Low-cost temperature loggers as stove use monitors (SUMs)

Authors

Ilse Ruiz-Mercado[1,2], Nick L. Lam[3], Eduardo Canuz[4], Gilberto Davila[4], Kirk R. Smith[5]

[1]Systems Program, Civil and Environmental Engineering, University of California Berkeley, CA 94720-1710, USA.
[2]Envionmental Health Sciences, School of Public Health, University of California Berkeley, CA 94720-7360, USA. Email: ilse@berkeley.edu
[3]Envionmental Health Sciences, School of Public Health, University of California Berkeley, CA 94720-7360, USA. Email: nllam@berkeley.edu
[4]Centro de Estudios en Salud, Universidad del Valle de Guatemala, 01015, Guatemala. Email: ecanuz@gt.cdc.gov
[5]Envionmental Health Sciences, School of Public Health, University of California Berkeley, CA 94720-7360, USA. Email: krksmith@berkeley.edu

Accurately determining stove use is important in assessing the impacts and dissemination dynamics of improved stoves programmes. It is also a key component in the calculation of emission reductions for trading carbon offsets, understanding changes in fuel use and estimating impacts on indoor air quality. This article outlines the use of small, rugged, commercially available temperature dataloggers as stove use monitors (SUMs). Monitoring results are presented of the first weeks of use of 40 newly built and 10 5-year old improved chimney wood-fired cook stoves in the CRECER project area in the Guatemalan highlands. A gradual increase with time was found in the number of hours that new stoves were used, almost equal to that of the old stove group by the third week of use. When coupled with carbon monoxide monitors placed in a sub group of kitchens, it is shown that some households continue to use their open fire for a number of weeks. This off the shelf technology promises to be of great use to groups interested in the standardisation of methods to quantify carbon emission reductions and other changes due to improved stoves, for evaluating dissemination strategies and for behavioural research.

There is a need for new methods to systematically collect stove use data in order to reduce the reliance on household surveys, which are often resource intensive, rely on householder memory and are subject to bias. In addition, there has not previously been a method to determine the details of use by meal, time, food type etc other than having a permanent presence in the kitchen, which is extremely resource-intensive and disrupts normal household behaviour. This article outlines the use of simple electronic temperature dataloggers that can provide reliable estimates of stove use so avoiding the need for survey information. Because they give precise and unbiased measurements of a simple physical parameter, statistically reliable information is provided using smaller sample sizes than are required for a household survey.

SUMs: stove use monitors

The use of temperature loggers as SUMs underwent pilot testing as part of the CRECER (Chronic Respiratory Effects of Early Childhood Exposure to Particulate Matter) chimney-stove intervention trial in the Guatemalan highlands (CRECER 2008, RESPIRE 2008). The work took place in an area of about 23 villages comprising principally an indigenous (Mayan) population, all initially using wood for cooking in open indoor fires. As part of the studies, selected households were provided with an improved chimney cookstove called the *Plancha*. This report details the period of weeks after the households started to use their *Plancha* stoves.

Thermochron iButtons® were used as SUMs, each costing about $20 and the size of a coin cell battery (about 1.5 cm in diameter, see Figure 1A). These stainless steel sensors record time/date and temperature with 1°C accuracy up to 85°C. Communication with the monitors is by momentary contact with a special probe, and programming and downloading of the data can be easily done in the field with a PDA or laptop computer (Figure 1B). The SUMs store up to 2048 readings, which can be programmed to be recorded at different rates from 1 minute to 4.25 hours. The SUMs' battery life is likely to exceed 1 year in stove monitoring conditions if kept within the manufacturers specifications, after which the whole unit must be replaced as the battery cannot be changed. They are easy to use, unobtrusive, waterproof, and tamper resistant.

Figure 1. *The temperature logger used as SUMs in this study (A), downloading SUMs data after deployment with a PDA and field readout interface (B), SUMs placed in the back of the Plancha stove surface (C) (Photos: I. Ruiz-Mercado)*


Figure 1A


Figure 1B


Figure 1C

Pilot study

The SUMs were programmed to store temperature readings every 20 minutes on a total of fifty *Plancha* stoves, comprising of 40 newly built and 10 older stoves that had been in use for 4-6 years. In the new stoves the SUMs were installed during the final drying phase of construction, when the householders had been warned not to use their stoves. Thus, the monitoring period included the very first usage of each new stove.

