# 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.

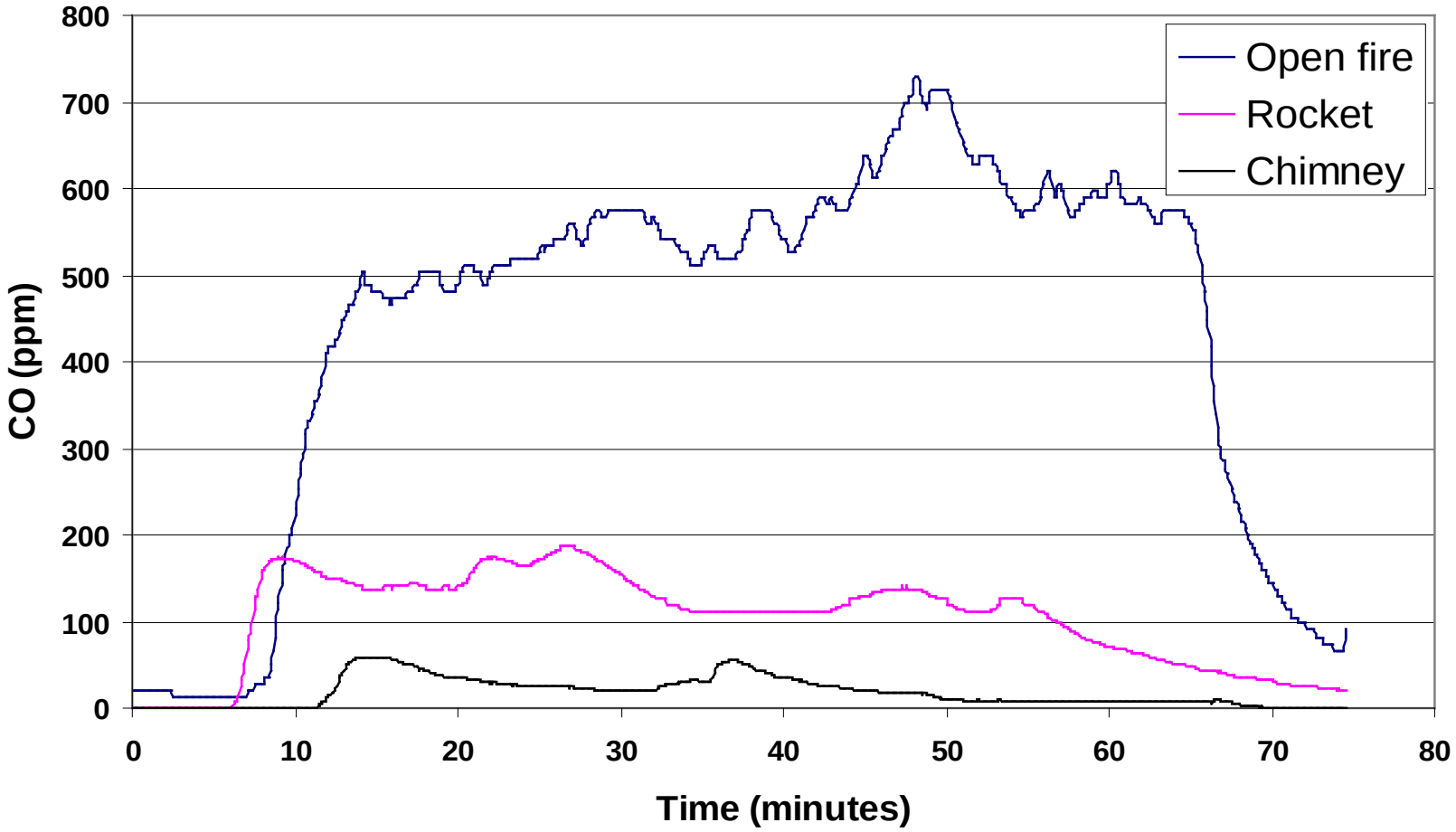
# Good, but what does it mean?

