Webinar: ASHES Science to Achieve Results (STAR) Webinar Series #4: What do we know (and need to know) about emission factors from biomass burning?

Date/Time: April 27, 2021, 8:00-9:30 Mountain Daylight Time

Unasked/answered Panelist Questions

1. Considering your results about the importance of pyrolysis in PM emissions, would better oxygenation lower PM emissions?

Mariam F: Yes, the proper mixing of oxygen in the reaction zone and the suitable heating conditions could lead to a higher oxidation reactions rate that would consume PM precursors. However, sufficient temperature is also needed.

2. How do the models used in the Global Burden of Disease Study estimate health impacts? Do they use that same process you described?

Tami B: For outdoor air pollution, the process is similar, but concentrations are estimated by combining satellite measurements and models before estimating health impact. I don't actually know the full GBD process for indoor smoke emissions. I believe that increased health risks are calculated simply from the use of polluting fuels rather than concentrations.

3. To better understand the link PM emissions and health impacts, is it preferable to speak about numbers and size of particles than mass (not really adapted)?

Tami B: It's possible that particle number at different sizes has a better relationship with some health impacts than total particle mass, but there haven't been enough particle-count measurements to do epidemiology. It's also easier to measure particle mass than to measure number. This doesn't mean we should avoid investigating particle number - just that we are less able to speak confidently about the relationship.

4. Completely agree that household energy services are a huge missing piece in understanding and data. There are many in the energy access space working on this problem, do you feel that enough is being done to communicate between these research areas? If not, how can we better ensure that these synergies are developed?

Tami B: I agree that we are <u>not</u> doing enough to communicate between these research areas. I think that somebody needs to work on aligning the conferences or gatherings and on promoting cross-talk.

5. Can you give practical advice on how to understand and categorise household energy service needs?

Tami B: Sure, I would like the time to write this paper. Total quantity; power; specificity of energy-type; specificity of timeliness; portability. I might add flux. You can classify each household service that way. But as a simple guideline, I would look at the largest 3 weekly uses of energy in the coldest and hottest seasons. If you can come up with a good, reliable solution for each of those, you are probably well on the way to serving the household.

6. (I think) there was indication that when calculating emission inventories, the activity rates are somewhat easy/simple to estimate (or easier than emission factors at least). Can you elaborate on that? For non-cooking activities (e.g., charcoal kilns and the like), where there are few records available in LDICs especially, how can we reliably estimate activity for a full region?

Tami B: We must have miscommunicated, because I think that activity rates are just as uncertain as emission factors, and less likely to become constrained. I'm not sure we can ever "reliably" estimate activity rates; again, defining the purpose is important - are you interested in reducing exposure, providing energy access, estimating regional emissions, identifying market size? At some point (and we may be there now) people should put their creativity into solving problems rather than describing them. But to answer the question posed, engage with local NGOs or universities and teach them the skill of triangulation. For example, you might approach charcoal kilns with number of kilns x period of operation; number of laden trucks returning to urban areas; fraction of urban dwellers who use charcoal. All of these may have large uncertainties, at which point you return to "Why are you asking? Is this level of certainty good enough?"

7. Do you know how far along is the development of pyrolysis biomass stoves?

Tami B: People are working on different designs. My understanding is that a lot of attention needs to be paid to human factors involved in operating these stoves with low emissions, and that is a worthy endeavor.

8. A comment! I think RTKC's with profit/ non profit organisations have lots of issues for their sustainability in terms of their capacities. One of the solutions could be to relate them with academia. And yes, academia labs / services need to be cheaper.

Tami B: I think a lot of models have been tried, and perhaps some universities will be able to house testing services. But we also have to acknowledge that it's often difficult to house service models like this at universities, because it doesn't lead to an academic product. It depends on the region and the university model. I also doubt we can make this service cheaper "enough." In fact, you often get what you pay for - it is not cheap to maintain quality control, calibration gas and so on. Instead, I think we have to identify what's valuable (confirmation that devices work and satisfy people in real situations) and find ways to monetize that.

9. Are field measurements a lot harder to do than lab measurements? Why?

Tami B: They are definitely more labor-intensive, because you are setting up and taking down the measurement equipment each time. This entails not only putting the equipment together, but doing checks such as measuring flow rates. Every time the equipment is transported, you have a risk of breakage. You also have to work around the family's schedule, so if they take an early breakfast, for example, you need to be there quite early to set up. Field days that capture all the cooking events are usually 14-16 hours in the field, not counting transport, and are often followed by cleaning sampling equipment in the hotel.

10. Is there any chance that lab measurements can become more representative of real emissions?

Tami B: Yes, if the causes behind emission variability are represented in the lab, the emissions should be the same. However, not enough attention has been paid to those causes of variability.