Among recipients of the new stoves, 86% had attended hands-on workshops on proper stove use, maintenance and the health effects of indoor air pollution. The SUMs were placed on the tile surface in the back of the stove, near to the chimney base (Figure 1C). This location is the least obtrusive, and the maximum temperatures reached at that location did not compromise the lifetime of the devices. The SUMs stopped recording when their memories were full (approximately 4 weeks) and were downloaded to a PDA in the field within a few days. In a sub sample of households, a HOBO datalogging carbon monoxide (CO) monitor was placed on the wall of the kitchen, using protocols developed for other University of California Berkeley projects.

Results

Figure 2 shows a typical plot of one day's cooking on the *Plancha* stove. Note that three separate meals can be discerned.

Patterns of use

Figure 3 shows the pattern over several days in a kitchen with both a new *Plancha* and a CO monitor. Note the high CO levels through Sunday due to the use of the open fire in the kitchen. The small variations in minimum stove temperature reflect the daily changes in ambient temperature in this highland location. On Monday and Tuesday, the family began using their *Plancha*, as shown by the much higher than ambient temperature. However, they apparently continued to use their open cookfire, as evidenced by the CO readings. By Wednesday households seemed to be using only the *Plancha*, as indicated by the small amount of CO in the kitchen, due to the majority of smoke being vented through the chimney. The pattern and timing of fuel use and meals can also be ascertained by the temperature profile.

Pace of adoption

In order to combine data across households for comparison, "stove use" is defined as the total time that the stove temperature is above 30°C. This seemed an appropriate threshold at this highland location to isolate diurnal patterns and temperature increases due to other sources of heat in the room from the temperature increase due to combustion in the stove itself.

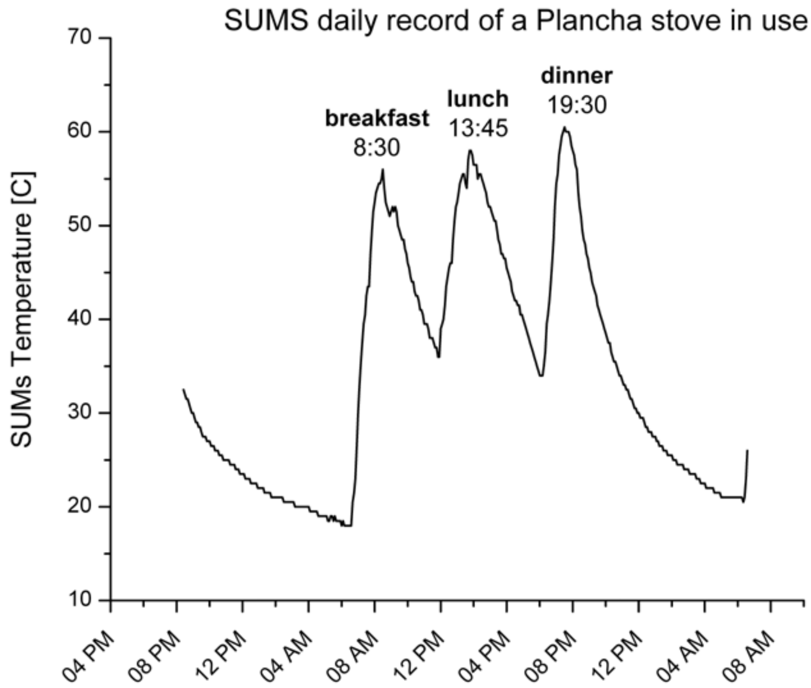


Figure 2. *Typical daily use pattern from a SUMs in a house with a Plancha. The breakfast, lunch and dinner times of stove use can be clearly distinguished.*

