

The Effects of Carbon Monoxide and Particulates on the Human Body

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- Full document is available on net
- A few paper copies available today
- Spreadsheet to perform CO calculations available on request

We can measure CO and particulates

- CO as a function of time.
- Particulates as function of time, or time average.
- Range of sizes in particulates.

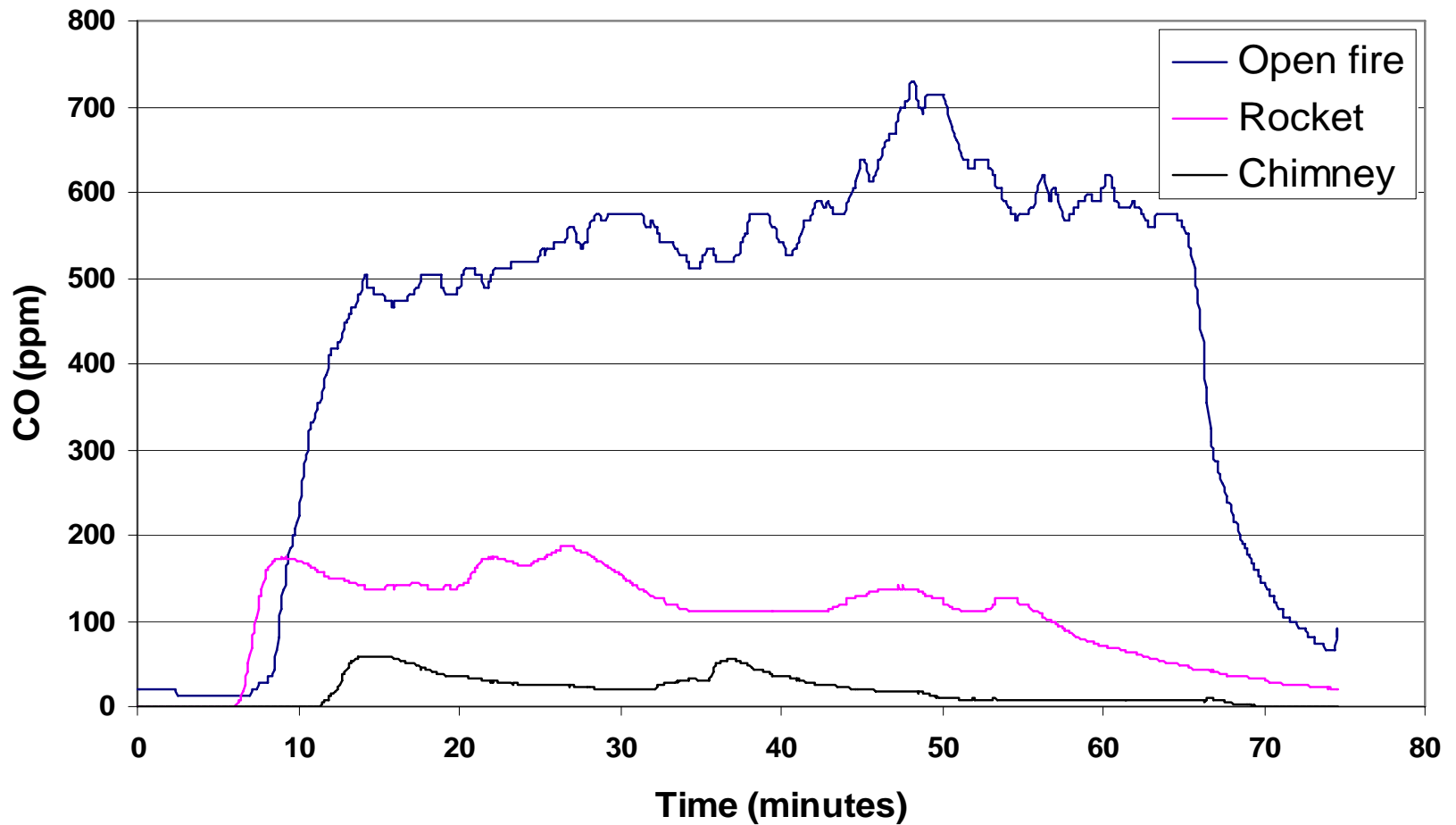
Good, but what does it mean?

Are better stoves beneficial? How much?

Are better fuel beneficial? How much?