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



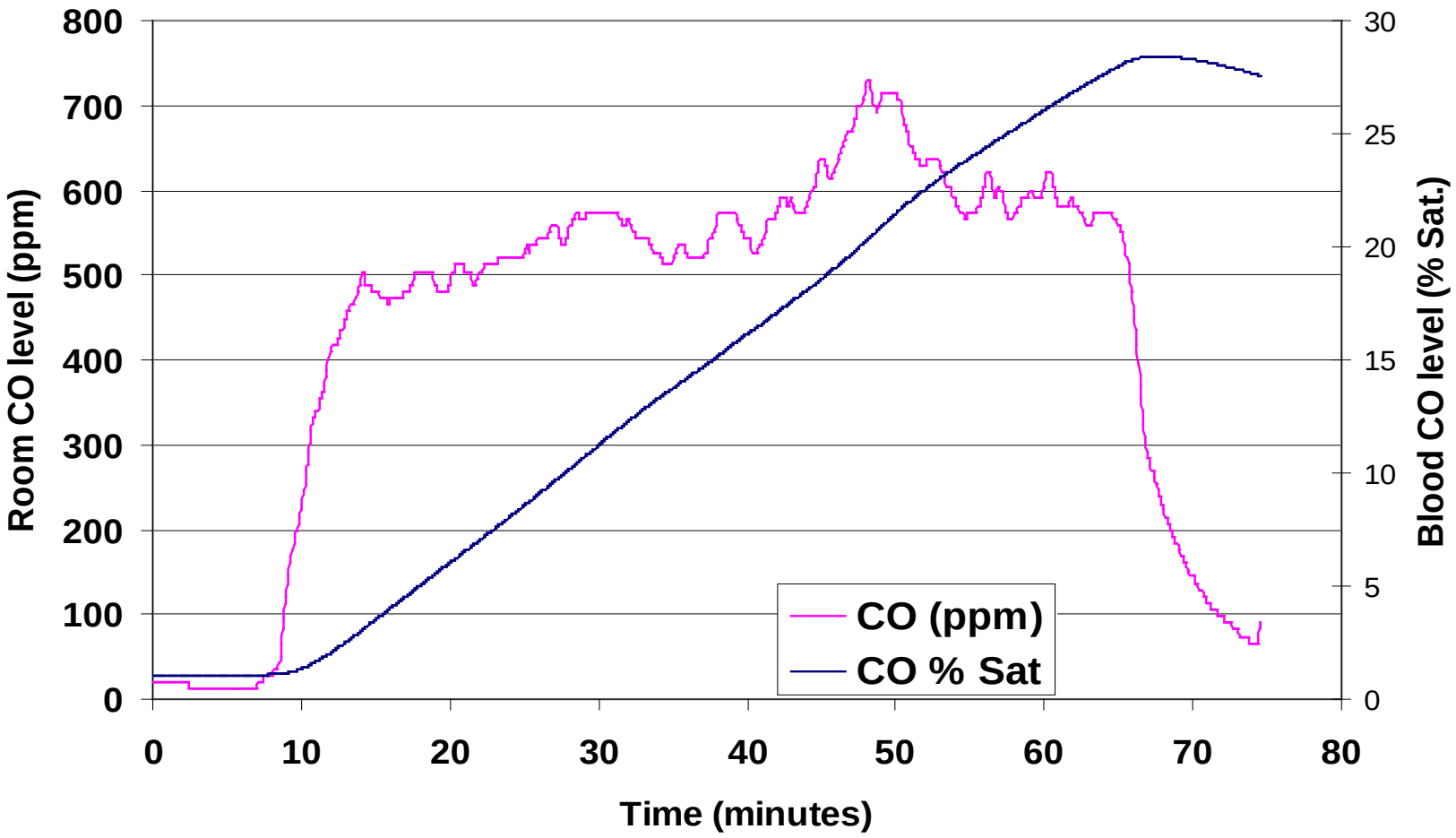
# The Coburn Equation (first published in 1965)

