

Gregory P. Brorby, DABT
Senior Managing Scientist

Professional Profile

Mr. Gregory P. Brorby is a Senior Managing Scientist in Exponent's Health Sciences Center for Exposure Assessment and Dose Reconstruction. He is a board-certified toxicologist with more than 20 years of experience in the fields of human health risk assessment, exposure simulation and dose reconstruction, and toxicology. Mr. Brorby has evaluated potential human health risks according to risk assessment methodologies prescribed in CERCLA, RCRA, and other guidance specified by state or federal agencies. These evaluations have involved a wide variety of chemicals (asbestos, metals, VOCs, SVOCs, pesticides/PCBs, dioxins and furans, petroleum hydrocarbons, and radionuclides; environmental media (air, soil, groundwater, surface water, plant material); and exposure scenarios (residential, commercial/industrial, recreational). Mr. Brorby focuses on integrating risk assessment into an overall risk management approach to site investigation and remediation. This approach uses site conceptual models to design risk-based sampling and analysis plans based on the current or proposed future site use; the scope of the investigation is thus streamlined to collect only data needed to support a risk-based decision.

Mr. Brorby has directed or participated in studies to estimate exposure to chemicals from use of consumer products (e.g., PVC-coated electrical cables, children's toys, jewelry, and food and beverage containers), particularly with regard to potential exposure via incidental hand-to-mouth contact, to assess compliance with CPSC, FDA, and California Proposition 65 requirements. Mr. Brorby has also directed or participated in studies to reconstruct historic exposures in occupational settings (e.g., vehicle mechanic exposure to asbestos in friction materials).

Mr. Brorby also specializes in conducting independent review of risk assessment-related work performed by others. He played an instrumental role in the dose reconstruction projects at Rocky Flats and the Oak Ridge Reservation, the Environmental Restoration Project at the Los Alamos National Laboratory, and the RCRA/CERCLA process at Pantex Plant. In this capacity, he worked closely with advisory panels and steering committees to develop risk assessment strategies and communicate complicated technical information to a non-technical audience.

Academic Credentials and Professional Honors

B.S., Zoology, University of California, Davis, 1984

Diplomate, American Board of Toxicology (1994; re-certified 2000–2004; 2005–2009)

Publications

Brorby GP, Sheehan PJ, Berman DW, Greene JF, Holm SE. Re-creation of historical chrysotile-containing joint compounds. *Inhalation Toxicol* 2008; 20:1043–1053.

Buffler PA, Kelsh MA, Kalmes RM, Lau EC, Chapman PS, Wood SM, Brorby GP, Silva JM, Hooper, HC, Rizzo BD, Wood R. A nested case-control study of brain tumors among employees at a petroleum exploration and extraction research facility. *J Occup Environ Med* 2007; 49(7):791-802.

Buffler PA, Kelsh M, Chapman P, Wood S, Lau E, Golembesky A, Wood R, Kalmes R, Brorby G. Primary brain tumor mortality at a petroleum exploration and extraction research facility. *J Occup Environ Med* 2004; 48(3):257–270.

Paustenbach DJ, Finley BL, Lu ET, Brorby GP, Sheehan PJ. Environmental and occupational health hazards associated with the presence of asbestos in brake linings and pads (1900 to present): A “state-of-the-art” review. *J Toxicol Environ Health B* 2004; 7:33–110.

Brorby GP, Zemo DA. Cutting through the regulatory maze toward site closure. pp. 1–9. In: *Contaminated Soils, Volume 3*. E.J. Calabrese, P.T. Kosteki, and M Bonazountas (eds.), Amherst Scientific Publishers, 1998.

Brorby GP, Job LB, Spencer AL, Zemo DA. An argument against developing TPH-based Tier 1 ecological screening values to evaluate petroleum hydrocarbon releases to soil and groundwater. In: *Proc. National Groundwater Association Conference, Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Remediation*, Houston, TX, November 11–13, 1998.

