Personal exposure to particulate matter in peri-urban India: predictors and association with ambient concentration at residence

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Abstract

Scalable exposure assessment approaches that capture personal exposure to particles for purposes of epidemiology are currently limited, but valuable, particularly in low-/middle-income countries where sources of personal exposure are often distinct from those of ambient concentrations. We measured 2x24-hr integrated personal exposure to $PM_{2.5}$ and black carbon in two seasons in 402 participants living in peri-urban South India. Means (sd) of $PM_{2.5}$ personal exposure were 55.1(82.8) µg/m^3 for men and 58.5(58.8) µg/m^3 for women; corresponding figures for black carbon were 4.6(7.0) µg/m^3 and 6.1(9.6) µg/m^3. Most variability in personal exposure was within participant (intraclass correlation ~20%). Personal exposure measurements were not correlated ($R_{spearman}$<0.2) with annual ambient concentration at residence modeled by land-use regression; no subgroup with moderate or good agreement could be identified (weighted kappa ≤0.3 in all subgroups). We developed models to predict personal exposure in men and women separately, based on time-invariant characteristics collected at baseline (individual, household, and general time-activity) using forward stepwise model building with mixed models. Models for women included cooking activities and household socio-economic position, while models for men included smoking and occupation. Models performed moderately in terms of between-participant variance explained (38-53%) and correlations between predictions and measurements ($R_{spearman}$: 0.30-0.50). More detailed, time-varying time-activity data did not substantially improve the performance of the models. Our results demonstrate the feasibility of predicting personal exposure in support of epidemiological studies investigating long-term particulate matter exposure in settings characterized by solid fuel use and high occupational exposure to particles.

Keywords

Black carbon; Peri-urban; Personal exposure; Exposure modeling; PM2.5; India.

Introduction

The epidemiological evidence linking particulate matter with diameter <2.5 μm ($PM_{2.5}$) with premature mortality and morbidity is large[1,2]. However, most of this evidence is based on populations in high-income countries, despite indications that the majority of the attributable burden of $PM_{2.5}$ comes from populations from low- and-middle-income countries (LMICs)[3]. The relative lack of epidemiological evidence in LMICs, especially for long-term effects of air pollution, has been highlighted previously[4].

Epidemiological studies of long-term exposure typically rely on spatial contrasts to estimate between-individual exposure. Land-use regression approaches aim to model ambient levels at residential address and have been widely used in the epidemiological literature[5,6]. They have generally shown good performance in predicting spatial patterns of ambient air pollution, especially within urban areas dominated by traffic sources[6].

New technology allows researchers to directly measure personal exposure and integrate it with individual characteristics, time-activity-features, and residence characteristics, moving beyond traditional estimates of ambient air pollution at residence[7–10]. Although measurements may be more accurate than models, both have limitations. Measurements are often limited to small groups and short durations. Extrapolating measurements to larger populations for epidemiological research is also challenging. One source of complexity in measuring and modeling personal exposure is the relative contribution of within-individual (temporal) and between-individual (spatial) variability in exposure, which has been stressed before[11,12]. Understanding these sources of variability is essential to advance approaches aiming at better approximate long-term personal exposure to air pollution.

Personal exposure prediction is especially attractive for air pollution epidemiology in many LMIC settings where traffic is not necessarily the dominant source. In settings with high prevalence of cooking with solid fuels or with high occupational exposures, personal exposure is likely to differ substantially from estimates of ambient air pollution at residence. There is a need for population-level exposure estimates to enable epidemiology that reflect the complexity of LMIC settings.

We measured and analyzed 24-hr integrated personal exposure to $PM_{2.5}$ and black carbon in a relatively large sample of the general population in peri-urban South India. We specifically aimed to: 1) compare measured personal exposure with annual ambient concentration estimated at residence using land-use regression models (previously developed for the study area) and 2) develop prediction models that could be used in epidemiological analyses to predict long-term personal exposure to $PM_{2.5}$ and black carbon.

Methods

Study population

We used data collected through the Cardiovascular Health Effects of Air Pollution in Telangana, India (CHAI) project nested in the Andhra Pradesh Children and Parents Study (APCAPS) cohort[13,14]. APCAPS is a large prospective, intergenerational cohort study including ~6000 participants living near the city of Hyderabad, India. The study area consists of 28 villages each with 187 to 5065 households spread over 543 km^2 southeast of Hyderabad. Villages vary in terms of area, population size, socioeconomic status, level of urbanization, and primary cooking fuel. Ethics approval was granted by the Parc de Salut Mar, Public Health Foundation of India, National Institute of Nutrition, Sri Ramachandra University, and the European Research Council. All participants provided informed consent.

In 2015, CHAI recruited a stratified (by sex and village) random sample of 402 adult participants of APCAPS. They were invited to participate in two non-consecutive 24-hr monitoring sessions that included detailed measurements of self-reported time-activity patterns and particulate air pollution exposure. The first session occurred between May and July 2015 during summer season (including monsoon); the second session occurred between December 2015 and March 2016 during winter season.

Of the 402 selected participants, 81 completed one monitoring session and 278 completed two or three monitoring sessions, leading to 639 measurements of 24-hr personal exposure to $PM_{2.5}$ and black carbon. We excluded 13 measurements due to device malfunction (e.g., run time <70% of the expected 24 hours or missing data) or poor compliance (the collocated accelerometer recorded no motion during monitoring) and 13 measurements due to missing covariates. We additionally excluded three measurements showing negative $PM_{2.5}$ concentrations and 41 measurements with negative black carbon concentrations (potentially due to concentrations below the lower end of the standard curve used for correction). We therefore analyzed 610 participant-days of $PM_{2.5}$ – 569 participant-days of black carbon – 24-hr personal exposure, corresponding to 349 unique participants (207 men and 142 women).

Personal exposure

Participants were asked to wear a secured backpack containing a personal exposure monitor to measure their 24-hr integrated gravimetric exposure to $PM_{2.5}$. The inlet of the personal monitor was placed near the breathing zone on one strap of the backpack. The pump (model 224-PCMTX8, SKC Ltd, Dorset, UK) was placed inside the backpack and drew air through a sharp cut cyclone attached to a cassette containing a 37-mm filter (Emfab, 113 Pallflex®). Filters were weighed pre- and post-monitoring according to previously described protocol that follows the RTI (Research Triangle Institute) guidelines[15]. Daily $PM_{2.5}$ concentrations were derived from filter mass after correction for mass accumulated on blank filters (session-specific correction using median blank weights based on 31 blank filters overall). Daily black carbon concentrations were derived from optical attenuation (880 nm) of the mass collected on sampled filters, using a Magee OT21 Sootscan Optical Transmissometer (Magee Scientific, Berkeley, California, USA). The factor value used for conversion was consistent with previous literature[16].We detected a sensitivity of the OT21 output to the weight of the unexposed filter, so we corrected the attenuation factor value for filter weights.

Sessions began with a field worker setting up the monitoring equipment at the participant's house (average time: 8 a.m.) and finished the following day around the same time. Scheduling was designed to minimize disruption to participants' daily life. Participants were asked to wear the backpack during their usual activities for 24 consecutive hours. If the backpack interfered with activities (e.g., sleeping, sitting, bathing), participants were instructed to place the backpack nearby, on a stool or a chair.

Ambient air pollution

Background measurements – Continuous monitoring of $PM_{2.5}$ was implemented from 2015 to 2016 at one site in the North of the study area[17]. Hourly $PM_{2.5}$ concentrations were measured using an e-BAM device (model 9800, Met One, Grants Pass, OR). Missing hourly data (22% of the monitoring sessions) were imputed using a linear regression of temperature, relative humidity, wind speed (measured at the Rajiv Gandhi International Airport, located 15.8 km from North site) and ambient $PM_{2.5}$ concentrations measured at the US embassy in Hyderabad, located 23.7 km from North site. The adjusted-R^2 of the model was 0.49 and the 10-fold cross-validation mean absolute error was 10.3 μg/m^3 (standard deviation of the hourly ambient time series being 21.3 μg/m^3). We calculated daily average ambient $PM_{2.5}$, temperature, and relative humidity to correspond with the monitoring sessions.

Ambient concentration at residence – We previously developed land-use regression models for the study area to estimate annual ambient concentration to $PM_{2.5}$ and black carbon at the residence of all participants[18]. Briefly, the $PM_{2.5}$ model included indicators of vegetation and urbanicity and explained 58% of the spatial variation; the black carbon model included indicators related to roads, natural spaces, and non-residential places and explained 78% of the spatial variation.

Questionnaires

A baseline questionnaire was administered to participants by members of the field staff at most one month prior to personal exposure sampling. The questionnaire included data on general individual characteristics (e.g., age, occupation, smoking habits), usual activities (e.g., average time spent at work, cooking habits), and residence characteristics (e.g., primary stove type, kitchen type, fuel use for cooking) of the participants. After each monitoring session, participants completed a post-monitoring questionnaire in which they were asked by member of the field staff about major sources of air pollution they had been exposed to during the session (e.g., solid fuel use for cooking, passive and active smoking, being in traffic or near open fires). The questionnaire included an hourly time-activity diary (1-hr slot with up to two main locations and activities). The questionnaire, developed at Sri Ramachandra University, has been validated in a previous study involving $PM_{2.5}$ measurements[19]. Questionnaires are available in the Supplementary Information.

Statistical analysis

We performed all analyses in men and women separately as previous results showed strong difference in lifestyle and behaviors by sex in the study population[20,21].

Ambient-adjusted personal exposure – For analysis, measurements of personal exposure were adjusted in order to account for the day-to-day variability driven by ambient factors ($PM_{2.5}$ concentration, temperature, and humidity) not related to individual characteristics. We used the background data measured by the e-BAM device located in the North of the study area. We regressed 24-hr average of log-transformed ambient $PM_{2.5}$, 24-hr average temperature, and 24-hr average relative humidity on log-transformed 24-hr personal exposure ($PM_{2.5}$ and black carbon), with a random intercept per participant. The ambient adjustment decreased the within-participant variance component by 35% and 26% – relative to the empty model – for $PM_{2.5}$ and black carbon personal exposures, respectively. The relationship between the outcome and predictors was considered as linear. These predictors were uncorrelated with the variables used in the prediction models (see below) as pair-wise Pearson correlations were all <0.1. Log transformation was used to ensure normal distribution of residuals. The resulting marginal residuals were considered ambient-adjusted personal exposure and used throughout subsequent analyses.

Variance component of personal exposure – A linear mixed model with only a random intercept per participant (i.e., empty model) was used to partition personal exposure variability into within-participant (residual variance) and between-participant (random effect variance) variability components. We calculated intra class correlation coefficients (ICC) i.e., the proportion of total variability attributable to between-participant variability. Subgroups analysis were performed.

Personal exposure compared to ambient concentration at residence – We calculated Spearman correlation coefficients between personal exposure and ambient concentration at residence modeled by land-use regression. We assessed the degree of agreement across rank quintiles of the different exposure indicators with weighted Kappa. Agreement more directly assesses whether modeled concentration at residence can be used as a proxy for measured personal exposure. Subgroups analysis were performed.

Prediction models of personal exposure – First, we developed a model including only time-invariant characteristics of the participant or his/her household (collected once at baseline, complete list available in Supplementary Table S1). We identified predictors of $PM_{2.5}$ and black carbon following a data-driven, forward stepwise procedure. Starting from an empty mixed model with random intercept per participant, we tested each of the time-invariant candidate predictors as a fixed effect. We selected the predictor that yielded the greatest decrease in the marginal Akaike Information Criterion (AIC) and we repeated the procedure until no additional variable provided any further decrease in AIC. Within each iteration, we verified whether any of the included variables could be removed without increase in AIC and we checked multicollinearity using the Variance Inflation Factor (if >5, the predictor was excluded). After final iteration, we dropped predictors with p-values>0.1 according to a likelihood ratio test that compared the model with and without the predictor. We detected influential observations using adapted Cook's distance (if >4/sample size) for mixed model[22]. Predictors that were sensitive to the removal of influential observations (i.e., >20% change toward the null in the corresponding estimates) were excluded from the final model. We checked model residuals and random effects for normality and homoscedasticity. Second, we repeated the full process including time-varying characteristics as potential predictors. These characteristics related to specific activities or events that occurred during monitoring and were reported in the post-monitoring questionnaire (complete list in Supplementary Table S1). Finally, for the two models, we calculated the proportion of within- and between-participant variance of personal exposure explained by each final model as compared to the empty model (expressed in percent change) as previously used[12]. We calculated the root-mean-square error (RMSE) and Spearman correlation between averaged exposure and averaged prediction per participant, among those with ≥2 sessions.