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

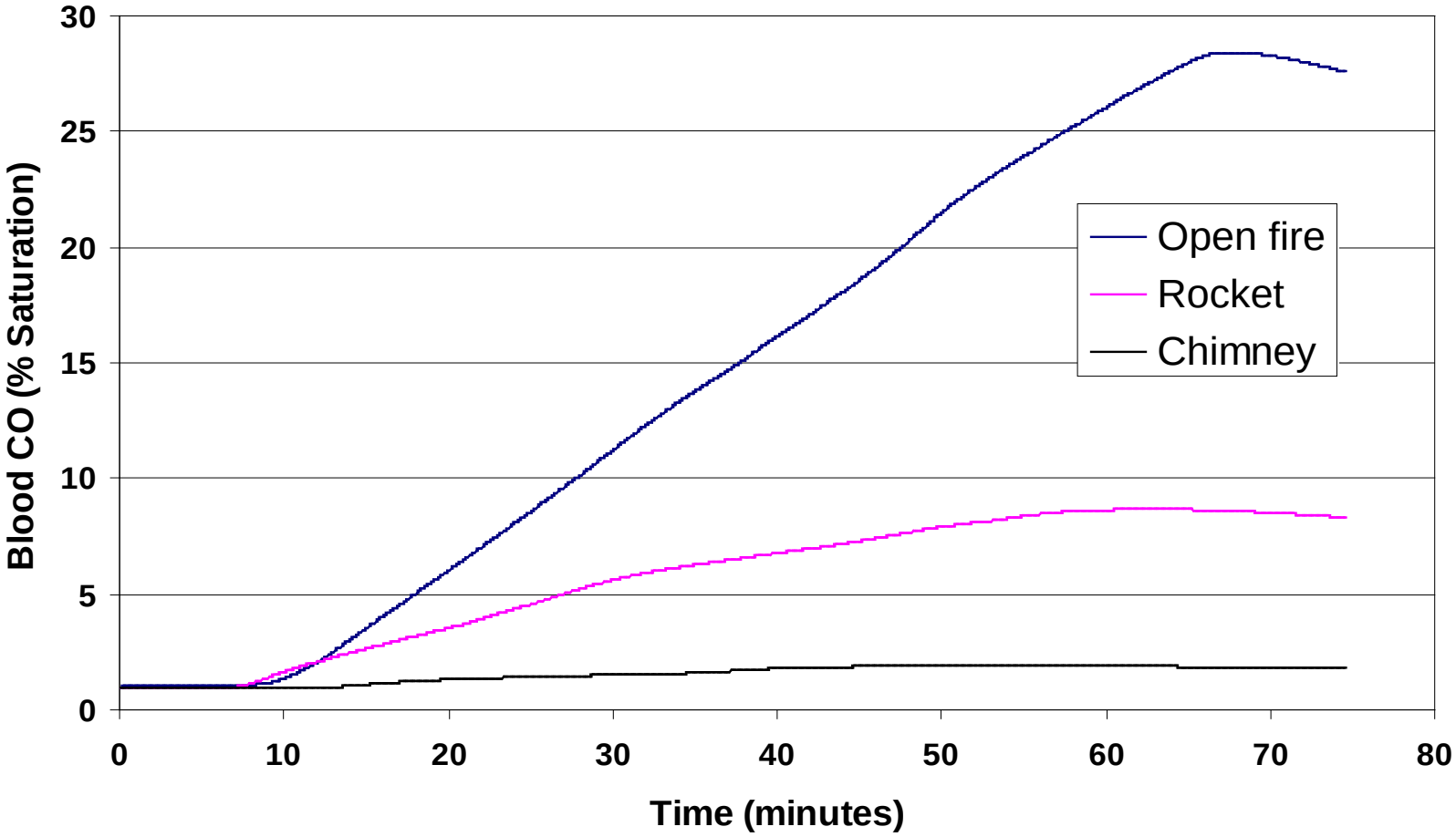
# We can relate air CO to blood CO, and to effects.

- 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


Room CO level (ppm)
Blood CO level (% Sat.)
Time (minutes)
CO (ppm)
CO % Sat
800
700
600
500
400
300
200
100
0
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80

# 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

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

# 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/m3 | 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 μg/m$^3$ over a 24-hour period is the short-term limit, while 50 μg/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