Job LB, Brorby GP. Feasible alternatives to TPH-Based Tier 1 ecological screening levels to evaluate petroleum hydrocarbon releases to soil and groundwater. In: *Proc. 5th Annual International Petroleum Environmental Conference*, Albuquerque, NM, October 20–23, 1998.

Spencer AL, Brorby GP. Hitting a home run for the Giants’ stadium: A risk management approach to site investigation and remediation. In: *Proc. Conference of the American Society of Civil Engineers*, Boston, MA, October 18–21, 1998.

Zemo DA, Brorby GP, Bloes MB, Jefferson JL. Roadmap for closure: development and implementation of a risk-based “consistent approach” for a pipeline system. In: *Proc. 5th Annual International Petroleum Environmental Conference*, Albuquerque, NM, October 20–23, 1998.

Brorby GP, Spencer AL, Graf TE. 1997. Risk-based corrective actions begin with risk-based investigations—a case study. In: *Proc. National Ground Water Association Conference, Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Remediation*, Houston, TX, November 12–14, 1997.

Presentations

Brorby G, Kalmes R, Goswami E, Mowat F, Sheehan P. Evaluating exposures to consumer products. Society for Risk Analysis 2006 Annual Meeting, Baltimore, MD, December 3–6, 2006.

Sheehan P, Brorby G, Kalmes R, Mowat F, Richter R, Finley B. Characterization of the cumulative exposures of U.S. automobile mechanics. AIHce, Anaheim, CA, May 23–26, 2005.

Finley B, Mowat F, Richter R, Brorby G, Craven V, Sheehan P. Evaluation of proposed threshold doses for chrysotile exposure and respiratory disease. Society of Toxicology 44th Annual Meeting, New Orleans, LA, March 6–10, 2005.

Greene J, Brorby G, Paustenbach D. Reentry criteria for dioxin and dioxin-like compounds for building surfaces. Society of Toxicology 43rd Annual Meeting, Baltimore, MD, March 21–25, 2004.

Paustenbach DJ, Brorby GP, Finley BL. Environmental and occupational health hazards associated with the presence of asbestos in brake linings and pads (1900 to present). Society for Risk Analysis 2003 Annual Meeting, Baltimore, MD, December 8–10, 2003.

Paustenbach D, Williams P, Brorby G, Sheehan P. Residential exposures to elemental mercury due to releases from gas pressure regulators. Society for Risk Analysis 2003 Annual Meeting, Baltimore, MD, December 8–10, 2003.

Brorby GP, Foote GR, Zemo DA. Update on petroleum hydrocarbon issues in California: implications for site closure. Workshop, 10th Annual West Coast Conference on Contaminated Soils and Water, San Diego, CA, March 20–23, 2000.

Brorby GP, Zemo DA. What's my risk? An innovative approach to assessing health risks in an established neighborhood. National Groundwater Association Conference, Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Remediation, Houston, TX, November 17–19, 1999.

Bloes MB, Spencer AL, Brorby GP. How deep do we go and what do we look for? Risk-based/planned use investigations. 9th Annual West Coast Conference on Contaminated Soils and Groundwater, Oxnard, CA, March 15–18, 1999.

Brorby GP, Hicks J, Otani-Wilson JM, Tull JD. Health risk assessment in the DOD base closure process. 2-Day Short Course, University of California at Davis Extension, Sacramento, CA, May 9–10, 1996.

Brorby GP, Dorries AM, Lewis JL, Smith V, Black KJ, McCann JP. Phased development of a background data set for evaluating polycyclic aromatic hydrocarbons in soil at the Los Alamos National Laboratory. Society for Risk Analysis 1995 Annual Meeting, Honolulu, HI, December 3–6, 1995.

Brorby GP. Designing the risk-based remedial investigation, basic applications in risk assessment short course. Society of Toxicology 1995 Annual Meeting, Baltimore, MD, March 5–9, 1995.

