Memorandum

To: Mayflower Wind **Date:** October 28, 2020

From: Gradient

Subject: EMF Technical Memo

This memorandum was created by Gradient, an environmental and risk sciences consulting firm that specializes in Toxicology, Epidemiology, Risk Assessment, Product Safety, Contaminant Fate and Transport, Industrial Hygiene, Geographic Information Systems, and Environmental/Forensic Chemistry. Since 1985, Gradient has employed sound science to assist national and global clients with resolving their complex environmental and health challenges. Gradient scientists are nationally recognized experts and active contributors to the advancement of knowledge for science solutions. Focusing on rigorous, high-end science and creative problem solving, our engagements are led by teams with top credentials and unparalleled client focus.

The team working on this matter is led by Gradient Principal Peter Valberg, Ph.D., ATS and Gradient Principal Scientist Christopher M. Long, Sc.D., DABT.

Dr. Valberg is an expert in human health risk assessment, inhalation toxicology, and modeling of human exposure to environmental chemicals. He has 30 years of experience on the faculty of the Harvard School of Public Health and at Gradient. Dr. Valberg has provided air quality expertise to the Department of Justice, US EPA, and the National Academy of Sciences. He is the author of more than 100 scientific articles on biological effects of environmental exposures (including EMF) on humans and animals. Dr. Valberg's risk assessment expertise covers air pollutants, chemical exposures, biologicals, radionuclides, and EMF (including power lines, radio waves, and cellular telephones). Dr. Long is an expert in the area of exposure and risk assessment, with particular expertise in indoor and outdoor air pollution, inhalation toxicology, and EMF. He is a board-certified toxicologist and has published over 30 peer-reviewed journal articles and book chapters. Full CVs are attached.

Executive Summary

Gradient has completed preliminary Electric and Magnetic Field (EMF) assessments to determine expected EMF levels associated with the project's proposed offshore and onshore underground power transmission cables.

Modelling of all anticipated landfall/onshore underground cable configurations indicates **magnetic field levels well below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) health-based guideline** of 2,000 milligauss (mG) for acceptable public exposure to 60-Hz magnetic fields.

In all cases, there are **no aboveground electric fields from the underground cables,** both due to the metallic shielding used in the cable construction as well as their below-ground location.

EMF Limits

The United States has no federal standards limiting general public or residential exposure to 60-Hz EMF.

Gradient has carefully considered various EMF guidelines produced by national and global health- and safety-focused organizations. These guidelines recommend limitations of between 2,000 mG and 10,000 mG for continuous power-line magnetic field exposure for the general public. The studies performed by Gradient on behalf of Mayflower Wind show magnetic field values well below the lowest of these thresholds.

60-Hz EMF Guidelines Established by Health and Safety Organizations:

Organization	Magnetic Field	Electric Field
American Conference of Governmental and Industrial Hygienists (ACGIH) (occupational)	10,000 mG[1] 1,000 mG[2]	25 kV/m[1] 1 kV/m[2]
International Commission on Non-Ionizing Radiation Protection (ICNIRP) (general public, continuous exposure)	**2,000 mG**	**4.2 kV/m**
Non-Ionizing Radiation (NIR) Committee of the American Industrial Hygiene Association (AIHA) endorsed (in 2003) ICNIRP's occupational EMF levels for workers (occupational)	4,170 mG	8.3 kV/m
Institute of Electrical and Electronics Engineers (IEEE) Standard C95.6 (general public, continuous exposure)	9,040 mG	5.0 kV/m
UK, National Radiological Protection Board (NRPB) (which was formerly part of the Health Protection Agency [HPA], but is now part of Public Health England [PHE])	2,000 mG	4.2 kV/m
Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (Draft Standard, December 2006[3])	3,000 mG	4.2 kV/m

Notes:
EMF = Electric and Magnetic Field; kV/m = Kilovolts Per Meter; mG = Milligauss; ROW = Right of Way.
(1) The ACGIH guidelines for the general worker (ACGIH, 2015, pp. 128-131).
(2) The ACGIH guidelines for workers with cardiac pacemakers (ACGIH, 2015, pp. 128-131).
(3) ARPANSA (2006, 2008).

The World Health Organization (WHO) maintains a website[1] for its International EMF Project where it provides summaries of existing standards and guidelines, as well as scientific reviews of EMF health effects research. On this website[2], WHO states, "The main conclusion from the WHO reviews is that EMF exposures below the limits recommended in the ICNIRP international guidelines do not appear to have any known consequence on health."

The ICNIRP MF guideline of 2,000 mG (equivalent to 200 µT), which incorporates a safety factor of 5[3], is specifically intended to be protective of acute effects of short-term exposures to low frequency EMF on the nervous system, including direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes. ICNIRP concluded that there was not sufficient evidence to support the development of an exposure guideline specific to long-term exposure.[4]

[1] http://www.who.int/peh-emf/en/
[2] http://www.who.int/peh-emf/standards/en/
[3] Safety factors are typically incorporated into health-based guidelines to add an additional layer of protectiveness, such that levels near to or exceeding guidelines will remain below actual adverse effect levels and thus should not be interpreted as indicating that adverse health effects will occur.
[4] International Commission on Non-Ionizing Radiation Protection (ICNIRP). 2010. "ICNIRP Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 Hz)." Health Phys. 99(6):818-836. doi: 10.1097/HP.0b013e3181f06c86.

EMF Study Results

Gradient, a third-party EMF specialist working on behalf of Mayflower Wind, has assessed several cases which represent the expected physical cable configuration offshore, at landfall, and onshore. The preliminary results from this assessment (which will be subject to slight variation based on specific final cable configurations) are presented below.

First, Gradient assessed the EMF impacts of buried submarine cables offshore (2 m burial depth). For this case, the expected peak MF levels at the sea floor are ≤100 mG directly above the buried cables and ≤10 mG at 25 ft from the cable centerlines.

At the cable landfall, Gradient studied multiple cases that represent the cables coming ashore via horizontal directional drilling (HDD). The cables transition between submarine cables and land cables in an onshore transition vault which will be buried at least 1 m (3.3 ft) beneath either a parking lot or a street median. Due to the nature of the HDD construction method, the submarine cables will be buried significantly deeper (8 m to 10 m depth) beneath the beach under which they will pass in approach to the shore. As such, the MF levels on the beach will be much lower. For this preliminary assessment, cable landfall at Falmouth Heights beach has been assumed.

As the cables are run onshore, they will be installed *via* burial underneath the street at a depth of at least 3 ft. Multiple possible cable duct bank configurations were studied to determine worst-case EMF impacts, and to see how different cable configurations affect magnetic field levels.

The expected magnetic field levels resulting from these assessment cases are presented in the tables below. It is important to note that there is an increasing drop-off of magnetic field levels with increasing lateral distance away from the circuit centerline. For example, for the buried cable duct bank in roadways, magnetic field levels drop to values ≤ 20 mG at 25 feet from the duct bank centerlines.

Mayflower Wind Expected Maximum Magnetic Field Levels *vs*. WHO/ICNIRP Health-Based Guideline

Magnetic Field (MF) Health-Based Guideline (ICNIRP)	**2,000 mG**
Directly above buried cables, at sand surface, in middle of beach	≤ 10 mG
Directly above buried cables, at sand surface, at edge of beach	≤ 10 mG
Directly above buried cable transition vault, at ground surface, in parking lot or street median	≤ 350 mG
Directly above buried cable duct bank, at a 1-meter height, in roadway	≤ 500 mG

While these results are preliminary and will be subject to slight variation based on specific final cable specifications and configurations, MF levels are expected to be equal to or lower than what has been studied. Additionally, the results presented represent the cables operating at full power transmission capacity, which will only occur part of the time (during periods of high wind) due to the intermittent nature of wind energy.

Peter A. Valberg, Ph.D., ATS
Principal
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Areas of Expertise

Public health, inhalation toxicology, epidemiology, human health risk assessment, risk communication, indoor/outdoor air quality, comparative toxicology, modeling of human exposure and retained dose, health effects of ionizing and non-ionizing radiation.

Education

M.S., Human Physiology and Inhalation Toxicology, Harvard School of Public Health, 1975

Ph.D., Physics, Harvard University, Graduate School of Arts and Sciences, 1970

M.A., Physics, Harvard University, 1966

A.B., Physics and Mathematics, *summa cum laude*, Taylor University, 1964

Professional Experience

2001 – Present (and 1990 – 1998) GRADIENT, Boston, MA
Principal. Environmental consulting practice includes inhalation toxicology, environmental health, human health risk assessment, use of epidemiology in public health decisions, health effects of airborne gases and particles, and health effects of ionizing and non-ionizing radiation.

