Indoor Air Pollution measurement options



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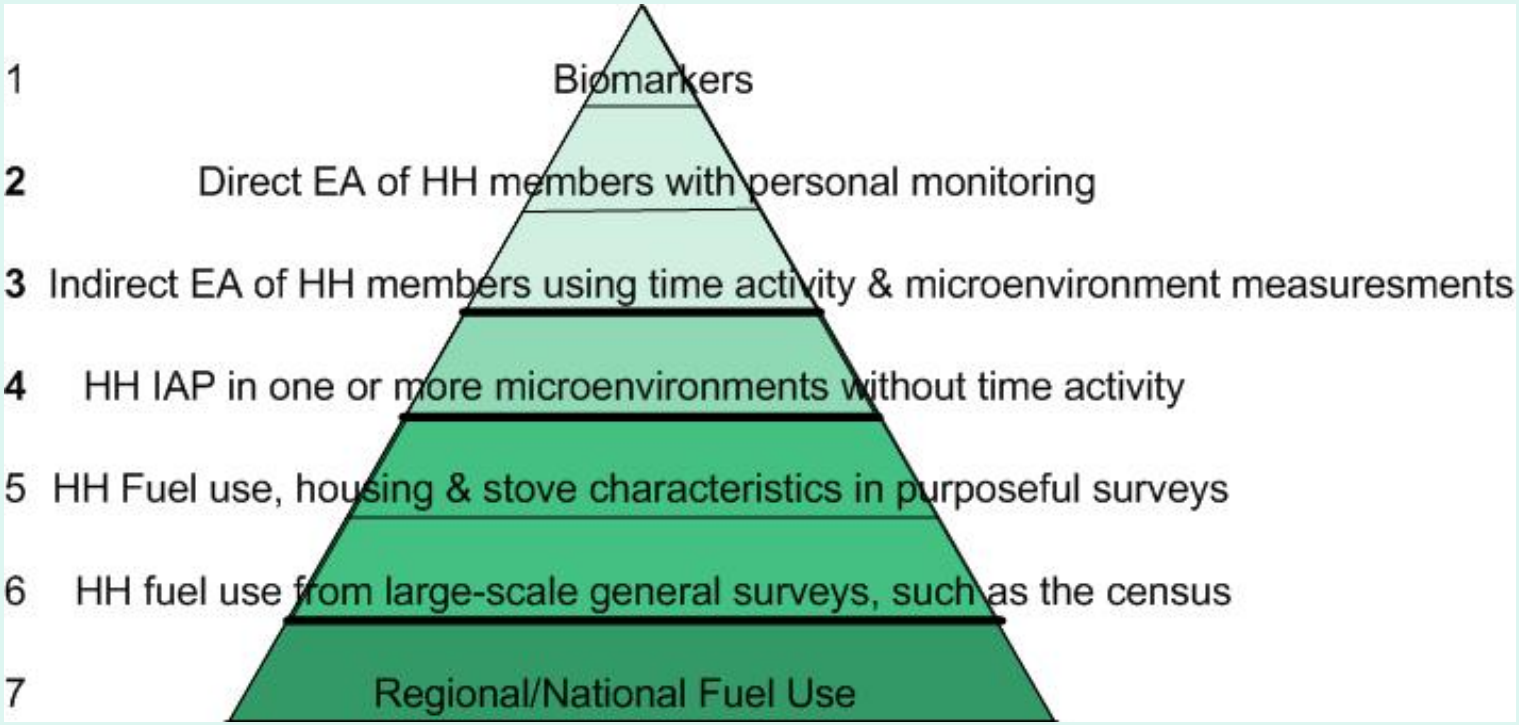
May 3. 2005

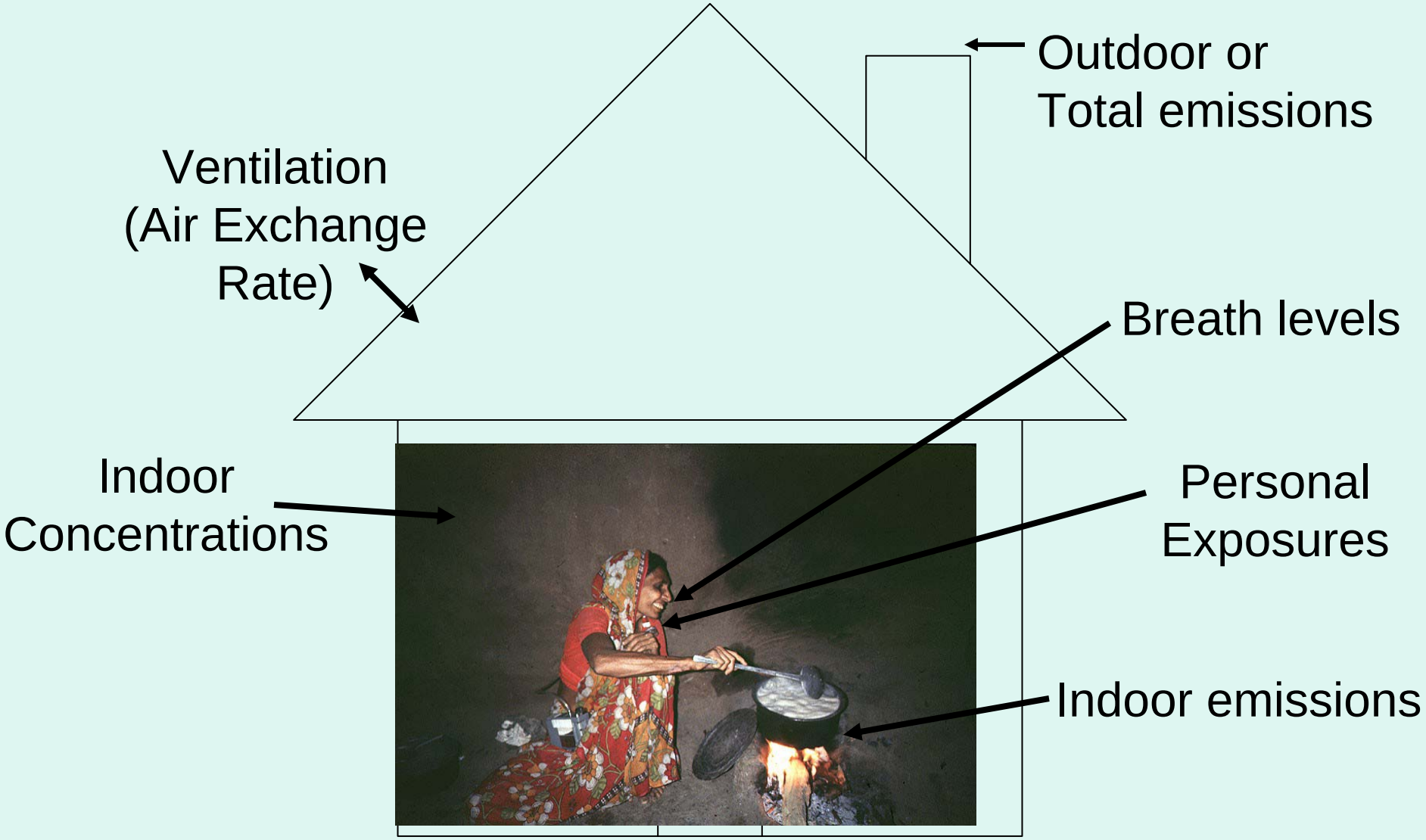
exposure assessment pyramid overview of options



Accuracy

Cost

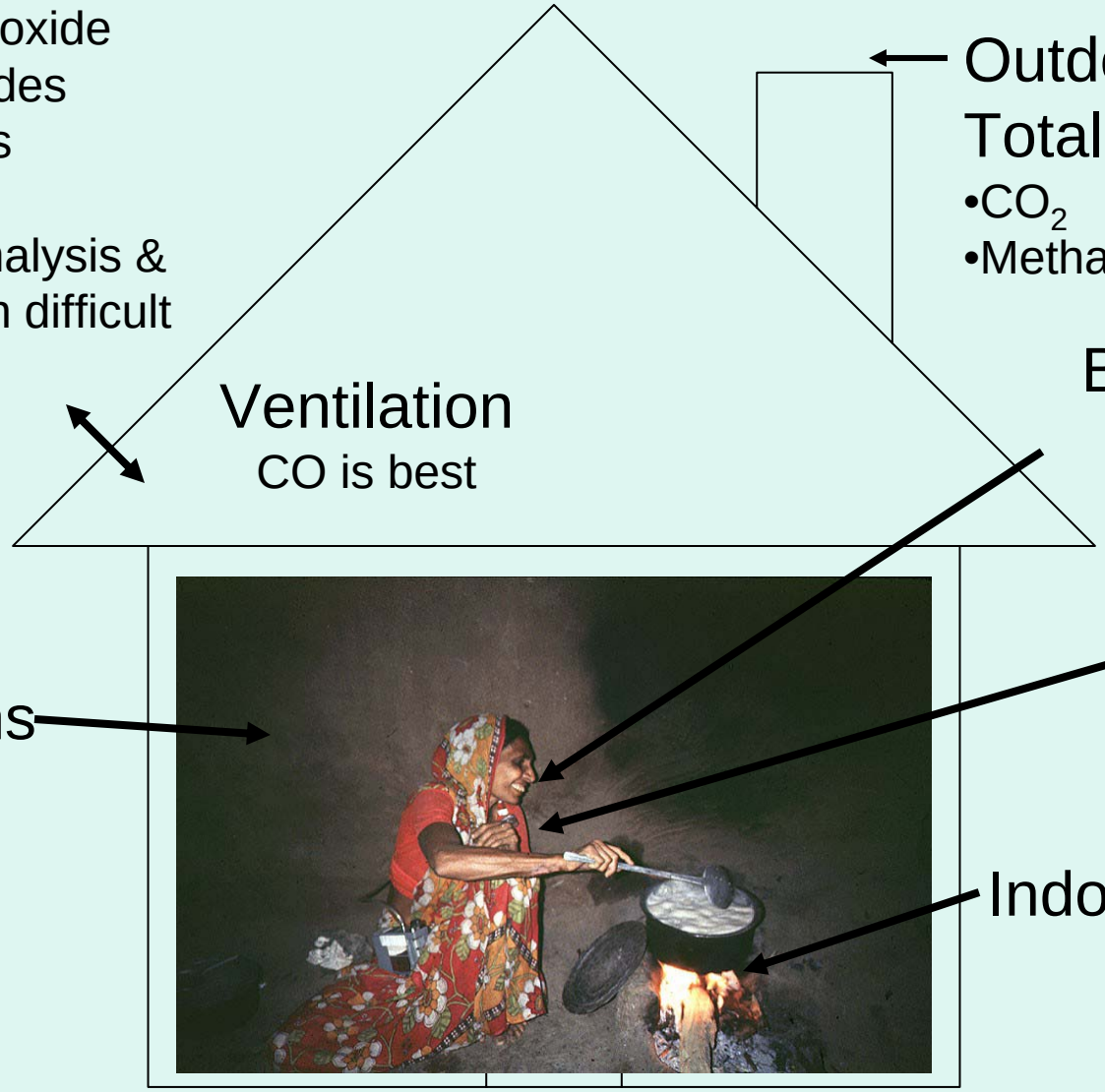
what characteristics can be measured?



