Kirk R. Smith, MPH, PhD, Professor of Global Environmental Health
Household Energy, Climate, and Health Research Group
School of Public Health, University of California, Berkeley
http://ehs.sph.berkeley.edu/krsmith/

The UCB-PATS Monitor: A Short History With List of Publications from Around the World November 2014

The original idea of adapting smoke alarm sensors as particulate matter (PM) monitors was developed in 1992 in the context of planned work in Guatemala as part of the search organized by World Health Organization to find the best site for a hoped-for randomized controlled trial on household air pollution. Consultation with the smoke alarm experts at the National Institute of Standards and Technology indicated it was feasible, but no funding was found until 2000 with a grant from the then newly formed Shell Foundation. Rufus Edwards, now at University of California Irvine, was hired as a research associate in 2001 to move the project forward. After issuing an RFP for the technical development with little response, we made contact with Dave Litton, then at NIOSH, and Tracy Allen of EME Systems early in the decade. They were central in the theoretical and practical development of a usable monitor from a simple smoke alarm. Two post-docs in our group, Zohir Chowdhury and Amanda Northcross, contributed to its development as well. Three publications (below) established the theoretical, lab, and field performance

The original UCB monitor retained both the ionization and light-scattering chambers of modern smoke alarms (using a model made by First Alert), which offered substantial technical advantages for field particulate matter monitoring. As we were considering adding a control chamber for the ion chamber, however, it became clear that in spite of being off the shelf and off license by the Nuclear Regulatory Commission as a smoke alarm, using it with its ion chamber containing the radioactive isotope AM-241 for a new purpose would not be approved by campus and other health and safety offices. Thus, in 2006 we moved to the current UCB design retaining only the optical chamber.

With the formation of Berkeley Air Monitoring Group in 2008, the renamed UCB-PATS (Particle and Temperature Sensor) became available commercially.[1] In 2013, First Alert ceased production of the smoke alarm model that had been the basis of the UCB-PATS and in 2014, manufacture of the UCB-PATS ended at the time a more advanced monitor, the PATS+, was being developed.

Many others were also involved in the development of the monitor and its software over the decade, mostly in their roles within our research group. Below is a listing of formal publications documenting the development and use of the UCB-PATS organized primarily by country in which the study was conducted.

Original Theoretical Justification and Laboratory and Field Validations

Litton CD, Smith KR, Edwards R, Allen T, 2004, Combined optical and ionization measurement techniques for inexpensive characterization of micrometer and submicrometer aerosols, *Aerosol Science and Technology*, 38(11): 1054-1062.

Edwards R, Smith KR, Kirby B, Allen T, Litton CD, Hering S, 2006, An inexpensive dual-chamber particle monitor: laboratory characterization, *J Air and Waste Management Assoc*, Jun;56(6): 789-799.

[1] http://berkeleyair.com/services/ucb-particle-and-temperature-sensor-ucb-pats/

Chowdhury Z, Edwards RD, Johnson M, Naumoff Shields K, Allen T, Canuz E, Smith KR, 2007, An inexpensive light-scattering particle monitor: field validation, *J Environ Monitoring*, Oct;9(10): 1099–1106 doi:39/b709329m.

Bangladesh

Chowdhury Z, Le LT, Masud AA, Chang KC, Alauddin M, Hossain M, Zakaria ABM, Hopke PK, 2012, Quantification of indoor air pollution from using cookstoves and estimation of its health effects on adult women in Northwest Bangladesh, *Aerosol Air Qual Res*, 12(4):463–475. doi: 10.4209/aaqr.2011.10.0161

Gurley ES, Salje H, Homaira N, Ram PK, Haque R, Petri WA Jr, Bresee J, Moss WJ, Luby SP, Breysse P, Azziz-Baumgartner E, 2013, Seasonal concentrations and determinants of indoor particulate matter in a low-income community in Dhaka, Bangladesh, *Environ Res*, Feb;121:11-6. doi:10.1016/j.envres.2012.10.004.

Salje H, Gurley ES, Homaira N, Ram PK, Haque R, Petri W, Moss WJ, Luby SP, Breysse P, Azziz-Baumgartner E, 2013, Impact of neighborhood biomass cooking patterns on episodic high indoor particulate matter concentrations in clean fuel homes in Dhaka, Bangladesh, *Indoor Air,* Apr;24(2):213-20. doi: 10.1111/ina.12065.

Gurley ES, Salje H, Homaira N, Ram PK, Haque R, Petri WA, Bresee J, Moss W, Luby SP, Breysse P, Assiz-Baumgartner, 2014, Indoor Exposure to Particulate Matter and Age at First Acute Lower Respiratory Infection in a Low-Income Urban Community in Bangladesh, *Am J Epidemiol,* Apr 15;179(8):967-73. doi:10.1093/aje/kwu002.