Brorby GP, Bruce GM, Ripple SR, Widner TE. Use of screening methods to focus future investigations of off-site health risks from past Oak Ridge operations. Society of Toxicology 1994 Annual Meeting, Dallas, TX, March 13–14, 1994.

Brorby GP, Finley B. Standard probability density functions for routine use in environmental health risk assessment. Society for Risk Analysis 1993 Annual Meeting, Savannah, GA, December 5–8, 1993.

Brorby GP. The hazards of risk communication. National Safety Council, Research and Development Executive Committee 1993 Meeting, April 22, 1993.

Prior Experience

Principal Toxicologist, Geomatrix Consultants, Inc., 1994–2000
Senior Health Scientist, ChemRisk, a Division of McLaren/Hart, 1989–1994
Toxicology Associate, Chevron Environmental Health Center, 1984–1989

Project Experience

Exposure Simulation and Dose Reconstruction

Played a key role in an assessment of the state of the knowledge through time as to the magnitude of asbestos exposure and relative risk to workers in various occupations making or using asbestos products. This assessment was intended to provide information as to when specific asbestos-related diseases were recognized in worker populations from epidemiology studies, when exposures to these workers were quantified, what information was being provided by regulatory agencies and what information was being collected or developed by various companies and what may have been provided to their workers.

Managed research on a number of asbestos-related issues, including concentrations of amphibole fibers in ambient air in the U.S., lung tissue fiber burden in mesothelioma patients vs. the general population, influence of fiber type on *in vitro* and *in vivo* toxicity, possible alternative causes of mesothelioma, mechanism of action of mesothelioma, and evidence supporting or disputing a threshold for asbestos carcinogenicity.

Directed an assessment of the state of the knowledge through time related to the potential risks associated with exposure to tremolite, including when tremolite was first recognized as a carcinogen, whether there was a debate regarding the relative potency of tremolite as compared to other forms of asbestos, and how regulatory agencies treated tremolite in terms of potency as compared to other asbestos fibers.

Participated in an evaluation of potential exposures and risks posed by historical releases of small amounts of elemental mercury. Initial sampling activities characterized mercury concentrations in the areas affected by the historical releases and in the breathing zones of living areas in the houses. A second, statistically-based, sampling program was undertaken to assess the incidence of unreported mercury releases and to characterize potential exposures.

Played a key role in an exposure assessment for a mortality study of petrochemical research workers at a Southern California facility. This assessment entailed detailed examination of a wide variety of possible sources of quantitative and qualitative exposure information, including systematic file reviews, facility closure and feasibility reports, and key informant interviews. The extensive information reviewed indicated that employees were not exposed to elevated levels of ionizing radiation, electromagnetic fields, or any chemical known or suspected to be associated with an increased risk of brain cancer.

Conducted a detailed exposure assessment in preparation for Proposition 65 litigation involving lead in consumer products. Designed experimental studies with volunteers to measure the content of lead in cables, the amount of lead that can be wiped from cables, and the transfer of lead from cables to hands during the typical use of a variety of products, including kitchen and bathroom appliances, electrical wiring, and office products. Also evaluated preliminary data from plaintiff studies, and developed a second protocol to better evaluate potential exposure to lead transferred to the hands via hand to mouth contact.

Conducted or assisted in CPCS, FDA, and Proposition 65 compliance evaluations for numerous clients, including manufacturers of consumer products (PVC-coated electrical cables, children's toys, jewelry, and food and beverage containers) and medical devices, and chemicals, including lead, cadmium, silica, and phthalate esters. Several of these evaluations entailed estimating potential exposures under typical use conditions and deriving no significant risk levels or no-observed-effect levels.

Human Health Risk Assessment/Brownfields Redevelopment

Currently advising a municipal redevelopment agency regarding upcoming transfer of property formerly used as a military base. Significant issues include adequacy of site investigation data collected by others to make risk-based decisions; soil affected by lead, PAHs, PCDDs, and PCBs adjacent to buildings and/or in areas intended for residential housing; and communication of technical information to a diverse and largely non-technical residential community and Restoration Advisory Board.

