels JI, Wilder LA, Neher LA. Strategic Environmental Assessment and Risk Characterization for Effective Response and Recovery (SEARCHER): A proposal for strategic systems development to support the U.S. Department of Homeland Security. UCRL-TR-201949 (limited distribution). Lawrence Livermore National Laboratory, Livermore, CA, 2004.

Bogen KT, Hickman DP, Hamilton TF, Brown TA, Cox CC, Marchetti AA, Martinelli RE. Application of accelerator mass spectrometry to analyze ²³⁹Pu in archived occupational samples. LDRD 01-ERD-108 Final Report. UCRL-TR-205744. Lawrence Livermore National Laboratory, Livermore, CA, 2004.

Bogen KT. Recommendations for SZ/TSPA model uncertainty analysis concerning the Yucca Mountain project. UCRL-TR-201447. Lawrence Livermore National Laboratory, Livermore, CA, 2003. <https://e-reports-ext.llnl.gov/pdf/302344.pdf>

Bogen KT. RiskQ 4.2: An interactive approach to probability, uncertainty and statistics for use with Mathematica[®]. UCRL-MA-110232 Rev. 3. Lawrence Livermore National Laboratory, Livermore, CA, 2002.

Bogen KT. Methods for addressing uncertainty and variability to characterize potential health risk from trichloroethylene contaminated ground water at Beale Air Force Base in California: Integration of uncertainty and variability in pharmacokinetics and dose-response, UCRL-ID-135978 Rev. 1, Lawrence Livermore National Laboratory, Livermore, CA, 2001. <https://e-reports-ext.llnl.gov/pdf/244403.pdf>

Robison WL, Noshkin VE, Hamilton TF, Conrado CL, Bogen KT. An assessment of the current day impact of various materials associated with the U.S. Nuclear Test Program in the Marshall Islands. UCRL-LR-143980. Lawrence Livermore National Laboratory, Livermore, CA, 2001.

Bogen KT. RiskQ 4.0: An interactive approach to probability, uncertainty and statistics for use with Mathematica[®]. UCRL-MA-110232, Rev. 1. Lawrence Livermore National Laboratory, Livermore, CA, 2000.

Bogen KT. Lung cancer risk of low-level exposures to alpha emitters: Critical reappraisal and experiments based on a new cytodynamic model: Final Report on LDRD Project 97-ERD-050, UCRL-ID-133251, Lawrence Livermore National Laboratory, Livermore, CA, 1999.

Daniels JI, Bogen KT, Hall LC. Procedures for addressing uncertainty and variability in exposure to characterize potential health risk from trichloroethylene contaminated groundwater at Beale Air Force Base in California, UCID-CR-135784, Rev. 1, Lawrence Livermore National Laboratory, Livermore, CA, 1999.

Robison WL, Conrado CL, Bogen KT. Utirik Atoll dose assessment, UCRL-LR-135953, Lawrence Livermore National Laboratory, Livermore, CA, 1999.

Bogen KT. A cytodynamic two-stage model that predicts radon hormesis (decreased, then increased lung-cancer risk vs. exposure). UCRL-JC-123219. Lawrence Livermore National Laboratory, Livermore, CA, 1996.

Robison WL, Bogen KT, Conrado CL. A dose assessment for a U.S. nuclear test site—Bikini Atoll. In: Assessing the Radiological Impact of Past Nuclear Activities and Events, IAEA-TECDOC-755, pp. 11–24, International Atomic Energy Agency, Vienna, Austria, 1994.

Robison WL, Bogen KT, Conrado CL. An updated dose assessment for Rongelap Island. UCRL-LR-107036. Lawrence Livermore National Laboratory, Livermore, CA, 1994.

Bogen KT. Uncertainty vs. inter-individual variability. In: EPA/UVA Workshop on When and How Can You Specify a Probability Distribution Function When You Don't Know Much? April 19–21, 1993, Haines YY, Barry TM (eds), Center for Risk Management of Engineering Systems, University of Virginia, Charlottesville, VA; and U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Washington, DC, 1993.