Bolivia

Alexander D, Larson T, Bolton S, Vedal S, 2014, Systolic blood pressure changes in indigenous Bolivian women associated with an improved cookstove intervention, *Air Qual Atmos Health*, 31 May, doi:10.1007/s11869-014-0267-6.

China

Chowdhury Z, Campanella L, Gray C, Masud AA, Marter-Kenyon J, Pennise D, Charron D, Zuzhang X, 2013, Measurement and modeling of indoor air pollution in rural households with multiple stove interventions in Yunnan, China, *Atmospheric Environment*, 67: 161-169, ISSN 1352-2310, http://dx.doi.org/10.1016/j.atmosenv.2012.10.041.
(http://www.sciencedirect.com/science/article/pii/S1352231012010230)

Alnes LWH, Mestl HES, Berger J, Zhang H, Wang S, Dong Z, Ma L, Hu Y, Zhang W, Aunan K, 2014, Indoor PM and CO concentrations in rural Guizhou, China, *Energy for Sustainable Develop*, 21: 51-59, ISSN 0973-0826, http://dx.doi.org/10.1016/j.esd.2014.05.004.
(http://www.sciencedirect.com/science/article/pii/S0973082614000465)

Denmark (village museum)

Ryhl-Svendsen M, Clausen G, Chowdhury Z, Smith KR, 2010, Fine particles and carbon monoxide from wood burning in 17th–19th century Danish kitchens: Measurements at two reconstructed farm houses at the Lejre Historical–Archaeological Experimental Center, *Atmospheric Environment*, 44(6): 35-744, ISSN 1352-2310, http://dx.doi.org/10.1016/j.atmosenv.2009.11.045.

(http://www.sciencedirect.com/science/article/pii/S1352231009010073)

Christensen JM, Ryhl-Svendsen M, 2014, Household air pollution from wood burning in two reconstucted houses from the Danish Viking Age, *Indoor Air*, Jul;26, doi:10.1111/ina.12147

Ethiopia

Pennise D, Brant S, Agbeve SM, Quaye W, Mengesha F, Tadele W, Wofchuck T, 2009, Indoor air quality impacts of an improved wood stove in Ghana and an ethanol stove in Ethiopia, *Energy for Sustainable Development*, 13 (2): 71-76, ISSN 0973-0826, http://dx.doi.org/10.1016/j.esd.2009.04.003. (http://www.sciencedirect.com/science/article/pii/S0973082609000234)

Sanbata H, Asfaw A, Kumie A, 2014, Indoor air pollution in slum neighbourhoods of Addis Ababa, Ethiopia, *Atmospheric Environment*, 89: 230-234, ISSN 1352-2310, http://dx.doi.org/10.1016/j.atmosenv.2014.01.003. (http://www.sciencedirect.com/science/article/pii/S1352231014000120)

Guatemala

Northcross A, Chowdhury Z, McCracken J, Canuz E, Smith KR, 2010, Estimating personal PM2.5 exposures using CO measurements in Guatemalan households cooking with woodfuel, *J of Environmental Monitoring* Apr;12(4):873-8. doi:10.1039/b916068j

Northcross AL, Hammond SK, Canuz E, Smith KR, 2012, Dioxin inhalation doses from wood combustion in indoor cookfires, *Atmospheric Environment*, 49: 415-418, ISSN 1352-2310, http://dx.doi.org/10.1016/j.atmosenv.2011.11.054. (http://www.sciencedirect.com/science/article/pii/S1352231011012416)

India

Dutta K, Shields KN, Edwards R, Smith KR, 2007, Impacts of improved biomass cookstoves on indoor air quality near Pune, India, *Energy for Sustainable Development*, Jun;11 (2): 19-32, doi:10.1016/S0973-0826(08)60397-X.

Chengappa C, Edwards R, Bajpai R, Shields KN, Smith KR, 2007, Impact of improved cookstoves on indoor air quality in the Bundelkhand Region in India, *Energy for Sustainable Development*, Jun;11 (2): 33-44, doi:10.1016/S0973-0826(08)60398-1

Balakrishnan K, Ghosh S, Ganguli B, Sambandam S, Bruce N, Barnes DF, Smith KR, 2013, State and national household concentrations of PM2.5 from solid cookfuel use: results from measurements and modeling in India for estimation of the global burden of disease, *Environmental Health*, Sep 11;12 (1): 77. doi: 10.1186/1476-069X-12-77.