1998 – 2000 CAMBRIDGE ENVIRONMENTAL, INC., Cambridge, MA
Senior Scientist.

1985 – 2000 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA
Associate Professor of Human Physiology. (Adjunct, after 1990) Research work included: (1) human health effects of air toxics, (2) lung macrophage function measured with magnetic particles, and (3) lung deposition and clearance of radioactive tracer particles.

1987 INSTITUTE OF OCCUPATIONAL HEALTH, Helsinki, Finland
Visiting Researcher. Developed a magnetometric assay to be used for studying pulmonary macrophage function for lung cells lavaged from human subjects.

1984 INHALATION TOXICOLOGY RESEARCH INSTITUTE, Albuquerque, NM
Visiting Scientist. Examined the effect of exercise and hypercapnia on deposition, lung clearance, and lung distribution of inhaled radioactive aerosol.

1976 – 1985 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA
Assistant Professor of Respiratory Physiology.

1970 – 1976 AMHERST COLLEGE, Amherst, MA
Assistant Professor of Physics.

Professional Activities

- Center for Indoor Air Research, grant-application reviewer (1989-1994).
- DOE: Office of Health and Environmental Research, reviewer.
- Editorial Board, *Journal of Aerosol Medicine* (1987-2000).
- Harvard Center for Risk Analysis: Review of Cellular Telephones (1994-1999).
- Harvard School of Public Health: Research Advisory Committee Member for NIH-Sponsored Research on "Mechanisms of mortality/morbidity due to air particulate" (1997-2005).
- Health Effects Institute, Cambridge, MA, ad hoc reviewer (1984-1994).
- International Committee for Electromagnetic Safety (ICES) (2014-present).
- Member of the Committee on Man and Radiation (COMAR) (1999-2006).
- National Academy of Sciences and National Research Council, Evaluating Health-Risk-Reduction Benefits of US EPA Regulations (2001-2003).
- National Research Council, Commission on Life Sciences: Committee on Passive Smoking (1986-1988).
- NIH Reviewer: Cardiovascular and Pulmonary Study Section, Radiation Study Section, and Health of the Population Study Section.
- NIOSH: Environmental Center Grants, Site Visit Delegation (1990).
- Physical and Biological Sciences Study Committee, Town of Needham Planning Board.

Professional Affiliations

Fellow of the Academy of Toxicological Sciences; Society of Toxicology (full member); International Society for Environmental Epidemiology; Society for Risk Analysis; Health Physics Society (full member); Sigma Xi; American Conference of Governmental Industrial Hygienists (associate member)

Projects *(abbreviated)*

Brockton Power, Co. LLC: Reviewed and analyzed the projected air quality and public health effects regarding a proposed gas-fired electric-power generating plant to be located in Brockton, MA. Ground level air concentrations predicted by dispersion modeling were compared to health protective guidelines. The Air Permit was approved by Massachusetts Department of Environmental Protection and the Air Permit Approval was Affirmed upon appeal.

Carbon Black Manufacturers: Evaluated the toxicology and epidemiology of carbon black inhalation and ingestion.

Charter School in Washington, DC: Prepared a health risk assessment for the school board on the health risks of handling asbestos-containing materials that might release fibers.

City of Newton Health Department: Measured RF levels from a local transmitting antenna, reviewed RF field calculations, and provided scientific literature critique on RF health effects.

City of Philadelphia: Prepared a health risk analysis of firefighting occupation and how firefighter exposures during work may be associated with altered disease risk.

Confidential Client: Evaluated exposure concentrations, toxicity, and risk of adverse health effects of diacetyl and butter flavorings.

Confidential Client: Prepared a model predictive of asbestos fiber drift and inhalation health hazard applicable to industrial processes where asbestos-containing materials are used.

Confidential Client: Prepared a risk assessment for a Massachusetts landfill containing both chemical and radioactive waste and including multiple pathways of contaminant uptake by a trespasser.

Confidential Client: Prepared an analysis of health risk due to hexavalent chromium (Cr^{6+}) being in groundwater that might be used either for drinking or crop irrigation.

Confidential Clients: Prepared an analysis of relative risks of TCE in drinking water *versus* health hazards from background levels of chemicals in air, water, and soil, as well as other routine risks to life and health.

Electric Power Research Institute: Reviewed and analyzed the mechanisms by which biological systems may be affected by environmental electric and magnetic fields (EMFs). Organized a public workshop on the causes and characteristics of childhood leukemia.

Electric Utility: Analyzed the relationship between inhaled carbon monoxide concentration and blood carboxyhemoglobin. Performed sensitivity analysis on all the variables involved.

Electric-Power Generating Companies: Prepared and delivered expert reports and public testimony on the potential health effects of airborne emissions from coal fired, gas-fired, oil-fired, and wood-fired electric utility power generating plants.

Harvard School of Public Health: Continuing Education for Professionals: Prepared material on special topics on inhalation toxicology for graduate students and health professionals. Presented lectures on risk assessment and risk communication.

Health Effects Institute: Prepared an analysis entitled "Ozone Molecular Dosimetry and Interaction with Biological Macromolecules."

Health Effects Institute: Supervised and documented a feasibility study for the Health Effects Institute initiating a national research program on the health effects of electric and magnetic fields.

Manufacturing Company/FUSRAP Site: Prepared a radionuclide health risk assessment and site management plan for site contaminated by nearby storage of uranium ore.

Manufacturing Company: Analyzed multi-pathway human health risk for a site contaminated with polychlorinated biphenyls (PCBs) and chlorinated organic solvents. Analyzed experimental data to derive a fraction of PCBs that are picked up from concrete when touching the concrete.

Massachusetts Department of Public Health: Prepared a public communications essays on what citizens can do to support improved air quality.

Medical Product Manufacturer: Prepared a risk assessment for air toxics produced during malfunction of a medical device used to assist breathing.

Michigan Occupational and Environmental Medical Association (MOEMA): Prepared and delivered a risk assessment tutorial for MOEMA's Continuing Education program.

Mining Company: Evaluated the epidemiological basis for the toxicity of arsenic in soils. Evaluated metals toxicity factors and site-specific bioavailability of metals.

National Institute of Environmental Health Sciences – Division of Research Grants: Reviewed grant applications for the Radiation Study Section Panel on Health-Effects Research.

National Institute of Environmental Health Sciences / Environmental Protection Agency: Asbestos Workshop, assisted in the review of the summary publication, "A Science-Based Examination of Asbestos and Related Mineral Fibers".

Navy Occupational Health and Preventive Medicine Program: Prepared and delivered seminars and workshops to US Navy medical personnel on the current research on EMFs.

New Mexico Environmental Department: Prepared a health risk assessment for measured and modeled concentrations of 80 airborne chemicals in Albuquerque, NM.

Refineries in US and Canada: Prepared a multi-pathway human health risk assessment for air emissions from petroleum refineries. The risk assessment process was monitored by task forces composed of regulators, educators, union members, and local officials.

School District on Long Island: Assessed possible environmental, occupational, and lifestyle risk factors for early-term miscarriage.

University of Denver: Analyzed the potential health impact of uranium disposal from munitions testing ("depleted uranium") as it was practiced in the 1960s and 1970s.

Uranium Mill: Evaluated the health implications of radioactive substance migration as predicted by different US EPA and DOE models.

US Department of Energy: Prepared a risk communication strategy for a nuclear test site where detonation of underground atomic devices had the potential to contaminate groundwater.

US Department of Justice: Prepared a report and provided expert testimony on human toxicology with regard to soil contamination at a RCRA site.

US Department of Justice: Prepared an analysis of the health hazards of the Love Canal Superfund site (Niagara Falls, NY).

US Department of Justice: Prepared reports and provided expert testimony in several different cases on asbestos, sulfuric acid, and airborne particulate inhalation toxicology.

US Environmental Protection Agency, Environmental Criteria and Assessment Office: Evaluated research proposals on "Indoor and Ambient Air Risk Assessment Methodologies."

US Environmental Protection Agency, Health Effects Research Laboratory: Assisted in preparing a database of non-cancer health effects for 189 Hazardous Air Pollutants.

US Environmental Protection Agency: Analyzed the health risks of a remediation alternative at the Bloody Run Creek section of the Hyde Park Landfill superfund site (Niagara Falls, NY).

US Environmental Protection Agency: Provided US EPA with a peer review (scientific critique) of the agency's draft guidance on risk assessment for VOC's present in household water..

US Environmental Protection Agency: Provided US EPA with a peer review (scientific critique) of the agency's draft reference concentration (RfC) methodology for risk assessment.