Currently advising a San Francisco Bay Area developer regarding environmental conditions and potential human health risks associated with residual chemicals in soil, soil vapor, and groundwater at a former industrial property in Nevada County, California, that is slated for redevelopment for mixed commercial and residential use. Previous site investigations indicate the presence of petroleum hydrocarbons, VOCs, PAHs, PCBs, dioxins/furans, and metals (including arsenic, copper, lead, and zinc) in soil, soil vapor, and/or groundwater. Because the property will be developed in phases, human health risk assessment (HHRA) reports are being written for portions of the property as sufficient information regarding environmental conditions

and redevelopment plans become available. In conjunction with the developer and the local RWQCB and County Environmental Health Department, the results of the HHRAs will be used to evaluate the need for remediation or implementation of other risk management practices prior to or during site development.

Advised a municipal redevelopment agency and private developer regarding potential health risks associated with a former terminal facility used to store and transfer cargo and bulk liquids. Residual chemicals in soil and groundwater include petroleum hydrocarbons and trichloroethene (TCE) and other chlorinated solvents. Proposed redevelopment plans for the site include multifamily residential housing and open space. Used the Johnson & Ettinger model to estimate potential health risks associated with vapor migration into indoor air. Although preliminary modeling results suggested that remediation or other engineering control measures might be necessary prior to redevelopment, worked with oversight agency to approve collection of flux chamber measurements to refine estimate of vapor migration.

Directed supplemental evaluation of potential health risks associated with a former chemical storage facility. Chemicals of potential concern included TCE and other chlorinated solvents. A previous baseline risk assessment considered future industrial use of the site, but did not include an evaluation of potential health risks associated with emissions from an on-site treatment plant or inhalation of vapors in indoor air. Worked with the oversight agency to develop a limited soil gas sampling plan and an agreed upon approach for evaluating emissions from the treatment system. Utilized both the Jury Model and the Johnson & Ettinger model to estimate indoor air concentrations. Results of both models indicated that potential risks to future onsite workers were below levels of concern, allowing for return of the site to productive economic use.

Conducted a series of evaluations of potential health risks to support the sale and redevelopment of a former chemical distribution and packaging facility for industrial chemicals, including caustics, chlorine, and TCE and other chlorinated solvents. Potential redevelopment scenarios included residential, commercial, and recreational use. Previous remedial activities, including soil removal and operation of a soil vapor extraction system, had significantly reduced the concentrations of chlorinated solvents in soil; treatment of the underlying groundwater was ongoing. Regardless of redevelopment scenario, migration of vapors into indoor air was the primary exposure pathway of concern. Utilized EPA's volatilization factor (VF) model and Johnson & Ettinger's model to estimate indoor air concentrations. Results of both models indicated that potential risks to future site users, including residents, would not be of concern. These evaluations were approved by the oversight agency, and used in negotiations with potential buyers.

Evaluated the potential health risks associated with vapor emissions from a former municipal landfill. Soil gas monitoring data indicated the presence of chlorinated solvents, including TCE, and petroleum hydrocarbons in the subsurface. In addition, significant quantities of methane and carbon dioxide were being generated, facilitating vapor migration to the surface. Used EPA's nonmethane organic compounds (NMOC) model to estimate vapor flux from the landfill and EPA's Industrial Source Complex (ISC) model to estimate off-site air concentrations. Preliminary modeling results suggested that potential risks to nearby workers and residents may

be unacceptable. Vapor flux chamber samples were collected to refine estimates of vapor migration. Revised estimates of off-site air concentrations were orders of magnitude lower than previously estimated, indicating that off gassing from the landfill did not pose a significant health risk to nearby populations.