Evaluation of prediction models – We evaluated the models by performing 10-fold cross-validation at the participant level. Briefly, we randomly partitioned participants in 10 similar-size subgroups – all measurements of each participant being in the same group. Each subgroup was used once as a validation dataset for the models previously developed, which were then fitted in the other nine groups. To evaluate the robustness of the selected predictors, we further performed a 10-fold cross-holdout validation[23]. Briefly, the predictor selection procedure was repeated using nine of the 10 previously partitioned subgroups and then used to predict personal exposure on the remaining subgroup, leading to 10 different model applications. We calculated the RMSE and Spearman correlation between the averaged exposure and out-of-sample predictions per participant, among participants with ≥2 sessions.

Analysis and figures were done using the statistical software R version 3.4.0 (R Foundation for Statistical Computing, Vienna, Austria)[24] using several packages[25–28].

Results

Women were slightly older than men (mean (sd): 45 (11) *vs*. 41 (17), respectively) (Table 1). Most women were illiterate (80%) and engaged in manual unskilled (agricultural) work (60%). At baseline, men reported more working hours per day than women (6.7 (3.7) *vs*. 5.1 (3.5), respectively) and most men reported zero hours spent cooking with biomass fuel (93%). Forty percent of the participants reported biomass as the primary cooking fuel in the household. Mean number of personal exposure monitoring sessions was similar across men and women.

Personal exposure to $PM_{2.5}$ and black carbon was slightly higher in women than in men (Table 2). Relative to women's, men's $PM_{2.5}$ personal exposure showed larger variability and higher maximum values (up to 1331 μg/m^3). On average, ambient concentrations, whether measured at fixed background site or modeled at residence using land-use regression, were lower than personal exposure.

Variance components of personal exposure

Log-transformed measured personal exposure to $PM_{2.5}$ and black carbon showed much higher within-participant than between-participant variance, resulting in ICC of 0% in men and of 12-18% in women. Adjusting for daily ambient factors decreased the within-participant variance, resulting in higher ICC for men (18-20%) and slightly higher ICC for women (21-22%, Supplementary Table S2). The greatest between-participant variability was observed among participants without separate kitchen (36-39% for $PM_{2.5}$ and 56-60% for black carbon) and actively smoking men (32% for $PM_{2.5}$ and 46% for black carbon). Patterns of ICC according to subgroups were not always the same across $PM_{2.5}$ and black carbon or across men and women.

Measured personal compared to ambient concentration at residence

Figure 1 compares the probability distribution of measured personal exposure and ambient concentration at residence of $PM_{2.5}$ and black carbon in the study population. Distributions were overlapping but measured personal exposure showed a much wider distribution. Very weak correlations were observed between measured personal exposure and ambient concentration at residence of the same pollutant (Spearman correlation coefficients between -0.18 and 0.06). Figures were similar when considering averaged personal exposure among participants with ≥2 sessions (between -0.16 and 0.09). In men, averaged personal exposure to black carbon was more correlated with residential $PM_{2.5}$ than with residential black carbon (0.25 and 0.07, respectively).

Agreement between rank quintiles of averaged personal exposure and ambient concentration at residence of the same pollutant was poor (weighted Kappas <0.09). Poor agreement between rank quintiles was consistent across population subgroups (≤0.33). The highest level of agreement, though still poor, was found for black carbon in the subgroup of women living close to Hyderabad. The direction of the discrepancy (personal exposure being higher or lower than ambient concentration at residence) varied with subgroups (Supplementary Figure S1-A, Supplementary Figure S1-B). For example, for most participants living close to Hyderabad, $PM_{2.5}$ concentrations were ranked lower for personal exposure than for ambient concentration at residence, while the reverse was observed for most participants with biomass as primary stove type.

Predictive models of personal exposure

Figure 1 compares the probability distribution of measured and predicted personal exposures. Distributions were overlapping with similar means but the distributions for predicted exposures were much narrower.

In women, predictors of $PM_{2.5}$ and black carbon exposure mostly related to cooking activities, whether time-invariant (Table 3) or time-varying (Supplementary Table S3). For example, 24-hr average $PM_{2.5}$ personal exposure increased by 13% for each hour spent cooking with biomass, as reported at baseline. Other predictors likely reflected the socio-economic status of the household (occupation of the household head, vehicle ownership, and time spent in vehicle). Predictors selected during validation process were highly consistent (Table 4). Models with time-invariant predictors explained 38% ($PM_{2.5}$) and 57% (black carbon) of the between-woman variability in personal exposure but explained no within-participant variability (Table 3). Correlations between measurements and predictions were moderate (0.42-0.50) and decreased during validation process, particularly for $PM_{2.5}$ (from 0.42 to 0.12, Table 4). The inclusion of time-varying variables increased the explained between-participant variance by 26% for $PM_{2.5}$ and 10% for black carbon (Supplementary Table S4) but it improved none of the other metrics considered (within-participant variability, RMSE, and correlations between predictions and measurements).

Predictors of $PM_{2.5}$ and black carbon exposure were more diverse for men compared to women. Predictors associated with increased personal exposure primarily related to occupation (time-invariant or time-varying) and smoking (Table 3, Supplementary Table S3). Non-smoking was associated with a 21% decrease in $PM_{2.5}$ personal exposure as compared to active smoking, but was not a predictor for black carbon. Annual ambient $PM_{2.5}$ at residence was associated with an increase in personal exposure for black carbon. Black carbon personal exposure increased by 4% for each hour spent working during the monitoring session. Time-invariant predictors explained 53% ($PM_{2.5}$) and 20% (black carbon) of the between-man variability in personal exposure; correlation coefficients between predicted and measured values were low (~0.30). Similar predictors were selected during validation process but correlation coefficients halved (Table 4). Inclusion of time-varying predictors did not improve the model performance metrics (between- or within-participant variance, RMSE, and correlation coefficients) for either $PM_{2.5}$ or black carbon in men (Supplementary Table S3, Supplementary Table S4).

Discussion

We analyzed personal exposure to $PM_{2.5}$ and black carbon in a relatively large sample of the general population of peri-urban South India. Personal exposures to $PM_{2.5}$ and black carbon were, on average, higher than and relatively poorly correlated with annual ambient concentrations at residence. Personal exposure variability was substantially larger within participant than between participant. Predictors of personal exposure to $PM_{2.5}$ and black carbon included cooking activities (women), occupation (men) and smoking (men). Prediction models explained a moderate amount of between-person variability in measured personal exposure, except for black carbon in men where model performance was poor.

We observed larger within-participant variance compared to between-participant variance in measured personal exposure for both $PM_{2.5}$ and black carbon, even after temporal adjustment for daily ambient factors. Compared to published results for other populations in LMICs, our results showed lower between-participant variation (Supplementary Table S5). McCracken et al. reported an ICC of 33% in children and 29% in adult women for personal exposure to CO in Guatemala[12,29]. Dionisio et al. reported an ICC of 39% for personal CO for children in The Gambia[30]. Several studies from high-income countries have reported higher between-participant variation in $PM_{2.5}$ personal exposure[31–34], but not all[35]. The relatively low ICC observed in our study may be due to the limited number of measurements (two days in two different seasons). However, a nested panel study within this population with up to 6 measurement-days per person throughout the year observed similar between-participant variability in $PM_{2.5}$ personal exposure[36]. The large within-participant variability of personal exposure we observed for women may reflect the variability generally observed in cooking stove emissions[37], a major source of particulate matter for women. This high temporal variability in personal exposure likely reduces the precision of these measurements as surrogates for long-term exposure in the study population.

Measured personal exposure to $PM_{2.5}$ and black carbon showed neither correlation nor agreement (between quintiles) with annual ambient concentration at residence modeled by land-use regression. No subgroup with moderate or good level of agreement could be identified. However, some subgroups were identified as having notably low agreement, for example for $PM_{2.5}$: male smokers, males with non-manual occupation, and women with biomass primary stove. Previous studies from high-income countries have found modest correlation coefficient between measured personal exposure and long-term ambient (measured or modeled) concentrations of $PM_{2.5}$[38–40] or black carbon[41,42], but generally higher than what we observed. Although methods may differ across studies (e.g., population characteristics, modeling method, monitoring time and period), the literature generally supports the use of modeled long-term ambient levels as a surrogate of personal exposure in areas where ambient sources (e.g., traffic) are major contributors of personal exposure. This is not the case in our study area, in which biomass cooking fuel, smoking, and occupational exposures are dominant sources of personal exposure. The high variability observed in personal exposure due to these diverse sources likely contributes to the poor agreement with ambient concentrations at residence. Land-use regression models aim to estimate spatial variability in ambient concentrations, while personal exposure is a mixture of temporal and spatial variations in ambient and non-ambient levels. They likely capture different components of the true exposure and reflect the contribution from different sources[43]; they are therefore both potentially relevant in epidemiological studies.

To predict personal exposure, we developed an empirical, data-driven model based on a stepwise predictor selection using individual data, residence characteristics, and general time-activity data. Consistently with literature in LMICs, women's personal exposure to $PM_{2.5}$ and black carbon were driven by cooking activities or habits (use of biomass, time spent cooking, and ventilation) and socio-economic position of the household (use of biomass, separate kitchen, and motorcycle ownership)[44–47]. Occupational exposure was an important contributor of $PM_{2.5}$ personal exposure in men but we were unable to identify specific occupational tasks relevant for personal exposure, possible due to the wide variability in occupation types (e.g. industry or agriculture) and related tasks throughout the year. In the study area, some of the selected predictors of personal exposure (use of biomass, motorcycle ownership, occupation type, and smoking status) correlated strongly with the urbanization level. Urbanization level could thus contribute to total personal exposure through these interrelated aspects. Overall, our models performed moderately well (except the black carbon model for men) in terms of between-participant variance explained (38% to 53%) and correlations between predictions and measurements (Spearman coefficients from 0.3 to 0.5). These results are comparable with several previous publications. A model for personal CO exposure in Guatemalan children used *a priori* selected predictors and explained 47% of between-participant variability[12]. Using a backward stepwise procedure, a $PM_{2.5}$ model explained 43% of between-participant variability in pregnant Canadian women[32]. Personal $PM_{2.5}$ prediction model explained 74% of variability in summer but only 5% in winter in another study based in a Canadian population[34]. The PM_{10} personal exposure predicted in an Irish population correlated more strongly (Pearson coefficients between 0.55 and 0.84) with measurements than did ours[48]. Specific activities or locations can have a large impact on personal exposure through peaks of exposure e.g., commuting, smoking, and using a kerosene lamp[46,49,50]. More time-resolved data could thus help to explain variability in personal exposure. Yet, in the present study, the addition of more detailed, time-varying variables about activities performed during the monitoring did not improve the overall performance or predictive ability of our models – except for the addition of cooking activities performed during monitoring in women's model for $PM_{2.5}$ exposure. This overall lack of improvement might be a consequence of the coarse time resolution of the time-activity questionnaire and its inability to capture short-term activities or tasks that may be related to peak exposures[20,21]. Previous analyses in the study population showed better performance of the diary for women than for men; a result possibly related to the rather homogeneous activities (related to cooking) performed by women. This could explain why women's prediction models for $PM_{2.5}$ explained more variability after adding the diary data; however, the predictive ability remained similar.

Our results support the feasibility of using predicted long-term personal exposure for epidemiological studies in LMIC contexts. Our aim was to capture total personal exposure and not just the component of personal exposure due to ambient concentrations, which could be estimated using other approaches. Ambient concentrations appear to contribute little to total exposures for our study population in peri-urban India as compared to local sources (biomass burning, occupational exposures, and smoking). The prediction models showed better out-of-sample predictive ability for personal exposure (in terms of correlation with measurements) than annual concentrations at residence modeled by land use regression. The variance and interquartile range of the predicted values were also larger, potentially increasing the statistical power if used as exposure in an epidemiological analysis. A main advantage of the continuous predicted values is that they facilitate estimating an exposure-response function, a clear advantage over categorical indicators based on cooking fuel, which have been previously used for epidemiological studies in LMICs[51]. The literature in settings with prevalent biomass cooking fuel use is largely limited to women and children, shedding little light on exposure levels and health effects in men.

The limitations of the personal exposure predictions warrant consideration. First, the majority of the total variability in measured exposure was within participant, which the models did not explain beyond adjustment for ambient factors ($PM_{2.5}$ concentrations and meteorology). More time-resolved or detailed activity data could have improved the performance of our models (regarding within-participant variability) as such data could capture peaks in daily exposure. However, in the context of epidemiological studies of long-term exposure, between-participant variability is more relevant, for which most of our models had moderate performance. For other research objectives focusing on more time-resolved exposures (e.g., hourly concentrations), improved time-activity data is likely to be important as we previously demonstrated in a nested panel study using highly time-resolved activity information derived from wearable cameras. Second, we had available only 2 days of personal exposure measurements, which may not sufficiently representative of long-term exposure. Additional repeated measurements throughout a year would likely have provided a better reflection of long-term exposure. Nonetheless, in a nested panel study with up to six repeated measurements, the ICC remained low[36], suggesting a very large number of repeated measurements would be required for a notable improvement. Third, we did not have data to validate the prediction models in an independent external dataset. The models appeared robust during the extensive evaluation process but the evidence of applicability to other populations cannot be ensured. However, as the study population represents a stratified random sample, the prediction models could be applied to the general population of the study area. Finally, the uncertainties introduced when deriving black carbon measurements might be an explanation for the poorer predictive ability of the prediction models for black carbon as compared to $PM_{2.5}$.