Fuel & stove use patterns; Time-activity patterns

what pollutants can be measured?

- Particulate matter
- Carbon monoxide
- Nitrogen oxides
- Sulfur oxides
- Aldehydes
- More, but analysis & interpretation difficult



Outdoor or Total emissions
- CO_2
- Methane

Ventilation
CO is best

Breath levels
CO is easiest

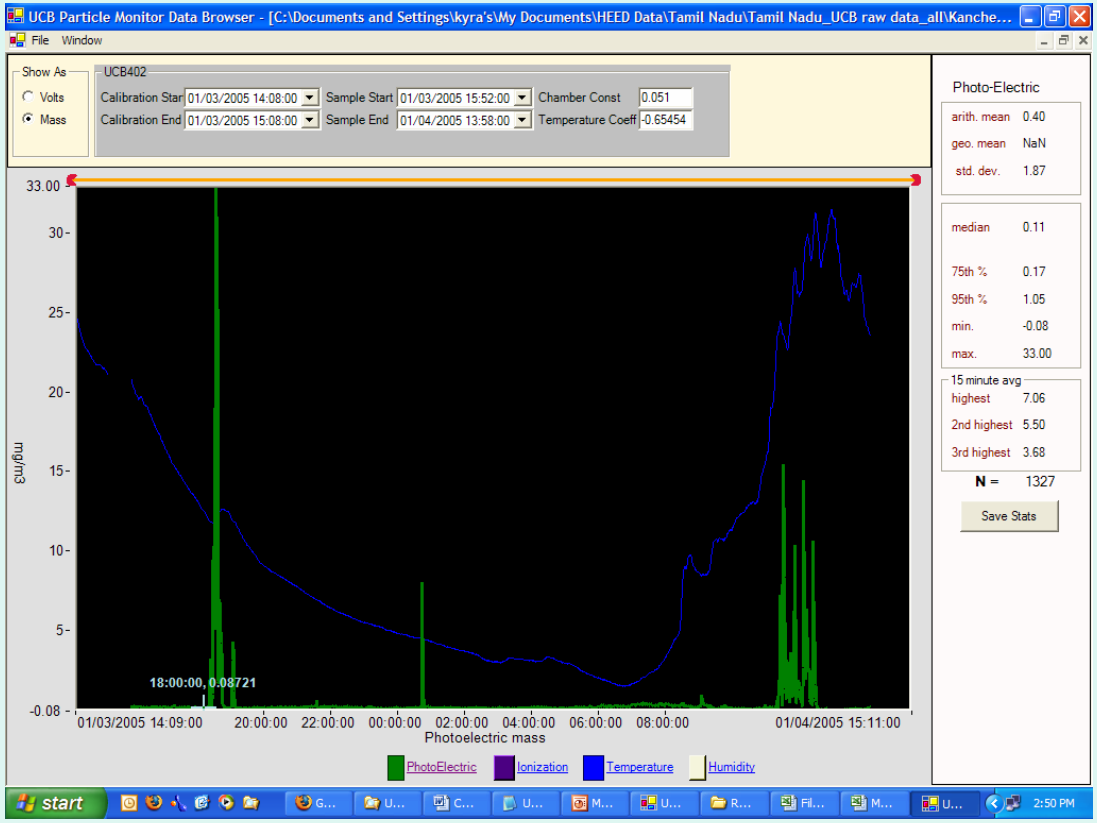
Indoor Concentrations

Personal Exposures

Indoor emissions

when to measure?

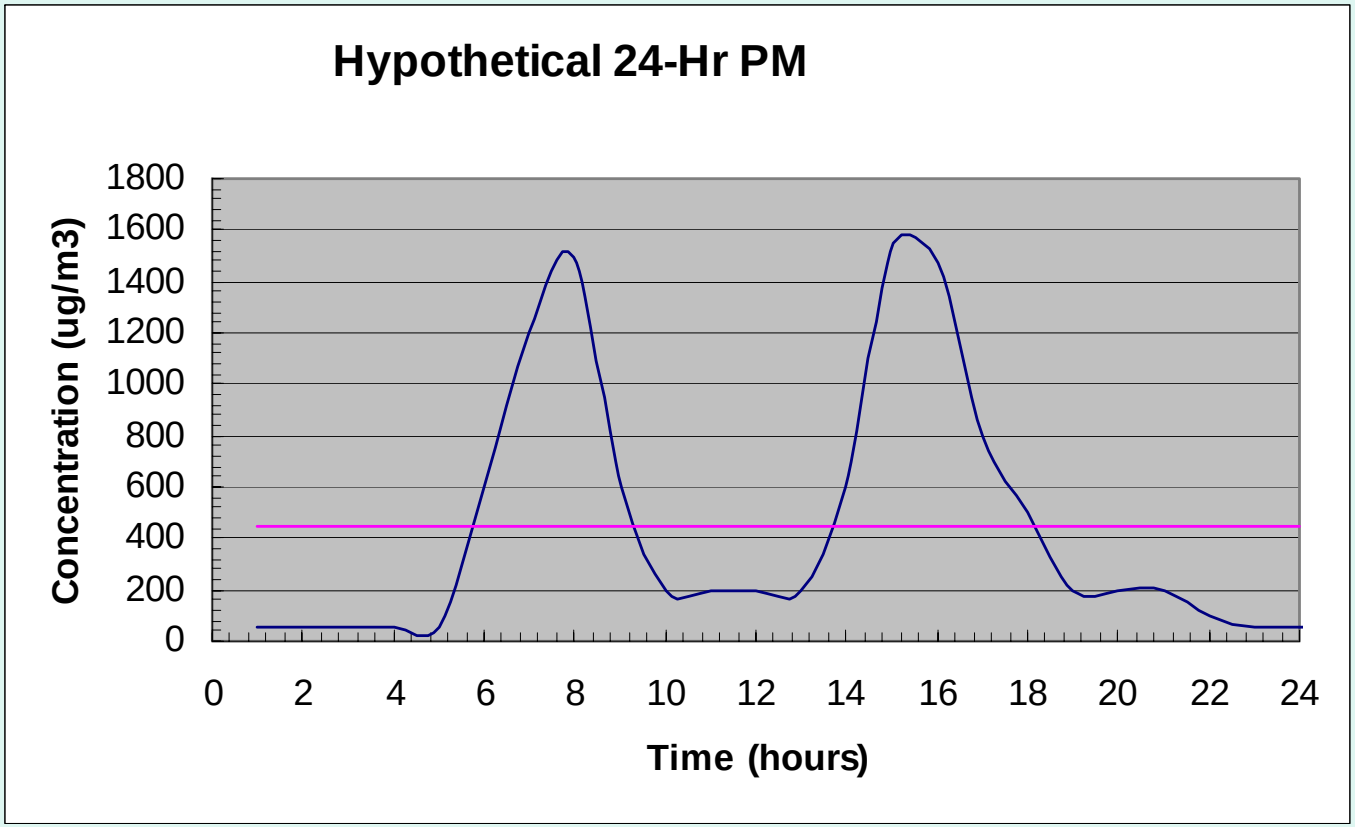
- Duration
  - Cooking time
  - Morning to evening
  - ~24 h
  - ~48 h
  - ~7 day
- Different Seasons



- Generally much variation in a single household during short-term measurements = longer monitoring is better

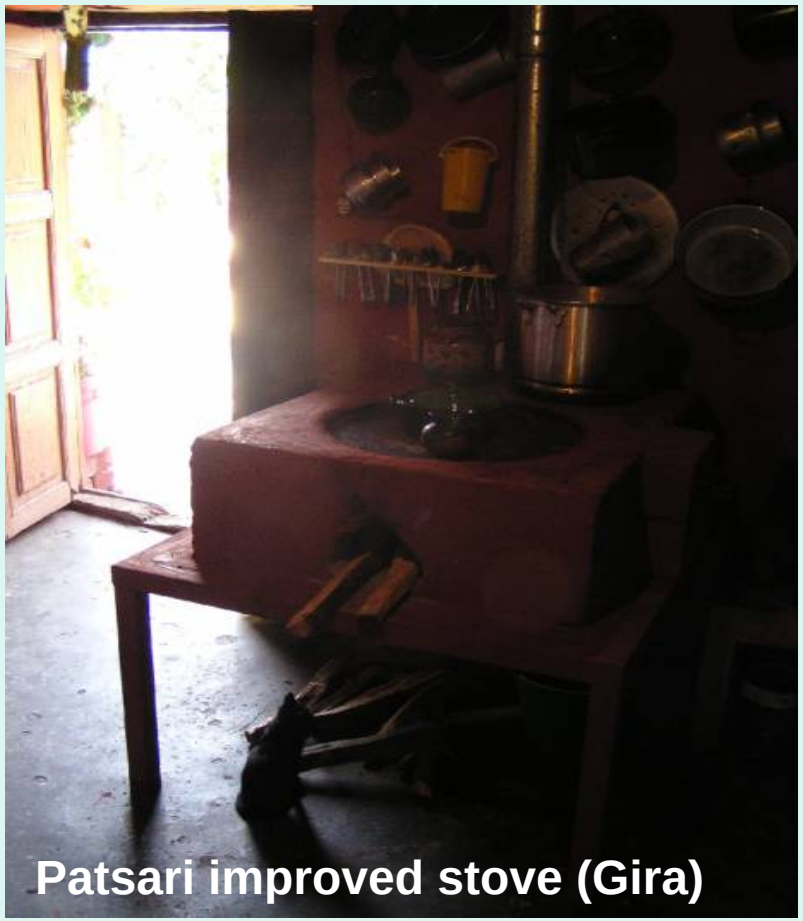
sampling intervals

- Grab sample
- Integrated sample (average)
- Continuous (idea of peaks)