Bogen KT, Seilkop S. Investigation of independence in inter-animal tumor-type occurrences within the NTP rodent-bioassay database, UCRL-ID-115092, Report prepared for the National Research Council, Board on Environmental Studies and Toxicology, Committee on Risk Assessment of Hazardous Air Pollutants. Lawrence Livermore National Laboratory, Livermore, CA, 1993. <http://www.osti.gov/bridge/purl.cover.jsp?purl=/10121101-KgaleS/native/>

Layton DW, Anspaugh LR, Bogen KT, Straume T. Risk assessment of soil-based exposures to plutonium at experimental sites located on the Nevada Test Site and adjoining areas. In: Pilot Study Risk Assessment for Selected Problems at the Nevada Test Site (NTS), UCRL-LR-113891, pp. 19–67, Daniels JI (ed.), Lawrence Livermore National Laboratory, Livermore, CA, 1993.

Bogen KT. RiskQ: An interactive approach to probability, uncertainty and statistics for use with Mathematica. UCRL-MA-110232. Lawrence Livermore National Laboratory, Livermore, CA, 1992.

Bogen KT, Hall LC, McKone TE. Health risk assessment of chloroform in California ground water. UCRL-21170. Lawrence Livermore National Laboratory, Livermore, CA, 1992.

Bogen KT, Hall LC, Wright K, McKone TE. Health risk assessment of dichloromethane (methylene chloride) in California ground water. UCRL-CR-21218. Lawrence Livermore National Laboratory, Livermore, CA, 1992.

Bogen KT, Lucas JN, Straume T. Cancer-risk assessment for chemicals. In: Laboratory Directed Research and Development FY1992, UCRL-53689-92, pp. 156-175, Struble GL, et al. (eds), Lawrence Livermore National Laboratory, Livermore, CA, 1992.

Layton DW, Anspaugh LR, Bogen KT, Straume T. Risk assessment of soil-based exposures to plutonium at safety-shot sites located on the Nevada Test Site and adjoining areas. UCRL-ID-112605DR. Lawrence Livermore National Laboratory, Livermore, CA, 1992.

McKone TE, Bogen KT. Uncertainties in assessing risks from groundwater contamination. In: Energy and Technology Review, pp. 62-63, UCRL-JC-52000-91-7/8, Lawrence Livermore National Laboratory, Livermore, CA, 1991.

Hall LC, Bogen KT. Appendix D: Toxicity assessment of VOCs. In: Baseline Public Health Assessment for CERCLA Investigations at the LLNL Livermore Site, pp. D-1 to D-41, Layton, DW, Daniels JI, Isherwood WF (eds.), UCRL-53953. Lawrence Livermore National Laboratory, Livermore, CA, 1990.

Bainer R, Bogen K, Carlsen T, et al. CERCLA remedial investigations report for the LLNL Livermore Site. UCAR-10299. Lawrence Livermore National Laboratory, Livermore, CA, 1990.

Layton DW, McKone TE, Hall, LC Bogen KT. In: Baseline Public Health Assessment for CERCLA Investigations at the LLNL Livermore Site, pp. 5-1 to 5-36, Layton, DW, Daniels JI, Isherwood WF (eds.), UCRL-53953. Lawrence Livermore National Laboratory, Livermore, CA, 1990.

Bogen KT, Hall LC, Perry L, Fish R, McKone TE, Dowd P, Patton SE, Mallon B. Health risk assessment of trichloroethylene in California drinking water. UCRL-21007. Lawrence Livermore National Laboratory, Livermore, CA, 1988.

Bogen KT, Hall LC, McKone TE, Layton DW, Patton SE. Health risk assessment of tetrachloroethylene (PCE) in California drinking water. UCRL-15831. Lawrence Livermore National Laboratory, Livermore, CA, 1987.

Layton D, Mallon B, Mitchell W, Hall L, Fish R, Perry L, Snyder G, Bogen K, Malloch W, Ham C, Dowd P. Conventional weapons demilitarization: A health and environmental effects database assessment, explosives and their co-contaminants. Final Report, Phase II. UCRL-21109. Lawrence Livermore National Laboratory, Livermore, CA, 1987.

Reed NR, Olsen HE, Marty M, Beltran LM, McKone TE, Bogen KT, Tablante NL, Hsieh DPH. Health risk assessment of 1,2-dibromo-3-chloropropane (DBCP) in California drinking water. Department of Environmental Toxicology, University of California, Davis, CA, 1987.

Tsuji J, Hentz K, Rosenbloom S, Bogen K, Yost L. Health risk of internal nickel exposure from medical devices. Presented at the 49th Annual Meeting of the Society of Toxicology, , Salt Lake City, UT, March 7–11, 2010.