Our results provide valuable insights into the limited agreement between measured personal exposure and estimates of annual ambient concentration at residence in a LMIC setting, where exposure is not dominated by sources correlated with land use. This has important implications for epidemiology in this and similar settings, as estimates of exposure to ambient pollution are likely to capture only a small fraction of true personal exposure. Our results demonstrate the feasibility of combining personal exposure measurements with questionnaire data on usual activities to generate estimates of particulate matter exposure for a relatively large population. These estimates appear to capture aspects of exposure independent of what is captured by land-use regression. Epidemiological studies of long-term exposure to particulate air pollution in LMIC settings will require exposure assessment approaches that consider both sources of ambient concentrations and of personal exposure.

Supplementary information is available at the Journal of Exposure Science and Environmental Epidemiology's website.

Acknowledgements

The research leading to these results received funding from the European Research Council under ERC Grant Agreement number 336167 for the CHAI Project. The third wave of data collection and village socio-demographic surveys for the APCAPS study were funded by the Wellcome Trust (Grant 084674/Z). C.T. was funded through a Ramón y Cajal fellowship (RYC-2015-17402) awarded by the Spanish Ministry of Economy and Competitiveness. We thank all participants and study teams of the APCAPS and CHAI studies.

Conflicts of interest

The authors declare that they have no conflict of interest.

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Table 1

Characteristics of the study population

		Women	Men
N unique participant		*142*	*207*
N sessions, m (sd)		1.7 (0.5)	1.8 (0.4)
N sessions, n (%)	Two	101 (71)	159 (77)
Age ≥45 years, n (%)		85 (60)	93 (45)
Education, n (%)	Illiterate	114 (80)	87 (42)
Occupation skill-level, n (%)	Unemployed	32 (22)	37 (18)
	Manual unskilled	85 (60)	72 (35)
	Skilled manual	25 (18)	84 (40)
	Non-manual	0	14 (7)
Occupation type, n (%)	Agriculture	75 (53)	75 (36)
	Industry, construction	4 (3)	30 (15)
Usual hours/day spent at work, m (sd)		5.1 (3.4)	6.7 (3.7)
Smoking status, n (%)	Non smoker	86 (61)	115 (55)
	Passive	56 (39)	37 (18)
	Active	0	55 (27)
Primary stove type, n (%)	Biomass	46 (32)	101 (49)
Kitchen type, n (%)	Separate	110 (77)	175 (84)
Usual ventilation during cooking, n (%)	Always	47 (33)	84 (41)
Usual hours /day spent cooking on biomass, n (%)	0	74 (52)	193 (93)
	1	51 (36)	13 (6)
	≥2	17 (12)	1 (1)

Abbreviations: m: mean; n: number; sd: standard deviation. Unemployed category includes housewives, retired participants, and students.

Table 2. $PM_{2.5}$ and black carbon exposures in the study population

		Men	Women
$PM_{2.5}$	*N sessions*	*367*	*243*
	Personal exposure (24-hr)	55.08 (82.78) [c]	58.51 (58.84) [d]
		[6 ; 1331]	[3 ; 564]
	Personal exposure (48-hr average)[a]	53.11 (59.26)	60.36 (45.31)
		[17 ; 730]	[11; 298]
	Annual ambient concentration at	33.02 (2.36)	32.77 (2.57)
	residence [b]	[25 ; 37]	[24 ; 37]
	Ambient fixed site (24-hr)	31.90 (16.10)	34.16 (18.06)
		[13 ; 92]	[13 ; 92]
Black carbon	*N sessions*	*339*	*220*
	Personal exposure (24-hr)	4.61 (7.04) [c]	6.06 (9.63) [d]
		[0 ; 111]	[0 ; 100]
	Personal exposure (48-hr average) [a]	4.72 (6.71)	6.18 (9.42)
		[0 ; 75]	[0 ; 95]
	Annual ambient concentration at	2.51 (0.19)	2.52 (0.24)
	residence [b]	[2 ; 3]	[2 ; 3]

Figures are mean (sd) [min;max]. Concentrations are expressed in µg/m^3. [a]Only participants with two sessions. [b]Estimated by land-use regression. [c]Corresponding geometric means (geometric standard deviations) were 41.36 (1.95) for $PM_{2.5}$ and 3.21 (2.40) for black carbon. [d]Corresponding geometric means (geometric standard deviations) were 44.78 (2.07) for $PM_{2.5}$ and 3.78 (2.82) for black carbon.

Table 3. Prediction models of personal exposure to $PM_{2.5}$ and black carbon using time-invariant predictors

			Regression equation	R^2_{within}	$R^2_{between}$	RMSE	$R_{spearman}$
Men		*Empty model*	$\alpha + \alpha_{participant} + \varepsilon_{session}$	(ref)	(ref)	-	-
(n=367)	$PM_{2.5}$	+ *Time-invariant predictors*	$\alpha + \alpha_{participant}$ – 21% if non smoking* –24% if passive smoking* + 30% if construction or industry job – 12% per 1 hour spent cycling + 16% if unemployed + 4% if skilled manual occupation + 30% if unskilled manual occupation + $\varepsilon_{session}$	0	53%	0.43	0.31
(n=339)	Black carbon	+ *Time-invariant predictors*	$\alpha + \alpha_{participant}$ + 38% if office or shop job + 27% if biomass primary stove + 4% per 1 µg/m³ of ambient $PM_{2.5}$† at residence + $\varepsilon_{session}$	1%	20%	0.68	0.30
Women		*Empty model*	$\alpha + \alpha_{participant} + \varepsilon_{session}$	(ref)	(ref)	-	-
(n=243)	$PM_{2.5}$	+ *Time-invariant predictors*	$\alpha + \alpha_{participant}$ + 13% per 1 hour spent cooking with biomass + 22% if biomass primary stove + 2% if unemployed household head + 23% if unskilled manual household head + $\varepsilon_{session}$	0	38%	0.53	0.42
(n=220)	Black carbon	+ *Time-invariant predictors*	$\alpha + \alpha_{participant}$ + 62% if biomass primary stove + 20% per 1 hour spent cooking with biomass − 26% if motorcycle household ownership + $\varepsilon_{session}$	1%	57%	0.70	0.50

Models based on personal exposure measurements previously adjusted for ambient factors (see methods). Time-invariant predictors collected at baseline questionnaire.

α and $\alpha_{participant}$ are overall and participant-specific random intercept, respectively. Estimates (β) are transformed to express percent change in personal exposure using 100*[exp(β)-1]. $R_{spearman}$ represents Spearman correlation coefficient between averaged measured and averaged predicted values *per* participant, among those with two measurements. RMSE represents root-mean-squared error between averaged measured and averaged predicted values *per* participant, among those with two measurements. R^2_{within} and $R^2_{between}$ represent the proportion of variance explained relative to the empty model. *Active smoking was used as reference category. † Ambient concentrations at residence were modeled by land-use regression (see methods).

Table 4. Cross-validation of the prediction models of personal exposure to $PM_{2.5}$ and black carbon using time-invariant only

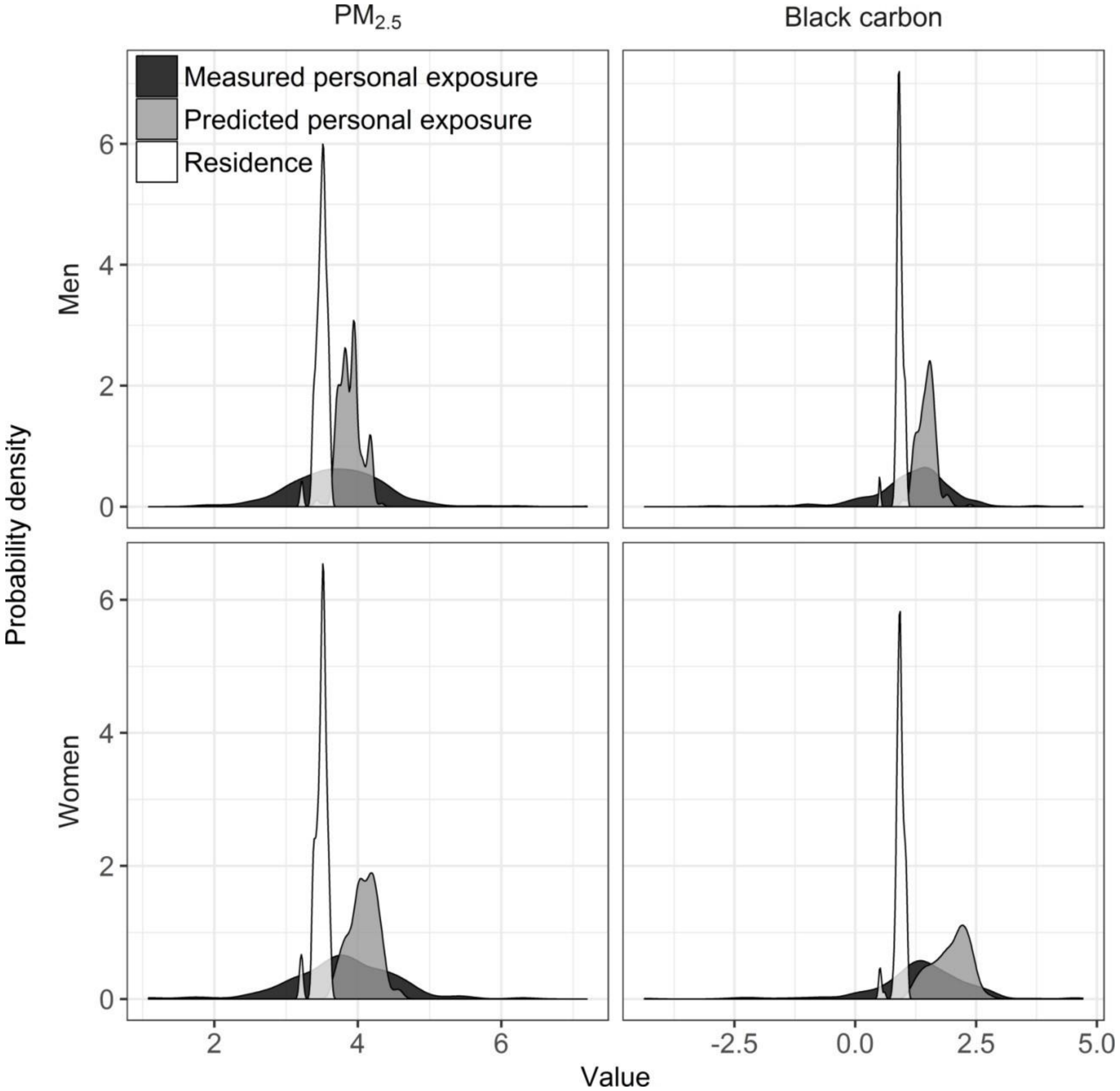
		10-fold cross-validation		10-fold cross-holdout validation		
		RMSE	**$R_{spearman}$**	**RMSE**	**$R_{spearman}$**	**Most-selected predictors (% of inclusion)**
Men	$PM_{2.5}$	0.45	0.24	0.47	0.14	Usual time cycling (80%), construction or industry job (70%), primary occupation skill level (60%), smoking status (40%)
	Black carbon	0.69	0.25	0.72	0.12	Ambient $PM_{2.5}$† at residence (50%), primary stove type (50%), office or shop job (40%)
Women	$PM_{2.5}$	0.55	0.33	0.59	0.12	Primary stove type (60%), ambient black carbon† at residence (40%), occupation of household head (40%), manual unskilled job (30%)
	Black carbon	0.73	0.43	0.75	0.39	Usual time cooking with biomass (60%), separate kitchen (50%)

Time-invariant predictors obtained from baseline questionnaire. $R_{spearman}$ represents Spearman correlation coefficient between averaged measured and averaged predicted values *per* participant. RMSE represents root-mean-squared error between averaged measured and averaged predicted values *per* participant. Only predictors included in ≥30% of the models are shown. †Ambient concentrations at residence were modeled by land-use regression (see methods).

Figure 1

Probability density of measured and predicted personal exposure and annual ambient concentration at residence in men and women

Values are natural log-transformed for clarity. Personal exposure predicted with model including time-invariant predictors. Annual ambient concentrations at residence estimated by previously developed land-use regression model.