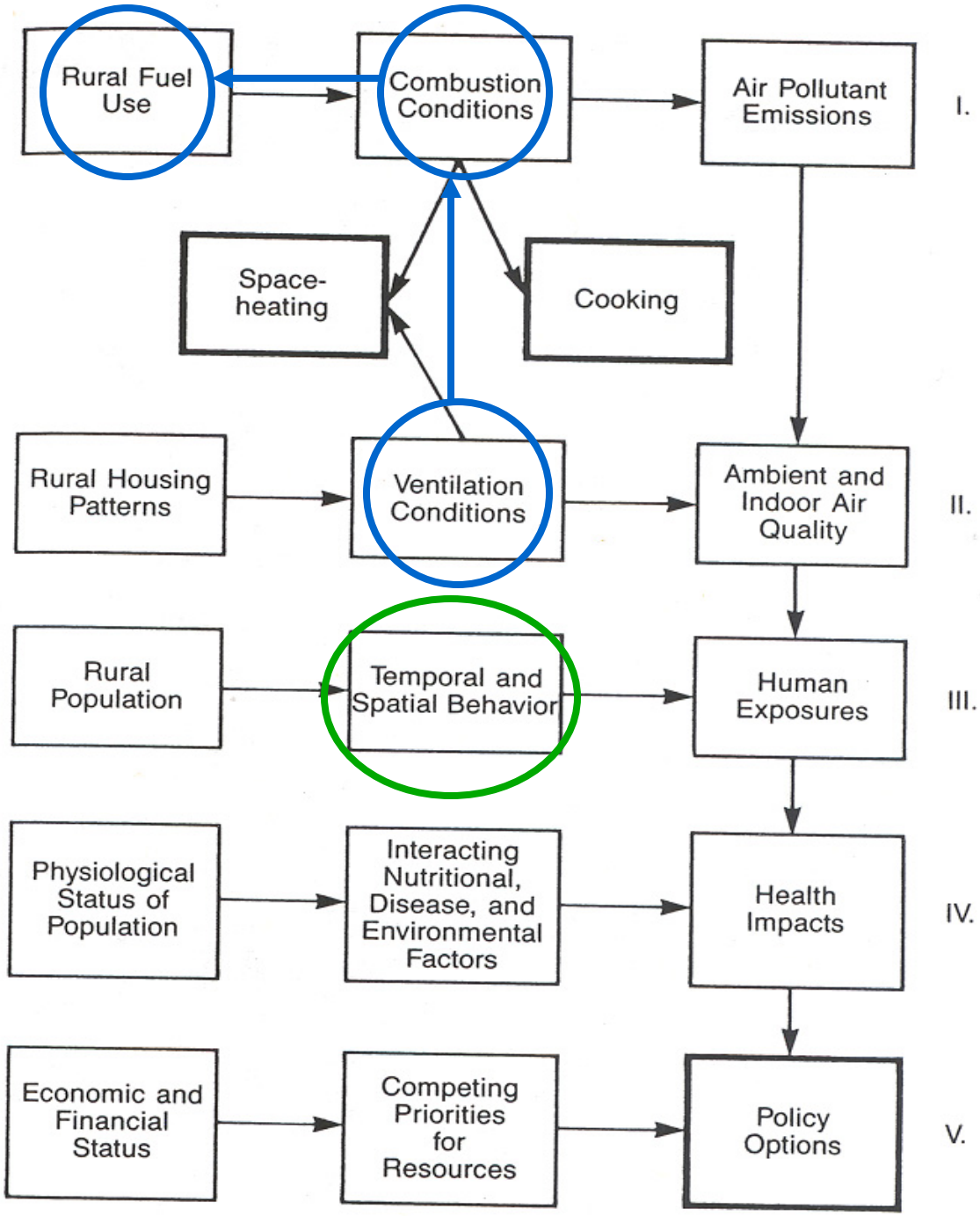
why measure indoor air pollution?

- Determine:
  - Distribution of exposures
  - Demographic characteristics affecting exposures
- Evaluate if interventions worked:
  - Fuel, stove, ventilation, education, etc.
  - Immediate
  - Over time



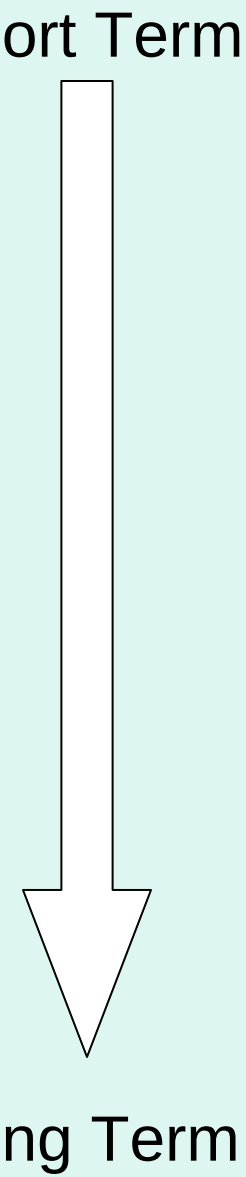
Patsari improved stove (Gira)

- Relate indoor air quality to health outcomes


Rural Fuel Use
Combustion Conditions
Air Pollutant Emissions
I.
Space-heating
Cooking
Rural Housing Patterns
Ventilation Conditions
Ambient and Indoor Air Quality
II.
Rural Population
Temporal and Spatial Behavior
Human Exposures
III.
Physiological Status of Population
Interacting Nutritional, Disease, and Environmental Factors
Health Impacts
IV.
Economic and Financial Status
Competing Priorities for Resources
Policy Options
V.

“technical” solutions

- Better Ventilation
  - Windows: ~10-30% reduction in IAP
  - Hoods: ~25-70%
- Better Stoves
  - Chimneys: ~30-90%
  - Fuel efficiency: - 30% to 30%
  - Combustion efficiency (varies)
- Better Fuels
  - Gases & liquids:~80-99%



Tamil Nadu, India

common IAP measurement methods

the dynamic duo

Carbon Monoxide

- Bag collection, lab analysis
- Color-change diffusion tubes
- Electro-chemical monitors

Particulate Matter (PM)

- Gravimetric (pump & filter)
- Light-scattering monitors

indoor & personal carbon monoxide measurement methods

- Diffusion tubes
  - Small (can be worn by participant)
  - Indicated by stain length in tube
  - Measures total exposure, not continuous

- Electrochemical sensors
  - Small, lightweight, can be worn easily by most participants
  - CO concentration determined by measuring current of a small fuel cell
  - Precision of 0.2-2 ppm

Source: EPA. Air Quality Criteria for Carbon Monoxide. June, 2000.


Coca-Cola

biological
carbon monoxide measurement methods

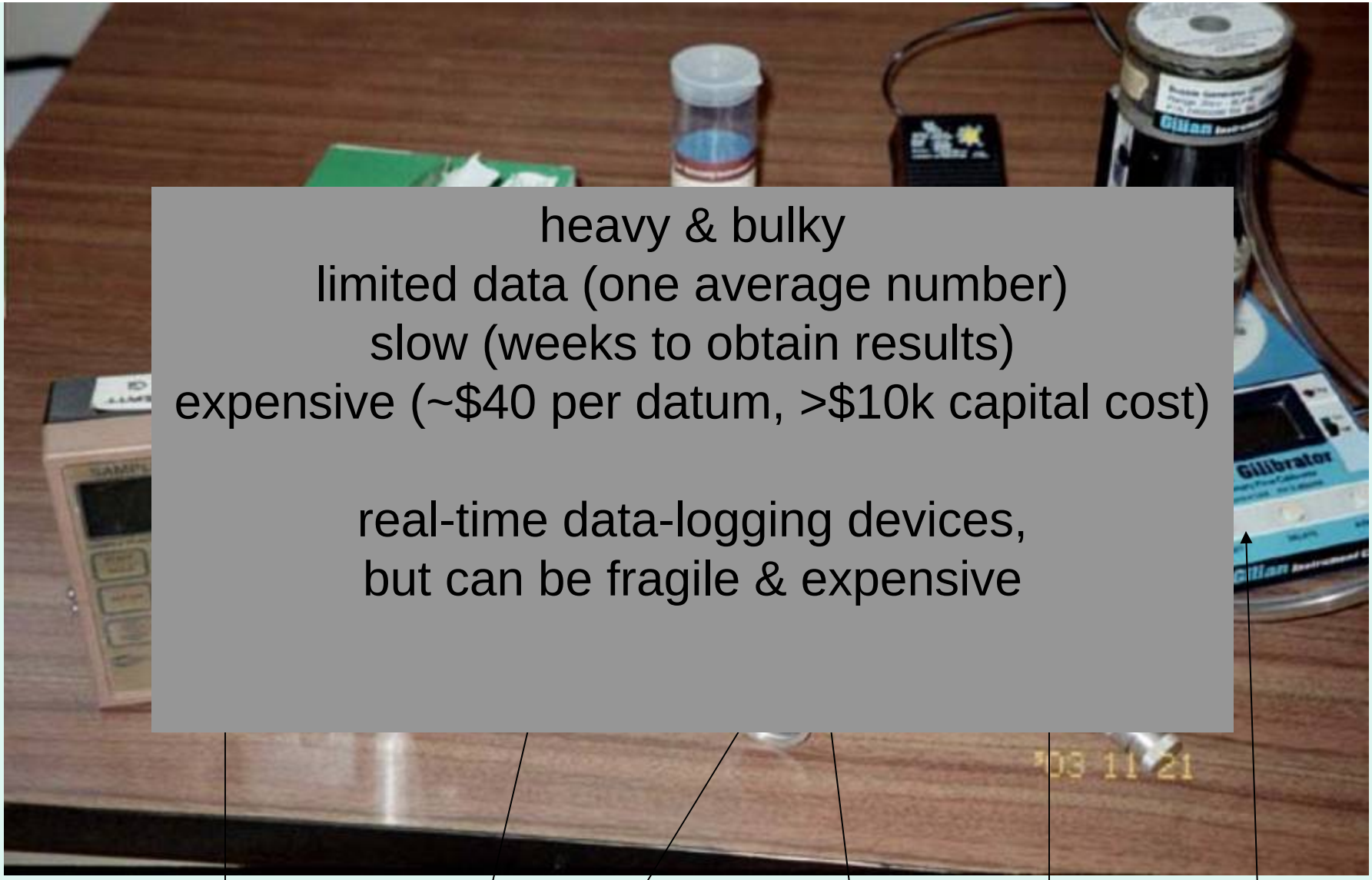
- Exhaled breath
  (measured in ppm or COHb)