Waste Management Company: Evaluated health risks for a medical waste incinerator, including a multiple-pathway (ingestion, inhalation, dermal, mothers' milk) health risk assessment.

World Health Organization: Helped prepare a WHO research report on EMF health effects. Presented a lecture on EMF health effects at a WHO workshop in Geneva, Switzerland. Published review article on RF health effects.

Academic Research Projects *(abbreviated)*

National Heart, Lung, and Blood Inst.:	"Physical Determinants of Lung Function and Dysfunction."
National Heart, Lung, and Blood Inst.:	"Pulmonary SCOR: Chronic Diseases of the Airways."
National Cancer Institute:	"Magnetic Field Effects on Macrophages."
National Inst. of Environ. Health Sci.:	"Inhaled Particle Retention in Normal and Diseased Lungs."
National Heart, Lung, and Blood Inst.:	"Particle Location and Ingestion by Lung Macrophages."
National Inst. of Environ. Health Sci.:	"Factors Influencing Deposition of Inhaled Aerosols."

Publications – *Articles*

Long, CM, Valberg, PA. 2019. "Low-frequency magnetic fields: Potential environmental health impacts." In *Encyclopedia of Environmental Health, 2nd Edition, Vol. 3*. (Ed.: Nriagu, JO), Elsevier, vol. 4, pp. 139-149.

Valberg, PA; Long, CM; Beyer, LA. 2019. "Toxicology of ambient-air particulate matter (PM)." Chapter 25 in *Toxicology Principles for the Industrial Hygienist, 2nd Ed.* (Eds.: Luttrell, WE; Still, KR; Church, J), American Industrial Hygiene Association, Falls Church, VA. pp. 343-364.

Valberg, PA. Still, KR. 2019. "Overview of airborne particulate matter properties" Chapter 23 in *Toxicology Principles for the Industrial Hygienist, 2nd Ed.* (Eds.: Luttrell, WE; Still, KR; Church, J), American Industrial Hygiene Association, Falls Church, VA. pp. 317-328.

Valberg, PA. 2019. "Toxicology of radioactive materials" Chapter 21 in *Toxicology Principles for the Industrial Hygienist, 2nd Ed.* (Eds.: Luttrell, WE; Still, KR; Church, J), American Industrial Hygiene Association, Falls Church, VA. pp. 291-304.

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Zu, K; Tao, G; Long, C; Goodman, J; Valberg, P. 2016. "Long-range fine particulate matter from the 2002 Quebec forest fires and daily mortality in Greater Boston and New York City." *Air Qual. Atmos. Health* 9(3):213-221. doi: 10.1007/s11869-015-0332-9.

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Hesterberg, TW; Long, CM; Valberg, PA. 2012. "Correspondence re: The diesel exhaust in miners study: a nested case-control study of lung cancer and diesel exhaust and a cohort mortality study with emphasis on lung cancer." *J. Natl. Cancer Inst*. 104(23):1841.

McCunney, RJ; Muranko, HJ; Long, CM; Hamade, AK; Valberg, PA; Morfeld, P. 2012. "Carbon black." In *Patty's Toxicology, Sixth Edition, Vol. 5*. (Ed.: Bingham, E; Cohrssen, B), John Wiley & Sons, Inc. 26p.

Hesterberg, TW; Bunn, WB; Valberg, PA; Long, CM. 2012. "Potential health effects of exposure to diesel engine exhausts." In *The Praeger Handbook of Environmental Health: Water, Air, and Solid Waste.* (Ed: Friis, RH), Praeger, ABC-CLIO, LLC, Santa Barbara, CA, p185-212.

Brain, JD; Kavet, R; Valberg, PA. 2012. "Observations on power-line magnetic fields associated with asthma in children." *Arch Pediatr Adolesc Med*. 166(1):97-8.

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Hesterberg, TW; Long, CM; Sax, SN; Lapin, CA; McClellan, RO; Bunn, WB; Valberg, PA. 2011. "Particulate matter in new technology diesel exhaust (NTDE) is quantitatively and qualitatively very different from that found in traditional diesel exhaust (TDE)." *J. Air & Waste Manage. Assoc.* 61:894-913.

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Hesterberg, TW; Bunn, WB; McClellan, RO; Hamade, AK; Long, CM; Valberg, PA. 2009. "Critical review of the human data on short-term nitrogen dioxide (NO_2) exposures: Evidence for NO_2 no-effect levels." *Crit Rev Toxicol.* 39(9):743-781.

Valberg, PA; Bruch, J; McCunney, RJ. 2009. "Are rat results from intratracheal instillation of 19 granular dusts a reliable basis for predicting cancer risk?" *Regul Toxicol Pharmacol*. 54(1):72-83.

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Abstracts & Reports *(list available on request)*

Invited Lectures *(past 10 years)*

2/8/16 "Inhalation Toxicology." Presented in the course "*Environmental Health 292: Aerosol Behavior,"* Harvard School of Public Health, Boston, MA.

7/13/15 "Portals of Entry: Pulmonary Deposition and Clearance of Particles." Presented in the course "*Comprehensive Industrial Hygiene*" Harvard School of Public Health, Boston, MA.

6/23/14 "Portals of Entry: Pulmonary Deposition and Clearance of Particles." Presented in the course "*Comprehensive Industrial Hygiene*" Harvard School of Public Health, Boston, MA.

6/05/13 "Portals of Entry: Pulmonary Deposition and Clearance of Particles." Presented in the course "*Comprehensive Industrial Hygiene*" Harvard School of Public Health, Boston, MA.

6/28/12 "Inhalation toxicology input to the fine-particle National Ambient Air Quality Standard." Presentation to the United States House of Representatives Committee on Energy and Commerce, Washington, DC.

6/11/12 "Portals of Entry: Pulmonary Deposition and Clearance of Particles." Presented in the course "*Comprehensive Industrial Hygiene*" Harvard School of Public Health, Boston, MA.

3/19/12 "Epidemiology of Diesel Exhaust: An Overview." Presented at the "*International Congress of Occupational Health*" Cancun, Mexico.

4/12/11 "Nanotechnology Products: Environmental Health and Workplace Safety." Presented in the Symposium: "Nanotechnology's Journey to Commercialization" University of Massachusetts, Lowell, MA.

6/14/10 "Portals of Entry for Workplace Chemicals / Lung Deposition and Clearance of Inhaled Particles." Presented in the course "*Comprehensive Industrial Hygiene: The Applications of Basic Principles"* Harvard School of Public Health, Boston, MA.

3/24/10 "Do Brain Cancer Rates Correlate with Ambient PM-Levels or with Hazardous Air Pollutant (HAP) Concentrations?" Presented at the AAAR Specialty Conference "*Air Pollution and Health: Bridging the Gap from Sources to Health Outcomes*," San Diego, CA.

6/23/08 "Routes of Entry into the Body: Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

6/25/07 "Routes of Entry into the Body: Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

3/29/07 "Non-linear Exposure-Response Relationships between Ambient PM_{10} and Daily Mortality." Presentation with Dr. T. Bowers at the Society of Toxicology Annual Meeting, Charlotte, NC. This presentation was selected as one of the *Top 12 Risk Assessment Abstracts at the SOT Meeting.*

11/7/06 "What is EMF? How EMF Interacts with Organisms." Presented at the Cyprus International Institute for the Environment and Public Health symposium on "Electromagnetic Fields: Sources, Health Effects, and Regulations, Nicosia, Cyprus.

6/19/06 "Pulmonary Deposition and Clearance of Particles." Presented in the course "Comprehensive Industrial Hygiene: Practical Applications of Basic Principles," Harvard School of Public Health, Boston, MA.

5/18/06 "Health Hazards of Nanoparticles." Presented at "A Mock Hearing: Environment, Health & Safety" at the NanoBusiness Alliance Meeting, New York City, NY.

4/25/06 "Inhalation Risk Assessment: Extrapolating from Macro-materials to Nano-materials." Overcoming Obstacles to Effective Research Design in Nanotoxicology, Cambridge, MA.

10/6/05 Panelist for: "A Reevaluation of the Association Between Diesel Exhaust Exposure and Lung Cancer." Air & Waste Management Association (AWMA) Specialty Workshop on "Diesel Exhaust," Chicago, IL.

6/20/05 "The Respiratory Tract as a Portal of Entry for Airborne Chemicals in the Work Environment." Lecture at the Harvard School of Public Health course on "Comprehensive Industrial Hygiene," Boston, MA.

6/16/05 "Electromagnetic Fields, Base Stations, and Wireless Networks: Exposures & Health Consequences." WHO Workshop, 15-16 June 2005, at the World Health Organization, Geneva, Switzerland.