Personal exposure to particulate matter in peri-urban India: predictors and association with ambient concentration at residence

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Supplementary Table S1. Variables used to develop the prediction models of personal exposure to $PM_{2.5}$ and black carbon

Category	Variable	Description
Individual	age	Age of the participant (continuous, from 18 to 75)
	education level	Education level of the participant: illiterate (ref), primary education, secondary education, or superior
	smoking status	Smoking status of the participant: active smoker (ref), passive smoker (i.e. non-smoker with active smoker in the household), or non-smoker
	N active smokes	Self-reported number of smokes per day, active smokers only (from 0 to 39)
	N passive smokes	Number of smokes per day by the active smoker(s) of the household, passive smokers only (from 0 to 44).
	primary occupation skill level	Skill level of the participant's primary occupation: non-manual (ref), skilled manual, unskilled manual, or unemployed.
	housework	Job type: housework (yes/no)
	unemployed	Job type: unemployed or retired (yes/no)
	agriculture	Job type: agriculture (yes/no)
	office or shop	Job type: office or shop (yes/no)
	transport	Job type: transportation (yes/no)
	student	Job type: student (yes/no)
	construction or industry	Job type: construction or industry (yes/no)
	manual unskilled	Job type: manual unskilled e.g., digging, loading, unloading (yes/no)
	craft	Job type: craft (yes/no)
Household	N people household	Number of people living in the participant's house, including the participant (from 1 to 12)
	N rooms	Number of rooms in the participant's house (from 1 to 12)
	household density	Population density in the participant's house (from 0.2 to 4)
	Clock ownership	Clock household ownership (yes/no)
	Television ownership	Television household ownership (yes/no)
	Bicycle ownership	Bicycle household ownership (yes/no)
	motorcycle ownership	Motorcycle household ownership (yes/no)
	refrigerator ownership	Refrigerator household ownership (yes/no)
	phone ownership	Phone household ownership (yes/no)
	household welfare indicator	Household welfare indicator, sum of owned items among clock, television, radio, refrigerator, bicycle, telephone, car, and motorcycle (from 0 to 8)
	toilet	Toilet facilities available for the household (yes/no).

Category	Variable	Description
	occupation household head	Skill level of the occupation of the household head: non-manual (ref), skilled manual, unskilled manual, or unemployed
	education household head	Education level of the head of the household: illiterate (ref), primary education, or secondary/superior education
Kitchen and cooking	usual time cooking with biomass	Usual time spent cooking with biomass (from 0 to 6 hours)
	separate kitchen	Having a separate kitchen (yes/no)
	house material	Material used in the construction of the house (kutcha, pucca, or semi-pucca)
	primary stove type	Stove type primary used for cooking in the household: clean (gas or electricity, ref) or biomass* (traditional Chula, coal stove, or kerosene)
	biomass still used	Biomass still used for cooking in the household (yes/no)
Usual time-activity	usual time in motorized vehicle	Usual time spent /day traveling to places on/in a motorized vehicle (from 0 to 10 hours)
	usual time cycling	Usual time spent /day cycling to places (from 0 to 6 hours)
	usual time walking	Usual time spent /day walking to places (from 0 to 5 hours)
	usual time working	Usual time spent /day at work (from 0 to 15 hours)
Ambient	ambient long-term $PM_{2.5}$	Residential estimates of ambient long-term $PM_{2.5}$ (continuous, obtained from land-use regression)
	ambient long-term black carbon	Residential estimates of ambient long-term black carbon (continuous, obtained from land-use regression)
During monitoring:	time near biomass (t)	Time spent near biomass burning (from 0 to 4.5 hours)
sources	time active smoking (t)	Time spent actively smoking (from 0 to 4 hours)
	N active smoking indoors (t)	Number of smokes taken indoors (from 0 to 20).
	time passive smoking (t)	Time spent near active smoker (from 0 to 10 hours)
	N passive smoking indoors (t)	Number of smokes that participant was exposed to (from 0 to 10)
	time in motorized vehicle(t)	Time spent in motorized vehicle (from 0 to 10 hours)
	time cycling near traffic (t)	Time spent cycling near traffic (from 0 to 2.5 hours)
	time walking near traffic(t)	Time spent walking near traffic (from 0 to 8 hours)
	time near outdoors fire (t)	Time spent outdoors near fire burning crop/rubbish (from 0 to 3 hours)
	time near construction (t)	Time spent near home or road construction (from 0 to 10 hours)
	near incense (t)	Being near incense (yes/no)
	near oil lamp (t)	Being near an oil lamp (yes/no)
	weekday (t)	Monitoring occurred Monday-Saturday or Sunday

Category	Variable	Description
During monitoring:	time cooking (t)	Time spent cooking (from 0 to 15 hours)
time-activity diary	time doing chores (t)	Time spent doing household chores (from 0 to 12 hours)
	time working (t)	Time spent working (from 0 to 21 hours)
	time traveling (t)	Time spent traveling to places (all modes) (from 0 to 10 hours)
	time sedentary activities (t)	Time spent in leisure or sedentary activities (from 0 to 18 hours)
	time sleeping (t)	Time spent sleeping (from 0 to 15 hours)
	time care (t)	Time spent on personal care (from 0 to 7 hours)
	time walking (t)	Time spent walking (from 0 to 13 hours)
	time at home (t)	Time spent indoor at home (from 0 to 24 hours)
	time indoor (t)	Time spent indoor (other than home) (from 0 to 20 hours)
	time in compound (t)	Time spent in house compound (from 0 to 19 hours)
	time outdoor (t)	Time spent outdoor in village (from 0 to 21 hours)
	time in fields (t)	Time spent outdoor in fields (from 0 to 21 hours)
	time at workplace (t)	Time spent at (indoor or outdoor) workplace (from 0 to 15 hours)

Time-varying variables are indicated by (t) and are derived from the post-monitoring questionnaires; other variables are time-invariant and are derived from the baseline questionnaire. Reference categories used in models are indicated by (ref). *As small proportion of the participants used kerosene for cooking, we refer to this category as “biomass”.

Supplementary Table S2. Between-participant variance component (% of total variance) in $PM_{2.5}$ and black carbon personal exposure according to sex and selected subgroups

		$PM_{2.5}$	Black carbon
Men (all)		**0.06 (18%)**	**0.13 (20%)**
Primary stove type	Clean	0.03 (13%)	0.10 (15%)
	Biomass	0.08 (20%)	0.13 (22%)
Separate kitchen	Yes	0.02 (8%)	0.05 (8%)
	No	0.19 (36%)	0.47 (56%)
Working in agriculture	Yes	0.03 (10%)	0.22 (33%)
	No	0.07 (21%)	0.03 (5%)
Working in industry	Yes	0.12 (21%)	0
	No	0.04 (15%)	0.17 (23%)
Smoking status	Active	0.18 (32%)	0.45 (46%)
Distance to Hyderabad ring road	< 8km	0.04 (20%)	0.09 (22%)
Women (all)		**0.10 (22%)**	**0.20 (21%)**
Primary stove type	Clean	0.10 (30%)	0.08 (9%)
	Biomass	0.08 (13%)	0.26 (29%)
Separate kitchen	Yes	0.05 (14%)	0.02 (2%)
	No	0.23 (39%)	0.64 (60%)
Working in agriculture	Yes	0.15 (34%)	0.32 (36%)
	No	0.02 (5%)	0.08 (8%)
Ventilation during cooking	Always	0.18 (31%)	0.32 (46%)
	Never, sometimes	0.06 (17%)	0.06 (7%)
Distance to Hyderabad ring road	< 8km	0.09 (26%)	0.08 (15%)

Considered personal exposure was adjusted for ambient concentrations (see methods). Figures are variance components (% of total variance, being intra-class correlation coefficient (ICC)).

Supplementary Figure S1-A

Comparison of rank quintiles of 48-hr average $PM_{2.5}$ personal exposure and annual ambient concentration of $PM_{2.5}$ at residence

Ambient-adjusted 48-hr average personal exposure was used. Annual concentrations at residence estimated by land-use regression. Only selected variables are presented.

Supplementary Figure S1-B

Comparison of rank quintiles of 48-hr average black carbon personal exposure and annual ambient concentration of black carbon at residence

Ambient-adjusted 48-hr average personal exposure was used. Annual concentrations at residence estimated by land-use regression. Only selected variables are presented.

Supplementary Table S3. Prediction models of personal exposure to $PM_{2.5}$ and black carbon using time-invariant and time-varying predictors

			Regression equation	R^2_{within}	$R^2_{between}$	RMSE	$R_{spearman}$
Men (n=367)		*Empty model*	$\alpha + \alpha_{participant} + \varepsilon_{session}$	(ref)	(ref)	-	-
	$PM_{2.5}$	*+ Time-invariant + time-varying predictors*	$\alpha + \alpha_{participant}$ – 21% if non smoking –24% if passive smoking + 30% if construction or industry job – 12% per 1 hour spent cycling + 16% if unemployed + 4% if skilled manual occupation + 30% if unskilled manual occupation + $\varepsilon_{session}$	0	53%	0.43	0.31
	Black carbon	*+ Time-invariant + time-varying predictors*	$\alpha + \alpha_{participant}$ + 36% if office or shop job + 4% per 1 µg/m^3 of annual ambient $PM_{2.5}$ at residence – 4% per 1 hour spent working (t) – 3% per 1 hour spent in sedentary activities (t) + $\varepsilon_{session}$	2%	10%	0.69	0.26
Women (n=220)		*Empty model*	$\alpha + \alpha_{participant} + \varepsilon_{session}$	(ref)	(ref)	-	-
	$PM_{2.5}$	*+ Time-invariant + time-varying predictors*	$\alpha + \alpha_{participant}$ + 32% per 1 hour spent near biomass (t) + 2% if unemployed household head + 21% if unskilled manual household head + 21% if biomass primary stove + $\varepsilon_{session}$	0	64%	0.51	0.47
	Black carbon	*+ Time-invariant + time-varying predictors*	$\alpha + \alpha_{participant}$ + 73% if biomass primary stove + 45% per 1 hour spent near biomass (t) + 26% per 1 hour spent in motorized vehicle (t) + $\varepsilon_{session}$	1%	67%	0.70	0.53

Models are based on personal exposure measurements previously adjusted for ambient concentrations (see methods). Time-invariant predictors were collected at baseline questionnaire. Time-varying predictors identified by (t) were collected in post-monitoring questionnaire. α and $\alpha_{participant}$ are overall and participant-specific random intercept, respectively. Estimates (β) are transformed to express percent change in personal exposure using 100*[exp(β)-1]. $R_{spearman}$ represents Spearman correlation coefficient between averaged measured and averaged predicted values *per* participant, among those with two measurements. RMSE represents root-mean-squared error between averaged measured and averaged predicted values *per* participant, among those with two measurements. R^2_{within} and $R^2_{between}$ represent the proportion of variance explained relative to the empty model.

Supplementary Table S4. Cross-validation of the prediction models of personal exposure to $PM_{2.5}$ and black carbon using time-invariant and time-varying predictors

		10-fold cross-validation		10-fold cross-holdout validation		
		RMSE	**$R_{spearman}$**	**RMSE**	**$R_{spearman}$**	**Most-selected predictors (% of inclusion)**
Men (n=367)	$PM_{2.5}$	0.45	0.24	0.47	0.13	Construction or industry job (80%), usual time cycling (80%), primary occupation skill level (60%), separate kitchen (30%), smoking status (30%), time walking (t) (30%)
	Black carbon	0.71	0.18	0.74	0.08	Time working (t) (60%), biomass still used (50%), near incense (t) (40%), ambient annual concentration of $PM_{2.5}$ at residence (40%), time traveling (t) (40%), time in motorized vehicle (t) (30%)
Women (n=220)	$PM_{2.5}$	0.53	0.38	0.56	0.26	Occupation of household head (70%), time in fields (t) (60%), primary stove type (30%)
	Black carbon	0.71	0.49	0.73	0.43	Time near biomass (t) (70%), time in motorized vehicle (t) (70%), motorcycle ownership (40%), primary stove type (30%), time walking (t) (30%)

Time-invariant predictors were collected at baseline questionnaire. Time-varying predictors identified by (t) were collected in post-monitoring questionnaire. $R_{spearman}$ represents Spearman correlation coefficient between averaged measured and averaged predicted values. RMSE represents root-mean-squared error between averaged measured and averaged predicted values. Only predictors included in ≥30% of the models are shown.

