D. Pollution levels and personal exposure

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What does this type of evaluation tell us?

From a health point of view, reducing exposure to IAP levels is the primary objective of household energy interventions. This section addresses understanding the impact of interventions on pollution levels and personal exposure to IAP. This is particularly important given the difficulty in assessing health outcomes directly (see Section E). Instead, reductions in pollution levels and personal exposure can be used as a proxy for likely reductions in adverse health outcomes.

The chain of events that links household energy practices to adverse health outcomes via IAP concentrations and exposures is referred to as the environmental health pathway. Figure 1 illustrates the variety of strategies to measure health impacts as a result of exposure to IAP. Moving along this pathway, assessing health impacts becomes more accurate but also more costly and difficult. Ultimately, the choice of strategy depends on an organization's technical and financial constraints as well as their objectives.

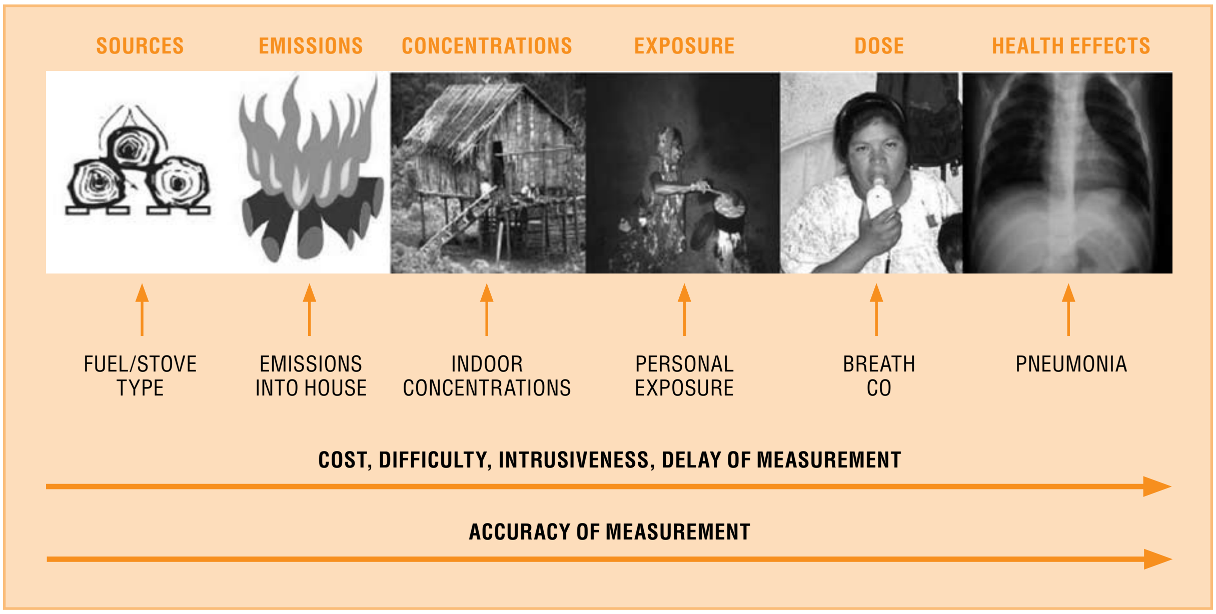
Given the difficulties of assessing health impacts directly, this section focuses on more achievable methods of estimating personal exposure to IAP:

1. The most simple and economical way to estimate exposure to IAP is through surveys.
2. In a next step, questionnaire data could be supplemented with area measurements.
3. The most sophisticated and expensive strategy is to conduct personal exposure monitoring.

Area monitoring. Measuring room pollution levels (i.e. area measurements) is a commonly used proxy for personal exposure. A monitor is placed in a standard location in a room and the concentration of a given pollutant is measured for a specific period of time. Such measurements reflect, for example, the exposure of individuals with limited mobility, such as infants, elderly or sick household members, who spend most of their time in the area being monitored. Most people, however, tend to move from high-pollution environments to low-pollution environments. In these cases, IAP monitoring can be combined with time-activity data that record participants' activities on an hour-by-hour basis on a time chart. Further accuracy might be gained from combining time activity data with pollution measurements taken on a minute-by-minute basis, to provide a better indication of levels of exposure at a given time.

Personal monitoring. The most accurate way of determining exposure is personal exposure monitoring, where participants are required to wear IAP monitors for a 24- or 48-hour period. The data account for their location and behaviour, including changes instigated by the intervention (e.g. spending more time in a less polluted kitchen), because the monitors move with the individual. Personal exposure monitoring also allows researchers to investigate exposures for specific vulnerable groups, such as women and children. Assessing the carbon monoxide level in a person's breath (CO breath) is a measure of recent exposure to IAP (within the last 5 to 6 hours) but interpreting the estimate is difficult as CO breath measures do not

Figure 1 The environmental health pathway[1]



SOURCE: KIRK SMITH, UCB

change linearly with dose. Moreover, CO breath is not suitable for assessing IAP exposure among small children as they have difficulty blowing into CO monitors.

