

PCBs: Exposures, effects, remediation, and regulation with special emphasis on PCBs in schools

By Gary Hunt (TRC Environmental), John Stegeman (Woods Hole) and Larry Robertson (University of Iowa)

(Environmental Science and Pollution Research, 23(3), 1971-1974.)

The Eighth International PCB Workshop: PCBs in Schools was held in Woods Hole, MA, October 5-9, 2014, and was attended by more than 130 scientists and other interested persons, including citizen's groups and concerned parents. The program included a wide range of thematic areas. Presentations addressed essential questions and progress toward understanding mechanisms of PCB toxication and risks of PCB exposure. Presentations were also held illuminating several key PCB contamination problems. The scientific program was kicked off Sunday evening by a fascinating historical narrative presented by **John Farrington**, Dean and Sr. Scientist Emeritus at the Woods Hole Oceanographic Institution, entitled "PCBs in New Bedford Harbor and Buzzards Bay: An Historical Perspective from 1970 to present" This presentation outlined the sources, discovery and distribution of the extraordinary contamination in New Bedford Harbor. There are several sources of the PCBs, as well as sources of a serious heavy metal problem in the harbor, and much litigation. The talk emphasized the interactions between Massachusetts and US federal agencies, in addressing the problem. There has been extensive work over the past 40 years to understand the effects of these PCBs, and efforts at remediation of the worst areas, which has been only partly successful. New Bedford Harbor is a good example of the persisting complexities regarding PCB contamination.

Monday, October 6, 2014

On Monday morning Session A "Analytical Methods & Environmental Response" was chaired by **Mitchell Erickson** (Department of Homeland Security). This session was concerned with methods in chemical analysis and detection of PCBs, including the detection of PCB enantiomers, increasingly seen as important. In the first presentation, **Takeshi Nakano**, Osaka University, addressed "Congener Specific and

Enantioselective Analysis of by-product PCBs". Highlighting the detection of chiral PCBs meshed with differing effects of enantiomers, addressed in other parts of the meeting. **Lisa Rodenberg**, Rutgers University, described a fingerprinting approach for identifying PCB sources, and **Mitch Erickson** presented the findings from the fire at a recycling plant where PCBs were involved. **Charles Menzie** (Exponent) rounded out the session with description of studies of *in-situ* treatment of PCBs to aid in remediation of wetlands and aqueous sediments.

Session B, entitled "Overview of Mechanisms of Toxicity" chaired by **John Stegeman** (Woods Hole Oceanographic Institute), dealt with advances in understanding of fundamental mechanisms of effects, of both the dioxin-like and the non-dioxin-like PCBs. The stage was set in the first presentation, where Stegeman summarized the expanding understanding of mechanisms of PCB effects, and in different species. **Miroslav Machala**, Veterinary Research Institute, Czech Republic, gave a comprehensive review of the relative potencies of dioxin-like PCBs in lung cells. **Thomas Zoeller**, University of Massachusetts, discussed endocrine disrupting properties of PCBs, particularly the involvement and interference with thyroid hormone signaling. Further studies of hormonal effects of PCBs involving disruption of development, were presented by **Surendra Sharma**, Brown University. **Lisa Cassis**, University of Kentucky, discussed the role of Ah receptor in dioxin-like PCB effects on glucose metabolism, and **Isaac Pessah**, UC Davis, presented the important findings on how non-dioxin-like PCBs affect specific calcium channels (ryanodine receptors) involved in muscle function. The ryanodine receptors are growing in importance as targets for these and related chemicals. At the conclusion of this session, the presenters gathered as a panel in the front of the auditorium, where they addressed questions from the audience and from the session chair.

On Monday evening there was a historical perspective of another serious PCB contamination site, in Anniston Alabama. **David Carpenter**, State University of New York, and **Linda Birnbaum**, Director US National Institute of Environmental Health Sciences, presented aspects of this problem, which derived from PCB manufacturing plant in Anniston, and health and other consequences for residents of the area.