Supplementary Table S5. Within- and between-participant variance components for personal exposure from selected publications

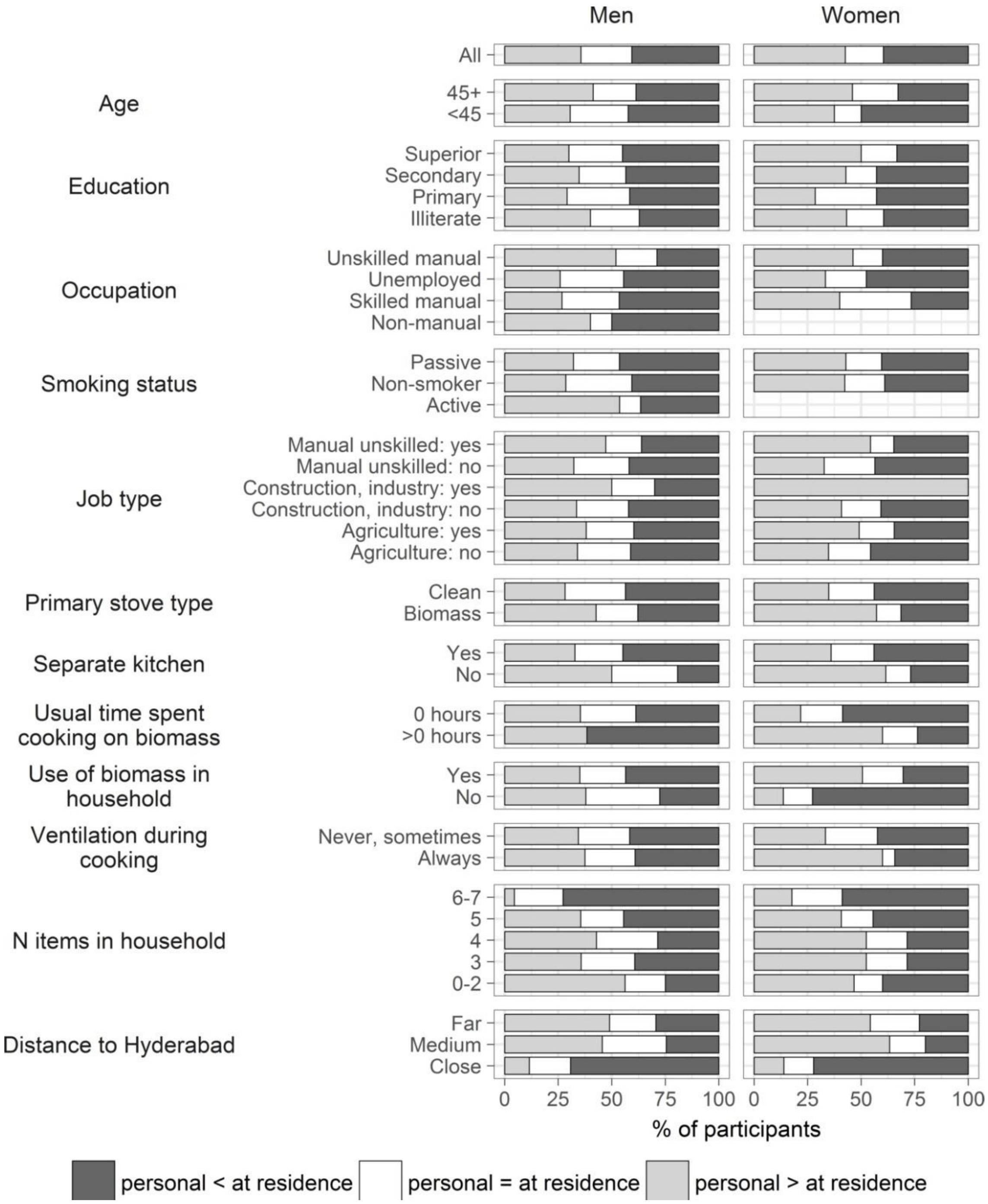
Reference	Population	Pollutant	Between-participant variance component (% of total variance i.e., ICC)
Present study	Adults in peri-urban South India	$PM_{2.5}$	Men: 0.06 (18%) Women: 0.10 (22%)
		Black carbon	Men: 0.13 (20%) Women: 0.20 (21%)
(Johannesson et al. 2007)	Adults in Sweden	$PM_{2.5}$	0.04 (16%)
(McCracken et al. 2009)	Children in Guatemala	CO	0.27 (33%)
		CO, open fire	0.20 (30%)
		CO, chimney	0.08 (11%)
(McCracken et al. 2013)	Adult women in Guatemala	CO	0.31 (29%)
(Lee, Bartell, and Paek 2004)	Adults in Korea	SO_2	0.26 (38%)
		NO_2	0.36 (45%)
(Nethery, Teschke, and Brauer 2008; Nethery et al. 2008)	Pregnant women in Vancouver, Canada	$PM_{2.2}$	0.06 (26%)
		PM Absorbance	0.02 (11%)
		NO_2	0.11 (55%)
(Sørensen et al. 2005)		Black smoke	0.08 (9%)
(Dionisio et al. 2012)	Children in The Gambia	CO	0.36 (39%)
(MacNeill et al. 2012)	Adults in Canada	Ambient personal $PM_{2.5}$	30-35%*
		Non-ambient personal $PM_{2.5}$	11-26%*
		Ambient indoor black carbon	40-63%*
		Non-ambient indoor black carbon	10-17%*
(Chen et al. 2018)	Adults in Hong Kong	$PM_{2.5}$	0.19 (54%)
		Elemental carbon	0.15 (52%)
		Organic carbon	0.12 (44%)

** Depending on the season. Abreviation: ICC: intraclass correlation coefficient.*

Supplementary Figure S1-A

Comparison of rank quintiles of 48-hr average $PM_{2.5}$ personal exposure and annual ambient concentration of $PM_{2.5}$ at residence

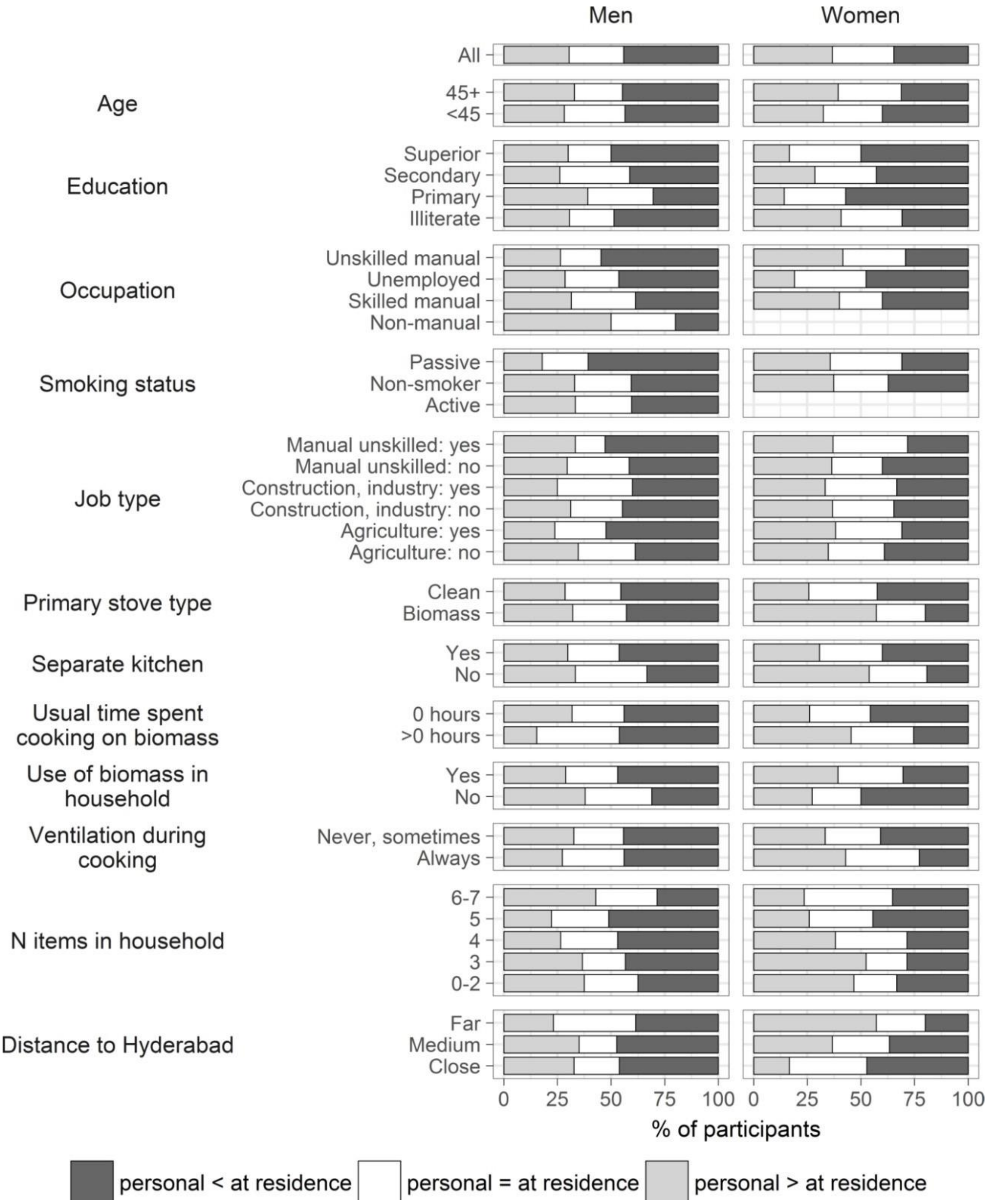
Ambient-adjusted 48-hr average personal exposure was used. Annual concentrations at residence estimated by land-use regression. Only selected variables are presented.



Supplementary Figure S1-B

Comparison of rank quintiles of 48-hr average black carbon personal exposure and annual ambient concentration of black carbon at residence

Ambient-adjusted 48-hr average personal exposure was used. Annual concentrations at residence estimated by land-use regression. Only selected variables are presented.



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BASELINE QUESTIONNAIRE

CHAI

Cardiovascular Health effects
of Air pollution in Telangana, India

	Now I would like to collect some personal information about you		
	Personal details		
3.1	Age last birthday	☐☐[In completed years]	
3.2	Day of birth	☐☐[DD]	
3.3	Month of birth	☐☐[MM]	
3.4	Year of birth	☐☐☐☐[YYYY]	
3.5	Sex	☐[1=Male; 2=Female]	
3.6	Current marital status	☐	1=Never married 2=Married 3=Widow/widower 4=Separated/divorced
	Primary occupation		
3.7	(a) Respondent:☐	(b) Spouse (if married):☐	
	1=At home doing housework 2=Unemployed, not seeking work: retired/ permanently disabled 3=Unemployed, seeking work	4= Student/ training 5=Unskilled manual 6=Semi-skilled manual 7=Skilled manual	8=Skilled non-manual 9=Semi-Professional 10=Professional
3.8	Briefly describe your primary job: ____		
3.9	For how long has this been your primary occupation? **If unemployed, length of unemployment*	☐☐years ☐☐months	

Skip 3.10 if Primary occupation in 3.7 is 1 or 2.				
3.10	Which types of work do you do throughout the year? [1=Yes]	Primary *Most of the year*	Secondary *At least 3mo/yr*	Tertiary *Less than 3 mo/yr*
	By agricultural work, I mean working in a field with fruit, vegetables, or flowers, preparing soil or planting, or working with animals used for food, wool or other products.			
	(a) Agricultural work on land you own or lease			
	(b) Agricultural work on land owned by someone else			
	(c) Cutting trees or wood			
	(d) Stone breaking			
	(e) Loading and unloading weights			
	(f) Construction			
	(g) Brick kiln			
	(h) Rice mill			
	(i) Toddy collector			
	(j) Restaurant worker			
	(k) Driver			
	(l) Office			
	(m) Shop keeper/ business person			
	(n) Teacher			
	(o) Domestic helper			
	(p) Student			
	(q) Prepare food for sale (Cart / at home)			
	(r) Street vendor (Goods / Produce)			
	(s) Tailoring			
	(t) Other industry (specify:___________________________)			
	(u) Other industry (specify:___________________________)			

	Highest educational level attained	
3.11	(a) Respondent: ☐	(b) Spouse (if married): ☐
	1=Illiterate 2=Literate, no formal education 3=Up to primary school (class IV)	4=Secondary school (ITI course, class X/XII, Intermediate) 5=Graduate (BA, BSc, BCom, Diploma) 6=Professional degree/postgraduate (MA, MSc, MBBS, MSW, BTech, PhD)

3.12	What is the monthly income of the household?	☐	1 = 0 – 999 INR 2= 1,000 – 2,999 INR 3= 3,000 – 14,999 INR 4= 15,000 – 99,000 INR 5= 1,00,000 and above

Now I am going to ask you some questions about your household

	Current household circumstances	
4.1	What kind of household do you currently live in?	☐
	1=Single 2=Hostel/shared accommodation 3=Nuclear family (married couple & offspring) 4=Extended family (2 related married couples of different generations i.e. married couple with one of the parents)	5=Joint family (two related married couples from same generation (i.e. two married siblings) 6=Joint-extended 7=Any other