Supervised assessment of potential health risks associated with residual dry cleaning chemicals in soil and groundwater at a site slated for redevelopment as senior housing. Designed a limited site investigation to demonstrate area of affected soil and groundwater was limited and chemicals in groundwater were not migrating from the site. Tailored risk assessment to proposed development plan, which indicated that affected soil and most highly affected groundwater were outside of the proposed building footprint, thereby reducing the potential health risks, as estimated using the Johnson & Ettinger model, to acceptable levels. Oversight agency granted site closure with no further action was required.

Evaluated potential health risks associated with residual petroleum in soil in an existing residential neighborhood built on a site previously used to store and dispense fuel oil. The facility had been closed and sold by the former operator approximately 20 years before it was redeveloped, without their knowledge, for residential use. Initial investigations suggested more than 100 individual lots over 45 acres were potentially affected. To avoid implying that potential risks could be evaluated on an individual scale, collected soil samples on a grid pattern across the affected area, and calculated acceptable concentrations to which the measured concentrations were compared; these concentrations were optimized using Monte Carlo techniques. Demonstrated to the satisfaction of both the community and oversight agency that residual petroleum in soil did not pose an unacceptable risk to residents or landscape maintenance workers. No further action for the affected soil was required.

Supervised completion of a baseline risk assessment of a former pole treating site used as a buffer zone for a California Department of Corrections (CDC) facility. Chemicals of potential concern included PCP, other chlorinated phenols, PAHs, and PCDDs and PCDFs. Potential receptors included current trespassers, offsite workers, offsite residents, and future site users under hypothetical residential and commercial land use scenarios. Used results of the risk assessment to reduce extent of site remediation. Worked with oversight agency to communicate the results of offsite sampling to nearby residents.

Evaluated potential health risks associated with residual petroleum at a former fuel pump station that was later developed into a migrant farm worker facility. Although preliminary investigations indicated that potential health risks were low, worked closely with the oversight agency to design a comprehensive site investigation to address potential environmental justice concerns. Results indicated that residual petroleum would not pose an unacceptable risk to residents or workers at the site. Worked with a translator to communicate the results to the local community.

Supervised site investigation and risk assessment of 8.5 acres of mine tailings in northeastern Oregon. Chemicals of potential concern included arsenic, lead, and mercury. Developed focused sampling plan to collect additional chemical data for mine tailings, sediment in an adjacent creek, and background soil. Conducted physiologically based extraction tests to

estimate site-specific oral bioavailability of arsenic in the tailings. Results indicated that the concentrations of arsenic, lead, and mercury in the tailings piles were not significantly different than background. Estimated human health risks using the bioavailability test results and reasonable exposure assumptions were within generally acceptable levels. Arsenic, lead, and mercury concentrations in the tailings exceeded ecological screening criteria; however, any potential health risks would be similar to background. No further action was recommended.

Participated in the assessment of the potential health risks associated with a former industrial/commercial site proposed for the San Francisco Giants baseball stadium. Previous investigations identified coal tar, petroleum compounds (e.g., benzene, PAHs), and metals (e.g., copper, lead, and zinc). Designed a focused investigation based on a site-conceptual model of potential sources, transport pathways, exposure media, and receptors given the proposed use of the site as a ball park. Results indicated that residual chemicals in soil and groundwater would not pose a significant risk to human health during or after construction or to aquatic receptors in adjacent San Francisco Bay. The oversight agency granted site closure, saving approximately \$2,000,000 to \$10,000,000 in investigation and remediation costs.

Evaluated potential health risks associated with excavation and offsite disposal of chemically affected soil in support of litigation. Significant issues included chemical volatilization during excavation, diesel truck emissions, and traffic safety during transport. Clearly demonstrated that offsite disposal presented significantly greater risks than in-place management.

Evaluated potential health risks associated with residual chemicals in soil and groundwater at a former agricultural chemical storage and redistribution facility. Previous investigations identified more than 70 pesticides, herbicides, solvents, and nitrogen compounds. Demonstrated that the majority of the estimated risk was associated with hypothetical ingestion of homegrown produce and domestic use of groundwater; estimated risks associated with other, more likely exposure pathways were within generally acceptable levels. Convinced oversight agency that no mitigation was required because of the significant uncertainties in the uptake of chemicals from soil to plants and the fact that groundwater was unlikely to be used for domestic purposes due to naturally occurring concentrations of arsenic.