At what point are we good enough? Are we there yet?

CO in Apro test kitchen



The Coburn Equation

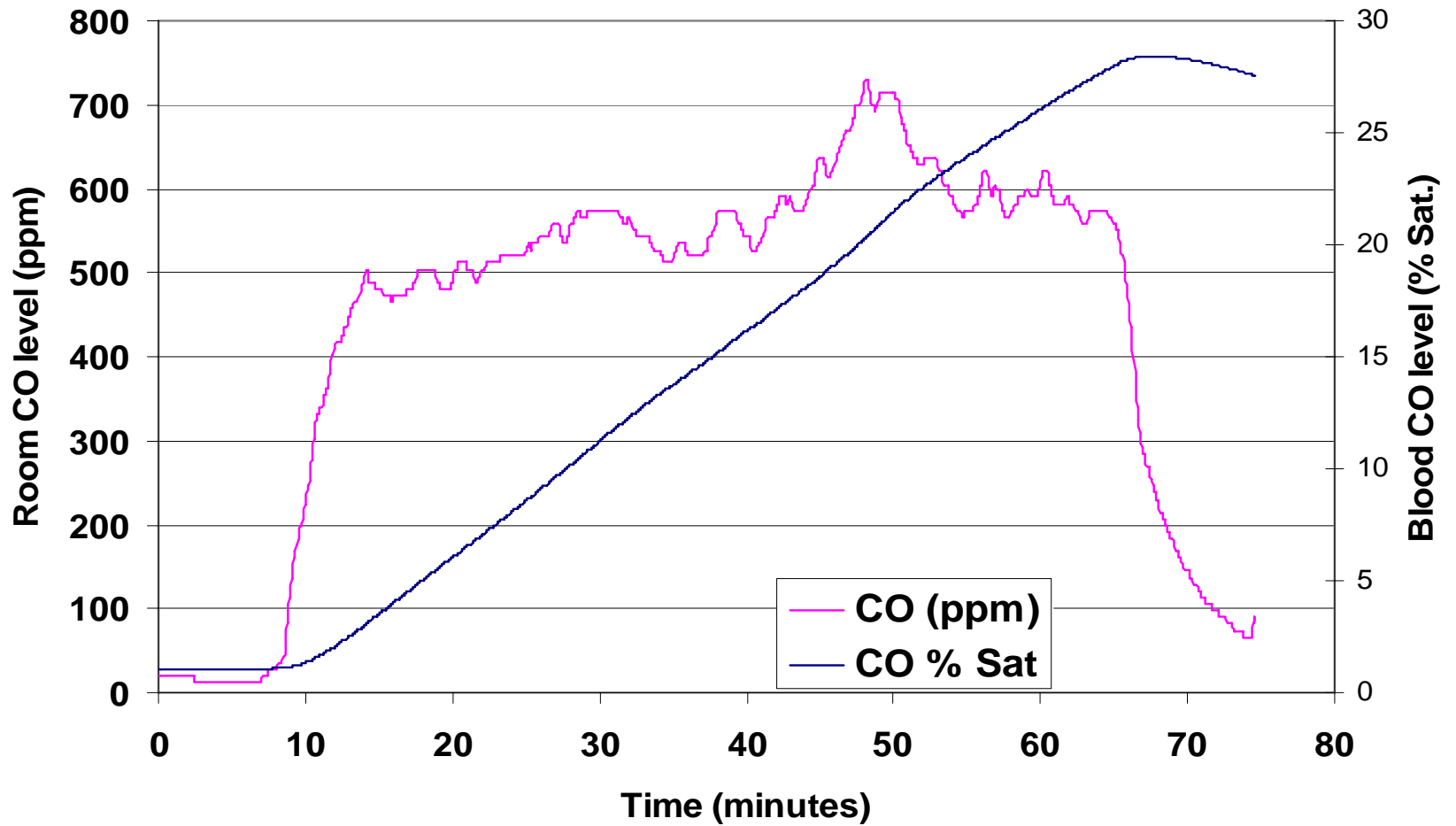
(first published in 1965)

$$\frac{d(CO)}{dt} = \dot{V}_{CO} + \frac{P_I(CO)}{\frac{1}{D_L} + \frac{(P_B - 47)}{\dot{V}_A}} - \frac{[COHb]}{[O_2Hb]} \frac{P_c(O_2)}{M} \frac{1}{\frac{1}{D_L} + \frac{(P_B - 47)}{\dot{V}_A}}$$