- Blood carboxyhemoglobin
  - -Optical Methods (CO-oximetry)
  - -Gas chromatography (gold standard)

Source: EPA. Air Quality Criteria for Carbon Monoxide. June, 2000.

ambient, indoor & personal particulate matter measurement methods

- pump & filter
- light-scattering devices
- many others



heavy & bulky
limited data (one average number)
slow (weeks to obtain results)
expensive (~$40 per datum, >$10k capital cost)

real-time data-logging devices,
but can be fragile & expensive

Self governing programmable pump

Chargeable battery (battery charger not shown)

Filter cassette

Petri dishes for transporting filters

Cyclone for size selection

Airflow calibrator

PM measurement options: light scattering instruments

- Continuous
  - TSI Dusttrak ($6500/unit)
  - TSI SidePak ($5400/unit)
  - Thermo Electron/MIE Personal DataRam ($4250/unit)
  - UCB Particulate Monitor (~$350/unit, to be determined)

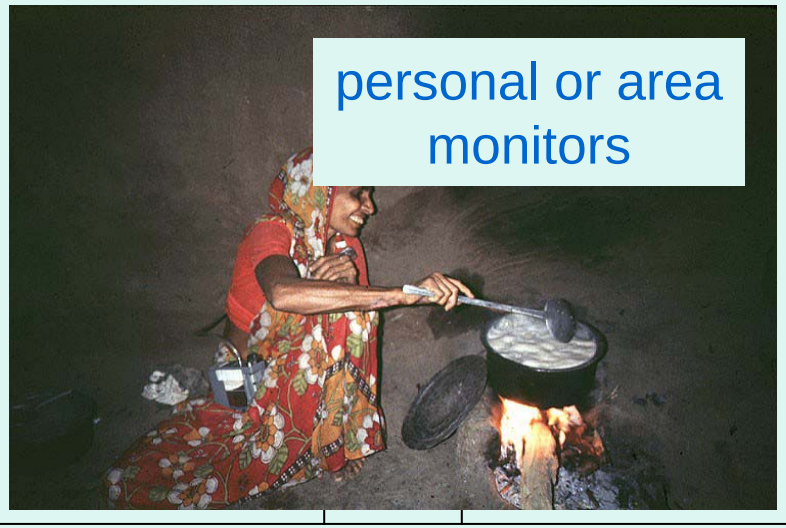
how do particulate matter instruments compare?

	Air Pump	Keeps Time	Size Selection	Minimum Detection Limit	Detection Method	Cost (US$)
Pump & filter	yes	no	specify with cyclone	depends on balance & volume sampled	gravimetric	~$1000/pump & cyclone plus $40/sample
TSI Dusttrak	no	yes	PM2.5 PM10	~1 µg/m^3	light scattering	$6500/unit
UCB Particle Monitor	no	yes	~0.5µm-5µm	~50 µg/m^3	light scattering	~$350/unit (to be determined)
Grimm Aerosol Monitor	no	yes	0.3 - >10µm	1 µg/m^3	laser light scattering	$17,000

Shell Foundation HEH IAP monitoring kit

Gastec CO diffusion tubes
- -integrated
- -simple
- -relatively cheap

Both devices require use of personal computers & software to launch & download data.

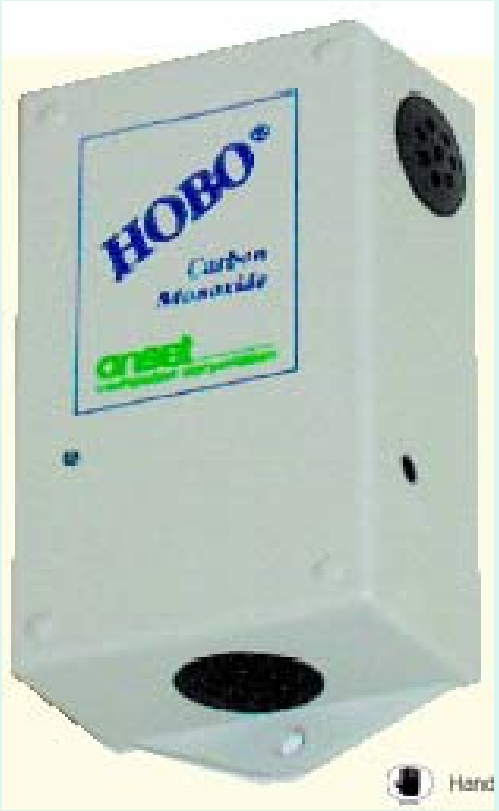


UCB Particle Monitor
- -continuous
- -datalogging
- -no direct readout
- -temperature
- -humidity
- -1 week+/battery
- -small particle sensitivity
- -no sensitivity to larger PM

HOBO CO monitor
- -continuous
- -datalogging
- -no direct readout
- -many weeks/battery

how does the HOBO CO data logger work?

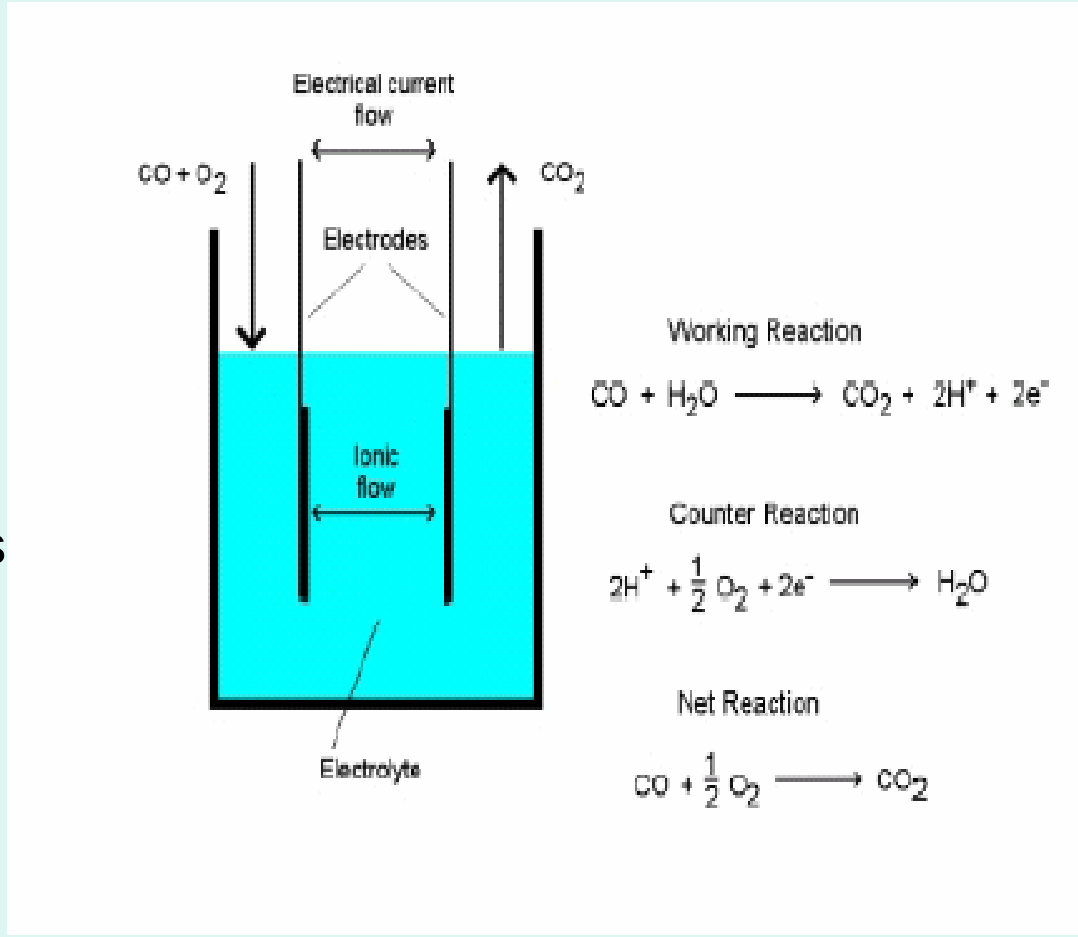
- electrochemical sensor
  - converts CO gas to an electric signal



http://www.onsetcomp.com

how does the electrochemical sensor work?

- 2 electrodes immersed in a highly conductive electrolyte solution (sulfuric acid)
- CO, in the present of O_2, is converted to CO_2
- voltage drop across resistor is measured using Ohm's law (V=IR)
- voltage related to CO concentration