Sheehan P, Bogen KT, Brorby G, Goswami E. Improved estimates of worker exposure to benzene during parts washing based on a new approach analyzing solvent and air data for other aromatic constituents. Presented at the 2009 American Industrial Hygiene Conference and Expo, Denver, CO, May 22–27, 2010.

Bogen KT. A Screening assessment of potential hazard posed by six phthalates in children's consumer products in California. Presented at The Toxicology Forum, 35th Annual Winter Meeting, 2–4 February 2010, Washington DC, 2010.

Sheehan P, Bogen KT, Brorby G, Goswami E. Worker inhalation exposure to benzene from solvents during parts washing. Presented at the 2009 Annual Meeting of the Society for Risk Analysis, Baltimore, MD, December 6–19, 2009.

Bogen KT. Human cancer risk of soluble cobalt: Biokinetic extrapolation from rodent bioassay data. Presented at the 48th Annual Meeting of the Society of Toxicology, Baltimore, MD, March 15–19, 2009.

Bogen KT. Mode of action (MOA) uncertainty for “dual mode” carcinogens: Impact on risk estimated from naphthalene-induced nasal tumors in rats. Abstract of presentation made at the 47th Annual Meeting of the Society of Toxicology, Seattle, WA, March 16–20, 2008.

Bogen KT. An adjustment factor to address mode of action (MOA) uncertainty for dual-mode carcinogens: The case of naphthalene-induced nasal tumors in rats. Abstract of presentation to be made at the Society for Risk Analysis 2007 Annual Meeting, San Antonio, TX, December 9–12, 2007.

Keating GA, Bogen KT, Chan J, Keating GA, Paine LJ, Simms EL, Holly EA, Felton JS. Elevated prostate-specific antigen in African American men with high meat-carcinogen intake: A prospective clinic-based study. Abstract. 2007 U.S. DOD Prostate Cancer Research Program, Atlanta, GA, September 14–18, 2007.

Bogen KT, Chan J, Keating GA, Paine LJ, Simms EL, Holly EA, Felton JS. Prostate-specific antigen levels and dietary PhIP in African Americans: A prospective clinic-based study. Abstract. 2007 Annual Meeting of the American Association for Cancer Research, Los Angeles, CA, April 14–18, 2007.

Bogen K. An adjustment factor to address mode of action (MOA) uncertainty for dual-mode carcinogens: The case of naphthalene-induced nasal tumors in rats. Presentation given as expert panelist at the National Research Council Standing Committee on Risk Analysis Issues and Reviews, Workshop on Uncertainty in Cancer Risk Based on Bioassay Data, Washington, DC, June 5, 2007.

Bogen KT, Burton EA, Freidmann SJ, Gouveia F. Source terms for CO₂ risk modeling and GIS/simulation based tools for risk characterization. GHGT8: 8th International Conference on Greenhouse Gas Technologies, Trondjheim, Norway, June 19–22, 2006.

Bogen KT, Homann SG, Gouveia FJ, Neher LA. Prototype near-field/GIS model for sequestered-CO₂ risk characterization and management. In: Proc. International Symposium on Site Characterization for CO₂ Geological Storage (CO2SC 2006), pp. 237–239, Lawrence Berkeley National Laboratory, Berkeley, CA, March 20–22, 2006.

Pickles WL, Gouveia F, Bogen K, Rau G, Burton E. Integrated monitoring and modeling of CO₂ leakage risk using remote sensing, ground-based monitoring, atmospheric models and risk-indexing tools. Abstract. Session H42. American Geophysical Union Meeting, Fall 2006.

Bogen KT. Cancer risk and hormesis: Plausibility and implications. 45th Annual Meeting of the Society of Toxicology, San Diego, CA, March 5–9, 2006.

Bogen KT, Keating GA, Holly EA, Chan J, Paine L, Simms EL, Nelson DO, Felton J. Prostate serum antigen levels and dietary heterocyclic amines in African Americans: A prospective clinic-based study. Abstract 2103. 97th Annual Meeting of the American Association for Cancer Research, Washington, DC, April 1–5, 2006.

Bogen KT, Hamilton TF, Brown TA, Marchetti AA, Martinelli RE, Kehl SR. Age-related trend in elevated plutonium-239 measured by AMS in urine samples collected in 1998–2003 from Enewetak residents and Rongelap resettlement workers. Presented at the 51st Annual Radiobioassay and Radiochemical Measurements Conference, Stateline, NV, October 24–28, 2005.

