

Indoor air pollution from wood burning in Danish country houses in open air museums:

Carbon monoxide and fine particle concentrations measured at the Lejre Experimental Centre

Morten Ryhl-Svendsen

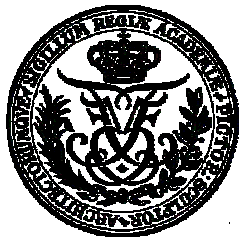
School of Conservation, Royal Danish Academy of Fine Arts

Kirk R. Smith

School of Public Health, University of California, Berkeley

Geo Clausen

International Centre of Indoor Environment and Energy,
Technical University of Denmark



Experimental centres

- Open air museums and historic centres are becoming increasingly popular
- The staging of the past is interesting as a tourist attraction as well as for education





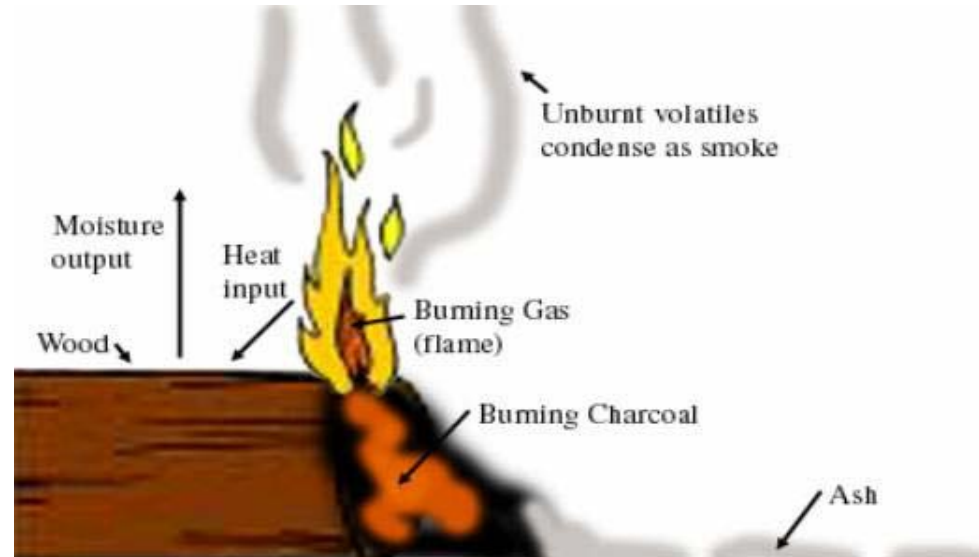
- The experimental centres are used as the field for research projects
- Staff and volunteers will be staying in historical houses, typically during the summer period



Indoor air quality in country houses

- We investigated to the indoor air quality in two country houses at the Lejre Experimental Centre, Denmark, summer 2006
- These houses are occupied each summer by volunteer families, staying for one week each in 19th century lifestyle
- All meals, hot water (and heating) are prepared over open fire
- **What is the level of exposure to wood-smoke (carbon monoxide and fine particles) for staff and visitors?**
- In the following results from one site, *the Tystrup House*, will be presented

Woodsmoke is natural – how can it hurt you?



Wood is mostly carbon, hydrogen, and oxygen: $[\text{CH}_2\text{O}]_x$ and thus should burn to only CO_2 and water

Unfortunately, in small-scale combustion much of the carbon is not combusted completely, but released as **carbon mono-oxide** and **small particles**

Not so long ago, Denmark was a low-technology
wood-burning society
not able to afford much metal.

How did its people solve the smoke problem?