Tuesday, October 7, 2014

The Tuesday sessions were dedicated to the conference theme PCBs in Building Materials and Schools. Session C which convened in the morning was chaired by one of the conference organizers, Mr. **Gary Hunt** (Principal Scientist at TRC Environmental Corporation) and focused on origins, sources and behavior of PCBs in indoor environments. This session provided a global perspective on PCBs in buildings as a number of speakers represented European Nations. Mr. **Rune Ostergaard Haven** addressed the audience about a national investigation of PCBs sources within buildings in Denmark. Results were presented representing 352 Danish buildings that were examined and deemed to be representative of 1,200,000 buildings nationwide. **Sharon Lee** and **Jennifer Burkhamer** spoke regarding the State of Massachusetts' program and related experience responding to PCBs in building materials and the environment. Case studies related to PCBs in the Sherwood Middle School and New Bedford High School were highlighted in this presentation. **Kent Thomas** (US EPA/NERL) presented a summary of research conducted by the US Environmental Protection Agency on PCBs in school buildings. Subject matter included sources, emissions and levels of PCBs found in New York City Schools. **Nadja Lyng** (Danish Building Research Institute, Aalborg University) presented data validating a strong log-linear/exponential relationship between room temperatures and concentrations of PCBs found in indoor air. Good agreement was found in comparison of actual concentrations measured and estimated concentrations based on modeling. Dr. **Keri Hornbuckle** (University of Iowa) spoke regarding measurements and modeling of sources and emissions of PCBs in homes and schools. **Niklas Johansson** (Karolinska Institute, Stockholm) presented the state of PCBs in Swedish schools and other construction programs. Topics included a national inventory of PCBs in Swedish buildings, remediation and outcomes. **Jennifer Denicola** (Malibu Unites) spoke regarding the current situation with PCBs in the Malibu California School District. **Gary Hunt** closed out the morning session with the first in a two part presentation entitled PCBs in Schools – What Have We Learned, Some Remaining Questions and Challengers Ahead. Topics included an historical perspective, PCBs in buildings is truly a global problem, PCBs in schools – key issues, PCB chemistry, analytical methods and costs. The second part of Mr. Hunt's presentation served as the Plenary Lecture delivered on Tuesday evening.

Session D, convened in the afternoon, was chaired by **Mark Maddaloni** (US EPA Region 2 New York). The session again was dedicated to the topic of PCBs in schools with special emphasis on sources, case studies such as New York City, levels, health risks, exposures and remediation. Dr. **Robert Harrick** (Harvard University) presented an historical overview of PCBs in schools in the United States. Ms. **Kimberly Tisa** (US EPA Region 1 New England) spoke regarding EPA's experience with PCBs in 90 schools/school systems in the New England region. Topics included recommended lighting ballast and caulk testing procedures, building assessment and design of remedial strategies to minimize potential exposure. **Mark Maddaloni** (US-EPA Region 2) spoke regarding the city wide remedy proposed for addressing and mitigating PCBs in New York City's 1190 schools built prior to 1979. **Geniece Lehmann** (US EPA) spoke regarding evaluating cancer risks associated with inhalation of PCBs. The presentation described critical areas of research needed to better evaluate health risks associated with inhaled PCBs. **Kent Thomas** (US EPA NERL) presented recent EPA sponsored research on exposure modeling of PCBs in school buildings. Model estimates predict that 70% of the estimated dose is attributable to the inhalation pathway. **Kathleen Ward Brown** (Environmental Health and Engineering) provided an informative presentation on control measures to reduce PCBs exposures indoors including the efficacy and costs of engineering based exposure interventions.

The Tuesday evening plenary consisted of two (2) parts. The first part entitled PCB Emissions from a Contaminated Lake Michigan Harbor was delivered by Dr. **Keri Hornbuckle** (University of Iowa). As a direct result of an extensive PCB monitoring program in harbor sediments, water and air it was shown that sediments represent major PCB sources and may result in increased air emissions of PCBs. The second plenary was presented by **Gary Hunt** (Principal Scientist TRC Environmental) and represented a continuation of the Session C oral entitled PCBs In Schools - What Have We Learned, Some Remaining Questions and Challenges Ahead. Mr. Hunt's plenary covered a number of topics as follows: lighting ballast and caulk as primary PCB sources, secondary/sink sources, encapsulation of caulk as a remedial measure, criteria for prioritizing and selecting schools for further study and challenges ahead.