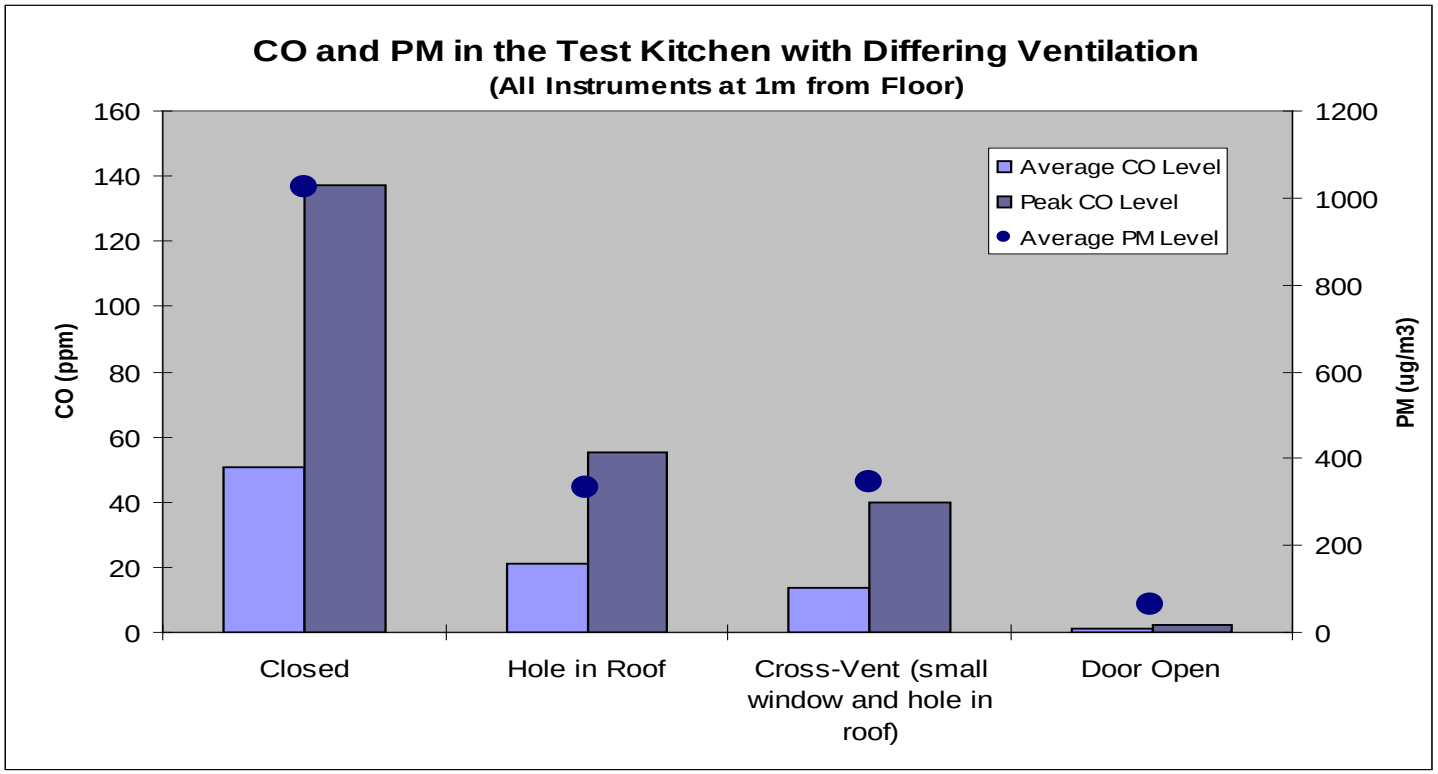
- Aprovecho test kitchen (3 air exch/hr) average particulate levels for carefully-operated stoves used to boil 5L of water and simmer for 30 minutes:

  - From 15,000 – 30,000 μg/$m^3$ – *thick smoke, limited visibility in the kitchen* –
    - open fire and portable stoves
  - About 10,000 μg/$m^3$ – *haze of smoke* –
    - rocket stove and charcoal stoves
  - Under 5,000 μg/$m^3$ – *some smoke visible* –
    - wood burning stoves with electric fan
  - Under 500 μg/$m^3$ – *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** | $\mu g/m^3$ |
| *Recommended Long-Term (Annual) Limit* | *USEPA* | *50* | *WHO Europe* | **50** | $\mu g/m^3$ |

| | | 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 | $\mu g/m^3$ | ***14,972*** | ***8,437*** | ***8,974*** | ***2,152*** | ***479*** | ***51*** |
| **Closed Kitchen -- No Added Ventilation** | | | | | | | |
| Average Concentration in 24hr | $\mu g/m^3$ | 2,059 | 1,274 | 865 | 247 | 50 | 8 |
| **Hole in Roof -- 70% Added Ventilation** | | | | | | | |
| Average Concentration in 24hr | $\mu g/m^3$ | 618 | 382 | 260 | 74 | 15 | 2 |
| **Door Open -- 95% Added Ventilation** | | | | | | | |
| Average Concentration in 24hr | $\mu g/m^3$ | 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.