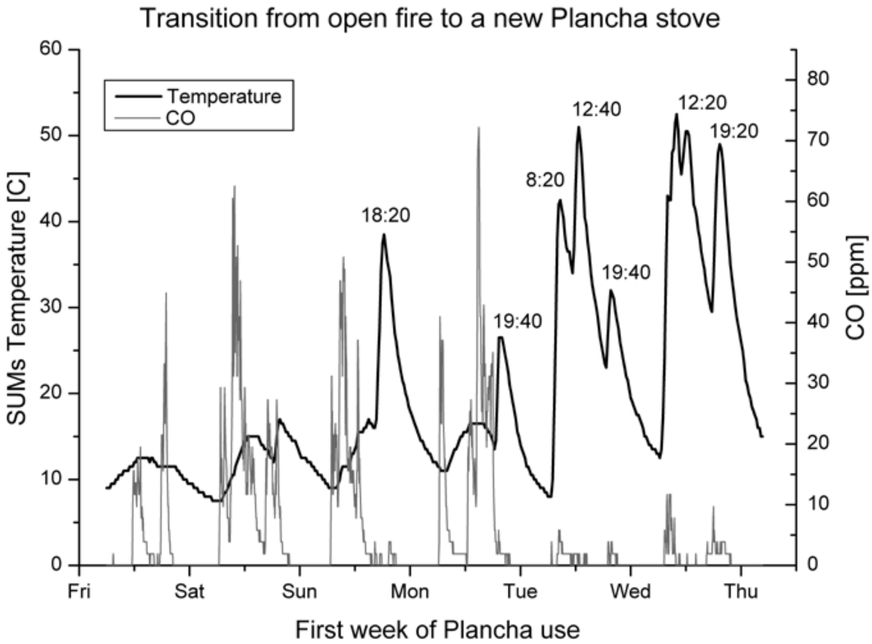


Figure 3. *Average hours of stove use for the newly built and old stoves (n is number of stoves monitored)*

Applying this stove use definition, Figure 4 shows the daily average hours of stove use over the monitoring period for both new and old stoves. It indicates that use of the new stoves gradually increases over the first few days, stabilising after the first week but not quite reaching the same hours of use as the old stove group. Future investigations are underway to explore this transition by examining, for example, the effect of household size and other factors that may affect stove use.

By separating the monitoring periods into weeks (Figure 5), it was found that a significant increase in the median hours of stove use from week one to week two was observed, followed by a period of greater stability during weeks two to three.

Although the new stoves display a relatively stable period of use in weeks two and three, similar to that of the older stoves, they exhibit a greater degree of variability despite a four times greater

Theme

sample size. This suggests that although many, if not most, of the new stove users will adopt the stove quickly after training, there may be a more gradual transition for some users that extends beyond the measurement period. If this is so, there may be a small set of users who might benefit from additional training or other measures. Further research may allow for the prediction in advance of households likely to be in this category based on household characteristics (size, occupation, education, etc.) or pre-dissemination questions about their interest in stoves. Special efforts could then be made to target these households in training or other programmes during dissemination (Rogers 2003).