11. Are there really a lot of other uses of energy in households, and do they affect the choice of cooking stoves?

Tami B: Space heating in cold regions is often a much bigger use of energy than cooking (as it is in most homes in North America and Europe). Food or agricultural processing or any small enterprise usually require more energy as well, although those may be episodic and not daily. Anecdotal observations suggest that these uses do affect cooking choice by bringing alternative energy-transformation devices into the household. But there hasn't been enough observation.

12. As a rough guess, does blacker smoke have more black carbon and whiter smoke has more organic carbon?

Tami B: That is not a bad rough guess. However, you have to remember that the perception of "black" and "white" also depends on the angle of light.

13. Have you considered how enclosed their kitchen was, as this contributes to concentration levels?

Tami B: Dilution, including kitchen air exchange, does not affect emission factors. It does affect concentration. When we measure concentrations (in plumes) to determine emission factors, they are normalized to the concentrations of CO2 and CO that are also in the plume.

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Emission Factors

Emission factors were the subject of the ASHES presentation. These publications include some emission measurements supported by another EPA-STAR grant: "Characterization of Emissions From Small Variable Solid Fuel Combustion Sources for Determining Global Emissions and Climate Impact"

Thompson, R. J., Li, J., Weyant, C. L., Edwards, R., Lan, Q., Rothman, N., Hu, W., Dang, J., Dang, A., Smith, K. R. & Bond, T. C. Field Emission Measurements of Solid Fuel Stoves in Yunnan, China Demonstrate Dominant Causes of Uncertainty in Household Emission Inventories. Environmental Science and Technology (2019) doi:10.1021/acs.est.8b07040.

Weyant, C. L., Chen, P., Vaidya, A., Li, C., Zhang, Q., Thompson, R., Ellis, J., Chen, Y., Kang, S., Shrestha, G. R., Yagnaraman, M., Arineitwe, J., Edwards, R. & Bond, T. C. Emission Measurements from Traditional Biomass Cookstoves in South Asia and Tibet. Environmental Science & Technology 53, 3306–3314 (2019).

Lam, N. L., Chen, Y. J., Weyant, C., Venkataraman, C., Sadavarte, P., Johnson, M. A., Smith, K. R., Brem, B. T., Arineitwe, J., Ellis, J. E. & Bond, T. C. Household light makes global heat: High black carbon emissions from kerosene wick lamps. Environmental Science & Technology 46, 13531–13538 (2012).

Energy Use

Lam, N. L., Upadhyay, B., Maharjan, S., Jagoe, K., Weyant, C. L., Thompson, R., Uprety, S., Johnson, M. A. & Bond, T. C. Seasonal fuel consumption, stoves, and end-uses in rural households of the far-western development region of Nepal. Environmental Research Letters (2017) doi:10.1088/1748-9326/aa98cc.

The Seasonal Kitchen Performance Test and a Semi-Structured Survey were developed by Berkeley Air under this grant.

Spatial Distribution and Impact

Winijkul, E., Fierce, L. & Bond, T. C. Emissions from residential combustion considering end-uses and spatial constraints: Part I, methods and spatial distribution. *Atmospheric Environment* **125**, 126–139 (2016).

Winijkul, E. & Bond, T. C. Emissions from residential combustion considering end-uses and spatial constraints: Part II, emission reduction scenarios. Atmospheric Environment 124, 1–11 (2016).

Conibear, L. A., Butt, E. W., Knote, C., Lam, N. L., Arnold, S., Tibrewal, K., Venkataraman, C., Spracklen, D. V & Bond, T. C. A complete transition to clean household energy can save one–quarter of the healthy life lost to particulate matter pollution exposure in India. Environmental Research Letters 15, 094096 (2020).

(*Article describing a high-resolution emission inventory for India, which supported the Conibear et al paper, is in prep*)

Indoor exposure modeling and measurement

Edwards, R., Princevac, M., Weltman, R., Ghasemian, M., Arora, N. K. & Bond, T. Modeling emission rates and exposures from outdoor cooking. Atmospheric Environment 164, 50–60 (2017).

Lam, N. L., Muhwezi, G., Isabirye, F., Harrison, K., Ruiz‐Mercado, I., Amukoye, E., Mokaya, T., Wambua, M. & Bates, M. N. Exposure reductions associated with introduction of solar lamps to kerosene lamp‐using households in Busia County, Kenya. *Indoor Air* **28**, 218–227 (2018).

Li, X., Clark, S., Floess, E., Baumgartner, J., Bond, T.C. and Carter, E. Personal exposure to PM2.5 of indoor and outdoor origin in two neighboring Chinese communities with contrasting household fuel use patterns, submitted to *Science of the Total Environment*, 2021.