2/11/05 "Generation of Charged Aerosols by High-Voltage Electric-Power Lines." American Association for Aerosol Research, Specialty Conference on Particulate Matter, Atlanta, GA.

2/4/05 "Magnetic Microparticles Detect and Probe Cytoplasmic Motions." Bioelectromagnetics Society Winter Workshop, Phoenix, AZ.

Manuscript Peer Reviewer for the Following Research Journals

American Industrial Hygiene Journal; American Journal of Physics; American Journal of Respiratory Cell and Molecular Biology; American Review of Respiratory Disease; Atmospheric Environment; Bioelectromagnetics; Biophysical Journal; Biorheology; Cancer Medicine; Cell Biophysics; Chemical Research in Toxicology; Critical Reviews in Toxicology; Environmental Geochemistry and Health; Environmental Health Perspectives; Environmental Research; Environment International; Environmental Science & Technology; Environment, Systems and Decisions; Epidemiology; Experimental Lung Research; Fundamental and Applied Toxicology; Hepatology; Human and Ecological Risk Assessment; Human and Experimental Toxicology; IEEE Biomedical Engineering; IEEE Transactions on Plasma Science; International Journal of Environmental Health Research; International Journal of Radiation Biology; Journal of Aerosol Medicine and Pulmonary Drug Delivery; Journal of Analytical & Bioanalytical Techniques; Journal of Applied Physiology; Journal of Applied Toxicology; Journal of Exposure Science And Environmental Epidemiology; Journal of Occupational and Environmental Hygiene; Journal of Nanomedicine & Nanotechnology; Journal of Occupational and Environmental Medicine; Journal of Physical Chemistry & Biophysics; Journal of Occupational Medicine and Toxicology; Journal of the Royal Society Interface; Journal of Toxicology and Environmental Health; Nature; Nonlinearity in Biology, Toxicology, and Medicine; Radiation Research; Risk Analysis: An International Journal; Regulatory Toxicology & Pharmacology; Science; Tissue & Cell; Toxicology and Applied Pharmacology; Toxicology & Environmental Chemistry; Toxicological Sciences; USGS Environmental Geochemistry of Mineral Deposits (Reviews in Economic Geology series).

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Areas of Expertise

Air quality and environmental health, with expertise in exposure assessment, indoor/outdoor air pollution, inhalation risk assessment and toxicology, particulate matter, air sampling/modeling, and electric and magnetic fields (EMF).

Education and Certifications

Sc.D., Environmental Health, Harvard School of Public Health, 2001

M.S., Environmental Engineering, Massachusetts Institute of Technology, 1995

A.B., Chemistry and Environmental Studies, *summa cum laude*, Bowdoin College, 1993

Diplomate of the American Board of Toxicology (DABT), 2013

Professional Experience

2000 – Present GRADIENT, Boston, MA
Principal Scientist, Air Quality & Environmental Health. Evaluate human exposures and health effects of environmental pollutants, specializing in airborne gases, particles, and fibers. Investigate indoor and outdoor air quality problems, and perform air sampling and exposure modeling. Conduct human health risk assessments, consumer product safety assessments, and worker safety evaluations; review and interpret epidemiological and toxicological studies. Prepare technical analyses, expert reports, and risk communication materials. Editor of Gradient's *Trends* newsletter (2011-present).

1997 – 2000 HARVARD SCHOOL OF PUBLIC HEALTH, Boston, MA
Research/Teaching Assistant. Designed and conducted indoor air particle characterization study of Boston-area homes. Also served as teaching assistant for two graduate courses: Seminar in Risk Analysis, Management, and Communication; and Air Pollution: Particles and Gases.

1995 – 1997 MENZIE-CURA & ASSOCIATES, INC., Chelmsford, MA
Environmental Scientist/Risk Assessor. Conducted human health and ecological risk assessments for state and federal hazardous waste sites. Modeled fate and transport of organic and inorganic contaminants in all environmental media. Responsibilities also included project management, proposal writing, and litigation support. Participated in environmental site assessments and field sampling activities of aquatic and terrestrial habitats. OSHA-certified 40-hour training.

1993 – 1995 MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, MA
Research Assistant. Conducted research in trace organic pollutant laboratory. Modeled the fate and transport of sewage-derived linear alkylbenzenes (LABs) in the Gulf of Maine.

1992 NASA GODDARD SPACE FLIGHT CENTER, Greenbelt, MD
Research Assistant. Selected as summer intern in Summer Institute on Atmospheric and Hydrospheric Sciences; worked with atmospheric scientists in GSFC's Atmospheric Chemistry and Radiation Branch. Used a photochemical box model to explore the potential for ozone depletion in the Northern Hemisphere stratosphere at middle and low latitudes.

Professional Activities

- Editorial Review Board, *Journal of Exposure Science and Environmental Epidemiology (JESEE)*.
- Member of City of Cambridge Nanomaterials Advisory Committee (NAC).
- Invited technical peer reviewer for the *Journal of the Air & Waste Management Association, Environmental Science & Technology, Atmospheric Environment, Environmental Health Perspectives, Environmental Forensics, Science of the Total Environment, Journal of Occupational and Environmental Medicine, and Journal of Exposure Science and Environmental Epidemiology.*
- Invited member of the National Institute of Environmental Health Sciences (NIEHS) Special Emphasis Panel ARRA-Standardized Testing of Nanoparticles for Their Safety to Human Health.
- Co-Editor, *Dose-Response*, Special Issue on Nanotoxicology, 2009-2010.

Awards/Honors

- US EPA STAR Graduate Fellow, 1998-2000.
- *Phi Beta Kappa.*
- Student abstract/presentation award at 1999 ISEA/ISEE Annual Conference in Athens, Greece.
- 2009 World of Coal Ash (WOCA) Poster Award for Excellence in the Field of Coal Ash Research.

Professional Affiliations

American Chemical Society (ACS); International Society of Exposure Science (ISES); Air & Waste Management Association (AWMA)

Projects

North American Railroad: Provided litigation support in FELA cases of former railroad workers alleging cancers due to occupational exposures to diesel exhaust, benzene, silica dust, asbestos, creosote, herbicides, and other substances. Evaluated general causation and provided expert testimony.

University of Washington: Analyzed $PM_{2.5}$ air quality data collected in the vicinity of a large urban construction project and assessed the health implications for children at the university's daycare center across the street from the project. Met with parents and staff of the daycare center at a public meeting to present the findings from our evaluation and to answer questions. Made recommendations for additional air monitoring activities.

Electric Utilities: Conducted human health risk assessments for multiple new natural gas-fueled power plant projects or natural gas boiler expansion projects at existing power plants. Served as human health risk assessment expert at hearings held by the Massachusetts Energy Facilities Siting Board (EFSB) and at public meetings.

Private Law Firm: Performed a comparative exposure assessment to examine how potential off-site incremental airborne quality impacts associated with diesel exhaust emissions from diesel-powered transport refrigeration units (TRUs) compared to common everyday exposures to the same air pollutants. Provided testimony related to diesel exhaust health effects at zoning board hearings, and responded to questions from opposing counsel and from board members.

Private Law Firm: Provided litigation support regarding health claims related to operations at an unconventional natural gas well pad. Assessed meteorological data, air sampling data, and odor inspection reports to develop expert opinions related to the relationship between air emissions at the well pad site and potential health risks at nearby residential properties.

Massachusetts Electric Utilities: Conducted modeling analyses of the electric and magnetic field (EMF) impacts of underground and overhead transmission line projects. Served as EMF expert at hearings held by the Massachusetts Energy Facilities Siting Board (EFSB) and at public open houses.

New York State Electric Utility: Conducted modeling analysis of the electric and magnetic field (EMF) impacts of a large overhead transmission line re-conductoring project in western New York State. Served as EMF expert at multiple public open houses and public meetings.

Private Electric Power Generation Development Firm: Prepared exposure-based comparisons to provide context on potential exposures to several US EPA criteria air pollutant and air toxics emissions that could occur as a result of emissions from a proposed natural gas power plant project as compared to everyday exposures to the same air pollutants from common indoor and personal exposure sources (*e.g.*, cooking, woodburning, driving a car). Presented the exposure comparisons and responded to questions at an open house held for residents of a 55+ residential community nearby to the proposed power plant.

Private Natural Gas Exploration and Production Companies: Prepared a report providing an overview of the current science bearing on the potential community-level air quality impacts and public health risks associated with natural gas development activities in the Marcellus Shale region. Served as public health expert at local municipal hearings.