The Complete Danish Hearth System



Chimney

Heater

Oven

Hot Water

Stove

The Tystrup House

- Replica of a 1790 house, original at the Danish Open Air Museum.
- Interior and furniture are 1850 style



Continuous monitoring locations

1) Hearth

2) Sitting room

3) Bed room

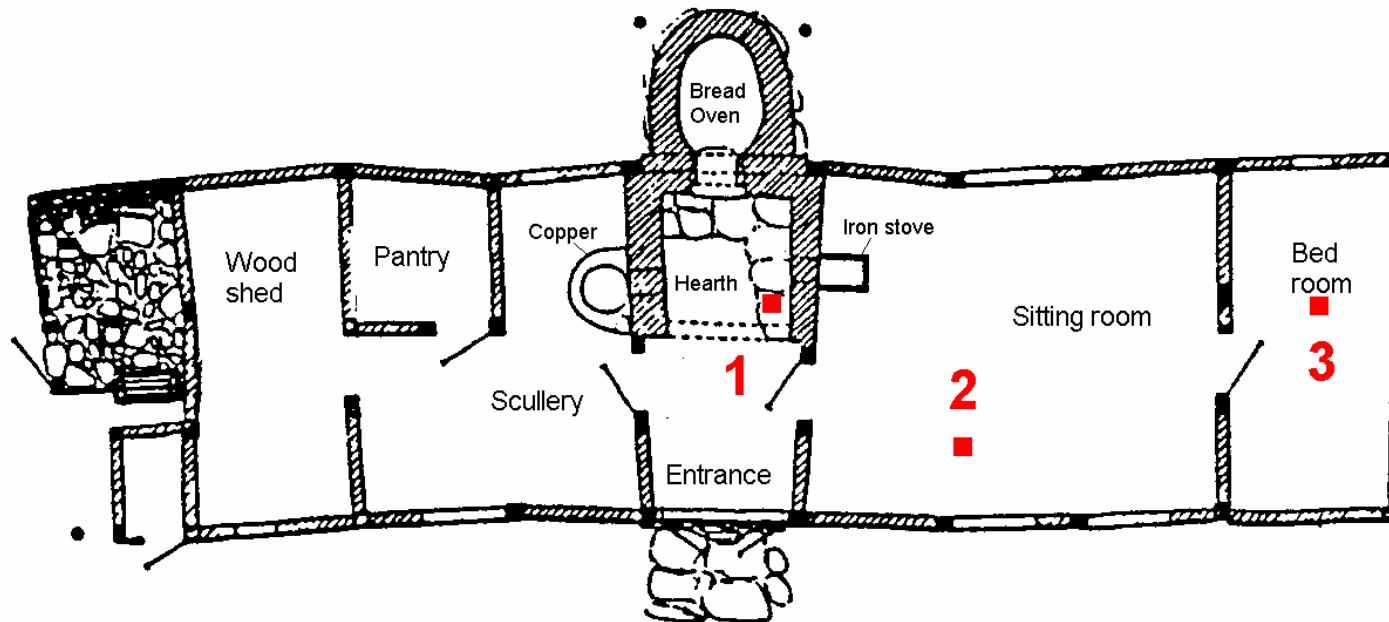
Species and Methods:

PM_{2.5} continous (Dustrak and UCB logger)

