

Thomas W. Armstrong, CIH, PhD, FAIHA

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Education

B.S. (Chemistry), Drexel University, 1974
M.S. (Environmental Health), Drexel University, 1978
Ph. D. (Environmental Engineering), Drexel University, 2006

Professional Experience

Principal Investigator, TWA8HR Occupational Hygiene Consulting, LLC. March 2008 to present
Exposure Sciences Section, Occupational and Public Health Division, ExxonMobil Biomedical Sciences, Inc. Annandale NJ October, 1989 to retirement, 15 March 2008, last as Senior Scientific Associate.
Airco Gases Divisions of The BOC Group, Murray Hill, NJ, May, 1986 to Sep., 1989, Manager, Loss Control
Airco Carbon Division of the BOC Group, Pittsburgh, PA & St. Marys, PA, January 1980 to May, 1986, Division Manager, Safety and Industrial Hygiene and Industrial Hygienist
Allied Chemical Company, Industrial Chemicals Division, Chicago, IL & Baltimore, MD September 1977 to December 1979. Industrial Hygienist
Academy of Natural Sciences, Limnology Department, Philadelphia, PA June, 1974 to September, 1976, Analytical Organic Chemist
U.S. Environmental Protection Agency, Raritan Arsenal, Edison, NJ, six months each year in 1971, 1972 and 1973 as an Environmental Chemistry Laboratory Cooperative Education Student.

Professional Activities, Society Memberships, Certifications

Certified Industrial Hygienist (Comprehensive Practice), American Board of Industrial Hygiene
American Industrial Hygiene Association, 1977 to present
American Conference of Governmental Industrial Hygienists, 1999 to present
Society for Risk Analysis, 2002 to 2007, 2011 to present
Fellow, American Industrial Hygiene Association as of 2009

Committees, Appointments

American Industrial Hygiene Association, Hygienic Guides Committee, 1983 to 1986, Exposure Assessment Strategies Committee, 1990 to present, Risk Assessment Committee 1996 to 1998, Occupational Epidemiology Committee 2006 to present, currently as past chair. Chaired subcommittee to develop and publish a User's Guide to Assessing and Managing Occupational Exposures, member of teaching teams for several AIHA professional development courses
Two National Academy of Sciences Committees evaluating risk assessments for new national infectious disease research laboratories

Member of peer review committees for two US EPA chemical risk assessments including dermal exposure risks

ExxonMobil Occupational Exposure Limit Committee, 1991 to 2002.
Adjunct Professor, Drexel University School of Public Health, Philadelphia, PA

Technical Publications

Armstrong, Thomas W. Considerations for Exposure Assessment of Consumer Products, Synergist, AIHA Press, September 2017.

Armstrong, Thomas W., Youxin Liang, Yimei Hetherington, Stephen M. Bowes, III, Otto Wong, Hua Fu, Min Chen, A. Robert Schnatter. Journal of Occupational and Environmental Hygiene, 8:561-572, 2011 Retrospective Occupational Exposure Assessment for Case-Control and Case-Series Epidemiology Studies Based in Shanghai China

Jayjock, M. A., T. Armstrong, et al. (2011). "The Daubert Standard as Applied to Exposure Assessment Modeling Using the Two-Zone (NF/FF) Model Estimation of Indoor Air Breathing Zone Concentration as an Example." *Journal of Occupational and Environmental Hygiene* 8(11): D114-D122.

Armstrong, T. W. (2005). A Quantitative Microbial Risk Assessment Model for Human Inhalation Exposure to Legionella. Doctoral Dissertation, Environmental Engineering. Philadelphia, Drexel University: 211. Available at: <http://dspace.library.drexel.edu/handle/1860/615>

Armstrong, T.W. and C.N. Haas (2008). Legionnaires' Disease: Evaluation of a Quantitative Microbial Risk Assessment Model. *Journal of Water and Health*. 6:149-166.

Armstrong, T.W. and C.N. Haas. (2006). A Quantitative Microbial Risk Assessment Model for Legionella: Summary of Methods and Evaluation Results, in *Legionella: State of the Art 30 Years after its Recognition*, N.P. Cianciotto, et al., Editor. Washington, D.C.: ASM Press.

Armstrong, T.W. and Haas, C.N. (2007). A Quantitative Microbial Risk Assessment Model for Legionnaires Disease: Animal Model Selection and Dose-Response Modeling. *Risk Analysis* 27(6):1581-1596

Armstrong, T. W. and Haas, C. N. (2007). A Quantitative Microbial Risk Assessment Model for Legionnaires Disease: Assessment of Human Exposures for Selected Spa Outbreaks. *J Occup Environ Hyg* 4:634-646

Armstrong, T.W. (2006). A Question of Time: A Short Review of Data on the Incubation Period Between Exposure and Symptom Onset for Legionellosis, in *Legionella: State of the Art 30 Years after its Recognition*, N.P. Cianciotto, et al., Editor. Washington, D.C.: ASM Press.