Coal Processing Facility: For a toxic tort, analyzed ambient particulate matter monitoring data, assessing the appropriateness of the measurement method, how the measured levels compared to background exposure levels, and implications for potential community exposures to coal dust. Provided deposition and trial testimony.

Personal Care Products Company: Conducted a safety assessment for synthetic amorphous silica (SAS), including nanoscale forms, used as an ingredient in a cosmetics product. Prepared a safety dossier consistent with 2012 guidance from the European Commission Scientific Committee on Consumer Safety (SCCS) for the safety assessment of nanomaterials in cosmetics.

Electric Power Research Institute (EPRI): Evaluated potential inhalation risks from mercury associated with the beneficial use of coal combustion products in wallboard, concrete, and structural fill. Characterized indoor off-gassing of Hg from building materials, as well as ambient mercury volatilization and wind-blown dust emissions for coal ash structural fills.

Coal Producing Company: For multiple toxic tort cases alleging health claims associated impacts of coal slurry operations on drinking water from domestic wells, evaluated exposures and potential health risks associated with inhalation of low levels of hydrogen sulfide during water use. Assessed the health effects evidence for H_2S health effects and the relationship between H_2S odors and health effect levels.

Private Law Firm: Provided expert opinions for a toxic tort case alleging elevated exposure to propane gas during routine venting operations at a liquid propane storage facility. Used a well-established heavy gas air dispersion model to estimate worst-case exposures to propane and the mercaptan odorant in the gas, and assessed the potential human health risks associated with these short-term model-predicted exposure concentrations.

Air Purifier Manufacturer: Evaluated potential exposures and health effects associated with usage of ozone-generator air purifiers. Reviewed extensive body of epidemiological studies of ozone health effects. Assisted client in development of health-related labeling for their products.

New Mexico Environment Department: Prepared an acute health risk assessment for measured and modeled concentrations of 80 airborne chemicals as detected or predicted for a suburb of Albuquerque, NM.

Utility Air Regulatory Group (UARG): Provided both oral and written comments on the August 2007 external review draft of the US EPA "Integrated Science Assessment for Oxides of Nitrogen: Health Criteria." Conducted an independent analysis of the US EPA proposed process for integrating and weighing scientific evidence on the potential health impacts of ambient NO_x including NO_2.

Large Midwestern Farm: Conducted air sampling and performed air dispersion modeling analysis to estimate the air quality impacts of hydrogen sulfide (H_2S) emissions from a large Ohio hog farm to address odor and health claims.

Health Effects Institute: Compiled comprehensive database of outdoor and indoor exposure concentrations for US EPA-designated mobile source air toxics (MSATs).

Printer Manufacturer: Designed a comprehensive measurement program to assess potential exposures associated with use of a commercially available printer. Assessed toxicological significance of indoor air and surface wipe measurements.

US DOJ: In support of litigation, assessed the exposure potential and public health impacts associated with airborne releases of asbestos from asbestos cement pipe fragments in an Illinois wetland.

Private Law Firm: Provided litigation support regarding residual asbestos contamination associated with the World Trade Center disaster on several floors of a Manhattan commercial office building. Assessed the adequacy of the testing protocols used to support re-occupancy of the building, and evaluated the level of health protection provided by asbestos clearance levels.

Private Law Firm: For a wrongful death case, analyzed available data on particulate matter (PM) levels associated with wood combustion in outdoor wood-fired boilers (OWBs) and evaluated the health effects evidence linking woodsmoke exposure with acute myocardial infarction. Provided scientific opinions regarding the relative toxicity of woodsmoke PM as compared to other types of PM with respect to cardiovascular health outcomes.

Salem and Beverly Water Supply Board: Conducted a human health and ecological risk assessment to characterize risks associated with disposal of arsenic-contaminated water treatment plant sedimentation residuals in a marsh adjacent to the Wenham Lake Reservoir, which is the source of drinking water for the towns of Salem and Beverly, MA.

Private Law Firm: Assisted in assessment of potential exposures to lead in air and residential yard soils alleged to have been derived from former mine waste piles. Evaluated the potential for wind-blown dust emissions of lead from mining residuals and conducted air dispersion modeling analysis to estimate airborne dust deposition. Compared predicted deposition patterns with the observed lead measurements in residential yard soils.

Private Law Firm: In order to address concerns about workplace air pollutant exposures and their relationship to worker cancer diagnoses, developed and implemented an indoor air evaluation for an office building and evaluated the incidence of cancer amongst employees. Helped develop multiple communication pieces, and prepared written responses to worker questions.

Private Law Firm: Designed and implemented an indoor/outdoor $PM_{2.5}$ sampling program in residential homes near a large industrial facility to investigate source contributions to residential particulate matter exposures. Prepared expert reports and provided deposition testimony.

Public School in Washington, DC: Assessed possible asbestos-fiber intakes that may have resulted from potential "worst-case" exposures during use of the building by children and staff.

Electric-Power Generating Companies: Prepared technical analyses on exposures and potential health effects associated with particulate matter (PM), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) from airborne emissions of coal-fired electric utility power generating plants.

Engine Manufacturers Association: Conducted reviews of various scientific and regulatory reports pertaining to the $PM_{2.5}$ National Ambient Air Quality Standards, and prepared written comments.

Private Law Firm: Provided litigation support for a class action lawsuit involving alleged health and environmental damages at a large lake associated with mercury emissions from several coal-fired power plants. As part of this multidisciplinary effort, conducted an air modeling analysis of mercury emissions, dispersion, and deposition from the power plants using the US EPA regulatory air models CALPUFF and ISCST3 and used the model results to assess the power plant impacts relative to other local/regional/global mercury sources.

Oakland County, MI: Prepared technical analyses of $PM_{2.5}$ measurement and meteorological data in support of the Oakland County, MI petition for reconsideration of US EPA's $PM_{2.5}$ non-attainment designation.

Private Law Firm: Provided expert witness testimony regarding the standard of care related to air quality management at a primary lead smelter.

Private Law Firm: Conducted an analysis of the possible relationship between exposures to indoor latex aeroallergens in healthcare settings and risk of adverse health effects.

PG&E National Energy Group: Prepared a multi-pathway (inhalation of wind-blown dust and vehicle-generated fugitive dust, incidental ingestion, dermal contact) human health risk assessment evaluating potential exposures of nearby residents to trace metals (*e.g.*, arsenic, hexavalent chromium, selenium, cadmium) from a coal ash disposal site. Prepared technical analyses and public communication materials regarding coal ash disposal and beneficial usage.

Electric Utility: Performed a health risk evaluation of the possible relationship between measured airborne concentrations of sulfuric acid and sulfur dioxide (SO_2) in vicinity of a large coal-fired power plant and acute health symptoms (*e.g.*, irritation of the eyes, nose, and throat; shortness of breath; asthma-like symptoms). Reviewed regulatory, medical, and research information on the potential health effects of SO_2 and sulfuric acid. Prepared both a technical report and a public communication document.

US Chamber of Commerce: Provided testimony at a public hearing on sources of uncertainty in OSHA's preliminary quantitative risk assessment for respirable crystalline silica, focusing in particular on exposure measurement errors as potential sources of biased risk estimates and of threshold-obscuring or threshold-shifting effects in the silica worker epidemiologic cohort studies. Addressed questions from OSHA, OSHA's peer reviewers, and members of the public.

International Carbon Black Association: Provided analyses of health effects data on carbon black, a manufactured substance generated as an airborne fine particulate aggregate of nano-sized subunits of elemental carbon. Reviewed toxicological and epidemiological studies of carbon black-exposed populations, and evaluated the evidence for the carcinogenicity of carbon black. Co-authored a peer-reviewed publication summarizing the findings of our analysis.

Renewable Energy Company: Conducted a human health risk assessment to support the permitting process for a biomass-burning power plant. Assessed potential cancer and non-cancer risks from inhalation of criteria air pollutants and air toxics in stack emissions from the plant. Helped prepare for a public meeting.

Large Oil Refinery: Conducted review of a human health risk assessment conducted for communities near a large Canadian oil refinery. Identified health-protective standards and guidelines for refinery emissions, including for short-term sulfur dioxide (SO_2) exposures.

Publications

Valberg, PA; Long, CM; Beyer, LA. 2019. "Toxicology of ambient-air particulate matter (PM). In *Toxicology Principles for the Industrial Hygienist, 2nd Edition, Chapter 25* (Ed: Luttrell, WE; Still, KR; Church, JA; Beyer, LA). American Industrial Hygiene Association (AIHA).