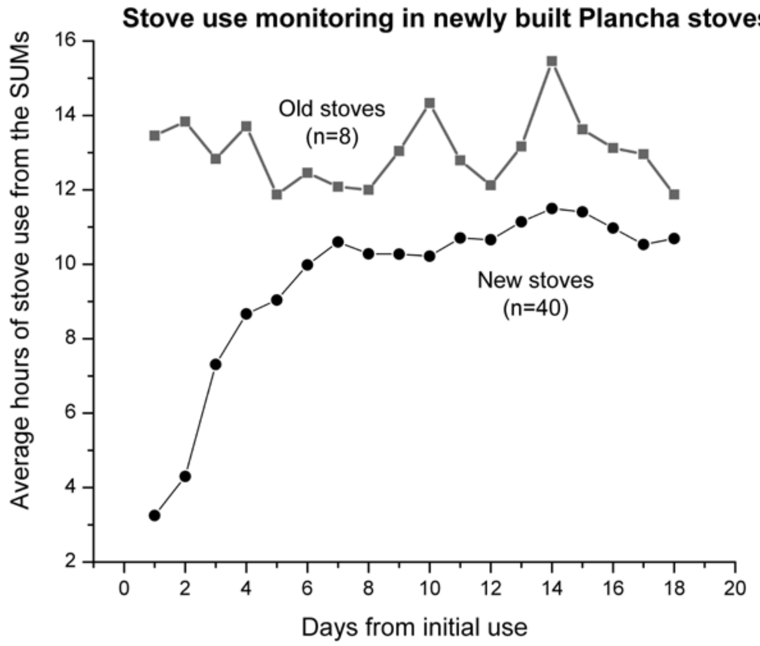
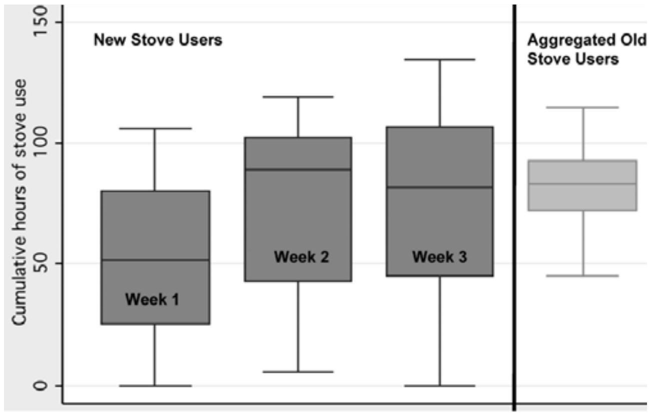


Figure 4. *Gradual adoption of a new Plancha stove as seen by the kitchen carbon monoxide concentrations and stove temperature patterns.*

Figure 5. *Cumulative hours of stove use for 3 weeks of monitoring in new users (n = 40) of the Plancha and old users with 5-6 years of experience (n = 8). Hourly use between weeks was not significantly different within old stove users so an average of weeks 1-3 is presented as a single aggregated column.*

Interpretation of boxplots: The horizontal line within the box represents the median hours of stove use during the week, the upper and lower edges of the box (quartiles) represent hours of stove use at which 75% and 25% of the measured homes fall below, respectively. Points outside the whiskers (no example from figure) are considered outliers.



Conclusions

The surface temperature of the stove away from the cooking surface might potentially be used as a direct indicator of some aspects of stove performance, for example loss of combustion heat into the body of the stove. Here however, its utility as an indicator of stove use is briefly explored, an important parameter for a range of assessments, including usage patterns after dissemination. It provides an unobtrusive, precise, relatively inexpensive, and objective measure, in contrast to telephone surveys, household questionnaires, diaries and other methods. It thus offers an efficient means to test the effectiveness of behavioural interventions on stove use.

In addition, it could provide an objective means to characterise usage over a population of stoves in the context of helping establish the degree to which the reduction of indoor air pollution, greenhouse emissions and fuel use have been achieved. We are now exploring these and other applications. In addition, based on long experience with other datalogging field instruments, we are working to develop efficient and reliable data management and analysis protocols, preferably menu driven using standard software.

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Profile of the authors

Ilse Ruiz-Mercado is a Ph.D. student in the Civil and Environmental Engineering Systems Program at the University of California, Berkeley. Her dissertation research focuses on instrumentation development for indoor air pollution monitoring and for carbon credits verification. She is a student researcher in the CRECER study.

Nick L. Lam is a graduate student in the Health, Environment and Development (HED) program within Environmental Health Sciences at the University of California, Berkeley. Prior to coming to Berkeley, he conducted indoor air and lead research with Dr. Rufus Edwards at the University of California, Irvine

Eduardo Canuz is currently the air pollution specialist for the CRECER study. Prior to CRECER, he worked as the air pollution specialist for the first randomized controlled trial for biomass smoke and respiratory health in children, RESPIRE. He holds a degree in Agricultural Engineering from the Universidad Rafel Landivar, Guatemala.

Gilberto Davila is the current field supervisor for the CRCER study. He has previously done fieldwork for several joint projects between the US Centers for Disease Control and the Universidad del Valle de Guatemala.

Kirk R. Smith is Professor of Global Environmental Health at the University of California Berkeley and has conducted research on the health, energy, climate, and policy implications of household energy in developing countries since 1978 with current studies in India, Nepal, China, and Guatemala.

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