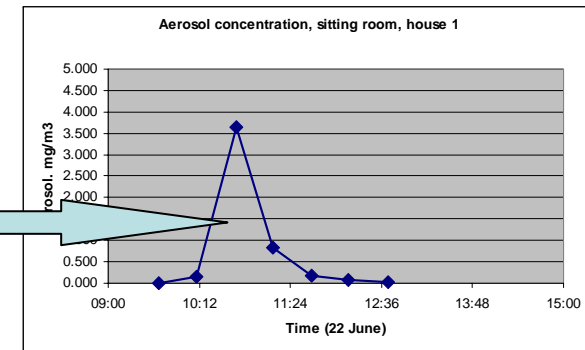
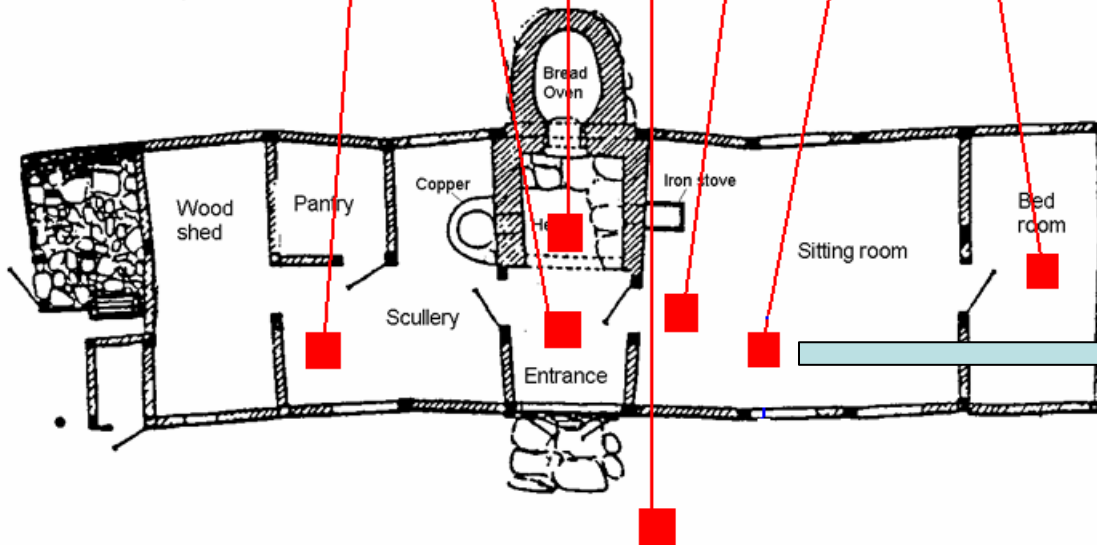
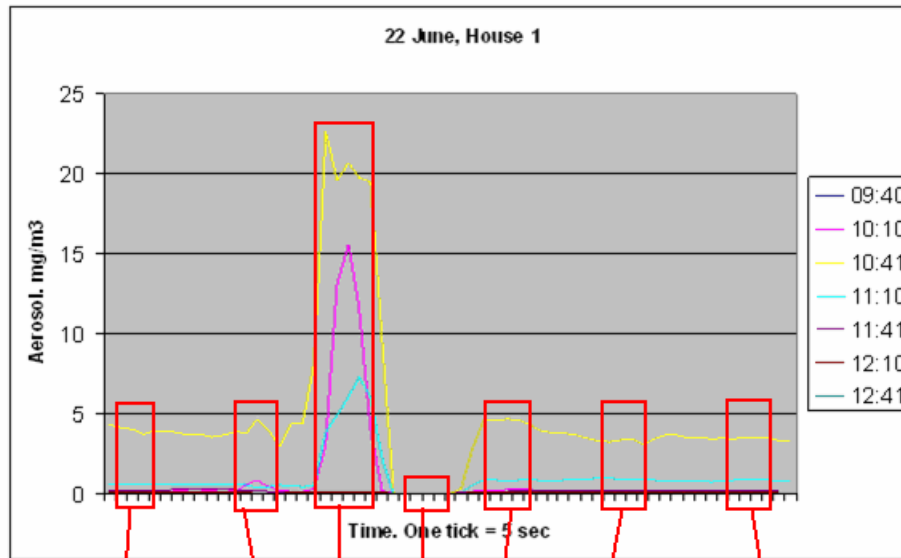
PM_{2.5}, 24h average (Gravimetric, sampling on filters)

CO continous (HOBO datalogger)

CO dosage, 24h average (diffusion tubes)



Transect measurements (Dustrak, PM_{2.5}) Every 30 min



Peak concentrations, 15 min av.