Long, CM; Briggs, NL; Bamgbose, IA. 2019. "Synthesis and health-based evaluation of ambient air monitoring data for the Marcellus Shale region." *J Air Waste Manag Assoc.* 69(5):527-547. doi: 10.1080/10962247.2019.1572551.

Long, CM; Valberg, PA. 2019. "Low-frequency magnetic fields: Potential environmental health impacts." In *Encyclopedia of Environmental Health, 2nd Edition, Vol. 4.* (Ed.: Nriagu, JO), Elsevier, Burlington.

Long, CM. 2018. "Community-based air quality monitoring using low-cost sensors." *Gradient Trends – Risk Science & Application* 73:1-2, 7. Fall.

Long, CM; Valberg, PA. 2017. "Indoor airborne particulate matter: Unregulated, but a major contributor to our everyday exposure." *Natural Resources & Environment* 32(1):8-12.

Briggs, NL; Long, CM. 2016. "Critical review of black carbon and elemental carbon source apportionment in Europe and the United States." *Atmos. Environ.* 144:409-427. doi:10.1016/j.atmosenv.2016.09.002.

Zu, K; Tao, G; Long, C; Goodman, J; Valberg, P. 2016. "Long-range fine particulate matter from the 2002 Quebec forest fires and daily mortality in Greater Boston and New York City." *Air Qual. Atmos. Health* 9(3):213-221. doi: 10.1007/s11869-015-0332-9.

Rohr, AC; Campleman, SL; Long, CM; Peterson, MK; Weatherstone, S; Quick, W; Lewis, AS. 2015. "Potential occupational exposures and health risks associated with biomass-based power generation." *Int. J. Environ. Res. Public Health* 12:8542-8605.

Hamade, AK; Long, CM; Valberg, PA. 2015. "Naturally occurring mineral fibers." In *Hamilton & Hardy's Industrial Toxicology, 6th Edition.* (Eds.: Bourgeois, M; Harbison, RD; Lee, RV; Stedeford, T), John Wiley and Sons, Inc., Chichester, UK.

Long, CM; Valberg, PA. 2014. "Evolution of cleaner solid fuel combustion." *Cornerstone* 2:36-40.

Long, CM; Nascarella, MA; Valberg, PA. 2013. "Carbon black versus black carbon and other airborne materials containing elemental carbon: Physical and chemical distinctions." *Environ. Pollut.* 181:271-86.

Beck, BD; Long, CM; Seeley, MR; Nascarella, MA. 2012. "A special issue on nanomaterial regulations and health effects." *Dose Response* 10:306-307.

Long, CM; Sax, SN; Lewis, AS. 2012. "Potential indoor air exposures and health risks from mercury off-gassing of coal combustion products (CCPs) used in building materials." *Coal Combustion and Gasification Products* 4:68-74.

Hesterberg, TW; Bunn, WB, III; Slavin, TJ; Malcore, J; Porter, ME; Harrison, EB; Grasso, NC; Long, CM. 2012. "Sustainability at Navistar: A model distinguished by sustainable innovation, proactive product stewardship, and sound science." *International Journal of Sustainable Strategic Management* 3(3):248-268.

Hesterberg, TW; Long, CM; Bunn, WB; Lapin, CA; McClellan, RO; Valberg, PA. 2012. "Health effects research and regulation of diesel exhaust: an historical overview focused on lung cancer risk." *Inhalation Toxicology*. 24(S1):1-45.

McCunney, RJ; Muranko, HJ; Long, CM; Hamade, AK; Valberg, PA; Morfeld, P. 2012. "Carbon black." In *Patty's Toxicology, Sixth Edition* (Vol. 5). (Ed.: Bingham, E; Cohrssen, B), John Wiley & Sons, Inc., New York, NY, p429-454.

Hesterberg, TW; Bunn, WB; Valberg, PA; Long, CM. 2012. "Potential health effects of exposure to diesel engine exhausts." In *The Praeger Handbook of Environmental Health: Water, Air, and Solid Waste* (Vol. 3). (Ed.: Friis, RH), Praeger, ABC-CLIO, LLC, Santa Barbara, CA, p185-212.

Valberg, PA; Long, CM. 2012. "Do brain cancer rates correlate with ambient exposure levels of criteria air pollutants or hazardous air pollutants (HAPs)?" *Air Quality, Atmosphere and Health* 5:115-123.

Hesterberg, TW; Long, CM; Valberg, PA. 2012. "Re: The diesel exhaust in miners study: A nested case-control study of lung cancer and diesel exhaust and a cohort mortality study with emphasis on lung cancer." *J Natl Cancer Inst.* 104(23):1841.

Hesterberg, TW; Long, CM; Sax, SN; Lapin, CA; McClellan, RO; Bunn, WB; Valberg, PA. 2011. "Particulate matter in New Technology Diesel Exhaust (NTDE) is quantitatively and qualitatively very different from that found in Traditional Diesel Exhaust (TDE)." *J. Air & Waste Manage. Assoc.* 61(9): 894-913.

Rhomberg, LR; Chandalia, JK; Long, CM; Goodman, JE. 2011. "Measurement error in environmental epidemiology and the shape of exposure-response curves." *Crit. Rev. Toxicol.* 41(8):651-71.

Hesterberg, TW; Long, CM; Lapin, CA; Hamade, AK; Valberg, PA. 2010. "Diesel exhaust particulate (DEP) and nanoparticle (NP) exposures: What do DEP human clinical studies tell us about potential human health hazards of nanoparticles?" *Inhalation Toxicology* 22:679-694.

Hesterberg, TW; Bunn, WB; McClellan, RO; Hamade, AK; Long, CM; Valberg, PA. 2009. "Critical review of the human data on short-term nitrogen dioxide (NO_2) exposures: evidence for NO_2 no-effect levels." *Critical Reviews in Toxicology* 39(9):743-81.

Long, CM; Beck, BD. 2009. "Study of Chinese print workers claims to provide the first human evidence of the clinical toxicity of long-term nanoparticle exposures." *InterNano* October 29. Accessed at http://www.internano.org/content/view/306/1/.

Hesterberg, T; Valberg, P; Long, C; Bunn, W; Lapin, C. 2009. "Laboratory studies of diesel exhaust health effects: Implications for near-roadway exposures." *EM Magazine, Air & Waste Management Association* 12-16.

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Valberg, PA; Long, CM; Hesterberg, TW. 2008. Comment on the nanoparticle conclusions in Cruts *et al.* (2008), "Exposure to diesel exhaust induces changes in EEG in human volunteers." *Part Fibre Toxicol.* 5(1):10.

Long, CM. 2008. "Development and application of an exposure-based framework for assessing nanomaterial safety." In *Nanotechnology 2008: Life Sciences, Medicine & Bio Materials - Technical Proceedings of the 2008 NSTI Nanotechnology Conference and Trade Show, Volume 2*, p134-137.

Long, CM; Valberg, PA. 2007. "Comment on 'An assessment of risk from particulate released from outdoor wood boiler' by Brown *et al." Human Ecolog. Risk Assess.* 13:681-685.

Valberg, PA; Long, CM; Sax, SN. 2006. "Integrating studies on carcinogenic risk of carbon black: Epidemiology, animal exposures, and mechanism of action." *Journal of Occupational and Environmental Medicine* 48(12):1291-1307.

Valberg, PA; Long, CM. 2006. Comment on "Vehicle self-pollution intake fraction: Children's exposure to school bus emissions." *Environ. Sci. Technol.* 40(9):3123.

Long, CM; Seeley, M; Beck, BD. 2005. "Tiny particles, large data gaps: A risk assessment perspective on nanotechnology." *Risk Policy Report* 12:12-14.

Long, CM; Sarnat, JA. 2004. "Indoor-outdoor relationships and infiltration behavior of elemental components of outdoor $PM_{2.5}$ for Boston-area homes." *Aerosol Science & Technology* 38(S2):91-104.

Sarnat, JA; Long, CM; Koutrakis, P; Coull, BA; Schwartz, J; Suh, HH. 2002. "Using sulfur as a tracer of outdoor fine particulate matter." *Environ. Sci. Technol*. 36:5305-5314.

Long, CM; Suh, HH; Kobzik, L; Catalano, PJ; Ning, Y; Koutrakis, P. 2001. "A pilot investigation of the relative toxicity of indoor and outdoor fine particles: *In vitro* effects of endotoxin and other particulate properties." *Environ. Health Perspect.* 109(10):1019-1026.

Long, CM; Suh, HH; Koutrakis, P. 2001. "Using time- and size-resolved particulate data to quantify penetration and deposition behavior." *Environ. Sci. Technol.* 25:2089-2099.