What are we interested in measuring?

Cookstove emissions contain a wide range of harmful pollutants. With respect to measuring exposure to IAP, researchers agree that particulate matter (PM) and carbon monoxide (CO) should be monitored as they are the pollutants considered most damaging to health. In areas where a variety of fuels (notably coal but also garbage or industrial waste) is used, additional emissions may need to be monitored such as carcinogens or locally specific pollutants from coal (e.g. fluoride or arsenic in certain parts of China).

The debate on which size of particles should be measured, given currently available evidence, continues. Smaller particles with a diameter of less than 2.5 microns ($PM_{2.5}$ and PM_1) are likely to be most harmful as they penetrate deep into the human lung. Larger particles (above PM_{10}) are more likely to get filtered by the upper respiratory tract, although it is argued that insufficient research has been done to rule out their importance. It is thought that measures of $PM_{3.5}$ match the respirable fraction more closely than $PM_{2.5}$. However, the emissions of $PM_{2.5}$ and $PM_{3.5}$ from wood combustion are approximately equal, therefore measurements of $PM_{2.5}$ can be considered a close approximation of $PM_{3.5}$. In summary, international air pollution standards are based on PM_{10} and $PM_{2.5}$, and these two particle sizes continue to be the basis for much of the outdoor and IAP monitoring undertaken around the world. Considering available technologies and the relative cost and technical difficulty of monitoring, it is recommended that organizations focus on measuring levels of $PM_{2.5}$.

What is considered to be a good reduction?

The level of IAP experienced in many homes is one or two orders of magnitude greater than existing internationally accepted guideline values. For example, the WHO global air quality guidelines, which apply to both outdoor and indoor environments, recommend that the limit for annual mean PM_{10} concentrations be set at 20 $\mu g/m^3$.[2] By comparison, the Chinese standard for indoor PM_{10} is set considerably higher, at 150 $\mu g/m^3$. China has been one of the first countries to establish such an indoor air qual-

[1] World Health Organization. *Indoor air pollution and household energy monitoring: workshop resources*. Geneva, WHO, 2005.

[2] World Health Organization. *WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. Global update 2005. Geneva, WHO, 2006.

ity standard (GB/T 1883-2002) although compliance for biomass stoves is not yet compulsory.

A dose-response relationship for IAP exposure and adverse health impacts is not known. Consequently, we cannot be sure by how much exposure to IAP needs to be reduced to realize benefits to health. Given the extreme starting levels of IAP, it is likely that a fairly gross reduction is required.

Key questions

- How large is the reduction in room pollution levels?
- How large is the reduction in personal exposure for mothers, children, the elderly or other specific target populations?
- What other factors, such as ventilation or personal behaviour may affect the results, and how have they been accounted for?

What are the challenges?

Assessing CO and PM levels and, even more so, personal exposure assessment is time- and labour-intensive and requires specialized equipment. In-depth training and institutional capacity is required to ensure effective monitoring and reliable results.

Choosing a time period over which to monitor will affect results. For example, monitoring undertaken during a single mealtime, over a period of 8 hours, 24 hours or a week may produce very different results and insights. It is important to appreciate that a single cooking activity may not be representative of general IAP levels, or indeed that cooking practices and fuel choices observed during one season may not reflect the situation during other seasons.

It is relatively simple to measure CO breath. It is, however, important to record when the measurement was taken in relation to smoking, cooking or other activities leading to high exposure as CO breath has a relatively short half-life of approximately five hours. Moreover, it is advisable to repeat CO breath measurements, for example, when visiting the house to place and collect equipment for room pollution monitoring.

Wearing personal monitoring equipment for an extended period of time and during all daily activities (such as cooking, sleeping, going to the market) is often considered intrusive by household members. Interacting with households prior to the study, for example through focus group discussions, is an important means of ensuring that study participants are willing to wear the monitors at all times.

Any research on human subjects, such as personal exposure monitoring, requires approval by an ethical review panel or an institutional review board to ensure that ethical issues are being considered (see Chapter 5).

Available methods

Boxes 4, 5, 6 and 7 provide a brief overview of different IAP-monitoring technologies. Available methods to evaluate pollution levels and personal exposure are listed in Table 6.

BOX 4 Carbon monoxide – colour-change diffusion tubes

Colour-change diffusion tubes, also known as stain tubes or dosimeter tubes, are small glass tubes containing a compound that changes colour on exposure to CO. The tubes give a time-weighted average for exposure to CO and are read by matching the colour change of the indicator compound with a colour key. They are small and discreet and can be easily worn on clothing although the breakable glass tube may make them unsuitable for use on children. As they do not give a precise numerical reading, they are subject to considerable inaccuracy.