15 min averages	Hearth PM_{2.5} [mg/m³]	Hearth CO [ppm]	Sitting room CO [ppm]
Day 1 (24h)	5.81	9.26	0.20
Day 2 (24h) *	25.5	262	30.5
Day 4 (24h) **		24.6	10.3

* Heating water in large copper pot

** With family staying in house, using baking oven

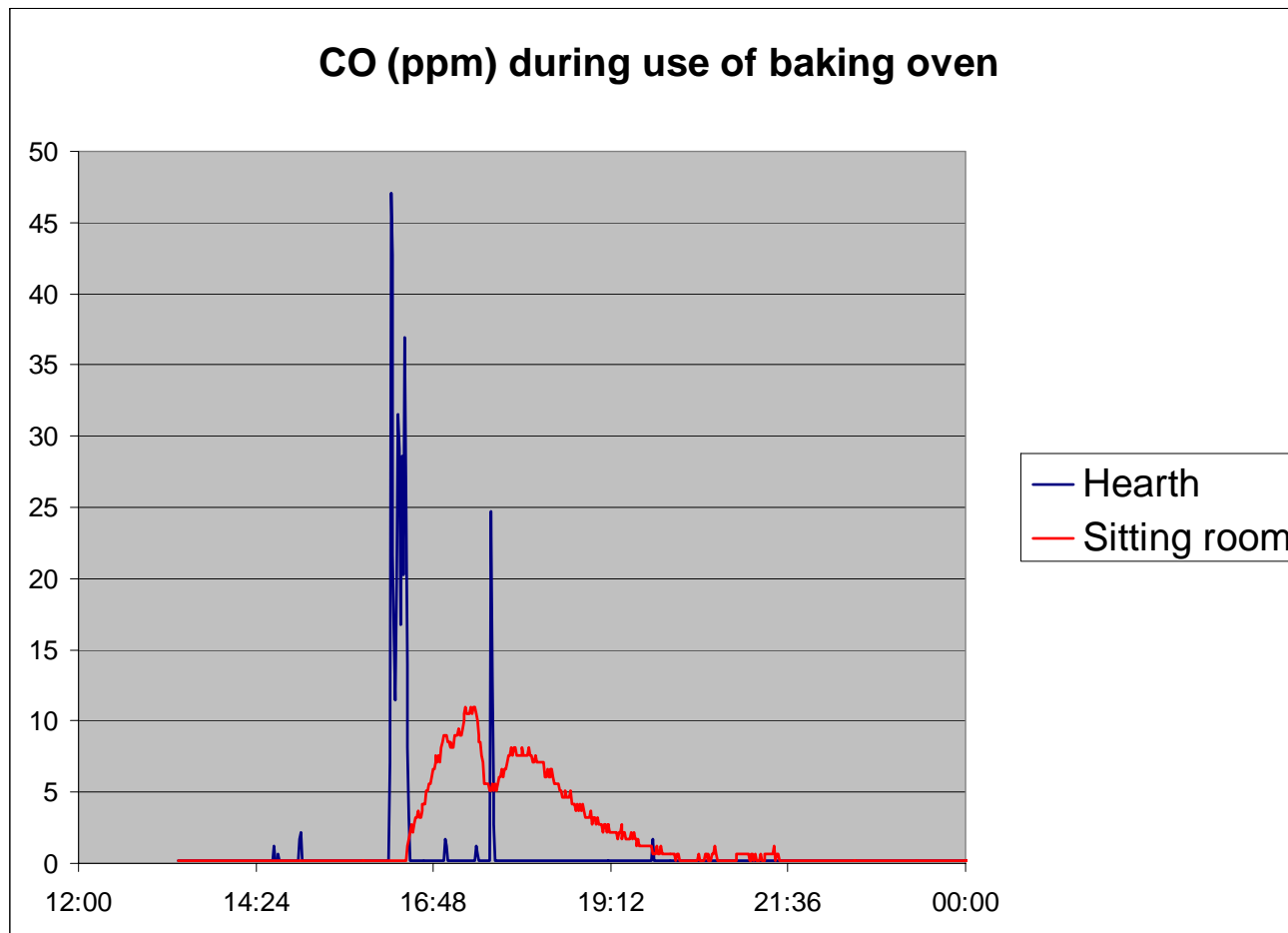
Exposures

	Hearth PM _{2.5} [mg/m ³ h]	Sitting room PM _{2.5} [mg/m ³ h]	Hearth CO [ppmh]	Sitting room CO [ppmh]
Day 1 (24h)	3.61	1.22	10.4	4.56
Day 2 * (24h)	3.00	1.86	566	43.7
Day 4 ** (24h)			13.4	22.9