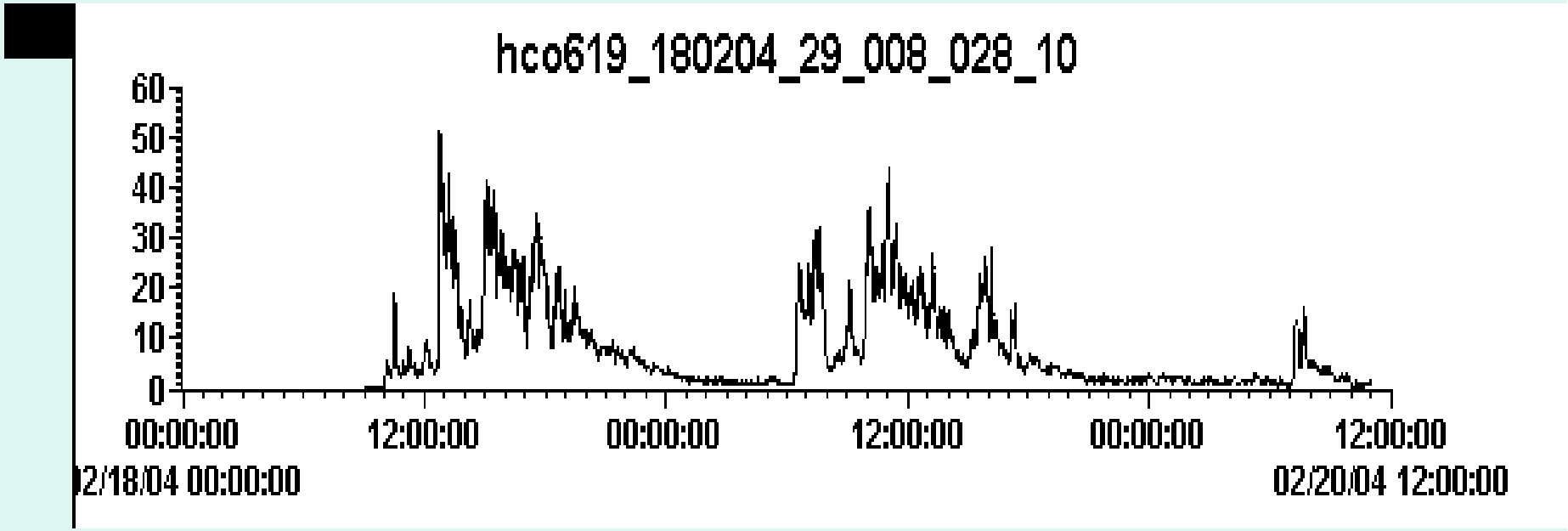
http://www.monox.com/

HOBO CO logger specifications

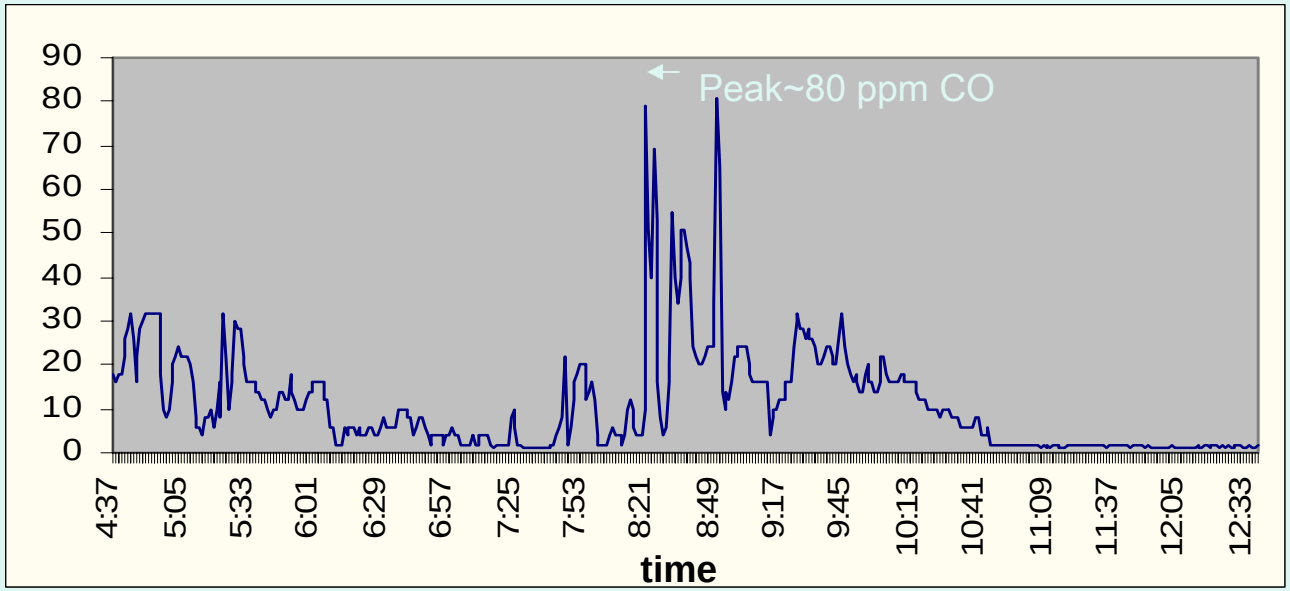
nominal range (ppm)	resolution (ppm)	maximum error (0º-40ºC)
0 to 125	0.5	±10.5 ppm ± 12% of reading
0 to 500	2.0	±12 ppm ± 12% of reading
0 to 2000	8.0	±18 ppm ± 12% of reading

Source: http://www.onsetcomp.com/

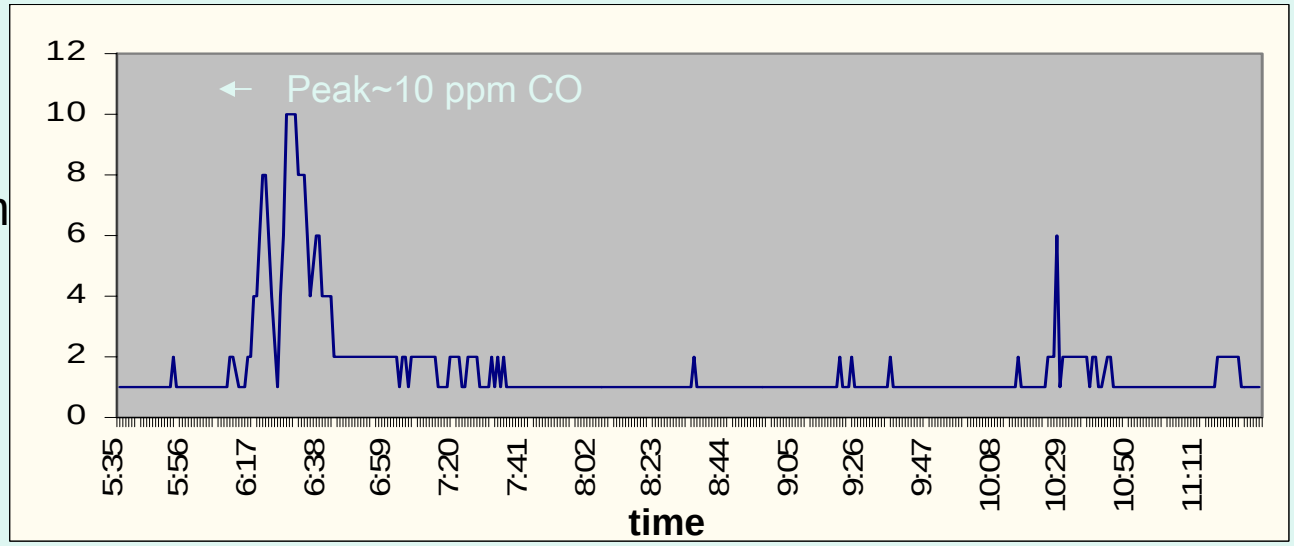
48 Hours of Continuous Carbon Monoxide Monitoring in a Guatemalan Home Using an Open Fire for Cooking, (HOBO monitor, ppm)



comparison of open fire & improved stove: carbon monoxide levels (HOBO monitor)