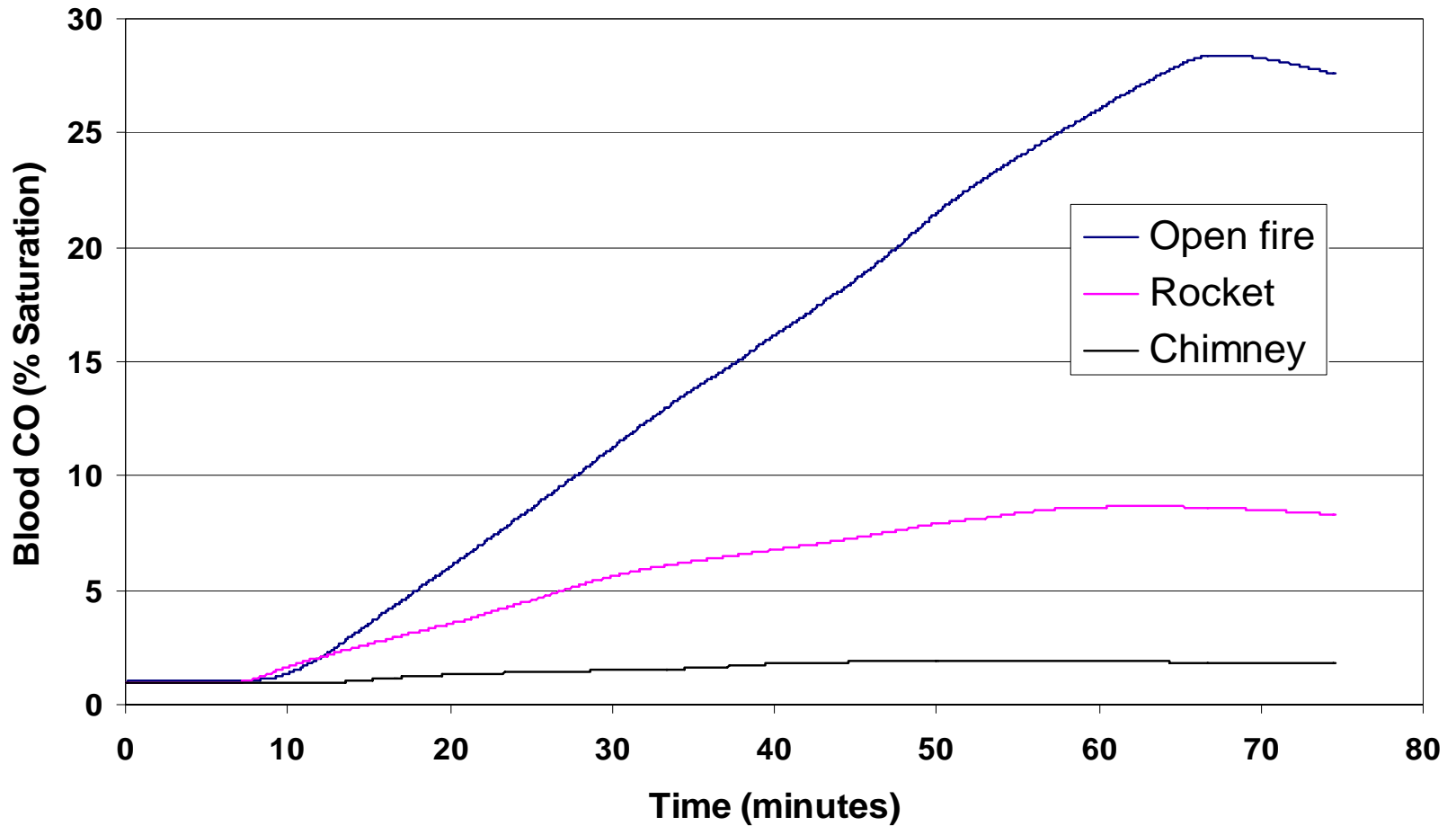
We can relate air CO to blood CO, and to effects.

- Some body variables need to be determined, but typical numbers can be found.
- Not perfect, but good enough to form a guideline.
- We are presenting a tool, with typical results as an illustration of the use of the tool.