* Heating water in large copper pot

** With family staying in house, using baking oven

Day 4, use of baking oven



**High CO peak in
hearth area,
however,
highest exposure
in adjacent
sitting room**

Discussion

- A typical day for woman in household:
- Cooking all meals, and a large work task in kitchen during afternoon

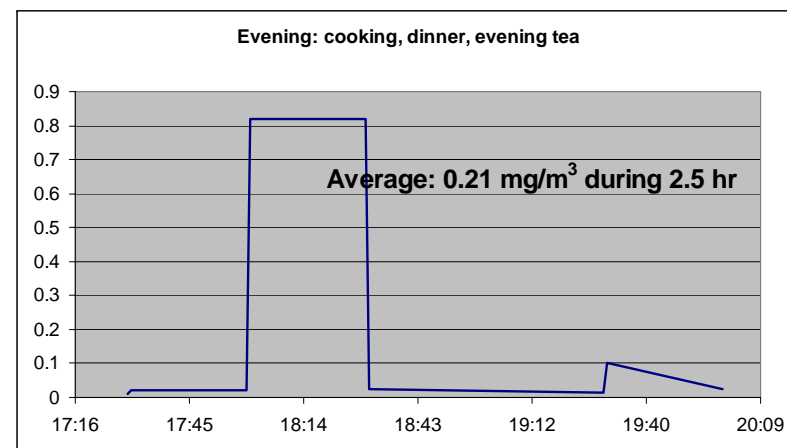
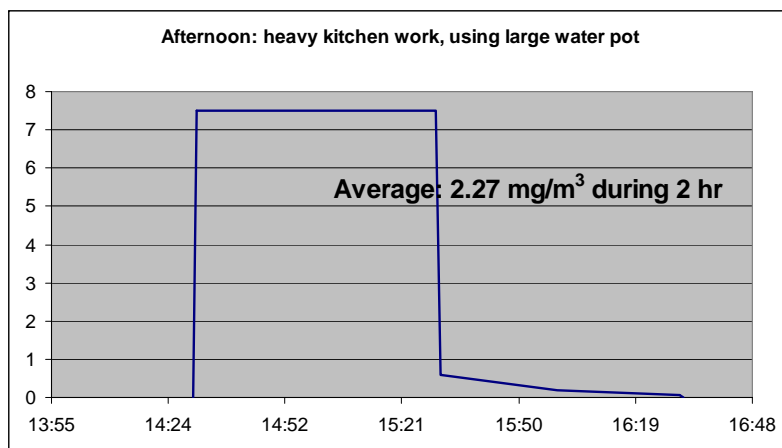
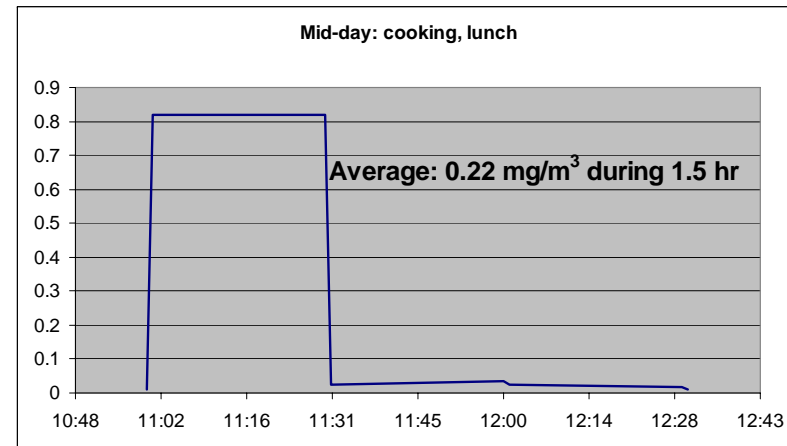
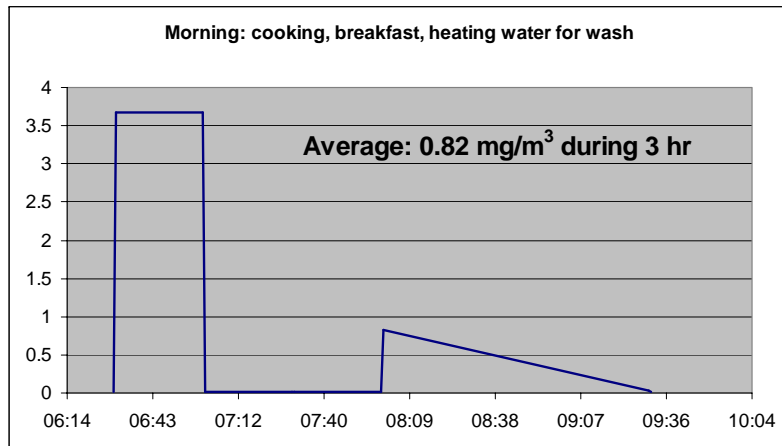