Puttaswamy N, Saidam S, Natarajan S, Siva R, Madhav S, Mukhopadhyay K, Sambandam S, Balakrishnan K, 2013, Reconstruction of daily average PM2.5 exposures in pregnant women: Preliminary results from the SICAPHE study. *Environ. Health Perspect*; doi.org /10.1289/ ehp. ehbasel13

Sambandam S, Balakrishnan K, Ghosh S, Sadasivam A, Madhav S, Ramasamy R, Samanta M, Mukhopadhyay K, Rehman H, Ramanathan V. 2014, Can currently available advanced combustion biomass cookstoves provide health relevant exposure reductions? Results from initial assessment of select commercial models in India, *EcoHealth,* Oct 8, doi:10.1007/s10393-014-0976-1

Indonesia

Huboyo HS, Tohno S, Lestari P, Mizohata A, Okumura M,2014, Characteristics of indoor air pollution in rural mountainous and rural coastal communities in Indonesia, *Atmospheric Environment*, Jan;82: 343-350, ISSN 1352-2310, http://dx.doi.org/10.1016/j.atmosenv.2013.10.044.
(http://www.sciencedirect.com/science/article/pii/S1352231013007978)

Malawi

Fullerton DG, Semple S, Kalambo F, Suseno A, Malamba R, Henderson G, Ayres JG, Gordon SB, 2009, Biomass fuel use and indoor air pollution in homes in Malawi, *Occup Environ Med*, Nov;66:777–783. doi:10.1136/oem.2008.045013.

Mexico

Masera O, Edwards R, Arnez CA, Berrueta V, Johnson M, Bracho VM, Riojas-Rodriguez H, Smith KR, 2007, Impact of Patsari improved cookstoves on indoor air quality in Michoacan, Mexico, *Energy for Sustainable Development*,Jun; 11 (2): 45-56, doi:10.1016/S0973-0826(08)60399-3

Amendariz Arnez C, Edwards RD, Johnson MJ Zuk M, Rojas-Bracho L, Serrano P, Riojas-Rodríguez H, Masera OR, 2008, Reductions in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico. *Indoor Air*, May; 18(2):93-105. DOI: 10.1111/j.1600-0668.2007.00509.x

Armendáriz-Arnez C, Edwards RD, Johnson M, Rosas IA, Espinosa F, Masera OR, 2010, Indoor particle size distributions in homes with open fires and improved Patsari cook stoves, *Atmospheric Environment* 44: 2881-2886. doi:10.1016/j.atmosenv.2010.04.049

Nepal

Singh A, Tuladhar B, Bajracharya K, Pillarisetti A, 2012, Assessment of effectiveness of improved cook stoves in reducing indoor air pollution and improving health in Nepal, *Energy for Sustainable Development*, 16 (4): 406-414, ISSN 0973-0826, http://dx.doi.org/10.1016/j.esd.2012.09.004.
(http://www.sciencedirect.com/science/article/pii/S0973082612000695)

Nicaragua

Clark ML, Bazemore H, Reynolds SJ, Heiderscheidt JM, Conway S, Bachand AM, Volckens J, Peel JL, 2011, A Baseline Evaluation of Traditional Cook Stove Smoke Exposures and Indicators of Cardiovascular and Respiratory Health among Nicaraguan Women, *Int. J. Occup. Env. Health*. Apr-Jun; 17(2):113-121, doi:10.1179/107735211799030942

Rwanda

Rosa G, Majorin F, Boisson S, Barstow C, Johnson M, Kirby M, Ngabo F, Thomas E, Clasen T, 2014, Assessing the impact of water filters and improved cook stoves on drinking water quality and household air pollution: a randomised controlled trial in Rwanda, *Plos One*, Mar 10;9(3): e91011, doi: 10.1371/journal.pone.0091011.

USA - Wildfires

Edwards R, Johnson M, Dunn K.H., Naeher LP, 2005, Application of real-time particle sensors to help mitigate exposures of wildland firefighters, *Arch Eviron Occup Health*, 60(1) 40-3, doi:10.3200/AEOH.60.1.40-43

Hom JL, Heilman WE, Patterson M, Clark KL, Skowrosnki N, Bian X, Saliendra N, Gallagher M, Strand T, Mickler R, Clemens C, Seto D, 2011, Monitoring CO, PM2.5, CO2 from low-intensity fires for the development of modeling tools for predicting smoke dispersion, poster for *9th Symposium on Fire and Forest Meteorology*, American Meteor Society**,** 18–20 Oct, Palm Springs, CA https://ams.confex.com/ams/9FIRE/webprogram/Paper192376.html