Bogen KT, Hickman DP, Hamilton TF, Brown TA, Cox CC, Marchetti AA, Martinelli RE. AMS analysis of ²³⁹Pu in archived occupational samples. Presented at the 51st Annual Radiobioassay and Radiochemical Measurements Conference, Stateline, NV, October 24–28, 2005.

Keating G, Bogen K, Holly E, Baker W, Paine L, Felton J. Prostate cancer screening and heterocyclic amine intake in African Americans. Presented at the 95th Annual Meeting of the American Association for Cancer Research, Anaheim, CA, April 16–20, 2005.

Bogen K, Baker W, Chan J, Nelson D, Holly E, Keating G, Paine L, Felton J. Prostate cancer screening and dietary HA exposure in African-Americans. Poster presented at the University of California Davis Health System Future Fair, Sacramento, CA, May 5, 2005.

Hamilton TF, Brown TA, Martinelli RE, Tumey SJ, Kehl SR, Bogen KT, Buchholz BA, Hickman DP, Wood-Zika AR, Langston RG. Urinary excretion of plutonium isotopes based on accelerator mass spectrometry: baseline measurements from the Marshall Islands. UCRL-ABS-234231. Abstract, Health Physics Society 41st Midyear Topical Meeting (Oakland,

January 2008), Lawrence Livermore National Laboratory, Livermore, CA, 2007.
https://marshallislands.llnl.gov/pdf/Hamilton_UCRL-ABS-234231.pdf

Bogen KT. Chemical risk analysis for environmental health triage and consequence management. Abstract. Presented at 2004 Annual Meeting of the Society for Risk Analysis Palm Springs, CA, December 5–8, 2004.

Bogen KT, Holly EA, Baker W, Keating GA, Paine L. Cooked meat carcinogens and prostate cancer screening in African Americans. Abstract. Presented at 14th Annual Conference of the International Society of Exposure Analysis, Philadelphia, PA, October 17–21, 2004.

Bogen KT, Holly EA, Baker W, Keating GA, Paine L. Cooked meat carcinogens and prostate cancer screening in African Americans. Abstract of poster presented at the 10th Annual Cancer Research Symposium, University of California Davis Cancer Center, Sacramento, CA, October 20–21, 2004.

Bogen KT, Keating GA, Holly EA. Prostate cancer screening and heterocyclic amine intake in African Americans. Abstract #1101 of poster presented to the 2004 Annual Meeting of the American Association for Cancer Research, Orlando FL, March 27–31, 2004.

Bogen K. Hypersensitivity to gamma radiation: LLNL/CCI Collaborative Studies Sponsored by the USDOE Low Dose Research Program. UCRL-PRES-152527. Lawrence Livermore National Laboratory, Livermore, CA, 2003.

Bogen KT, Marchetti A, Brown TA. Use of a correlated compound-binomial model to assess absence of non-counting noise in Pu-isotope ratios measured by AMS at LLNL. Poster presented at the 9th International Conference on Accelerator Mass Spectrometry, Nagoya University, Chikusa, Nagoya, Japan, September 9–13, 2002.

Bogen KT, Cullen J. Residential radon and lung cancer mortality in U.S. women who predominantly never smoked. Abstract 26.08. p. 90. In: 12th Conference of the International Society of Exposure Analysis (ISEA) and 14th Conference of the International Society for Environmental Epidemiology (ISEE), Vancouver, BC, August 11–15, 2002.

Enns, L, Murtha A, Bogen K, Weinfeld M. Low-dose dose-response of proliferating human cells exposed to low dose rate γ -radiation. Abstract. U.S. Department of Energy Office of Biological and Environmental Research Low Dose Radiation Research Program Workshop III, March 25–27, 2002.

Enns L, Weinfeld M, Hall L, Keating G, Murphy G, Bogen K, Langlois R. Low dose rate gamma radiation increases cytotoxicity as revealed by gel-microdrop (GMD) flow cytometry. Abstract. Annual Meeting of the Society of Toxicology, San Francisco, CA, March 2001.