Daily routine for woman in 19th-century household

06:30	Waking up
06:30-07:00	Working in hearth area, starting fire for morning wash and breakfast
07:00-07:30	Working in kitchen area
07:30-08:00	Breakfast, Sitting room
08:00-09:30	Working in kitchen area, washing dishes, preparing next meal
09:30-11.00	Outside, feeding animals, garden or field work
11:00-12:00	Preparing lunch (warm meal) spending half time in hearth area
12:00-12.30	Lunch, sitting room
12.30-13:00	Working in kitchen area
13.00-14:00	Outside. Garden or field work
14:00-16:00	Working in kitchen and hearth with large copper pot
16:00-17:00	Outdoor, garden or field work
17:00-18:30	Preparing dinner, one hour in hearth, one hour in kitchen area
18:30-19:30	Dinner, sitting room
19:30-20:30	Kitchen work, washing, preparing food for next day
20:30	Making evening tea (hearth area 15 min)
21:00	Fire out
22:00	To sleep

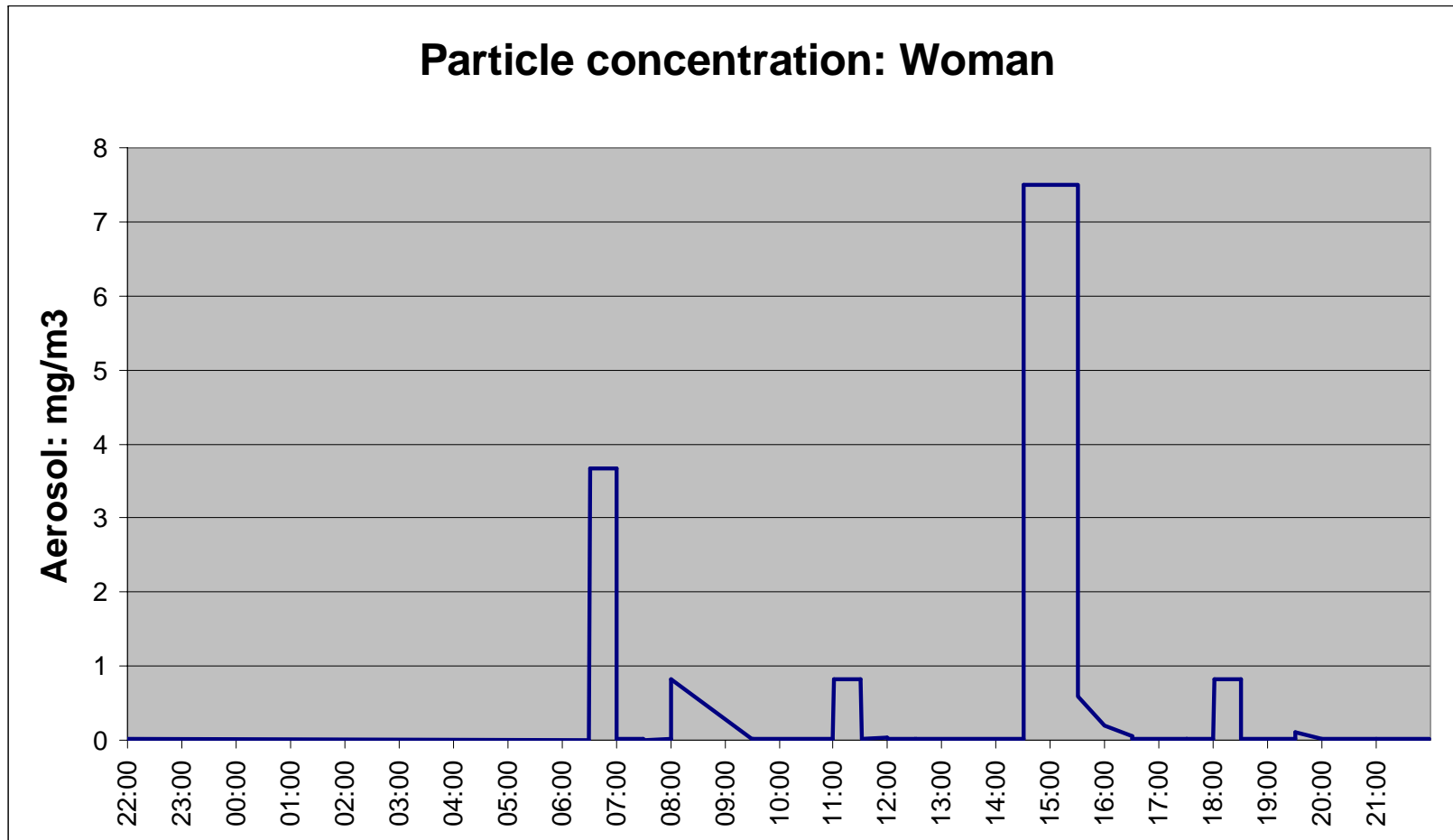
Time indoors: 19.5 hr, about 2.5 hr in hearth area

Average particle concentration during four typical work situations in kitchen and hearth area



Note: scales are different

Exposure to particles (PM_{2.5}) over one typical day



24 hr exposure: 10.3 mg/m³h

