WHO Household Multiple Emission Sources (HOMES) and Performance Target (PT) Model: Input Parameter Protocol – Indirect Measurements

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Version 2.3

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Model parameters: Fraction of emissions entering room, background concentrations, exposure factors, and emission rates

Objective

Obtain values for input parameters for the WHO Household Multiple Emission Sources (HOMES) and Performance Target (PT) models, including the fraction of emissions entering the room, background concentrations, exposure factors, and emission rates.

Background and context

The parameters described in this protocol are generally not directly measured when collecting data for use with the model, primarily due to the difficulty of making the measurements. These data are often best sourced from work which has already been conducted. Brief descriptions on how to find data on these input parameters are provided here.

Fraction of emissions entering room / mixing in room

For kitchens with open cooking fires or stoves with no chimneys, the fraction of emissions entering the room is assumed to be 1 (meaning that 100% of emissions enter the room) and therefore not important to measure as an input for the model. For homes where chimney stoves or venting hoods are used, the fraction of emissions entering the room can be important, since all of the emissions do not enter the room. The capture efficiency of these devices can be used to determine what fraction of total emissions from the device is estimated to enter the room (e.g. a capture efficiency of 90% would mean that 10% of the emissions are entering the room).

For chimney stoves where the fugitive emissions (emissions that escape into the room) are measured and known, the fugitive emissions can be used as the input emissions rate and the fraction of emissions entering the room can be set at “1”, just as is the case for open stoves. For cases where a capture efficiency is applied, one can measure this parameter by placing the stove under a dual-hood system, in which one hood covers the entire stove (with the exception of the chimney or exhaust duct), to collect the fugitive emissions (or those that exit through the chimney or exhaust duct), and the second hood is positioned to capture only the emissions that vent from the chimney or exhaust duct. This arrangement can be challenging as the hood will need to be placed above the chimney on a roof or high inside of a room. An example of this approach can be found in Ruiz and Masera 2018. The authors describe this dual capture system, as well as how the capture efficiency was used in a version of the model (Ruiz and Masera, 2018). The ratio of the fugitive emissions to the total emissions (which includes both the chimney/vent emissions and the fugitive emissions) will provide the capture efficiency.

For chimney stoves, if neither the capture efficiency nor fugitive emissions are known or able to be measured, then it is recommended to use the conservative default distribution from the WHO Guidelines for indoor air quality: household fuel combustion (WHO, 2014; Johnson et al., n.d.), which is that the fraction entering the room is 25% with a standard deviation of 12.5%.

Background contributions

Ideally, central ambient air sampling in the target communities is conducted to provide a local estimate of the contributions of background concentrations of pollutants to the household. For particulate matter, these measurements should be done with gravimetric equipment at locations that represent the ambient concentrations of the area. Good locations are often the tops of community buildings at the center of town, ensuring that the equipment is not located close to specific sources such as sites where trash is often burned or chimneys that are emitting smoke. If collection of such data is not possible, it may be possible to use literature-based values, if there is relevant information on background concentrations for the target region. Also, there may be pre-existing ambient monitoring stations in the region which can provide background concentration estimates, though care should be taken to ensure that they provide data indicative of the areas where the model is being applied. Specifically, monitoring stations in urban areas are unlikely to provide reasonable background estimates of nearby rural areas given the industrial, transport, and other sources that contribute to air pollution in cities.

Exposure factors

To estimate exposure using the model, the user must apply one of two different methods for determining exposure factors:

1. The first method uses the ratio of personal exposure and kitchen concentrations to estimate personal exposure (E_r). Specifically, this method multiplies the 24-hour mean concentration measured in the kitchen (C_k) by an exposure ratio (R), as shown in Equation 1. The kitchen-to-exposure ratios are, ideally, location-specific. One may look at what is available in the literature for the most relevant estimates of kitchen and personal exposure concentrations. A review of such data was done for the WHO Guidelines for indoor air quality: household fuel combustion (WHO, 2014) with the range of kitchen-to-exposure ratios for women being 0.24 to 1.02. The estimates used in the Global Burden of Disease Study (Smith K.R., Bruce N., Balakrishnan K., Adair-Rohani H., Balmes J., Chafe Z. et al., 2014) can also be applied (0.742 for women, 0.628 for young children, 0.450 for men).