Open fire



Results for 3 stoves



[COHb] (% Saturation)	Effects
0.4	Normal value for non-smokers
5	Typical value in heavy smokers
Below 10	No significant effects
10+	Headache and impaired manual coordination, changes in visual evoked response by electroencephalogram.
10-20	Heavy head
20-30	Headache, dizzy, weak
30-40	Pass out
40-50	Coma
50-60	In deadly peril
60+	Death

As a rule of thumb

$$\textit{Peak [COHb]} \approx 10 \frac{\textit{AverageCO}}{170} \frac{\textit{Time}}{60} \frac{50}{m}$$

Introduction to Particulates

- Health effects of Particulates are generally cumulative, not instantaneous like CO
- Long-term exposure to fine particulate matter results in
 - Acute Lower Respiratory Infection
 - Chronic Obstructive Pulmonary Disease
 - Scarring of Lung Tissue
 - Others
- PM Measured as Average Daily Exposure

Health Effects of Particulates

- The higher the concentration of particles, the greater the effect on human health:

Ambient levels of PM10 mg/m ³	Increase in human death	Hospitalization for heart disease	Hospitalization for Pneumonia and COPD
10	0.5	1%	2%
50	2.5%	5%	10%
65	4%	6.5%	13%
100	5%	10%	20%
150	7.5%	15%	30%

Based on Information from The Health Effects Institute, 2000, BI/Clean Air Revival, Inc. 2001

Particulate Exposure Standards

- Generally, $150 \mu\text{g}/\text{m}^3$ over a 24-hour period is the short-term limit, while $50 \mu\text{g}/\text{m}^3$ should not be exceeded as a long-term average.

Table 1. Reference Standards and Guidelines for Average Ambient Particulate Concentration
(micrograms per cubic meter)

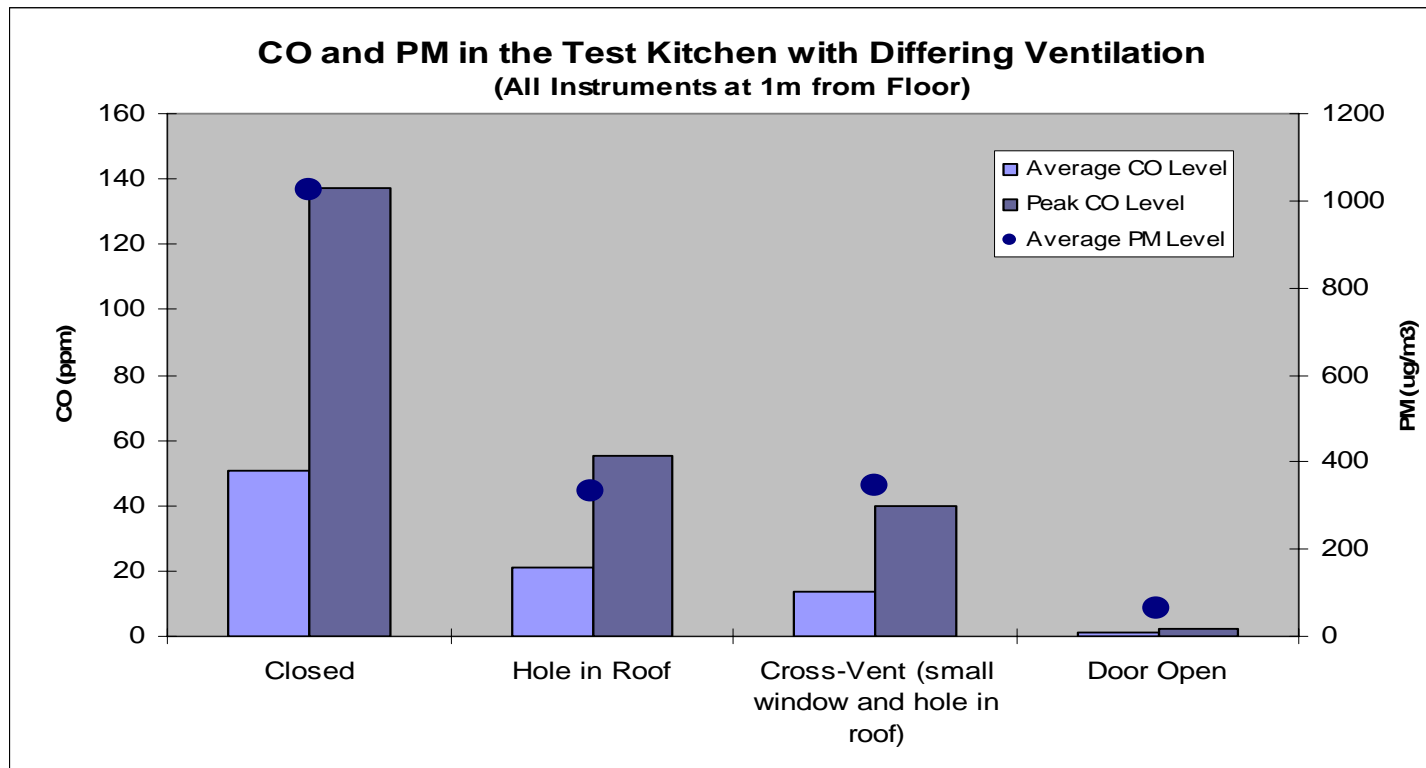
Standard or guideline	Long-term (annual)			Short-term (24 hours)		
	PM_{10}	BS	TSP	PM_{10}	BS	TSP
EU limit values		80 ^a	150 ^b		250 ^c	300 ^d
EU guide values		40–60 ^a			100–150 ^e	
USEPA primary and secondary standards	50 ^f			150 ^g		
WHO guidelines ^h		40–60	60–90		100–150	150–230
WHO guidelines for Europe ^g	50		70 ⁱ	125	120	