Our results: Exposure to CO



- Woman in family staying in house 1 was equipped with a Gastec CO diffusion tube
- **Exposure was <10 ppmh over 2 days (average c. 0.21 ppm)**
- Exposure at different locations inside house at same time (48h):
 - **18 ppmh in hearth area (0.38 ppm)**
 - **27 ppmh in sitting room (0.56 ppm)**

WHO Guidelines on CO

For CO max. 86 ppm short term
(15 min av.)

Exceeded in heart area

(up to 262 ppm), but not in other rooms

Our results: Fine particles

In kitchen areas we had: **0.21 – 2.27 mg/m³**

How does it compare?

Measurements in houses from Guatemala:
Average **0.93 mg/m³** in kitchens with open fire
(RESPIRE Research Group, Chowdhury et al)

Conclusion

- Staff and visitors may be exposed to a **moderate to high exposure** of CO and fine particles.
- For the **few days** that are typically involved, however, there is **unlikely to be a serious longterm health risk**
- Even in short stays, however, some people may be exposed to high peak concentrations, especially if unfamiliar with maintaining a wood fire.

Acknowledgements

Dyveke Larsen, Lejre Experimental Centre

Zohir Chowdhury, UCB

Claus Hansen, DTU student

Thomas Nielsen, DTU student

Our team.....