Armstrong, T.W., Caldwell, D.J., Verma, D. (2005). Occupational Exposure Limits: An Approach and Calculation Aid for Extended Work Schedule Adjustments. *J Occup Environ Hyg* 2(11):600-607.

Armstrong, T.W., R. T. Zaleski, W.J. Konkel, and T.J. Parkerton. (2002). A Tiered Approach To Assessing Children's Exposure: A Review of Methods and Data, *Toxicology Letters* 127:111-119.

Armstrong T.W., Hushka L.J, Tell J.G. and Zaleski R.T. (2000). A Tiered Approach for Assessing Children's Exposure, *Environmental Health Perspectives*, V. 108 No. 6:469-474.

Armstrong Thomas W. and Silverstein, Bernard D, Editors. (2000). *User's Guide to "A Strategy for Assessing and Managing Occupational Exposures (Second Edition)"*, AIHA Press, Fairfax, VA.

Armstrong, T.W., Pearlman, E.D., Schnatter, A.R., Bowes, S.P., Murray, N. and Nicolich, M., (1996). Retrospective Benzene and Total Hydrocarbon Exposure Assessment for A Petroleum Marketing and Distribution Worker Epidemiology Study, *Am. Ind. Hyg. Assoc. J.* 57(4) 333-343.

Armstrong, T.W. (1995). Past and Current Approaches to Occupational Exposure Databases in the Private Sector, *App. Occ. Envir. Hyg.*, 10(4) 257-263.

Copley, G. Bruce et al. Hospital-Based Case-Control Study of MDS Subtypes and Benzene Exposure in Shanghai. *Journal of Occupational and Environmental Medicine* 59.4 (2017): 349–355. PMC. Web. 30 Jan. 2018.

Caldwell, D.J., T.W. Armstrong, et al. (2001). Lessons Learned While Compiling a Quantitative Exposure Database from the Published Literature. *App. Occup. Envir. Hyg* 16(2):174-177.

Nicas M. and T.W. Armstrong. (2003). Using a Spreadsheet to Compute Contaminant Exposure Concentrations Given a Variable Emission Rate, *American Industrial Hygiene Association Journal* 64:368-375.

Nicas M and T.W. Armstrong. *IH Interface: Computer Implementation of Mathematical Exposure Modeling*. *Applied Occupational and Environmental Hygiene* 18:566-571 (2003)

Schnatter, A.R., T.W. Armstrong, L.S. Thompson, M.J. Nicolich, A.M. Katz, W.H. Huebner and E.D. Pearlman. (1996). The Relationship between Low-level Benzene Exposure and Leukemia in Canadian Petroleum Distribution Workers. *Envir. Health Persp.* 104(Supp. 6) 1375-1379.

Schnatter, A.R., T.W. Armstrong, F.S. Thompson, M.J. Nicolich, A.M. Katz, W.H. Huebner and E.D. Pearlman. (1996). Lymphohaematopoietic malignancies and quantitative estimates of exposure to benzene in Canadian petroleum distribution workers. *Occup. and Envir. Med.* 53, 773-781.

Glass, D. C., Armstrong, T. W., Pearlman, E. D., Verma, D. K., Schnatter, A. R., & Rushton, L. (2010). Ensuring comparability of benzene exposure estimates across three nested case-control studies in the petroleum industry in support of a pooled epidemiological analysis. *Chemico-biological interactions*, 184(1), 101-111.