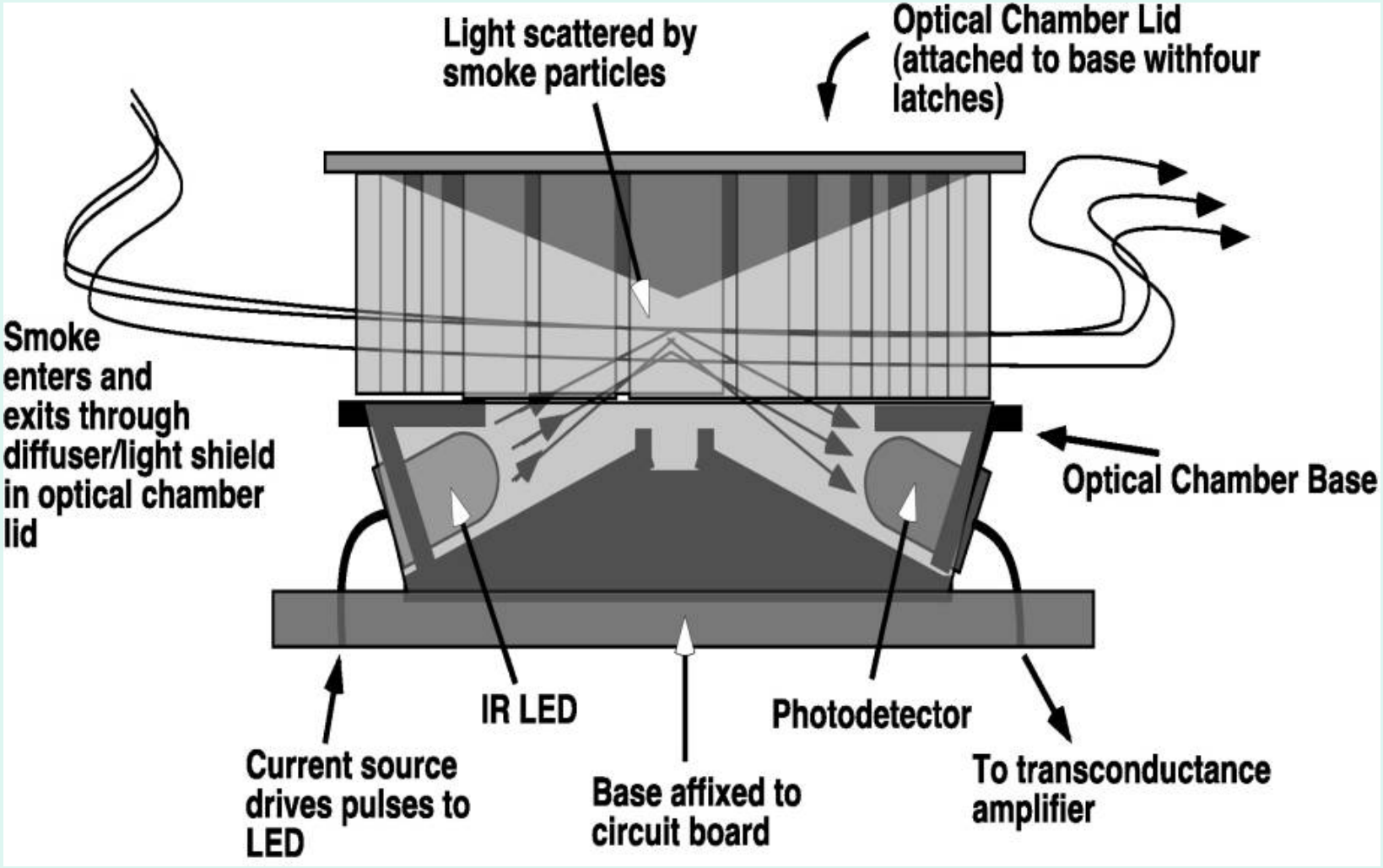


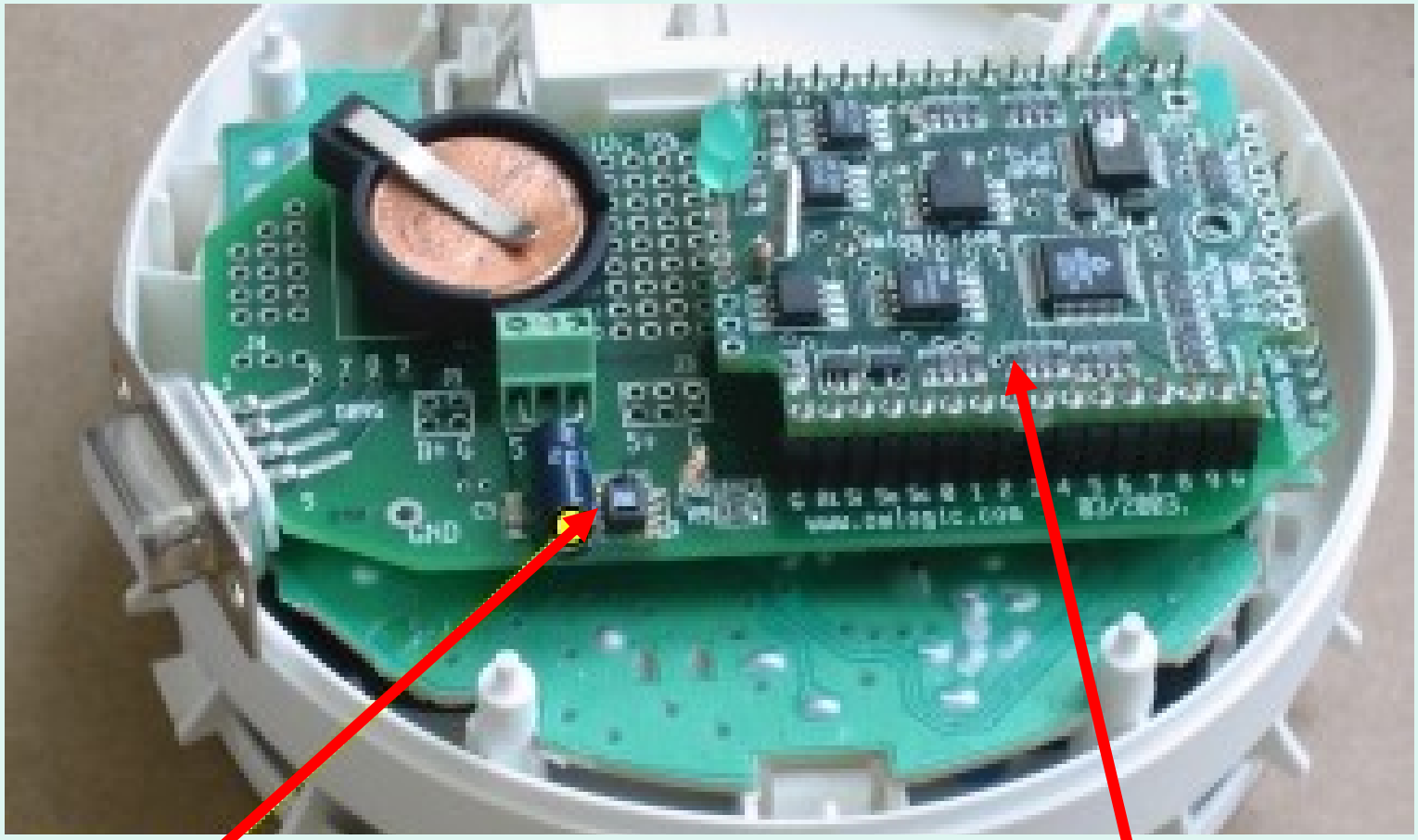
Open Fire



Plancha

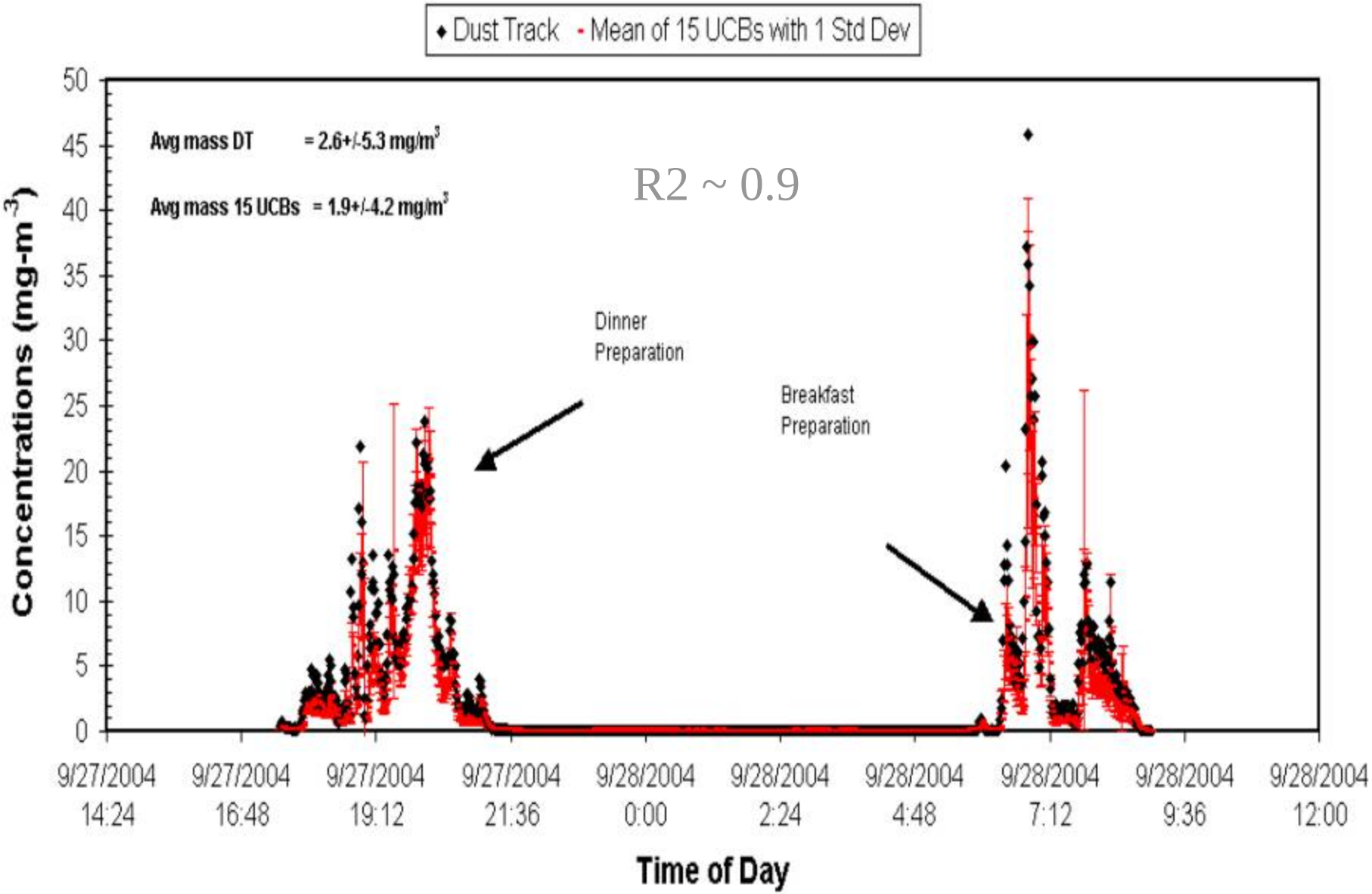
how does the UCB light scattering chamber work?



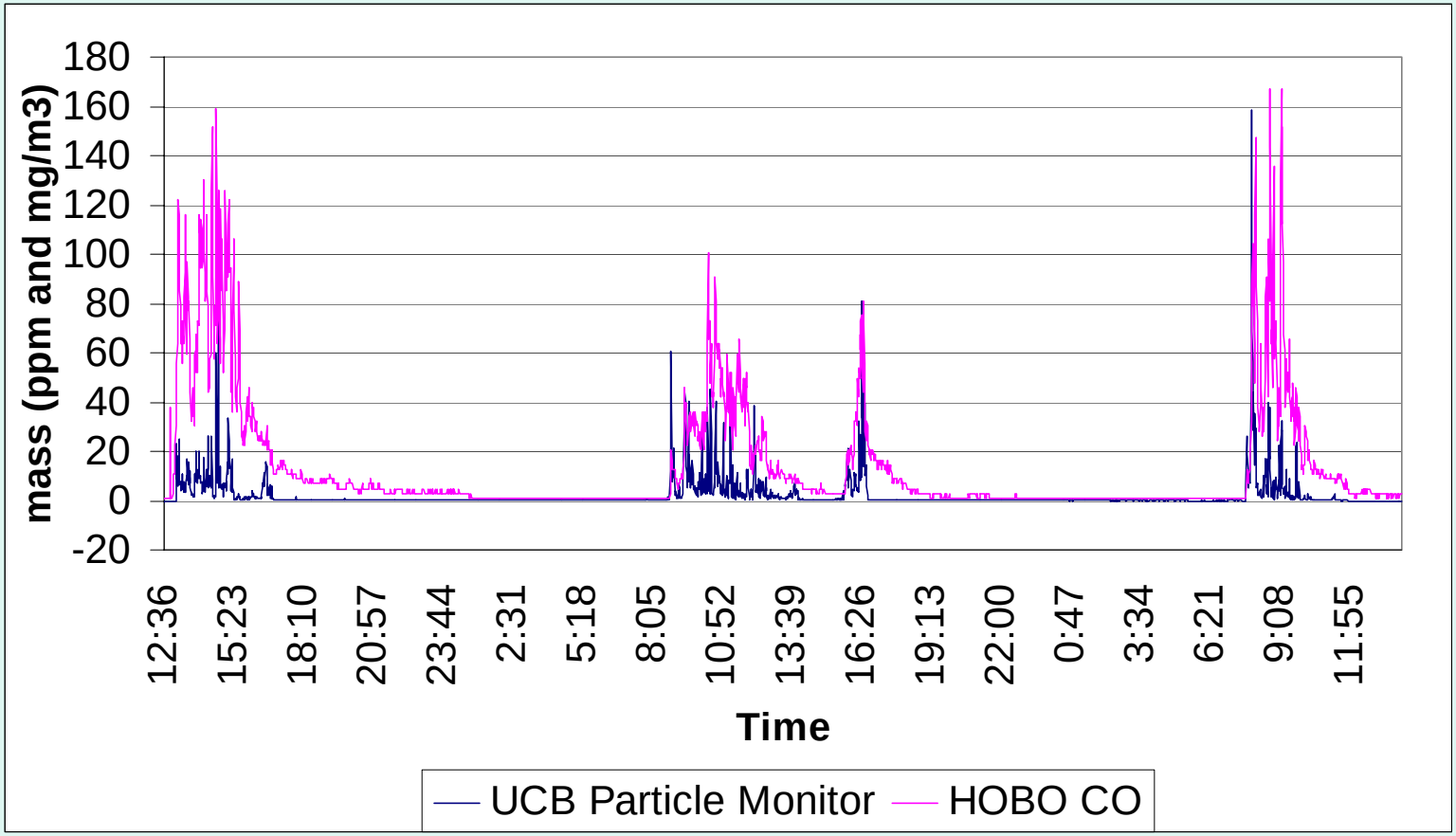

Temperature & Humidity Sensor
Data Logger

Dust Track and UCB Measurement in Guatemala

(minute by minute comparison in an Open Fire House)