4.2	Have you always lived in this house?	☐	1=Yes 2=No 9=Unknown/unspecified
4.3a	How long have you lived in this house?	☐☐years [00 if less than 1 year ; 99=Unknown]	
4.3b	Do you rent or own this house?	☐	1= Own 2= Rent
4.4 a	What kind of dwelling do you currently live in?	☐	1=Separate house 2=Shared wall with neighbour/ Apartment 3=Other (specify)_____________
4.4 b	Is the house surrounded by trees and plants?	☐	1 = Yes; 2= No 9= Unknown / unspecified
4.5	What type of location is your household?	☐	1=Residential 2=Commercial 3=Industrial 4=Other (specify) ____________________ 9=Unknown, unspecified

4.6	What is the primary source of lighting for your household?	☐	1=Electricity 2=Kerosene 3=Gas 4=Oil 5=Other
4.7	(a) Does your household ever use a diesel generator for electricity? **[If no, skip to 4.8]**	☐	1=Yes; 2=No
	If yes: (b) How often does your household use a diesel generator?	☐	1=5 or more times per month 2=3 to 4 times per month 3=less than once per month
4.8	(a)Where do you currently dispose of household garbage?	☐	1=Garbage bin 2=Open garbage in the neighbourhood 3=Open garbage inside the compound 4=Collection by vehicle 5=Other, Specify _________________ 9=Unknown/unspecified
	(b) How regularly does your household burn waste?	☐	1= Daily 2= Weekly 3= Monthly 4= Less than 12 times a year 5= Never 9= Unknown/unspecified
4.9	What is the main source of drinking water for members of your household?	☐	1=Pipe, hand pump, well (in residence/ plot) 2=Pipe, hand pump or well (public) 3= Mineral water 4=Other
4.10	What kind of toilet facility does the household have?	☐	1=Own flush toilet 2=Own pit toilet/latrine 3=No facility/field/bush 4=Other
4.11	Do you collect rations from a ration card?	☐	[1=Yes; 2=No]
4.12	a) How many hours per day do you typically **not** have electricity?		☐☐(hours)
	b) How many months out of the year do you typically have power-cuts?		☐☐(months)
	c) What do you use as alternate sources of lighting (when no electricity)?		
	1) Candles	☐	[1=Yes; 2=No]
	2) Kerosene Lamp	☐	[1=Yes; 2=No]
	3) Oil Lamp	☐	[1=Yes; 2=No]
	4) Battery Light/Emergency Light	☐	[1=Yes; 2=No]
	5) Inverter	☐	[1=Yes; 2=No]
	6) Other, specify____		

IF LIVING IN HOSTEL/SHARED ACCOMMODATION *SKIP QUESTIONS 4.14 - 4.17* [Responded 2 to Q 4.1]		
4.14	Including yourself, how many people normally live in your household?	☐☐ [Number of People]
4.15	How many rooms are there in your household? (count all rooms including kitchen, bathroom, etc)	☐☐ [Number of Rooms]
4.16	Does this household own any agricultural land?	☐ [1=Yes; 2=No]
4.17	**Does the household own any of the following WORKING:**	
	(a) Clock/Watch	☐ [1=Yes; 2=No]
	(b) Radio/Transistor/Tape recorder	☐ [1=Yes; 2=No]
	(c) Television	☐ [1=Yes; 2=No]
	(d) Bicycle	☐ [1=Yes; 2=No]
	(e) Motorcycle/scooter/moped	☐ [1=Yes; 2=No]
	(f) Car	☐ [1=Yes; 2=No]
	(g) Refrigerator	☐ [1=Yes; 2=No]
	(h) Telephone	☐ [1=Yes; 2=No]
	(i) Air conditioner	☐ [1=Yes; 2=No]
	(j) Inverter	☐ [1=Yes; 2=No]

	Now I will ask you a few questions about your lifestyle
	Lifestyle

		(i) Have you ever used tobacco on a REGULAR basis (atleast once a week)?		(ii)Age at starting	(iii) Duration of use	(iv) Number of days per week	(v) N of use or smoked per day	vi)Type of Product	
5.1	(a) Smoked	☐	1=Never 2=Former (stopped >6 months) 3=Current (in last 6 months)	☐☐[Yrs]	☐☐[Yrs]	☐[Days]	☐☐☐	☐	1= Cigarette 2=Beedi 3=Other
	(b) Chewed	☐	1=Never 2=Former (stopped >6 months) 3=Current (in last 6 months)	☐☐[Yrs]	☐☐[Yrs]	☐[Days]	☐☐☐	☐	1= Gutka 2= Khaini / Zarda 3= Pan masala
	(c) Snuffed	☐	1=Never 2=Former (stopped >6 months) 3=Current (in last 6 months)	☐☐[Yrs]	☐☐[Yrs]	☐[Days]	☐☐☐		

5.2	(a) Is there someone else in your household who smokes tobacco inside the house? **[If no, skip to 5.3]**	☐[1=Yes; 2=No]
	If yes, (b) How many cigarettes or bedis does this person smoke per day?	☐☐☐ bedis/cigarettes per day
5.3	(a) Has an indoor **<u>open fire</u>** with wood, crop residues or dung been used in your home as a primary means of cooking for more than 6 months in your life? **[If no, skip to 5.4]**	☐[1=Yes; 2=No]
	If yes, (b) For how many years has wood, crop residues or dung been used for cooking in your home?	☐☐[Years]
	(c) On average for how many hours a day have you personally spent cooking using wood, crop residues or dung?	☐☐ [Hours] [00 if none]
	(d) Is wood, crop residues or dung still used for cooking in your home?	☐[1=Yes; 2=No]
	If (d) is no, (e) When did your household stop using wood, crop residues or dung for cooking?	☐ 1=less than 1 year ago 2=1 to 3 years ago 3=4 to 6 years ago 4=more than 6 years ago
	(f)Is your stove or fire vented to the outside?	☐ [1=Yes; 2=No]
5.4	Would you describe your present alcohol intake as?	☐ 1=Daily/most days 2=Weekends only 3= 1-2 times/month 4=Special occasions 5=Never

	*Now I am going to ask you questions about the time you spent doing different types of activities. Please recall the activities that you did in the **LAST TYPICAL WEEK.*** *The first questions are about your work/college. This includes paid jobs, working in your farm, study/training, any volunteer work or college activities.* *Do not include unpaid work you might do around your home, like housework, garden work, and caring for your family.*
	Work related activity

6.1	Do you currently have a job or do any unpaid work or study/training outside the home?	☐[1=Yes; 2=No] **[IF NO, SKIP TO 6.6]**
6.2	How many days did you work at the job or unpaid work or study training in the last week?	☐[In completed days]
6.3	In the last week, how many hours per day did you spend at this?	☐☐.☐ [In completed half hours]

6.3	**Of the hours you spent at working/studying/training in a day during the last week I am going to ask you how many hours you spent in standing, sitting and walking (completed half hours):**		
	(a) **Standing:** E.g. talk, lab work, supervise, mild cleaning, cattle grazing done standing.	(b) **Sitting:** E.g. typing, computer work, cleaning grains, eating lunch, driving,studyingetc.	(c) **Walking**: E.g. walking around, strolling, walking with light loads
	☐☐.☐ [hours]	☐☐.☐ [hours]	☐☐.☐ [hours]

6.4	**Travel to and from work/college** *Now think about how you travelled to and from work or college over the LAST WEEK.*		
		(a) Days per week	(b) Total duration per day
	(a) During the last week, how many days did you travel on a motorised vehicle, like a car, bus, auto-rickshaw or motorcycle to and from?	☐ days	☐☐☐ [mins]
	(b) During the last week, on how many days did you cycle to and from?	☐ days	☐☐☐ [mins]
	(c) During the last week, on how many days did you walk to and from?	☐ days	☐☐☐ [mins]
	(d) What is the main destination you travelled to?	☐	1= Office / Shop 2=Field 3=Factory 4= College 5=Other, Specify ______________ 6=Not applicable

6.5	**Exposure from work/college** *Now think about how much time you are exposed to various sources of pollution during a TYPICAL WORK WEEK.*		
	Type of exposure	(a)1= Yes 2 = No	(b) Total duration per day
	(a)Road dust	☐	☐☐☐☐[mins]
	(b) Biomass fuel smoke	☐	☐☐☐☐[mins]
	(c) Kerosene fuel smoke	☐	☐☐☐☐[mins]
	(d) Brick kiln smoke	☐	☐☐☐☐[mins]
	(e) Rice mill dust	☐	☐☐☐☐[mins]
	(f) Vehicle emissions	☐	☐☐☐☐[mins]
	(g) Construction dust	☐	☐☐☐☐[mins]
	(h) Others, Specify ___________________	☐	☐☐☐☐[mins]
	(i) Others, Specify ___________________	☐	☐☐☐☐[mins]

6.6	**Travel apart from to and from work/college** *Now think about how you travelled from place to place over the LAST WEEK, including places like stores, movies, visiting relatives etc but excluding to and from work or college. Please do not include travelling activities you have already mentioned in the previous question about travel to and from work or college .*		
		(a) Days per week	(b) Total duration per day
	(a)During the last week, how many days did you travel to places on a motorised vehicle, like a car, bus, auto-rickshaw or motorcycle except to and from work?	☐days	☐☐☐[mins]
	(b) During the last week, on how many days did you travel to placeson a bicycle except to and from work?	☐days	☐☐☐[mins]
	(c) During the last week, on how many days did you travel to placesby walking except to and from work?	☐days	☐☐☐[mins]
	(d) What is the main destination you travelled to?	☐	1=Market 2=Relative /Friend home 3=Shopping 4= Restaurant 5= To city / town 6= Not applicable

SECTION Medical History

Now I am going to ask you questions about your family history of illness, and your medical history			
Medical history			
7.1	Is your father still alive?	(a) ☐ [1=Yes; 2=No]	(b) *If no, his* age at death ☐☐ [years]
7.2	(a) *If no*, what was the cause of his death?	☐ 1=Heart disease 2=high blood pressure 3=stroke 4=lung 5=cancer 6=accident/injury 7=old age 8=other 9 =Don't know	
	(b) If "other" specify:		
	Did/does your father suffer from any of the following?		
7.3	Diabetes / Sugar	☐[1=Yes; 2=No; 3=Don't know]	
7.4	High blood pressure	☐[1=Yes; 2=No; 3=Don't know]	
7.5	Heart disease	☐[1=Yes; 2=No; 3=Don't know]	
7.6	Overweight/obesity	☐[1=Yes; 2=No; 3=Don't know]	
7.7	Lung disease	☐[1=Yes; 2=No; 3=Don't know]	
7.8	Is your mother still alive?	(a) ☐ [1=Yes; 2=No]	(b) *If no,* herage at death ☐☐ [years]
7.9	(a) *If no*, what was the cause of her death?	☐ 1=Heart disease 2=high blood pressure 3=stroke 4=lung 5=cancer 6=accident/injury 7=old age 8=other 9 =Don't know	
	(b) If "other" specify:		
	Did/does your mother suffer from any of the following?		
7.10	Diabetes / Sugar	☐[1=Yes; 2=No; 3=Don't know]	
7.11	High blood pressure	☐[1=Yes; 2=No; 3=Don't know]	
7.12	Heart disease	☐[1=Yes; 2=No; 3=Don't know]	
7.13	Overweight/obesity	☐[1=Yes; 2=No; 3=Don't know]	
7.14	Lung disease	☐[1=Yes; 2=No; 3=Don't know]	
	Did/do any of your brothers or sisters suffer from any of the following?		
7.15	Diabetes / Sugar	☐[1=Yes; 2=No; 3=Don't know; 4=no brothers]	
7.16	High blood pressure	☐[1=Yes; 2=No; 3=Don't know; 4=no brothers]	
7.17	Heart disease	☐[1=Yes; 2=No; 3=Don't know; 4=no brothers]	
7.18	Overweight/obesity	☐[1=Yes; 2=No; 3=Don't know; 4=no brothers]	
7.19	Lung disease	☐[1=Yes; 2=No; 3=Don't know; 4=no brothers]	
Respiratory Health History			
8.1	(a) Have you had wheezing or whistling in your chest at any time in the last year?	☐[1=Yes; 2=No]	
	If yes, (b) In the last year have you had this wheezing or whistling only when you have a cold?	☐[1=Yes; 2=No]	