Wednesday, October 8, 2014

Wednesday morning began with Session E, entitled “Airborne PCB exposure: Possible toxic outcomes – what should we look for in teachers and school children?” chaired by **Avima Ruder** of NIOSH and **Larry Robertson** of the University of Iowa. The lead presentation by **Gabriele Ludewig** of the University of Iowa was entitled “PCBs metabolism to genotoxic compounds – potential biomarkers and / or indicators of susceptibility?” The various genotoxic effects observed with PCBs and their metabolites, perhaps the result of adduction and oxidation reactions, included strand breaks, sister chromatid exchanges, gene mutations, incorrect chromosome segregation and others. These studies provide convincing evidence that specific PCB congeners can be biotransformed to genotoxic and therefore potentially cancer-initiating metabolites. The next presentation “Potential Roles for Sulfotransferases and Sulfated Metabolites in PCB-mediated Endocrine Disruption” by **Michael Duffel**, also of the University of Iowa, propels the story of the interactions of OHPCBs with human sulfotransferases. OHPCBs may be substrates and inhibitors of sulfotransferases. These interactions may alter the concentrations of active forms of steroid hormones. Sulfated metabolites of OHPCBs are high affinity ligands of the thyroid hormone transport protein transthyretin that functions to carry the hormone to the central nervous system and to the developing fetus. While PCB-sulfates present as potential biomarkers of exposure, these presentations suggest that genotoxic and endocrine disruption endpoints may prove to be useful biomarkers of toxicity. The next presentation by **Bernhard Hennig** of the University of Kentucky, entitled “PCBs and Cardiovascular Disease Risks”, dealt with vascular inflammation, endothelial dysfunction, and onset of atherosclerosis related to PCB exposure. Nutritional interventions were proposed as modulators of the vulnerability to environmental insults, with plant derived polyphenols, such as flavonoids, and omega-3 polyunsaturated fatty acids as the most promising candidates. **Al Klingelutz** of the University of Iowa presented “Disruption of Adipogenesis by PCBs” focusing on a potential PCB target, namely adipose tissue. Elevated PCB levels in serum and fat have been associated with higher incidence of diabetes and increase risk of metabolic disorders. He illustrated that a PCB congener PCB 126 inhibits adipogenesis, the normal maturation of pre-adipocytes into adipocytes. PCB exposure inhibits their ability to upregulate a key adipocyte transcription factor PPAR gamma

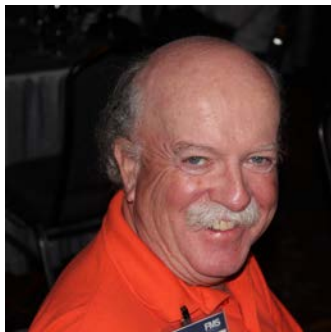
resulting in adipocyte dysfunction. An update of “Occupational and environmental polychlorinated-biphenyl-exposed cohorts” was presented by **Avima Ruder** of the CDC/NIOSH. The U.S. capacitor manufacturing cohort is now showing that standardized rates of stomach and uterine cancer and multiple myeloma mortality increased with estimated cumulative PCB exposure. Poisson regression modeling shows significant associations with estimated cumulative PCB exposure for prostate and stomach cancer mortality. **Kenneth Spaeth** of LIJ Health System, presented “Translational Medicine? Considerations of the clinical evaluations of individuals exposed to PCBs in schools (or elsewhere)” pointed out the challenges that clinicians face in evaluating PCB-exposed individuals. Issues include 1) clinicians are not prepared/educated to handle this kind of evaluation, 2) chronic long-term health effects tend to mirror common diseases, 3) analytical determination of body burden, and 4) lack of environmental background exposure data.

Session F “Regulation & Policy”, chaired by **David Osterberg** of the University of Iowa, began with a presentation by **Peter Thorne**, also of the University of Iowa, entitled “PCB Inhalation Exposure Assessment and Biomonitoring in the AESOP Study”. Findings of AESOP (Airborne Exposures to Semi-volatile Organic Pollutants), a community – based participatory research study, so far are: 1) indoor PCBs contribute more to body burden than outdoor levels, 2) rural PCB congener profiles are enriched with lower chlorinated biphenyls compared to urban homes, 3) blood samples demonstrate exposure to more-volatile lower molecular weight congeners, 4) mothers exhibit higher levels of serum PCBs and OHPCBs than their children, with a profile skewed toward more highly chlorinated congeners, 5) schools contribute more than half of children’s inhalation exposure, and 6) dietary PCB exposure is greater than inhalation for most subjects, however this difference disappears for lower-chlorinated congeners. **Vincent Cogliano** of the US EPA presented “Methods for evaluating PCB health outcomes at IARC and EPA” in which he compared the methods used by IARC and EPA and discussed the dose-response assessment developed at EPA to evaluate the cancer risks from environmental exposure to PCBs. This was followed by an in-depth discussion of IARC’s re-evaluation of the “Carcinogenicity of PCBs and PBBs” by **Beatrice Lauby-Secretan** of that agency. The reassessment was conducted in 2013 by 26 experts from 12 countries. On the basis of sufficient evidence of carcinogenicity in

humans and sufficient evidence in experimental animals, the Working Group classified PCBs as carcinogenic in humans (Group 1). **Jennifer de Nicola** of Malibu Unites, a parent advocacy group, presented “PCBs in Malibu Schools-How Regulations and Science Are Affecting Students, Teachers and Parents”. This presentation gave a current perspective of schools near Los Angeles, California, that are contaminated by PCBs in building materials, especially caulk, and what actions they wish.