Stove Emissions

- Aprovecho test kitchen (3 air exch/hr) average particulate levels for carefully-operated stoves used to boil 5L of water and simmer for 30 minutes:
 - From 15,000 – 30,000 $\mu\text{g}/\text{m}^3$ – *thick smoke, limited visibility in the kitchen* –
 - open fire and portable stoves
 - About 10,000 $\mu\text{g}/\text{m}^3$ – *haze of smoke* –
 - rocket stove and charcoal stoves
 - Under 5,000 $\mu\text{g}/\text{m}^3$ – *some smoke visible* –
 - wood burning stoves with electric fan
 - Under 500 $\mu\text{g}/\text{m}^3$ – *smoke not visible* –
 - liquid gas fuels and stoves with chimneys
 - Data from “Comparing Cooking Stoves” using an AP Buck

Ventilation

- Cutting a 20 cm X 25 cm hole in the kitchen roof reduced pollution levels in the kitchen by **70%**
- Opening the door alone reduced pollution by **95%**



Estimated Daily Average PM Exposure from Stoves

Recommended Short-Term (24-hour) Limit	USEPA	150	WHO Europe	125	$\mu\text{g}/\text{m}^3$
Recommended Long-Term (Annual) Limit	USEPA	50	WHO Europe	50	$\mu\text{g}/\text{m}^3$

		Open Fire	MaliCharcoal	WFP Rocket Stove	ElectricFan/Wood Stove	Two-Pot Chimney Stove	Propane
Time to Cook 5 Liters	min.	66	73	46	55	50	77
Average Concentration During Cooking	$\mu\text{g}/\text{m}^3$	14,972	8,437	8,974	2,152	479	51
Closed Kitchen -- No Added Ventilation							
Average Concentration in 24hr	$\mu\text{g}/\text{m}^3$	2,059	1,274	865	247	50	8
Hole in Roof -- 70% Added Ventilation							
Average Concentration in 24hr	$\mu\text{g}/\text{m}^3$	618	382	260	74	15	2
Door Open -- 95% Added Ventilation							
Average Concentration in 24hr	$\mu\text{g}/\text{m}^3$	103	64	43	12	2	0

INCREASING VENTILATION

DECREASING STOVE EMISSIONS

Findings

This study does not predict in-field measurements, but provides a comparison of the effect of stove type and ventilation factors on emission levels in a test kitchen.

- Carefully operated stoves with functional chimneys and propane stoves were safe to use inside the test kitchen, even without added ventilation.
- Two carefully operated wood burning stoves with electric fans were clean enough to use inside the test kitchen with a small hole in the roof.
- The carefully operated rocket stove required significantly increased amounts of ventilation to reduce CO and PM levels to reasonable levels.
- The carefully operated open fire and charcoal stove emitted too much pollution even when the door or hole in the roof were opened to be safely used indoors.