	(c) In the last year have you ever had an attack of wheezing or whistling that has made you feel short of breath?		☐[1=Yes; 2=No]
Now I am going to ask you questions about your illness, and your medical history			
9.1	(a) Have you been diagnosed with any of the following conditions?		(b) *If yes*, age when diagnosed
9.2	**High blood pressure**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) Are you on regular medication for your high blood pressure?		☐[1=Yes; 2=No]
	(d) Name of medicine:	____	
	(e) Who diagnosed condition	☐ [1=allopathic doctor; 2=homeopath; 3=ayurvedic doctor 4=RMP – registered medical practitioner; 5=Other]	
9.3	**Diabetes (high blood sugar)**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) Are you on a regular diet for your diabetes?		☐[1=Yes; 2=No]
	(d) Are you on regular tablets for your diabetes?		☐[1=Yes; 2=No]
	(e) Name of medicine:	____	
	(f) Are you on a regular treatment with insulin?		☐[1=Yes; 2=No]
	(g) Do you attend a hospital or GP diabetic clinic?		☐[1=Yes; 2=No]
	(h) Who diagnosed condition	☐[1=allopathic doctor; 2=homeopath; 3=ayurvedic doctor 4=RMP – registered medical practitioner; 5=Other]	
9.4	**Heart disease**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) Are you on regular medication for your heart disease?		☐[1=Yes; 2=No]
	(d) Name of medicine:	____	
	(e) Who diagnosed condition	☐[1=allopathic doctor; 2=homeopath; 3=ayurvedic doctor 4=RMP – registered medical practitioner; 5=Other]	
	(f) Type of heart disease	☐[1=angina; 2=heart attack; 3=heart failure 4=don’t know; 5=Other]	
9.5	**Stroke (paralytic attack)**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) Who diagnosed condition	☐[1=allopathic doctor; 2=homeopath; 3=ayurvedic doctor 4=RMP – registered medical practitioner; 5=Other]	
9.6	**Asthma, asthmatic bronchitis or allergic bronchitis?**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) Have you had an attack of asthma in the last year?		☐[1=Yes; 2=No]
	(d) *If you have asthma,* are you on regular medication for asthma? (tablets/inhaler)		☐[1=Yes; 2=No]
	(e) Name of medicine:		
	(f) Who diagnosed condition	☐[1=allopathic doctor; 2=homeopath; 3=ayurvedic doctor 4=RMP – registered medical practitioner; 5=Other]	
9.7	**Thyroid problem**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]

	(c) Are you on regular medication for your thyroid problem?		☐[1=Yes; 2=No]
	(d) Name of medicine:		
9.8	**Tuberculosis**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) Are you on regular medication for your tuberculosis?		☐[1=Yes; 2=No]
	Name of medicine:		
9.9	**Depression**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) Are you on regular medication for your depression?		☐[1=Yes; 2=No]
	Name of medicine:		
9.10	**Peptic ulcer**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
9.11	**Lung Disease - COPD**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
9.12	**Lung Disease - Emphysema**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
9.13	**Lung Disease - Chronic bronchitis**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
9.14	**Lung Disease – Unknown Type**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
9.15	**Cancer**	(a)☐[1=Yes; 2=No]	(b)☐☐ [Age in completed years]
	(c) *If yes,* what type of cancer:		

SECTION Kitchen and Bedroom - Observations and Measurements

We are going to take some details and measurements of where cooking takes place.

Kitchen Type	**Types of stoves**		**Primary Cook**	
1= Indoor with partition (Kitchen & Living same) 2= Indoor without partition (Kitchen & Living same) 3= Separate Kitchen attached – Share wall with home 4= Separate Kitchen detached 5= Outdoor cooking - 2 or less surfaces excluding floor	1=Traditional Chula – Single Pot 2=Traditional Chula – Double Pot 3=Three stone fire 4=Coal stove 5=kerosene stove-Wick	6=LPG-Stove 7=Electricity 8=Biogas 9=Other	1=Self 2=Mother/Mother-in-law 3=Wife/Partner	4=Sister/Sister-in-law 5=Daughter/Daughter-in-law 6=Other

		Kitchen #	1	2	3
10.1	**Kitchen Type (choose options from the above)**		☐	☐	☐
10.2	Number of stoves present in this kitchen		☐	☐	☐
10.3	**Stove #1**	a)**Stove Type (Choose options from the above)**	☐	☐	☐
		b) Is this a Primary or Secondary Stove? [1= Primary 2 = Secondary]	☐	☐	☐
		c) Who is the **primary cook** on this stove?**(Choose options from the above)**	☐	☐	☐
		d) Do you participate in cooking on this stove or are you present while cooking is taking place? [1 = Yes, 2= No, 9= Unknown / unspecified]	☐	☐	☐
		e) If yes, Number of minutes spent per day on each stove?	☐☐☐	☐☐☐	☐☐☐
10.4	**Stove #2**	a)**Stove Type (Choose options from the above)**	☐	☐	☐
		b) Is this a Primary or Secondary Stove? [1= Primary 2 = Secondary]	☐	☐	☐
		c) Who is the **primary cook** on this stove?**(Choose options from the above)**	☐	☐	☐
		d) Do you participate in cooking on this stove or are you present while cooking is taking place? [1 = Yes, 2= No, 9= Unknown / unspecified]	☐	☐	☐
		e) If yes, Number of minutes spent per day on each stove?	☐☐☐	☐☐☐	☐☐☐
10.5	**Stove #3**	a)**Stove Type (Choose options from the above)**	☐	☐	☐
		b) Is this a Primary or Secondary Stove? [1= Primary 2 = Secondary]	☐	☐	☐
		c) Who is the **primary cook** on this stove?**(Choose options from the above)**	☐	☐	☐
		d) Do you participate in cooking on this stove or are you present while cooking is taking place? [1 = Yes, 2= No, 9= Unknown / unspecified]	☐	☐	☐
		e) If yes, Number of minutes spent per day on each stove?	☐☐☐	☐☐☐	☐☐☐

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Now we are going to look at the doors and windows present in each kitchen and will take measurements

	Kitchen #		1	2	3
10.6	Number of walls in the kitchen (Count as wall if over 1 meter high)		☐	☐	☐
10.7	Does this kitchen have a roof [1=Yes; 2=No]		☐	☐	☐
10.8	a) Number of i) doors and ii) doors with perforated ventilations / screens		i)☐ ii) ☐	i)☐ ii) ☐	i)☐ ii) ☐
	b) Number of i) windows and ii) windows with perforated ventilations / screens		i)☐ ii) ☐	i)☐ ii) ☐	i)☐ ii) ☐
10.9.1	**Door#1**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
10.9.2	**Door#2**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
10.9.3	**Door#3**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
10.9.4	**Door#4**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm

	Kitchen #		1	2	3
10.10.1	**Window#1**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
10.10.2	**Window#2**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
10.10.3	**Window#3**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
10.10.4	**Window#4**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
10.10.5	**Window#5**	a) open during cooking ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		b) open during night ?[1=Never; 2=Sometimes; 3=Always / Permanently open]	☐	☐	☐
		c)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm

	Kitchen #		1	2	3
10.11.1	**perforated ventilation / screen#1**	a)Length	cm	cm	cm
		b)Width	cm	cm	cm
10.11.2	**perforated ventilation / screen#2**	a)Length	cm	cm	cm
		b)Width	cm	cm	cm
10.11.3	**perforated ventilation / screen#3**	a)Length	cm	cm	cm
		b)Width	cm	cm	cm
10.12	Is there a gap between the wall and roof inside the cooking area? [1=Yes; 2=No]				
10.13	Is any fan used in the kitchen at the time of cooking? [1=Yes; 2=No]				

Now I am going to ask you about the materials used in constructing the kitchen and sleeping area (bedroom)

Materials					
Primary wall material		**Roof material**		**Floor material**	
1 = Brick and cement 2= Brick and Clay 3= Brick and Cement and Clay 4 =Clay 5 = Coconut leaves 6 =Mud	7= Stone +Mud+ Bricks 8=Grass/ Thatch/ Bamboo/ Wood 9 =Plastic/ Polythene 10=Tiles/ Slate 11= Asbestos/GI metal sheet 12= Others	1 = Concrete 2=Earthen tiles 3=Coconut leaves 4= Palm leaves 5= Asbestos 6= Straw Hut	7= Grass/ Thatch/ Bamboo/ Wood 8= Plastic/ Polythene 9= Tiles/Slate 10= GI metal sheet 11= Others	1= Kadapa Stones 2=Cement 3=Mud 4=Half mud half Cement	5= Clay and Dung 6= Cement and Brick 7= Mosaic/ Marble/ vitrified/ Cement 8= Others

Use the appropriate codes from the above.

	Kitchen #		**1**	**2**	**3**
10.14	Kitchen	a)Primary wall material	☐	☐	☐
		b)Roof material	☐	☐	☐
		c)Floor material	☐	☐	☐
10.15	Kitchen Measurements	a)Length	☐☐☐cm	☐☐☐cm	☐☐☐cm
		b)Width	☐☐☐cm	☐☐☐cm	☐☐☐cm
		c)Height 1	☐☐☐cm	☐☐☐cm	☐☐☐cm
		d)Height-2	☐☐☐cm	☐☐☐cm	☐☐☐cm

11.1	Bedroom / Sleeping Area(record the primary material)			a) Wall material	☐
				b) Roof material	☐
				c) Floor material	☐
11.2	Measurements of sleeping room	a) Length	☐☐☐cm	c) Height-1	☐☐☐cm
		b) Width	☐☐☐cm	d) Height-2	☐☐☐cm

Ventilation in the sleeping room

11.3	Is there a gap between the wall and roof inside the sleeping area? [1=Yes; 2=No]		☐
11.4	Number of Bedroom walls		☐
11.5	Number of close-able door(s)		☐
11.6	Number of permanently open door(s)/opening		☐
11.7	Number of window(s) with close-able door(s)		☐
11.8	Number of Window(s) without door(s)		☐
11.9	a)Number of Perforated Ventilation / Mesh - Doors		☐
	b)Number of Perforated Ventilation / Mesh -Windows		☐
11.10.1	Door #1	a)Type of Door [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐
		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.10.2	Door #2	a)Type of Door [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐
		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.10.3	Door #3	a)Type of Door [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐
		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.10.4	Door #4	a)Type of Door [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐
		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.11.1	Window#1	a)Type of Window [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐

		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.11.2	Window#2	a)Type of Window [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐
		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.11.3	Window#3	a)Type of Window [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐
		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.11.4	Window#4	a)Type of Window [1=Closable2=Permanently open 3=Perforated Ventilation/ Mesh]	☐
		b)Length	☐☐☐cm
		c)Width	☐☐☐cm
11.12.1	perforated ventilation / screen#1	a)Length	☐☐☐cm
		b)Width	☐☐☐cm
11.12.2	perforated ventilation / screen#2	a)Length	☐☐☐cm
		b)Width	☐☐☐cm
11.12.3	perforated ventilation / screen#3	a)Length	☐☐☐cm
		b)Width	☐☐☐cm

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Now I'm going to ask you about the fuels used with various types of stoves used

12	**If use traditional stove:** What type of cooking fuel is commonly used in your home? [1=Yes; 2=No; 9=Unknown]			
	a) Shrubs/Twigs	☐	d) Coconut shells or branches	☐
	b) Wood	☐	e) Crop waste / leaves	☐
	c) Dung cakes	☐	f) Others (Specify)	________________
	g) How many days do you cook with biomass in a month?		☐☐99=Unknown	
	h) Do you still cook on traditional stove when it rains	☐	1=Yes, do not change location 2=Yes, Change location 3=No	
	i)If No, type of stove(s) used instead of traditional stove		1) ☐ 2) ☐	
	4=Coal stove 5=kerosene stove-Wick 6=LPG-Stove	7=Electricity 8=Biogas 9=Other		
	j) Describe the items prepared using this stove : ____			
13	**If use LPG stove:**			
	a) How many days do you cook with LPG in a month?		☐☐99=Unknown	
	b) How long have you been using LPG?	☐☐ (years; 99=Unknown)		
	c) What fuel were you using before LPG? [1=Yes; 2=No; 9=Unknown]			
	1) Shrubs/Twigs	☐	6) Dung cakes	☐
	2) Wood	☐	7) Kerosene	☐
	3) Coconut branches/ shells	☐	8) Biogas	☐
	4) Crop waste / leaves	☐	9) Other ,Specify	____________________
	5) Electricity	☐	10) Other, Specify	____________________
	d) Describe the items prepared using this stove : ____			
14	How much **kerosene** do you use?			
	a) Kerosene provided by ration dealer	☐☐(litres /month)		
	b) Kerosene purchased from retail shop	☐☐ (litres /month)		
	c) How many days do you use kerosene for cooking in your house in a month?		☐☐days/ month	
	d) Describe the items prepared using this stove : ____			
15	**If use Electric Stove:**			
	a) How many days do you cook with electricity in a month?		☐☐99=Unknown	
	b) How long have you been using electricity?		☐☐ (years; 99=Unknown)	
	c) Describe the items prepared using this stove: ____			