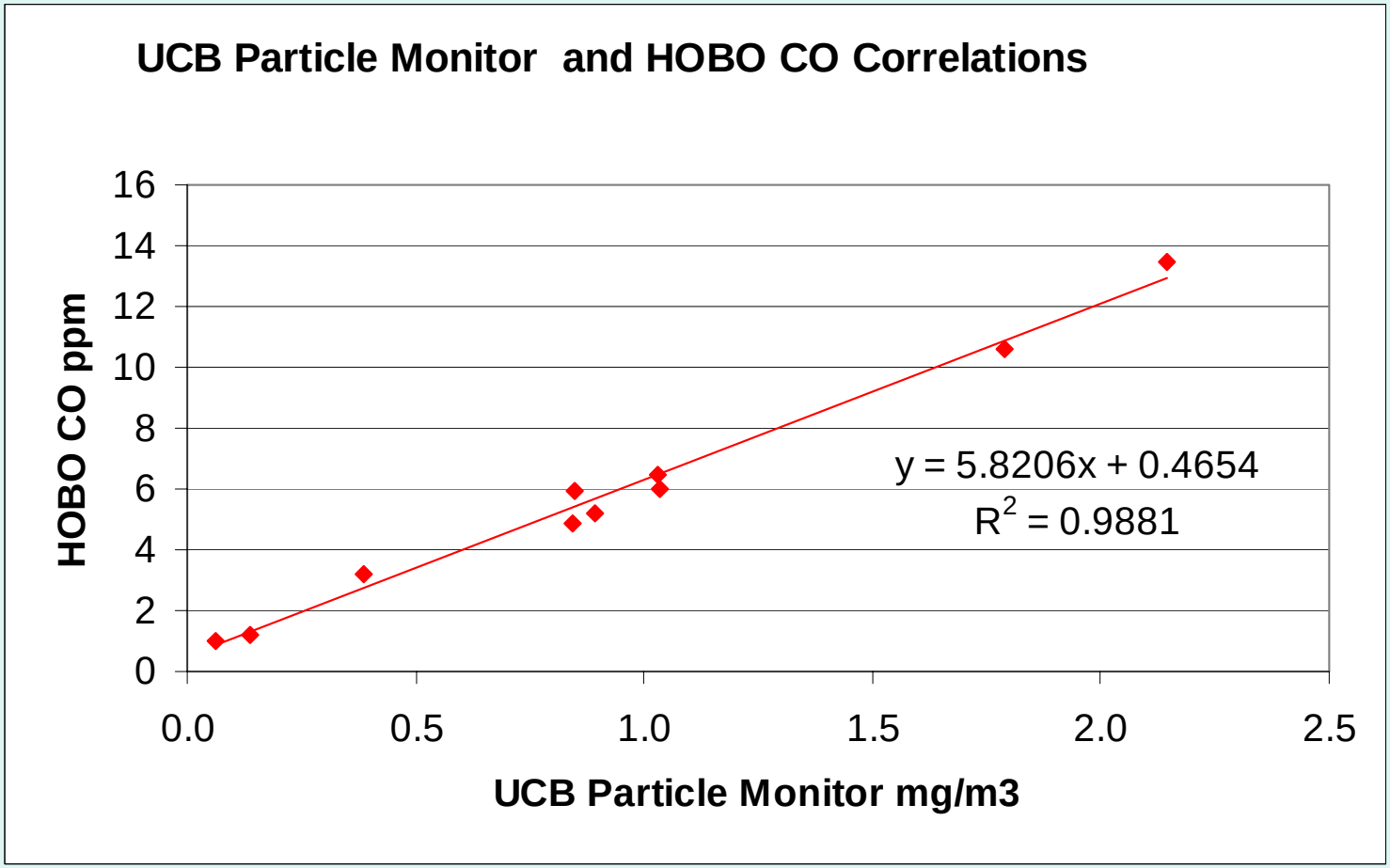


what do the smoke levels during 24 hours in an open fire home look like?



Although the HOBO-CO and UCB-PM monitors measure different pollutants - CO and small particles - both show the patterns of stove usage in the home.

CO & particle measurements agree well with each other in preliminary data from ten Mexican households (Gira)



48-h mean concentrations

limitations to CEIHD kit

- HOBO CO logger
  - requires recalibration
  - eventually replace sensor ($25)
  - lots of data

- CO dosimeter tube ($5/tube)
  - imprecise
  - one-time use
  - expensive for large studies

- UCB particle monitor
  - requires zeroing at every use
  - needs careful cleaning
  - new technology (not traceable to national standards)
  - lots of data

- None produce a physical sample

4 points to remember

- IAP measurements necessary for validating effectiveness of improved stoves
- many IAP measurement options that vary in cost and accuracy (tradeoffs)
- choice of method depends on context (purpose, capacity, finances)
- all methods require data management & quality assurance/quality control plans

thanks…

What new information did you learn about available indoor air pollution monitoring instruments?

extras

outdoor carbon monoxide measurement methods

- NDIR method: Nondispersive infrared technique
  - EPA reference method
  - Automated and continuous
  - Based on specific absorption of infrared radiation by the CO molecule (4.6 μm)
  - Stationary
- Gas Chromatography
  - Flame Ionization: CO converted to CH4, passed through flame ionization detector (FID), resulting signal proportional to amount of CO in air
  - Mercury Liberation
- Tunable Diode Laser Spectroscopy
- Resonance Fluorescence

Source: EPA. Air Quality Criteria for Carbon Monoxide. June, 2000.

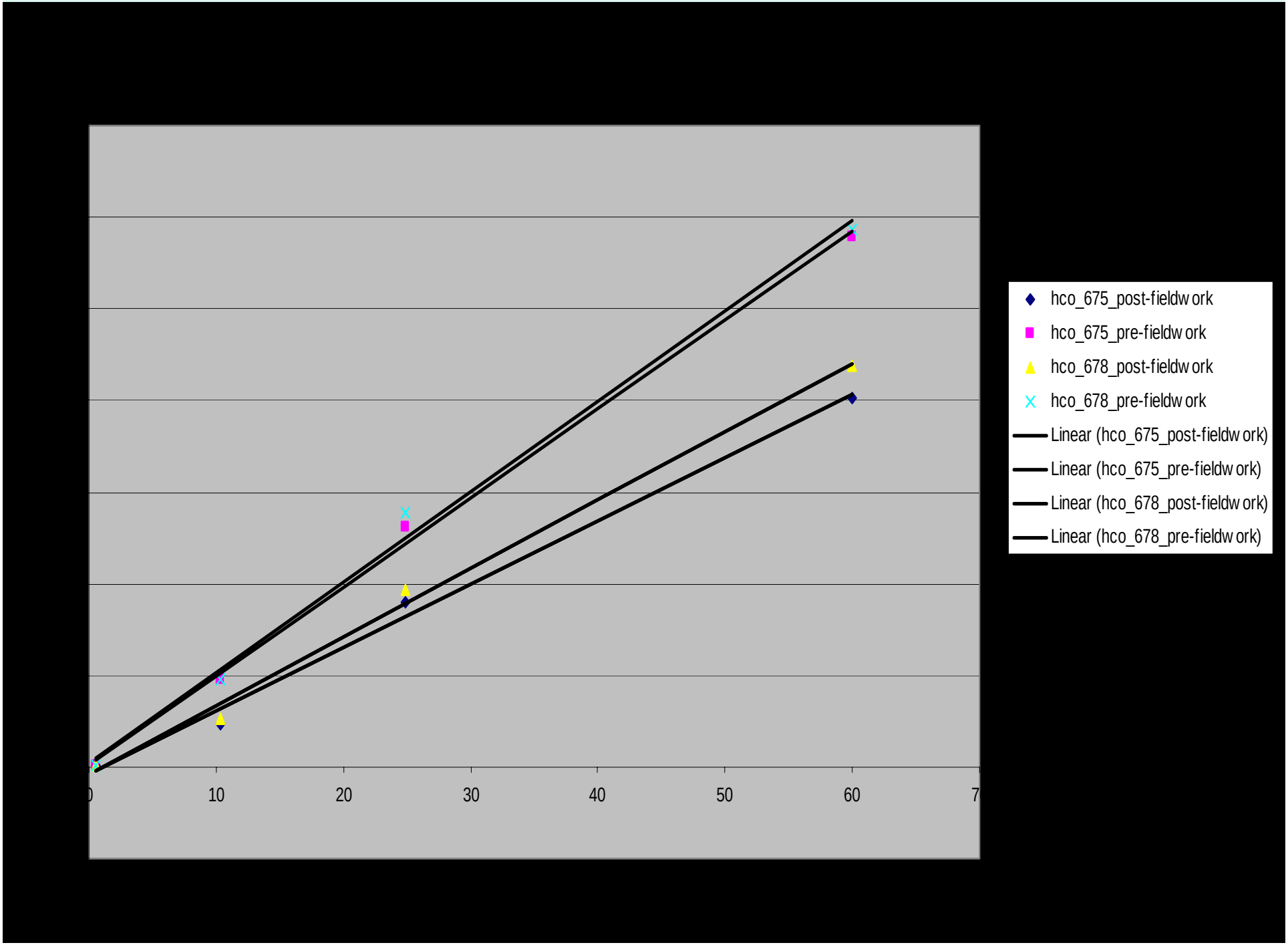
Partial Contents of Shell Foundation HEH IAP Monitoring Kit