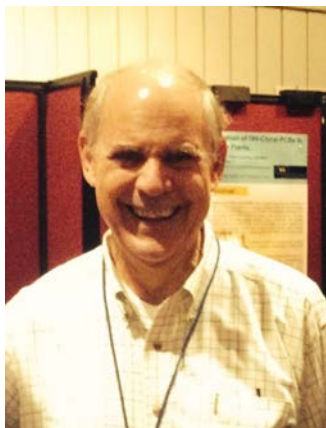
Short Poster Presentations followed on a range of topics, including sources and remediation strategies for older buildings, and interventions to reduce PCBs in humans. Finally a proposal was presented by Takeshi Nakano to hold the next PCB workshop in Japan in 2016, tentatively scheduled for October 9 – 13, 2016 at the Kobe Convention Center.

The meeting was concluded with a lobster boil, and the promise of much interesting research in the future.



Mr. **Gary Hunt** is a Vice President and Principal Scientist within TRC in their Lowell, MA office. Much of Mr. Hunt's professional career has focused on the measurement, distribution, occurrences, transport and fate of Persistent Organic Pollutants (POPs) in the global environment. Compounds of primary interest have included PCDDs/PCDFs, PCBs and other semivolatile organochlorine compounds. Current interests include PCBs present in indoor environments (eg schools).

Mr. Hunt, who holds a B.S. in Chemistry from Villanova University (1974) and an M.S. in Environmental Sciences from Rutgers University (1977), has more than 37 years of experience in environmental consulting. Mr. Hunt is a Qualified Environmental Professional (QEP) , Fellow Member of the Air & Waste Management Association, and a member of the International Advisory Board (IAB) that has direct oversight for the environmental conference that convenes annually dedicated to all aspects of PCDDs/PCDFs and other POPs. He is also a member of the American Chemical Society (Environmental Chemistry Division), Sigma XI, and the American Society of Mechanical Engineers. Mr. Hunt has authored more than 100 journal manuscripts and symposia presentations on environmental topics including most notably POPs in the environment.



John Stegeman received a Ph.D. in biochemistry in 1972 from Northwestern University in Illinois. He has studied pollutant chemical metabolism and effects, primarily in aquatic species for more than 30 years, emphasizing cytochromes P450 (CYP) genes and enzymes that metabolize drugs, chemicals and hormones. Dr. Stegeman has authored or co-authored about some 300 publications dealing with the biochemistry and molecular biology of chemical effects, carcinogenesis in fish, molecular biomarkers, and the evolution of the cytochrome P450 gene family. Dr. Stegeman has lectured at venues around the world. He serves on editorial boards of several journals and has served on NIH review panels, and chaired the Science

Advisory Board of the National Toxicology Program (U.S.). He has chaired committees for the U.S. National Academies of Science (NAS) and is a Lifetime National Associate of the NAS. In 2008 he was awarded a Doctorate (*honoris causa*) from Gothenburg University, for his influence on the growth of ecotoxicology worldwide, especially benefitting students. Dr. Stegeman was chair of the Biology Department at Woods Hole Oceanographic Institution, and currently is Director of the Woods Hole Center for Oceans and Human Health.



Larry W. Robertson PhD, MPH, ATS is Professor of Toxicology in the Department of Occupational and Environmental Health, College of Public Health at the University of Iowa. He is the Program Director of the Iowa Superfund Program, entitled, "Semi-volatile PCBs: Sources, Exposures, Toxicities" which was founded in 2005 and has just been renewed through 2020. Dr. Robertson is also the Director of the Interdisciplinary Graduate Program in Human Toxicology, a toxicology training program with more than 20 full – time doctoral students and over 30 faculty. Dr. Robertson has published more than 270 research papers describing the toxicity of polyhalogenated

hydrocarbons.