- Drummond, I., Murray, N., Armstrong, T., Schnatter, A. R., & Lewis, R. J. (2006). Exposure assessment methods for a study of mortality and cancer morbidity in relation to specific petroleum industry exposures. *Journal of occupational and environmental hygiene*, 3(10), 513-520.
- Liang, Y.X, Wong, O, Armstrong, T. et al. (2005). An Overview of Published Benzene Exposure Data by Industry in China, 1960-2003. *Chemico-Biological Interactions* 153-154: 55-65.
- Irons, R.D., Lv, L., Gross, S.A., Ye, X., Bao, L., Wang, X.Q., Ryder, J, Armstrong, T.W. et al. (2005). Chronic exposure to benzene results in a unique form of dysplasia, *Leuk Res* 29(12):1371-80.
- Wang, L., Y. Zhou, Y. Liang, O. Wong, T. Armstrong, A.R. Schnatter, et al. (2006). Benzene exposure in the shoemaking industry in China, a literature survey, 1978-2004. *Regul Toxicol Pharmacol.* 46(2): p. 149-56. Epub 2006 Sep 20.
- Y.X. Liang, O. Wong, T. Armstrong, X.B. Ye, L.Z. Miao, Y.M. Zhou, Q.E. Wu, H.J. Qian, H. Fu, An overview of published benzene exposure data by industry in China, 1960-2003, *Chem Biol Interact* 153-154 (2005) 55-64
- H. Liu, Y. Liang, S. Bowes, H. Xu, Y. Zhou, T.W. Armstrong, O. Wong, A.R. Schnatter, J. Fang, L. Wang, , L. Nie, H. Fu, R. Irons, Benzene Exposure in Industries Using or Manufacturing Paint in China—A Literature Review, 1956–2005, *Journal of Occupational and Environmental Health* 6(11) (2009) 1–12
- M. Abell, M. Woebkenberg, T. Armstrong, M. Stenzel, Research recommendations of the NORA Exposure Assessment Methods Team, *Appl Occup Environ Hyg* 16(2) (2001) 331-333.
- Wong, O., F. Harris, T. W. Armstrong, and F. Hua, 2010a. A hospital-based case-control study of acute myeloid leukemia in Shanghai: Analysis of environmental and occupational risk factors by subtypes of the WHO classification. *Chem Biol Interact* 184(1-2):112-128.
- Wong, O., F. Harris, T. W. Armstrong, and F. Hua, 2010b. A hospital-based case-control study of non-Hodgkin lymphoid neoplasms in Shanghai: Analysis of environmental and occupational risk factors by subtypes of the WHO classification. *Chem Biol Interact* 184(1-2):129-146.
- Gross, S. A., R. D. Irons, A. R. Schnatter, J. Ryder, et al. 2010. A hospital-based case control study of aplastic anemia in Shanghai, China. *Chem Biol Interact* 184(1-2):165-173.

Books, Book Chapters, Other

Armstrong, Thomas W. "Making Decisions with Uncertain Data, Practical Examples of Monte Carlo Simulation", The Synergist, January 2015 (non-peer reviewed journal)

Viet, S, Stenzel, M, Rennix, C, Armsrong, T, and Couch, J., Editors "Guideline on Occupational Exposure Reconstruction", AIHA Press, 2008.

Author/contributing author to four chapters of book, "Mathematical Models for Estimating Occupational Exposure to Chemicals", C. Keil, C. Simmons, C.R. Anthony, Editors AIHA Press 2009

Author/of chapter on mathematical modeling of exposure to chemicals in Patty's Industrial Hygiene and Toxicology.

Lead developer of IH MOD, a freeware Excel Spreadsheet package of mathematical models available for free download at : <https://www.aiha.org/get-involved/VolunteerGroups/Pages/Exposure-Assessment-Strategies-Committee.aspx>

Currently developing IH Mod MCS, a Monte Carlo Simulation capable suite of exposure assessment models in MS Excel

Initiated and continue to support development of IH SkinPerm, a mathematical model for estimating dermal absorption from skin deposition of chemicals

Lead Instructor of Professional Development Course "Use of mathematical Models to Estimate Exposure to Chemicals."

Lead Instructor of Professional Development Course "Monte Carlo Techniques in Exposure and Risk Assessment."

Expert witness support to two Legionnaires' disease litigations, a class-action suit on metals exposure to iron foundry workers and litigation for indoor exposure to VOC from paint

Member of a consulting team providing advice and support to NIOSH on a substantial update to the "Occupational Exposure Assessment Strategies Manual".

Reviewer for National Academies of Sciences Report Gain-of-Function Research: Summary of the Second Symposium, March 10-11, 2016

Presentations at Scientific Meetings

Armstrong, T.W. What is the Public Health Risk from Legionella pneumophila in Whirlpool Spas? Legionella 2013, Melbourne, Australia

Armstrong, T.W. A Short Review of Data on the Incubation Period Between Exposure and Symptom Onset for Legionellosis, 6th International Conference on Legionella, Chicago, IL October 2005

Armstrong, T.W and Haas, C.N. A Quantitative Microbial Risk Assessment Model for Legionella: Summary of Methods and Results, 6th International Conference on Legionella, Chicago, IL October 2005

Armstrong, T.W. and Haas, C.N. Analysis of Dose-Response in Guinea Pigs Following Inhalation Exposure to *Legionella pneumophila*, Society for Risk Analysis, New Orleans, December 2002.

Armstrong, T.W. and Haas, C.N. Inter-Species Factors in Quantitative Microbial Risk Assessment, Society for Risk Analysis, Baltimore, December 2003.