Gustafsson, Ö; Long, CM; MacFarlane, J; Gschwend, PM. 2001. "Fate of linear alkylbenzenes (LABs) released to the coastal environment near Boston Harbor." *Environ. Sci. Technol.* 25:2040-2048.

Long, CM; Suh, HH; Koutrakis, P. 2000. "Characterization of indoor particle sources using continuous mass and size monitors." *J. Air & Waste Manage. Assoc.* 50:1236-1250.

Menzie, CA; Freshman, JS; Long, CM. 1997. "Developing Environmentally Acceptable Endpoints for Soil Based on Ecological Considerations." In *Proceedings for the Air & Waste Management Association's 90th Annual Meeting & Exhibition, Toronto, Ontario,* June 8-13.

Presentations

Boomhower, SR; Goodman, JE; Li, AW; Long, CM. 2020. "A Systematic Review and Analysis of Personal and Ambient $PM_{2.5}$ Measurements: Implications for Epidemiological Studies." Poster #1135/P177. Prepared for presentation to the Society of Toxicology (SOT) 59th Annual Meeting & ToxExpo, Anaheim, CA, March 15-19 (Conference cancelled).

Long, CM; Zhao, S; Briggs, NL. 2019. "Validation Assessment of a Recently Developed Spatiotemporal Exposure Metric for Use in Epidemiological Studies of Populations Living Near Unconventional Oil & Gas Well Pads." Presented at AWMA's 112th Annual Conference & Exhibition, Quebec City, Quebec, June 25-28.

Long, CM; Valberg, PA. 2017. "Human Health Risk Assessment (HHRA) for Proposed Power Plant Projects: Methodology and Case Study." Presented at AWMA's 110th Annual Conference & Exhibition, Pittsburgh, PA, June 8.

Long, CM; Valberg, PA. 2016. "Human Health Risk Assessment (HHRA) for Power Plant Permitting Projects." Presented at the 2016 Northeast Energy and Commerce Association (NECA) Environmental Conference, Marlborough, MA, July 13.

Long, CM; Briggs, NL. 2016. "Integrative Assessment of Black Carbon and Elemental Carbon Source Apportionment Findings for Europe and the United States." Presented at the Air & Waste Management Association's 109th Annual Conference & Exhibition, New Orleans, LA, June 20-23.

Herman, K; Lewis, A; Bittner, AB; Dubé, E; Long, C; Hensel, B; Ladwig, K. 2016. "Framework for Evaluating Coal Ash Surface Impoundment Closure Options." Presented at the Battelle Tenth Annual Conference, Remediation of Chlorinated and Recalcitrant Compounds. May 26.

Long, CM. 2015. "Assessment of Particulate Matter Air Quality Impacts and Potential Health Risks Posed by an Urban Building Demolition Project." Presented at the 25th Annual Meeting of the International Society of Exposure Science (ISES), Henderson, NV, October 19-22.

Long, CM. 2015. "Human Health Risk Assessment for a Natural Gas-Fueled Power Plant Project." Presented at the EPRI/AWMA Env-Vision Conference, Crystal City, VA, May 12-14.

Lewis, A; Bittner, AB; Herman, K; Dubé, E; Long, C; Hensel, B; Ladwig, K. 2015. "Framework for Evaluating Relative Impacts for Surface Impoundment Closure Options." Presented at the 2015 World of Coal Ash Conference, Nashville, TN, May 8.

Tao, G; Zu, K; Long, CM; Goodman, JE; Valberg, PA. 2015. "Forest-Fire Fine Particulate Matter and Daily Mortality in Greater Boston and New York City." Presented at the 54th Annual Meeting of the Society of Toxiciology (SOT), San Diego, CA, March 22-26.

Zu, K; Tao, G; Long, C; Goodman, J; Valberg, P. 2014. "Forest-fire Fine Particulate Matter and Daily Mortality in Greater Boston." Presented at the 26th Annual International Society for Environmental Epidemiology (ISEE) Conference, Seattle, WA, August 24-28.

Long, CM. 2014. "Assessment of $PM_{2.5}$ Air Quality Impacts and Potential Health Risks Posed by a Large Urban Building Construction Project." Presented at the Air & Waste Management Association's 2014 Annual Conference & Exhibition, Long Beach, CA, June 24-27.

Long, CM; Valberg, PA. 2014. "Human Health Risk Assessment for a Biomass-Fueled Power Plant Project." Presented at 17th Annual Energy, Utility & Environment Conference (EUEC), Phoenix, AZ, February 3-5.

Long, CM; Valberg, PA. 2013. "Recent Developments Related to the Health Effects of Diesel Exhaust (DE): Implications for Hydraulic Fracturing and Oil & Gas Development." Presented at 20th International Petroleum Environmental Consortium (IPEC) Conference, San Antonio, TX, November 12-14.

Peterson, M; Valberg, P; Long, C. 2013. "The Association of Vascular Disease with Exposure to Diesel Exhaust." Presented at Society of Toxicology 52nd Annual Meeting, San Antonio, TX, March 10-14. *Toxicologist* 132(1):244.

Long, CM; Nascarella, MA; Valberg, PA. 2012. "Manufactured Carbon Black Differs in Physical-Chemical Properties and Biological Activity from Ambient Black Carbon, Soots, and Other Carbon-Containing Inhalable Particles." Poster Presentation at the 22nd Annual Conference of the International Society of Exposure Science (ISES), Seattle, WA, October 28-November 1.

Calabrese, PJ; Long, CM; Nascarella, MA; Niehaus, SE. 2011. "Nanotechnology Litigation to Come: A Case Study." One-hour audio briefing, Practicing Law Institute (PLI), September 12.

Long, CM; Lewis, AS; Sax, SN. 2011. "Indoor Air Inhalation Risks of Mercury Off-gassed from Building Materials Containing Coal Combustion Products (CCPs)." Platform Presentation at the Air & Waste Management Association's Annual Conference & Exhibition, Orlando, FL, June 21-24.

Hesterberg, TW; Bunn, WB; Long, CM; Sax, SN; Valberg, PA; Lapin, CA. 2011. "New Technology Diesel Exhaust (NTDE) Is Distinctly Different From Traditional Diesel Exhaust (TDE)." Platform Presentation at the Air & Waste Management Association's Annual Conference & Exhibition, Orlando, FL, June 21-24.

Hesterberg, TW; Long, CM; Hamade, AK; Valberg, PA; Lapin, CA. 2011. "Human Health Risks of Diesel Exhaust Particulate (DEP): Implications for Engineered Nanoparticle (NP) Exposures." Platform Presentation at the Air & Waste Management Association's Annual Conference & Exhibition, Orlando, FL, June 21-24.

Hesterberg, TW; Long, CM; Sax, SN; Lapin, CA; Bunn, WB; Valberg, PA; McClellan, RO. 2011. "Human Health Hazards of Exposure to New Technology Diesel Exhaust (NTDE)" Poster Presentation at the Health Effects Institute (HEI) Annual Conference, Boston, MA, May 1-3.

Valberg, PA; Hesterberg, TW; Long, CM; Lapin, CA; Hamade, AK. 2011. "Human Clinical Studies of Diesel Exhaust Particulate and Implications for Nanoparticle Exposures." Poster Presentation at the 50th Annual Meeting of the Society of Toxicology, Washington, DC, March 6-10.

Valberg, PA; Long, CM. 2010. "Do Brain Cancer Rates Correlate with Ambient PM-levels or with Hazardous Air Pollutant (HAP) Concentrations?" Platform presentation at the 2010 American Association for Aerosol Research (AAAR) Air Pollution and Health Meeting, San Diego, CA, March 22-26.

Long, CM; Lewis, AS; Sax, SN. 2009. "Mercury Inhalation Risks in Indoor Air from Use of Coal Combustion Products (CCPs) in Building Materials." Poster Presentation at the World of Coal Ash (WOCA) 2009 Conference, Lexington, KY, May 4-7.

Lewis, AS; Sax, SN; Long, CM. 2009. "Mercury Inhalation Risks from Use of Coal Combustion Products (CCPs) as Structural Fill and from Disposal of CCP-Containing Wallboard and Concrete in Landfills." Poster Presentation at the World of Coal Ash (WOCA) 2009 Conference, Lexington, KY, May 4-7.

Sax, SN; Lewis, AS; Long, CM. 2009. "Inhalation Risks of Mercury from Use of Coal Combustion Products (CCPs) as Structural Fill and from Disposal of CCP Building Materials in Landfills." Poster Presentation at the 48th Annual Meeting of the Society of Toxicology, Baltimore, MD, March 15-19.