Colour-change diffusion tubes are relatively inexpensive and do not require a power supply. These tubes can be purchased for around US$6 each and are not reusable. Re-usable plastic clips to allow the tubes to be worn for personal exposure monitoring cost around US$10 each.

Summary of requirements

Power supply:	✘	
Calibration device:	✔	Ruler
Computer & software:	✘	
Laboratory facilities:	✘	

BOX 5 Carbon monoxide – real-time electro-chemical gas monitors

Real-time gas monitors can give a digital output of CO levels at one minute (or even one second) intervals. Data can be downloaded to a personal computer. This allows peaks as well as mean values to be recorded that can in turn be related to particular events or activities. Some gas monitors are small, robust, battery-operated and can be worn by adults.

Several devices are available within the price range US$250 to US$600.

Summary of requirements

Power supply:	✔	Battery (cell)
Calibration device:	✘	
Computer & software:	✔	
Laboratory facilities:	✘	

BOX 6 Particulates – gravimetric pump and filter

This method of measuring airborne particulates involves a filtration device attached to a pump. The pump draws air through filter papers over a number of hours. This method measures the mass of total suspended particulates (TSP) to indicate average pollution levels. Measuring specific particle sizes, such as $PM_{2.5}$, necessitates the use of a cyclone, which requires specific flow rates. The amount of particles collected on a filter depends on the particle concentration in the environment, on the sampling time and on the flow rate. The flow rate for measuring TSP should be standardized at a low rate to avoid overloading of the filter.

Pumps can be used for measuring adult personal exposure by placing the devices in backpacks with an intake attachment in the participant's breathing zone.

The pump and filter method is considered the standard and has been widely used. It is, however, more expensive than many of the light-scattering monitors, because there are significant overheads involved in preparing and analysing filter papers (around US$40 per data point, undertaken in a climate-controlled laboratory with a 5–6 place analytical laboratory balance).

Commonly used pump and filter devices cost approximately US$1000.

Summary of requirements

Power supply:	✔	240V/ 120V/ 12V
Calibration device:	✔	
Computer & software:	✘	
Laboratory facilities:	✔	

BOX 7 Particulates – real-time light scattering monitors

These monitors measure the scatter of light resulting from suspended particles in the air. They are able to measure changes in PM concentrations from minute to minute rather than relying on daily mean values. Laboratory facilities are not needed and the monitors themselves are quieter and easier to use. Some devices are small enough to be worn by adults. Some training and skills are required to use the monitors effectively.

A number of light scattering monitors are available on the market, priced between US$500 and $6500 per unit.

Summary of requirements

Power supply:	✔	Battery (cell)
Calibration device:	✘	
Computer & software:	✔	
Laboratory facilities:	✘	

Table 6 Evaluating pollution levels and personal exposure

ID	Method	Organization	Relevant section of method	Rating
Recommended methods				
D1	UCB light-scattering particle monitoring protocol[a]	IAP team, UCB	All	✎✎✎
D2	CO dosimeter tube protocol[a]		All	✎✎
D3	HOBO CO logger and calibration check protocols[a]		All	✎✎✎
D1, D2, D3	IAP post-monitoring questions[a]		All	✎
D4	Indoor air quality post-monitoring questionnaire	TERI/HEED	All	✎
D5	House, household and monitoring[b]	Practical Action/ University of Liverpool	PM pump and filter area monitoring (Section B)	✎✎✎✎
D5	House, household and monitoring[b]	Practical Action/ University of Liverpool	Digital CO (area) and CO (personal exposure) monitoring (Section B)	✎✎✎
D5	House, household and monitoring[b]	Practical Action/ University of Liverpool	Post-monitoring questionnaire (Section C)	✎
D6	Measuring breath CO[b]	Practical Action/ University of Liverpool	All	✎✎
D7	Household energy practices, indoor air pollution and health perceptions survey	Winrock International	IAP monitoring datasheet and accompanying enumerator's manual for PM pump and filter area monitoring (Section G)	✎✎✎✎
D7	Household energy practices, indoor air pollution and health perceptions survey	Winrock International	IAP monitoring datasheet and accompanying enumerator's manual for digital CO (area) and CO (personal exposure) monitoring (Section G)	✎✎✎
D7	Household energy practices, indoor air pollution and health perceptions survey	Winrock International	Post-monitoring questions (Section H)	✎✎✎
Additional methods				
D8	Protocols for assessing daily integrated exposure	TERI/East-West Centre	All	✎✎✎✎✎
Y1	Indoor air pollution survey	World Bank Bangladesh	Questions on ventilation	✎

A – Adoption; B – Market development; C – Performance; D – Pollution levels and personal exposure; E – Health and Safety; F – Time and socio-economic impacts; G – Environmental impacts; Y – Generic methods.

[a] These methods are accompanied by a document that describes the installation of IAP monitoring instruments in homes as well as data forms.

[b] These methods are accompanied by an interviewers' and supervisors' manual as well as data collection forms.