Particles: ~$1800

--6 UCB P-3 particle monitors with pre-installed firmware and long-term batteries
--Software for desktop or laptop PC to launch, download, and manipulate data from monitors (CD-ROM)
--Ziploc bags for zeroing monitors before and after each use
--12 9V batteries for initial operation (additional alkaline batteries to be supplied locally)

Carbon monoxide: ~$2000

--6 Onset-HOBO datalogging CO monitors for routine monitoring
--1 “Gold-standard” Onset-HOBO CO monitor for calibration only
--Software for desktop or laptop PC to launch and download HOBOs (CD-ROM)
--7 extra batteries (additional 3V calculator-type batteries to be supplied locally)
--100 CO diffusion tubes for integrated sampling
--10 double labels and caps for diffusion tubes (plus six holders)
--Static free bags to protect HOBOs


hco_675_post-fieldw ork
hco_675_pre-fieldw ork
hco_678_post-fieldw ork
hco_678_pre-fieldw ork
Linear (hco_675_post-fieldw ork)
Linear (hco_675_pre-fieldw ork)
Linear (hco_678_post-fieldw ork)
Linear (hco_678_pre-fieldw ork)
10
20
30
40
50
60

HOBO CO Logger Specifications

Measurement Range:

Nominal Range (ppm)	Actual Range (ppm)	Resolution (ppm)	Typical Accuracy*** (over 0° to 40°C)	Maximum Error (over 0° to 40°C)
0 to 125	0.2 to 124.3	0.5	±4.5 ppm ±7% of reading	±10.5 ppm ±12% of reading
0 to 500	1 to 497.1	2.0	± 6 ppm ±7% of reading	±12 ppm ±12% of reading
0 to 2000	4 to 1988	8.0	±12 ppm ±7% of reading	±18 ppm ±12% of reading

* *Physical shocks or rapid changes in ambient pressure may show up as spikes in the data.*

** *Battery life is shorter when CO levels average 10 ppm or more. For example, battery life is 6 months at average concentrations of 100 ppm.*

*** *The CO sensor is temperature compensated over the entire operation range. In addition to specifications above, for temperatures 0° to 20°C readings may be lower by as much as 5% or 5 ppm, whichever is greater. For temperatures 20° to 40°C, the readings may be higher by as much as 5% or 5 ppm, whichever is greater.*

Source: http://www.onsetcomp.com/

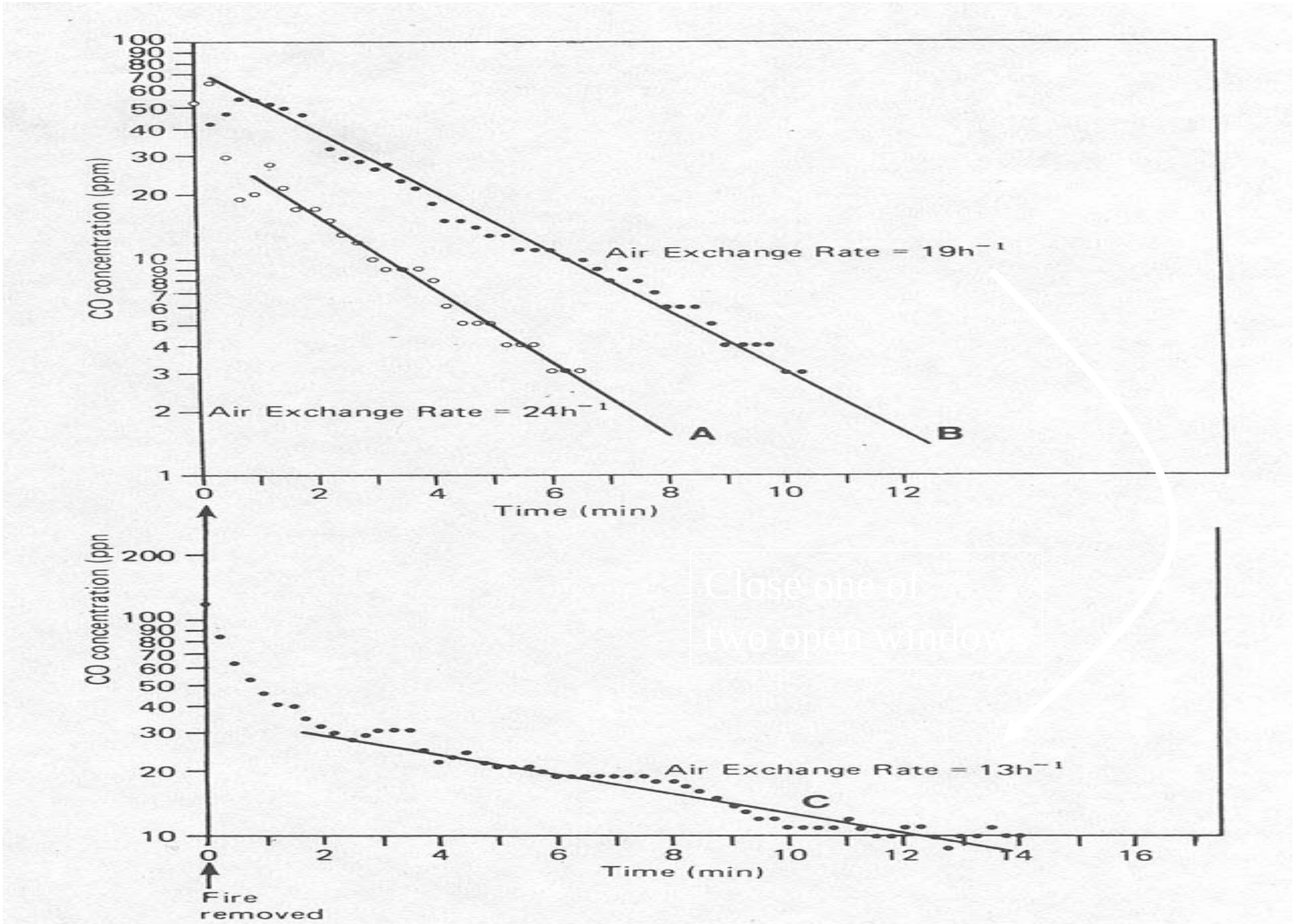
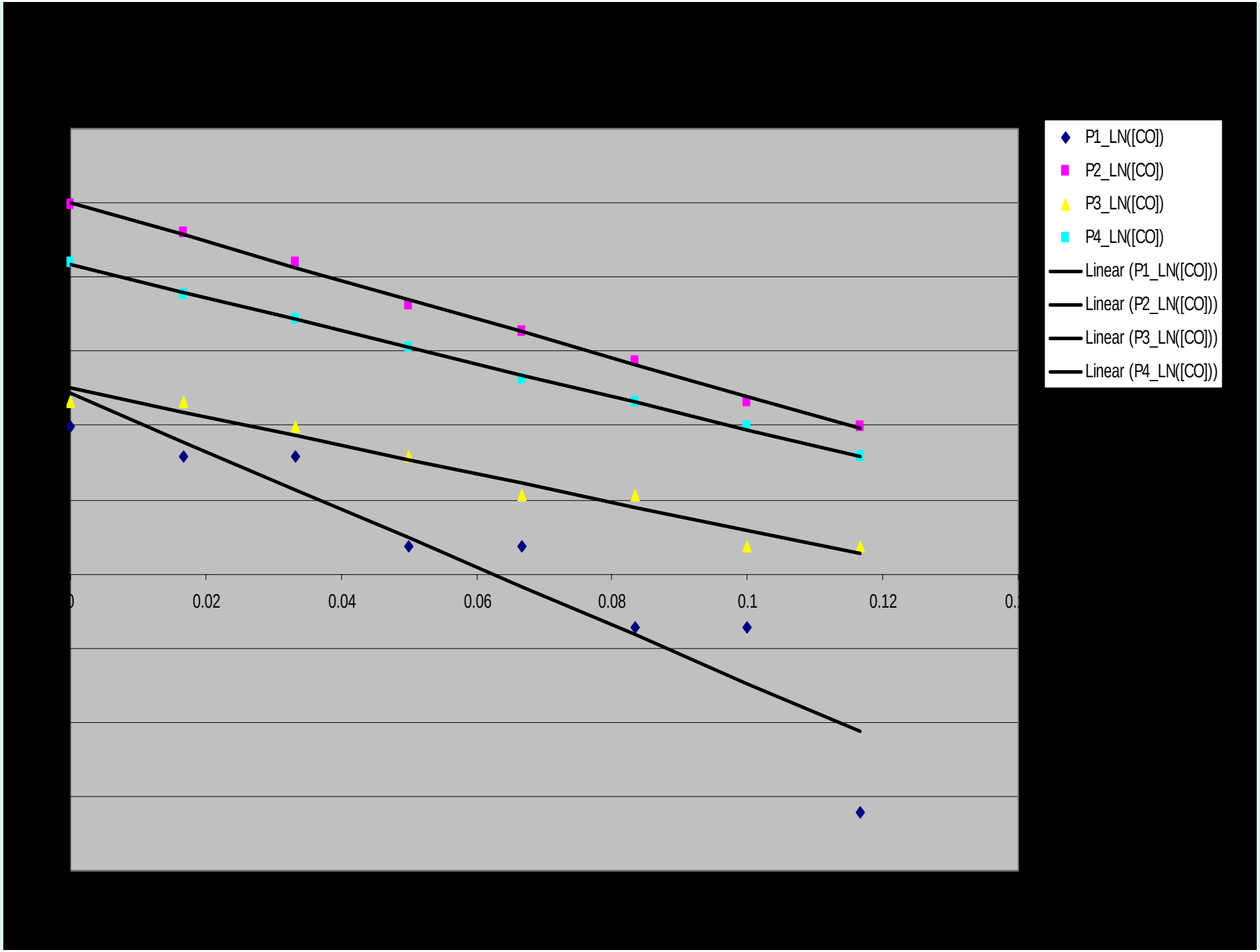


Figure 3.3. Air exchange rates in two Indian village houses as determined by decay of concentrations. Closing the window in the kitchen of house B resulted in a lowering of


P1_LN([CO])
P2_LN([CO])
P3_LN([CO])
P4_LN([CO])
Linear (P1_LN([CO]))
Linear (P2_LN([CO]))
Linear (P3_LN([CO]))
Linear (P4_LN([CO]))
0.02
0.04
0.06
0.08
0.1
0.12