Long, CM; Lewis, AS; Sax, SN. 2009. "Inhalation Risks of Mercury in Indoor Air from Beneficial Use of Coal Combustion Products (CCPs) in Building Materials." Poster Presentation at the 48th Annual Meeting of the Society of Toxicology, Baltimore, MD, March 15-19.

Hesterberg, TW; Lapin, CA; Long, CM; Valberg, PA. 2009. "Diesel-Exhaust Particulate (DEP) and Nanoparticle (NP) Exposures: Can DEP Tell Us About Potential Health Risks of NP?" Poster Presentation at the 48th Annual Meeting of the Society of Toxicology, Baltimore, MD, March 15-19.

Long, CM; Valberg, PA. 2008. "How Close Are We to Predicting the Toxic Potential of Engineered Nanomaterials Based on Physical-Chemical Properties?" Platform presentation at the 2008 Annual Meeting of the Society of Risk Analysis (SRA), Boston, MA, December 10.

Long, CM. 2008. "Development and Application of an Exposure-based Framework for Assessing Nanomaterial Safety." Poster presentation at the 11th Annual Nano Science and Technology Institute (NSTI) Nanotechnology Conference and Trade Show, Boston, MA, June 1-5.

Long, CM; Hakkinen, PJ; Valberg, PA. 2007. "Do We Know Enough to Apply the 'No Exposure, No Risk' Paradigm in Safety Assessments of Nanotechnology-Based Consumer Products?" Platform presentation and Session Chair for Oral Session: Exposure Processes for Manufactured Nanoparticles at 2007 International Society of Exposure Assessment (ISEA) Annual Conference, Research Triangle Park, NC, October 14-18.

Long, CM; Drivas, PJ. 2007. "Characterizing Airborne Hydrogen Sulfide Exposure Levels near a Midwestern Concentrated Animal Feeding Operation (CAFO) Using Both Measurement Data and Air Dispersion Modeling." Platform presentation at 2007 International Society of Exposure Assessment (ISEA) Annual Conference, Research Triangle Park, NC, October 14-18.

Valberg, P; Sax, S; Long, C. 2006. "Inhalation Health Risk Assessment: Extrapolating from Macromaterials to Nanomaterials." Poster presentation at Overcoming Obstacles to Effective Research Design in Nanotoxicology, Cambridge, MA, April 24-25.

Beyer, LA; Long, CM; Beck, BD; Slayton, TM. 2006. "Ambient Concentrations of Benzene are Below Those Associated with Significant Cancer Risk." Presented at the Society of Toxicology 45th Annual Meeting, San Diego, CA, March 5-9.

Long, CM. 2005. "Measurement, Fate, and Exposure Potential of Ultrafine Particles in Indoor Air: Lessons Learned for Nanotechnology." Poster presentation at 2nd International Symposium on Nanotechnology and Occupational Health, Minneapolis, MN, October 3-6.

Long, CM. 2004. "Indoor Ultrafine Particle Exposures: Small Particles, Large Data Gaps." Poster presentation at 2004 International Society of Exposure Assessment (ISEA) Annual Conference, Philadelphia, October 17-21.

Valberg, PA; Long, CM. 2003. "Is PM More Toxic than the Sum of its Parts? Discordance between 'Effect Functions' for PM Mass *vs.* Risk-Assessment Toxicity Factors." Poster presentation at 2003 AAAR PM Meeting: Particulate Matter: Atmospheric Sciences, Exposure and the Fourth Colloquium on PM and Human Health, Pittsburgh, PA, March 31-April 4.

Long, CM; Beck, BD. 2002. "An Evaluation of Potential Human Exposures to Trace Metals and Radionuclides in Construction and Building Materials Containing Coal Combustion Products." Poster presented at 2002 International Society of Exposure Assessment (ISEA)/International Society of Environmental Epidemiology (ISEE) Annual Conference, Vancouver, BC, August 11-15.

Long, CM; Suh, HH; Koutrakis, P. 2001. "Understanding Indoor Exposures to Ambient Particulate Matter: Estimates of Penetration Efficiencies and Deposition Rates for Residential Homes." Poster presented at the 2001 Society for Risk Analysis Annual Meeting, Seattle, WA, December 2-5.

Sarnat, JA; Long, CM; Koutrakis, P; Suh, HH. 2001. "Evaluating Tracers of Ambient $PM_{2.5}$." Platform presentation at the ISEA 2001 Conference, Charleston, SC, November 4-8.

Long, CM; Suh, HH; Koutrakis, P. 2000. "Using Time- and Size-Resolved Particulate Data to Investigate Infiltration and Deposition Behavior." Platform presentation at the ISEA 2000 Conference, Monterey Peninsula, CA, October 24-27.

Long, CM; Suh, HH; Koutrakis, P. 2000. "Using Time- and Size-Resolved Particulate Data to Investigate Infiltration and Deposition Behavior." Platform presentation at the AWMA PM2000 Specialty Conference, Charleston, SC, January 24-28.

Long, CM; Suh, HH; Koutrakis, P. 2000. "Characterization of Indoor Particle Sources Using Continuous Mass and Size Monitors." Poster presentation at the AWMA PM2000 Specialty Conference, Charleston, SC, January 24-28.

Long, CM; Suh, HH; Koutrakis, P. 1999. "Characterization of Indoor Particulate Source Strengths Using Continuous Mass and Size Monitors." Platform presentation at 1999 Annual ISEE/ISEA Conference, Athens, Greece, September 5-8.

Bernays, WH; Vorhees, DJ; Long, CM; Eremita, P. 1997. "Trial Guideline for Protecting Residents from Inhalation Exposure to Petroleum Vapors." Poster presentation at 1997 Annual Meeting of the Society for Risk Analysis, Washington, DC, December 7-10.

Invited Presentations, Seminars, and Lectures

Long CM. 2018. "Overview of Marcellus Shale Ambient Air Monitoring Data and Health Studies." Invited Panelist for Session "Is Natural Gas Development Affecting Public Health," Pittsburgh, PA, October 23-25.

Long, CM. 2017. "Assessing Air Quality Impacts of Marcellus Shale Development: Fact or Fiction?" Invited Presentation at Shale Insight 2017, Pittsburgh, PA, September 27.

Long, CM. 2015. "Unconventional Shale Gas Development and Hydraulic Fracturing: Perspectives on Community-level Air Exposures." Continuing Legal Education Seminar for the Washington County Bar Association Energy Section, Pittsburgh, PA, September 8.

Long, CM. 2009. "Nanotechnology: What You Should Know to Avoid Liability." Lecture given at the 21st Annual Product Liability Conference, University of Wisconsin-Madison Department of Engineering Professional Development, September 22-24.

Lewis, AS; Long, CM; Sax, SN. 2009. "Evaluation of Mercury Risks from Building Materials Containing CCPs and Opportunities for Risk Communication." Presented at the American Coal Ash Association (ACAA) 2009 Membership Meeting "Advancing the Management & Use of Coal Combustion Products," Phoenix, AZ, January 20-21.

Long, CM. 2008. "The State of the Science on Exposure Assessment of Engineered Nanoparticles: Challenges, Progress, Opportunities." Invited presentation at the November 2008 meeting of the Society of Risk Analysis – New England Chapter (SRA-NE) on Nanomaterials, Nanotoxicology, and Risk Assessment, Boston, MA, November 19.

Long, CM. 2007. "Development and Application of an Exposure-Based Framework for Assessing Nanomaterial Safety." Speaker and panelist, NanoTX '07 Conference and Expo, Environmental, Health & Safety Summit, Dallas, TX, October 2-4.

Long, CM. 2006. "Particulate Matter Exposure Assessment: State of the Science and New Challenges." BU School of Public Health, Environmental Health Seminar Series, September 29.

Long, CM. 2006. "Air Quality Exposure Assessment: Challenges Posed by Ambient Particles and Engineered Nanoparticles." Massachusetts Institute of Technology (MIT) Course 1.082 Air Pollution, April 26.

Long, CM. 2006. "Indoor Ultrafine Particle Exposures: Small Particles, Large Data Gaps." Poster presentation at the US EPA Board of Scientific Counselors (BOSC) Science to Achieve Results (STAR)/Greater Research Opportunities (GRO) Fellowship Subcommittee Meeting, Washington, DC, March 2-3.

Long, CM; Sarnat, JA. 2003. "Infiltration Behavior of $PM_{2.5}$ Chemical Components: Implications for Exposure Assessment and Epidemiological Associations." Platform presentation at the Particulate Matter: Atmospheric Sciences, Exposure and the Fourth Colloquium on PM and Human Health, Pittsburgh, PA, March 31-April 4.