   Eq 1. $E_r = C_k R$

   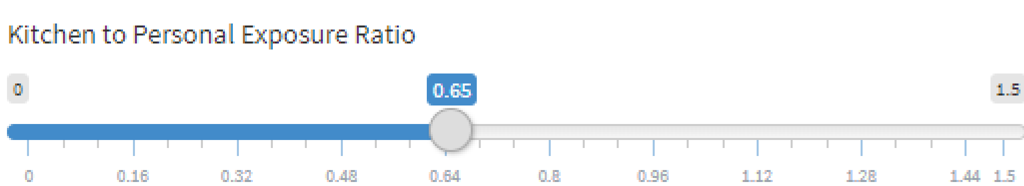

   Figure 1. Screenshot showing where the kitchen-to-personal exposure ratio (R) is entered into the HOMES model

2. The second method is to estimate the fraction of minutes in a day that the user spends in the kitchen (t_k) compared to time spent elsewhere in that same day ($1440-t_k$), as shown in Equation 2. Exposure outside of the kitchen is assumed to be equal to the background ambient concentration (C_b). These data can be collected by time-activity surveys or diaries (Balakrishnan, K., Sambandam, S., Ramaswamy, P., Mehta, S., & Smith, K.R., 2004; Cynthia, A. A., Edwards, R.

D., Johnson, M., Zuk, M., Rojas, L., Jiménez, R. D., Masera, O., 2008) or by direct location tracking (Allen-Piccolo, G., Rogers, J. V., Edwards, R., Clark, M. C., Allen, T. T., Ruiz-Mercado, I., Smith, K. R., 2009).

Eq 2. $$E_t = C_k\left(\frac{t_k}{1440}\right) + C_b\left(\frac{1440 - t_k}{1440}\right)$$

The amount of time spent in the kitchen is directly entered into the HOMES model.

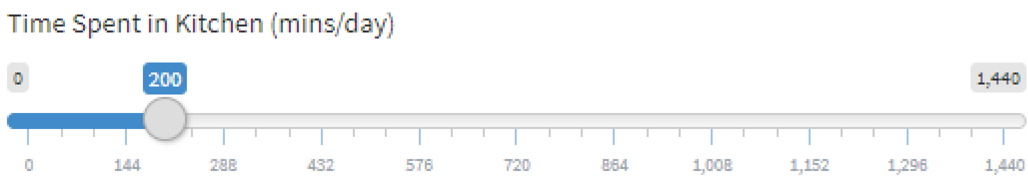

Figure 2. Screenshot showing where the time spent in kitchen (T_k) is entered into the HOMES model

Additional details are provided in te section on estimating exposure in the WHO HOMES model documentation available here (WHO 2020): https://worldhealthorg.shinyapps.io/who_homes/_w_9930add7/who_homes_model_documentation.pdf.

Emission rates

The model requires that emission rates (in milligram per minute) be entered for each emission source. If it is feasible to collect in-field emissions performance data for the devices of interest in households in the target region, this is the best option. The methods for measuring emission rates, however, are relatively complex and these types of studies can be expensive. Example publications which describe these methods can be found in the following references:

- Roden, C.A., Bond, T.C., Conway, S., and Pinel, A.B.O. (2006). Emission factors and real-time optical properties of particles emitted from traditional wood burning cookstoves. *Environ. Sci. Technol.* 40: 6750–6757.

- Grieshop, A.P., Jain, G., Sethuraman, K., and Marshall, J.D. (2017). Emission factors of health- and climate-relevant pollutants measured in home during a carbon-finance-approved cookstove intervention in rural India. *GeoHealth* 1, https://doi.org/10.1002/2017GH000066

- Garland, C., Delapena, S., Prasad, R., L'Orange, C., Alexander, D., and Johnson, M. (2017). Black carbon cookstove emissions: A field assessment of 19 stove/fuel combinations. *Atmospheric Environment,* 169: 140–149.

Methods for testing laboratory and field performance of cookstoves are also available through the International Organization for Standardization (ISO) (ISO 2018).

Should collecting field data on emission rates not be feasible, the largest source of emissions performance data can be found in the Clean Cooking Catalogue (Global Alliance for Clean Cookstoves, 2018). The database contains hundreds of test results on stove performance. However, almost all of the stove performance data are from laboratory testing, and emission rates derived from controlled testing are not likely to accurately represent real-world performance. In previous studies, emissions performance has generally been shown to be better during laboratory testing than during normal operation in homes (Berkeley Air, 2012). Thus, if data from controlled testing are used, the limitations and potential bias in the results should be considered when interpreting and reporting the model's output.

References

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Global Alliance for Clean Cookstoves (2018). Clean Cooking Catalog. Accessed on May 26 2018 from http://catalog.cleancookstoves.org/

Indoor air quality guidelines: household fuel combustion review 5, http://www.who.int/airpollution/guidelines/household-fuel-combustion/Review_5.pdf?ua=1

ISO 2018. Clean cookstoves and clean cooking solutions -- Harmonized laboratory testing protocols –Part 1: Standard test sequence for emissions and performance, safety and durability. Retrieved from https://www.iso.org/standard/66519.html

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Ruiz, V., & Masera, O. (2018). Estimating Kitchen PM2.5 and CO Concentrations out of Stove Emissions: The case of Mexican Plancha-type Stoves. Morelia, Mexico: Laboratorio de Innovación y Evaluación de Estufas de Biomasa, Universidad Nacional Autónoma de México. Retrieved from http://cleancookstoves.org/resources/543.html

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