Enns L, Weinfeld M, Bogen K, Murtha A. Hypersensitive-nonlinear low-dose dose-response for arrested proliferation of human A549 cells exposed to low-dose gamma radiation, detected

by gel-microdrop flow cytometry. Abstract. p. 247. In: DOE/NASA Radiation Investigators' Workshop. U.S. Department of Energy, Washington, DC, June 2001.

Bogen KT. A unified approach to characterizing risks involving an uncertain carcinogenic mechanism: Groundwater trichloroethylene at a USAF Base [Abstract]. *Toxicologist* 2000; 54(1):421.

Witschi HP, Bogen KT. Carcinogenic potency of environmental tobacco smoke (ETS) in strain A/J mice [Abstract]. *Toxicologist* 2000; 54(1):183–184.

Keating GA, DuTeaus SB, Bogen KT. The effect of surface contact on dermal absorption of pesticides from house dust. Abstract. Presented at the 10th Annual Conference of the International Society of Exposure Analysis, Pacific Grove, CA, October 24–27, 2000.

Keating GA, Bogen KT. Cooked-meat carcinogen exposure: New data and proposed study of possible effects on prostate cancer risk in African-Americans. Abstract. p. 1F-10o. 10th Annual Conference of the International Society of Exposure Analysis, Pacific Grove, CA, October 24–27, 2000.

Keating GA, Sinha R, Layton D, Salmon CP, Knize MG, Bogen KT, Lynch CF, Alavanja M. Comparison of heterocyclic amine levels in home-grilled meats with exposure indicators. Abstract. p. 1F-11p. 10th Annual Conference of the International Society of Exposure Analysis, Pacific Grove, CA, October 24–27, 2000.

Bogen KT, McKone TE. Prediction of risk from indoor exposure to tetrachloroethylene: Pharmacokinetic considerations under steady-state and dynamic exposure conditions. Proc. 80th Annual Meeting, Air Pollution Control Association, New York City, NY, June 21–26, 1987.

Prior Experience

Environmental Scientist, Energy and Environment Directorate L-396, University of California, Lawrence Livermore National Laboratory (1986–2007)
Program Analyst, U.S. Environmental Protection Agency Region 9, Office of Policy, Technical and Resource Management (1982)
Science Policy Analyst, U.S. Library of Congress, Congressional Research Service, Science Policy Research Division (1980–1981)

Academic Appointments

- Member, University of California Davis Cancer Center, 2002–2007

Research Experience

As a University of California environmental scientist at Lawrence Livermore National Laboratory (LLNL), Dr. Bogen most recently served as PI and/or project leader of the following studies pertaining to environmental carcinogen risk assessment:

- PI, "Mode-of-Action uncertainty for dual-mode carcinogens: Lower bounds for naphthalene-induced nasal tumors in rats implied by PBPK and 2-stage stochastic cancer risk models," ORNL funded by USEPA ORD (2007). Project comprised drafting a white paper of USEPA regulatory interest addressing treatment of uncertainty in cancer risk estimated from animal bioassay data.
- PI, "PSA-Based Screening Outcome, Dietary Heterocyclic Amine Exposure, and Prostate Cancer Risk in African Americans," DOD Prostate Cancer Res. Prog. competitive award W81XWH-05-1-0153 (2005-2007). A LLNL-led 3-year, partially overlapping supplement/extension of the 5-year clinic-based epidemiological study described just below, to expand the study to 700 men through 2007 and to add an additional (percent-free) PSA measure to the other prostate-cancer screening tests performed as described below. Collaborating investigators were based at Alta Bates Summit Hospital (Oakland, CA) and UC San Francisco Medical School.
- Project Leader, "Determining the Carcinogenic Significance of Heterocyclic Amines, Project 5: Prostate cancer screening and dietary HA exposure in African-Americans," NIH/NCI P01 grant 2 NIH P01 CA55861-09A2 (2002-2006). A LLNL-led 5-year clinic-based epidemiological study of association between dietary exposure to cooked-meat (heterocyclic amine) mutagens (particularly, PhIP) and screening indicators of prostate cancer risk in 500 African-Americans. Collaborating investigators were based at Alta Bates Summit Hospital (Oakland, CA) and UC San Francisco Medical School.
- Co-investigator, "Environmental Epidemiology of Essential Tremor," NIH/NINDS grant R01 NS03422 (2006-2010). This 5-year study of environmental and occupational risk factors for essential tremor, led by Dr. Elan Louis, M.D. of Columbia University Medical School, uses an LLNL-developed dietary meat-intake questionnaire and corresponding data analysis for 900 subjects planned over the period of study. In this work, a total of 1,235 meat questionnaires will be provided to Columbia University in annual lots, together with initial training on questionnaire interpretation and administration, and annual analysis of resulting data on estimated daily dietary intake of total heterocyclic amines (HAs), including the primary dietary HA (PhIP), for each participant completing a questionnaire.
- PI, "Retrospective Plutonium Biodosimetry by Modeling Urinary ²³⁹Pu from Archived Occupational Samples," 3-year LLNL competitively awarded RandD project 01-ERD-108 (2001-2003). This project successfully developed and demonstrated the application of accelerator mass spectrometry (AMS)--which is ~20- to 40-fold more sensitive than traditional alpha spectrometry methods for the purpose of Pu-exposure assessment--to analyze archived alpha-spectrometry urinalysis disks obtained from LLNL Pu workers in accordance with an approved LLNL IRB protocol. This study showed that AMS can be