POST MONITORING QUESTIONNAIRE

CHAI

Cardiovascular Health effects
of Air pollution in Telangana, India

PART 1: PERSONAL MONITORING EQUIPMENT LOG - NIN

1.0	**Village ID:**		**1.1**	**Participant ID:**		**1.2**	**Pre-Monsoon = 1** **Post-Monsoon = 2**	☐	**1.3**	**Sample Number:**

2.1	**a)Interviewer 1 Code:** ☐☐ **b) Initials:** ☐☐☐	**2.2**	**a) Interviewer 2 Code:** ☐☐ **b) Initials:** ☐☐☐

3.0	**Sampling** **Date & Time:** dd/mm/yy | hh:mm	**a) MONITORING START** ☐☐/☐☐/☐☐☐☐ |☐☐:☐☐	**b) MONITORING END** ☐☐/☐☐/☐☐☐☐| ☐☐:☐☐

4.0	**a) Accelerometer ID:**	**b) Accelerometer In-field Remarks:**	
	Accelerometer Download	**c)Completed by:**______________________	**d)Date:** ___ ___ / ___ ___ / ___ ___ **(dd/mm/yy)**
	e) Accelerometer Download Remarks:		
5.0	**a) Autographer ID:**	**b) Autographer In-field Remarks:**	
	Autographer Download	**c)Completed by:**______________________	**d)Date:** ___ ___ / ___ ___ / ___ ___ **(dd/mm/yy)**
	e) Autographer Download Remarks:		
6.0	**a) GPS ID:**	**b) GPS In-field Remarks:**	
	GPS Download	**c)Completed by:**______________________	**d)Date:** ___ ___ / ___ ___ / ___ ___ **(dd/mm/yy)**
	e) GPS Download Remarks:		

Participant ID: ☐

PART 2: FUEL USE MONITORING

I'm going to measure all the cooking fuels which may be used during the monitoring period. I would like to measure them now, before the monitoring period and 24 hours later, after the monitoring period. Please try to avoid using any fuels during the monitoring period other than those we measured. Now, please set aside all the fuels that you may use (may be more than you might need).

<table>
<tr><td rowspan="2">1</td><td colspan="4">What are the types of cooking fuels used in your home?
(Record all types of cooking fuel that could be used during the monitoring period)</td></tr>
<tr><td colspan="2">1= Shrubs/Twigs
2=Wood
3=Dung cakes</td><td>4=Coconut shells / branches
5=Crop waste/leaves
6=LPG</td><td>7= Kerosene stove-Wick
8= Coal
9= Other</td></tr>
<tr><td>Sl.No</td><td>a)Fuel</td><td>b) Type
Primary = 1; Secondary = 2</td><td>c) Initial Weight</td><td>d) Final Weight</td></tr>
<tr><td>1.1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1.2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1.3</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1.4</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1.5</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1.6</td><td></td><td></td><td></td><td></td></tr>
</table>

PART 3: POST-MONITORING QUESTIONNAIRE
SECTION A. COOKING ACTIVITIES

I am going to ask you some questions about cooking that occurred <u>over the monitoring period.</u>								
2	During the monitoring period did you cook or were you near the stove during any of the cooking?					☐	1=Yes 2=No	
3	**a) Type of stove used for cooking**	**b&c) Fuels used**	**d&e) Who cooked on the stove?**	**f) Location of Stove**	**g) Number of Windows Open**	**h) Number of Doors Open**	**i) Total cooking time**	**j) Time spent near stove**
	1=Traditional Chula – Single Pot 2=Traditional Chula – Double Pot 3=Three stone fire 4=Coal stove 5=Kerosene stove-Wick 6=LPG-Stove 7=Electricity 8=Biogas 9=Other	1= Shrubs/Twigs 2=Wood 3=Dung cakes 4=Coconut shells / branches 5=Kerosene 6=LPG- 7=Electricity 8=Biogas 9= Coal 10=Crop waste/leaves 11= Other	1= Self 2=Mother/Mother-in-law 3=Spouse 4=Sister/Sister-in-law 5=Daughter/Daughter-in-law 6= Other	1= Indoor with partition (Kitchen & Living same) 2= Indoor without partition (Kitchen & Living same) 3= Separate Kitchen attached 4= Separate Kitchen detached 5= Outdoor cooking (2 or less surfaces excluding the floor)	Count permanently open and openable windows that were open in cooking area during cooking	Count permanently open and openable doors that were open in cooking area during cooking	Total number of minutes stove was in use during monitoring period.	Total number of minutes participant in front of / in same room as stove type 2a
3.1	☐	**b)** ☐ **c)** ☐	**d)** ☐ **e)** ☐	☐	☐	☐	☐☐☐	☐☐☐
3.2	☐	**b)** ☐ **c)** ☐	**d)** ☐ **e)** ☐	☐	☐	☐	☐☐☐	☐☐☐
3.3	☐	**b)** ☐ **c)** ☐	**d)** ☐ **e)** ☐	☐	☐	☐	☐☐☐	☐☐☐
3.4	☐	**b)** ☐ **c)** ☐	**d)** ☐ **e)** ☐	☐	☐	☐	☐☐☐	☐☐☐

SECTION B. OTHER SOURCES OF INDOOR AIR POLLUTION

Now, I would like to ask you if you used other items that could cause exposure air pollution during the monitoring period.						
4	**Were any of the following used while you were present?**					
No.	**Source**	**Used:** 1 = Yes 2= No 9= Unknown	**Location:** 1= Indoor with partition (Kitchen & Living same) 2= Indoor without partition (Kitchen & Living same) 3= Separate Kitchen attached 4= Separate Kitchen detached 5= Living Room 6= Bedroom 7= Outdoor near Household	**Number Used**	**Duration in AM**	**Duration in PM**
4.1	**Kerosene Lamp**	☐	a) Location 1 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			b) Location 2 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			c) Location 3 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
4.2	**Incense**	☐	a) Location 1 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			b) Location 2 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			c) Location 3 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
4.3	**Camphor**	☐	a) Location 1 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			b) Location 2 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			c) Location 3 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
4.4	**Sambrani dhoop**	☐	a) Location 1 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			b) Location 2 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)
			c) Location 3 ☐	1) ☐☐ (#)	2) ☐☐☐ (min)	3) ☐☐☐ (min)

SECTION B. OTHER SOURCES OF INDOOR AIR POLLUTION CONTINUED

No.	Source	Used: 1 = Yes 2= No 9= Unknown	Location: 1= Indoor with Kitchen & Living partition 2= Indoor without Kitchen & Living partition 3= Separate Kitchen attached 4= Separate Kitchen detached 5= Living Room 6= Bedroom 7= Outdoor near Household	1) Number Used	2) Duration in AM	3) Duration in PM
4.5	Mosquito Coil	☐	a) Location 1 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			b) Location 2 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			c) Location 3 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
4.6	Liquid Mosquito Repellent	☐	a) Location 1 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			b) Location 2 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			c) Location 3 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
4.7	Oil Lamp (Divine)	☐	a) Location 1 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			b) Location 2 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			c) Location 3 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
4.8	Candle	☐	a) Location 1 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			b) Location 2 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			c) Location 3 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
4.9	Active smoking cigarettes or bedis	☐	a) Location 1 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			b) Location 2 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			c) Location 3 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
4.10	Passive smoking cigarettes or bedis	☐	a) Location 1 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			b) Location 2 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)
			c) Location 3 ☐	☐☐ (#)	☐☐☐ (min)	☐☐☐ (min)

SECTION B. ACTIVITY-BASED SOURCES OF AIR POLLUTION CONTINUED

Now I am going to ask you questions about the time you spent doing different types of activity. Please recall the activities that you did ***during the monitoring period.***			
	During the monitoring period….	**(i) Duration Outside of Work**	**(ii) Duration at Workplace**
5.1	Were you near (within 20m) a fire burning crop waste?	☐☐☐[mins]	☐☐☐[mins]
5.2	Were you near (within 10m) a fire burning rubbish?	☐☐☐[mins]	☐☐☐[mins]
5.3	Were you near (within 10m) home or road construction?	☐☐☐[mins]	☐☐☐[mins]
5.4	Were you near (within 10m) a brick kiln / rice mill /flour mill?	☐☐☐[mins]	☐☐☐[mins]
5.5	Were you in a motorised vehicle: car, bus, auto-rickshaw or motorcycle with open windows on unpaved roads or in traffic?	☐☐☐[mins]	☐☐☐[mins]
5.6	Were you cycling on unpaved roads or in traffic along with motorised vehicles?	☐☐☐[mins]	☐☐☐[mins]
5.7	Were you walking on unpaved roads or in traffic along with motorised vehicles?	☐☐☐[mins]	☐☐☐[mins]
5.8	Did you smoke cigarettes or bedis outdoors?	☐☐☐[mins]	☐☐☐[mins]
5.9	Was someone smoking around you outdoors?	☐☐☐[mins]	☐☐☐[mins]
5.10	Not wearing the monitoring equipment? (not counting sleeping time)	☐☐☐[mins]	☐☐☐[mins]
5.11	Was a generator used to provide electricity?	☐☐☐[mins]	☐☐☐[mins]
5.12	Outside of home kerosene/biomass fuel smoke	☐☐☐[mins]	☐☐☐[mins]
5.13	Other source of air pollution (Dust, charcoal smoke, etc…): ______________________________	☐☐☐[mins]	☐☐☐[mins]

6.0	a) Did the participant sleep in the measured bed room? [1=Yes; 2=No]	☐
	b) If no, where did the participant sleep? 1 = Outside, next to the road; 2 = On the terrace; 3 = outside in the compound; 4 = Other indoor room; 5 = on the roof	☐

SECTION C. Time-activity survey

Activity codes:		**Location codes:**	
1. Cooking 2. Household chores 3. Work 4. Study 5. Playing 6. Travel	7. Leisure/Sedentary 8. Sleep 9. Personal Care (bath, dressing, etc) 10. Exercise 11. Walking 12.Others (Specify)__________	1. Indoor - Home 2. Indoor - Classroom/Office/Shop 3. Playground / Complex / Compound 4. Outdoor in Village 5. Outdoor in Fields	6. Workplace 7. Travel – Vehicle with closed windows 8. Travel – All other modes of transportation

7.0	a)	b)	c)	d)	e)	f)	g)	h)	i)	j)
Hour	**4-5 AM**	**5-6 AM**	**6-7 AM**	**7-8 AM**	**8-9 AM**	**9-10 AM**	**10-11 AM**	**11-12 AM**	**12-1 PM**	**1-2 PM**
Activity										
Location										
Time (min) without monitoring bag										
	k)	l)	m)	n)	o)	p)	q)	r)	s)	t)
Hour	**2-3 PM**	**3-4 PM**	**4-5 PM**	**5-6 PM**	**6-7 PM**	**7-8 PM**	**8-9 PM**	**9-10 PM**	**10-11 PM**	**11 PM - 4 AM**
Activity										
Location										
Time (min) without monitoring bag										

SECTION D. Weather during monitoring period

Now I am going to ask you about the weather changes that might have happened ***during the monitoring period.***			
8	Was the weather constant during the monitoring period?	☐	1 = Yes; 2 = No
9	Please describe the weather throughout the monitoring period and any weather changes with approximate time of change:		

SECTION E. Observations of monitoring period

10	Other observations by participant or interviewer regarding monitoring period.
a) Day 1:	
b) Day 2:	

SECTION F. Reimbursement

11.1	**Reimbursement given**	☐	1 = Yes 2= No
11.2	If No, Specify reason:		

PART 4: AIR SAMPLING EQUIPMENT LOG – SRU

1.0	**Village ID:**		**1.1**	**Participant ID:**		**1.2**	**Pre-Monsoon = 1** **Post-Monsoon = 2**	□	**1.3**	**Sample Number:**		**1.4**	**a) Interviewer 1 Code:**	□□	**b) Interviewer 1 Initials:**	□□□

2.0	**Sampling:**	**a) MONITORING START**	**b) MONITORING END**
	Date & Time: dd/mm/yy | hh:mm	□□/□□/□□□□ |□□:□□	□□/□□/□□□□| □□:□□

3.0	**a)SKC Pump ID:**		**b)Emfab Sample Filter ID:**		**c) Cyclone ID:**		**d) Emfab Field Blank Filter ID:**	
	e) SKC Pump In-Field Remarks							

4.0	**a)MicroPEM ID**		**b)Teflo Sample Filter ID:**		**c)Teflo Field Blank Filter ID:**		-	-
	d) MicroPEM In-Field Remarks							
	e) MicroPEM Download	**f)Interviewer 1 Code:**	□□	**g) Interviewer 1 Initials:**	□□□	**h)Date: ___ ___ / ___ ___ / ___ ___ (dd/mm/yy)**		
	e) MicroPEM Download Remarks	**Note Sample Duration, Battery Life, any issues in connection and successful save/upload.**						