Evaluated potential health risks associated with the presence of metals (including arsenic, chromium, and copper) and PAHs in soil at a former railroad yard in northern California. Potential receptors included current youth trespassers, future onsite construction workers, future onsite maintenance workers, and future onsite office workers assuming redevelopment of the site for commercial purposes. Estimated risks were equal to or below 1×10^{-6} for all identified receptors. The HHRA was approved by the oversight agency, allowing site redevelopment to move forward.

Prepared a position paper supporting the application of EPA's 1996 guidance on the toxicity of PCBs to the modification of soil cleanup levels at a former transformer service shop in eastern Washington. Addressed the state regulator's concern that EPA's guidance could not be applied in the absence of congener-specific data, and demonstrated that the proposed revised cleanup levels were consistent with EPA's guidance and protective of human health. Based in part on this analysis, no further remediation of site soils was required.

Participated in re-evaluating cleanup goals established in the Record of Decision (ROD) adopted 10 years ago for a former wood treatment site. Cleanup goals had been established for arsenic, chromium, PCP, and PCDDs and PCDFs in soil based on protection of human health and water quality. Re-evaluated cleanup goals within the context of current regulatory policy for these chemicals as well as additional soil and groundwater data collected since the ROD was adopted. EPA followed recommendation that the original cleanup goals were sufficiently consistent with current regulatory policy as to not warrant reopening the ROD.

Radionuclides

Provided third party review of chemical and radionuclide risk assessments conducted for Pantex Plant. Several areas of the site have been affected by radionuclides, primarily depleted uranium. Risk assessments were conducted according to EPA's methodologies. Currently developing a highly graphical summary report to communicate complex risk assessment and subsurface fate and transport modeling concepts and results to the public

Provided risk assessment support as part of the Environmental Restoration (ER) Project at the Los Alamos National Laboratory. Supervised all aspects of risk assessment projects being completed for the largest of five field units, including preparation of RCRA Facility Investigation (RFI) reports and development of Voluntary Corrective Action (VCA) or Expedited Cleanup (EC) plans for sites affected by chemicals and/or radionuclides. Contributed to the development of Laboratory-wide risk assessment strategies as a member of the ER Project's Decision Support Council.

Served as task manager of a quantitative screening evaluation to identify important contaminants and exposure pathways for the Oak Ridge Reservation Dose Reconstruction Feasibility Study. Out of more than 50 chemicals and radionuclides, including plutonium, thorium, and uranium isotopes, identified in earlier tasks as potentially being released from the reservation in sufficient quantities to pose a potential health risk, identified three radionuclides and two chemicals as warranting additional study; recommended further study of five additional radionuclides and two additional chemicals due to a lack of information. Presented results to the Oak Ridge Health Agreement Steering Panel.

Served as task manager of the dose assessment for the Rocky Flats Toxicological Review and Dose Reconstruction Project. Working closely with a 12-member Health Advisory Panel and the interested public, estimated chemical and radiation doses that a person residing near the Rocky Flats Plant between 1953 and 1989 could have received as a result of routine plant operations and accidents. Used Monte Carlo simulation and other techniques to combine uncertainties in material usage and release information, environmental monitoring data, and model predictions to quantify the overall uncertainty in the dose estimates.

Professional Affiliations

- Society for Risk Analysis
- Society of Toxicology
- Genetic and Environmental Toxicology Association of Northern California

Depositions

Equilon Enterprises, LLC, dba Shell Oil Products US v California State Board of Equalization, an agency of the State of California, and California Department of Health Services, an agency of the State of California, Superior Court of the State of California in and for the County of Sacramento, Case No. 05AS02406, November 2006.