used to recover otherwise inaccessible information on urinary Pu excretion patterns over 10- to 20-year periods.

- PI, “DNA Damage vs. Cell Killing by Low-Dose-Rate Radiation: Ultrasensitive Measures, and Implications for Mechanistically Modeled Cancer Risk,” USDOE Low Dose Res. Prog. and Cross Cancer Institute, Alberta Cancer Board (2000-2002). This 3-year study developed and applied a gel-microdrop flow cytometry assay to assess low-dose dose-response of gamma-radiation-induced cell killing in human cells *in vitro*. This study showed that a previously well characterized “hyper-radiosensitivity” (HRS) low-dose dose-response phenomenon is induced very early after radiation exposure and that its underlying molecular mechanism involves dose-induced suppression of p53-triggered “apoptosis” or programmed cell death.

Research Awards

Society of Toxicology, Risk Assessment Specialty Section, Top 10 Publications in 2008 Demonstrating an Application of Risk Assessment (2008), for: Bogen (2008), *supra*.

Society for Risk Analysis Best Paper Award, Decision Science (2006), for: Bogen and Jones (2006), *supra*.

Science Advisory Boards/Panels

- ILSI, International Life Sciences Inst., Dose-Response Working Group (1991–1992)
- NRC, National Academy of Sciences, National Research Council, Committee on Risk Assessment of Hazardous Air Pollutants (1991–1994). *Science and Judgment in Risk Assessment*, 1994 [student ed., Taylor and Francis, Washington DC, 1996]
- U.S. EPA, Carcinogenicity, Reproductive/Developmental Toxicity and Systemic Toxicity of Drinking Water Disinfectant By-Products (1998)
- U.S. EPA, Ambient Water Quality Criteria Methodology: Human Health (1999)
- U.S. CPSC, Chairman, U.S. Consumer Product Safety Commission. Chronic Hazard Advisory Panel (CHAP) on Diisononyl Phthalate (DINP) (nominated by President of National Academy of Sciences; 2000–2001; CHAP report to USCPSC issued in June 2001, <http://www.cpsc.gov/LIBRARY/FOIA/Foia01/os/dinp.pdf>)
- U.S. EPA, Draft Frame Work for Cumulative Risk Assessment, peer consultant (<http://www.epa.gov/ncea/raf/pdfs/CumRisk/CumRiskWR042002.pdf>, US EPA Risk Assessment Forum, EPA/630/R-01/005, April 2002)
- NRC, National Academy of Sciences, National Research Council, Subcommittee on the Toxicological Risks to Deployed Military Personnel (2002-2004). Issued report: *Review of the Army's Technical Guides on Assessing and Managing Chemical Hazards to Deployed Personnel*, 2004.

Scientific Journal Editorial & Review

- *Risk Anal* (Editorial Board member, 2008–present; Peer Reviewer)
- *Toxicol Sci* (Peer Reviewer)
- *J Expos Sci Environ Epi* (Peer Reviewer)
- *Crit Rev Toxicol* (Peer Reviewer)
- *Adv Water Resources* (Peer Reviewer)

Professional Certification and Affiliations

- Diplomate of the American Board of Toxicology (DABT); 5-year certification awarded October 28, 2008 (2008–2013)
- Society of Toxicology (Full Member, 2008–present)
- Society for Risk Analysis (1984–present)
- Toxicology Forum (2008–present)
- American Association for Advancement in Science (1979–present)