Armstrong T.W., Hushka L.J, Tell J.G. and Zaleski R.T. Assessing Children's Exposure – A Tiered Approach. Poster given at symposium - The Role Of Human Exposure Assessment In The Prevention Of Environmental Disease, Rockville, Maryland, September, 1999

Armstrong, T.W., Field Evaluation of Sampling and Analytical Methods for Coal Tar Pitch Volatiles and Polycyclic Aromatic Hydrocarbons. American Industrial Hygiene Conference, Dallas, TX 1986

Armstrong, T. W., and Pearlman, E.D., An Algorithm for Quantitative Exposure Estimating; Development and Validation for Petroleum Marketing and Distribution Operations, American Industrial Hygiene Conference and Exhibition, Anaheim, CA, May, 1994

Armstrong T.W., and Zaleski, R.T. Assessing Children's Exposure: Methods and Data for a Tiered Approach, 3rd International Conference on Children's Health and the Environment, London, England, March 2004.

Pearlman, E.D., and Armstrong, T. W. An Algorithm for Quantitative Exposure Estimating; Application and Results for Petroleum Marketing and Distribution Operations, American Industrial Hygiene Conference and Exhibition, Anaheim, CA, May, 1994

Armstrong, T.W., Pearlman, E.D., Schnatter, A.R., Bowes, S.P., Murray, N. and Nicolich, M., A Quantitative Benzene and Total Hydrocarbon Retrospective Exposure Assessment for a Petroleum Marketing and Distribution Worker Epidemiology Study, XXI MEDICHEM Congress, Melbourne, Australia, October 1994

Schnatter, A. R., Rushton, L., and Armstrong, T.W., Summary of the Nottingham Workshop on Petroleum Distribution Worker Exposure Assessment, at IARC Conference on Retrospective Assessment of Occupational Exposures in Epidemiology, Lyon, France, 1994

Workshop on Harmonization of Serving Future Needs with Occupational Exposure Databases? Inhalation Modeling, Session IIIA

John Tickner, Thomas W. Armstrong & Thomas F. Bloom, Workshop on Harmonization of Serving Future Needs with Occupational Exposure Databases, Inhalation Modeling, Session IIIA Applied Occupational and Environmental Hygiene Vol. 16, Iss. 2, 2001

Additional presentations not listed.

Other Significant Reports

European Union Benzene Risk Characterisation, prepared on behalf of CONCAWE, CEFIC Aromatic Producers Association and EUROPIA

Source Apportionment of Polycyclic Aromatic Hydrocarbons in the Canadian Environment, prepared for the Canadian Petroleum Products Institute

Assessing Children's Exposure for Consideration Under the Children's Health Test Rule, prepared for the Chemical Manufacturer's Association

Numerous internal reports on exposure assessment, general population (and sensitive subpopulations) exposures to various environmental contaminants, exposure modeling, exposure monitoring statistics, PBPK based adjustments to OELs and dermal exposure assessments.

Other Activities of Note

Contributing Editor, American Industrial Hygiene Association Occupational Epidemiology Committee, Guideline on Retrospective Exposure Assessment for Epidemiology.

Contributor to four chapters in "Mathematical Models for Estimating Occupational Exposure to Chemicals" 2nd edition, AIHA Press, 2009

Contributor to several chapters in the book, "Assessing and Managing Occupational Exposures", 4th edition, AIHA Press 2015.

Member of Technical Workshop on Issues Associated with Considering Developmental Changes in Behavior and Anatomy when Assessing Exposure to Children. Report EPA/630/R-00/005. December 2000. USEPA, Washington, D.C.

Member of advisory team to develop a protocol for an epidemiologic investigation of Italian gasoline service station attendants and their families, for the European Institute of Oncology, Milan.

Technical advisor to the Institute of Petroleum, London, England study of Gasoline Marketing and Distribution Workers in the UK, and HealthWatch study of petroleum industry benzene exposures in Australia.

Lead Investigator for general population and occupational exposure assessments for epidemiology investigations of potentially benzene or other exposure-related lympho-hematopoietic diseases in Shanghai, China, under contract to University of Colorado Health Sciences Center.

Member of two National Research Council Committees commissioned to provide scientific analysis of a National Institutes of Health and Department of Homeland Security risk assessments for BSL4 and 3 pathogens as part of the process of site decision, construction and startup of new National Infectious Diseases Laboratories.

Developed a twenty-page summary of the American Industrial Hygiene Association book "A Strategy for Assessing and Managing Occupational Exposure", 4th edition for CDC NIOSH

Expert witness and consulting for litigation on multiple topics, including but not limited to benzene, foundry issues, Legionnaires Disease

Member of a team investigating exposure issues at a Department of Energy remediation site.

RELEVANT, UNPUBLISHED REPORT WHILE AT EXXONMOBIL

A Two-compartment PK Model to Evaluate the Effect of Exposure Pattern on Target Organ Damage Burden Utilizing Monte-Carlo Simulation Methods.

Industrial Hygiene Aspects of Polycyclic Aromatic Hydrocarbon Exposure

Multiple reports on issues associated with Legionella and Legionnaires' Disease