Introduction

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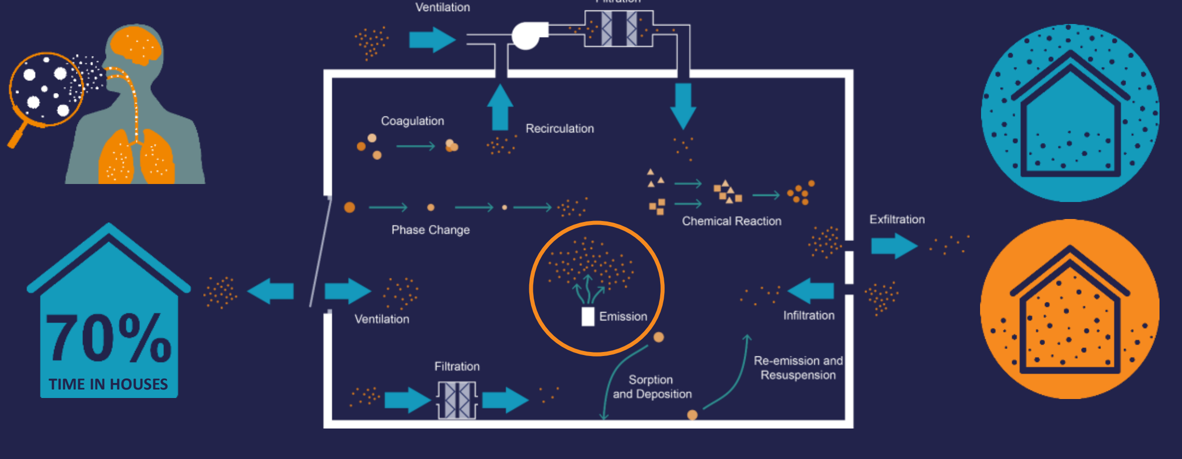
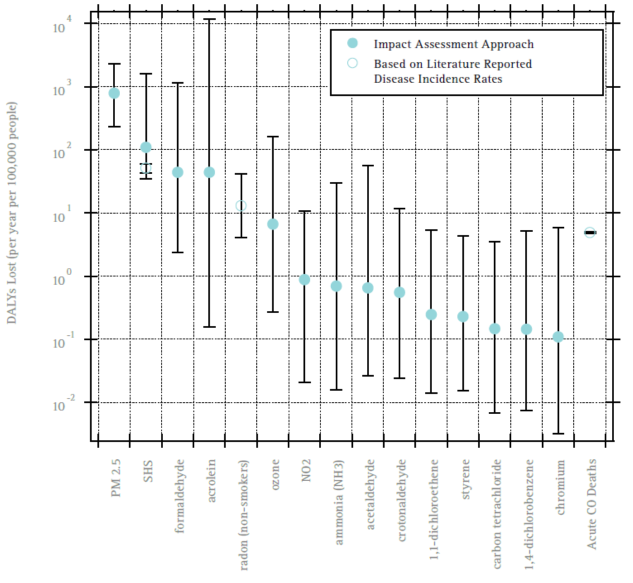
Pollutant behaviour



Which pollutants matter?

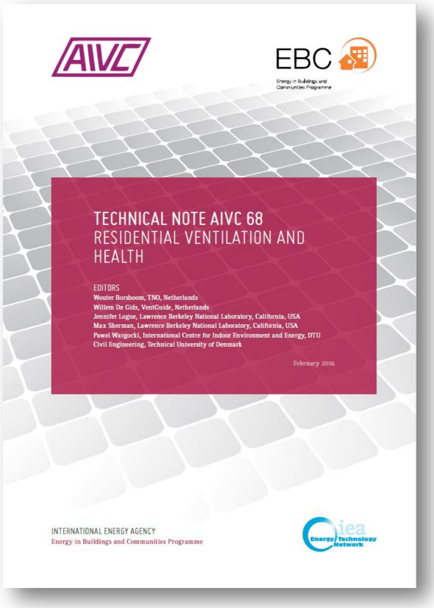


Borsboom W, De Gids W, Logue J, Sherman M, Wargocki P. Technical Note AIVC 68: Residential Ventilation and Health. Air Infiltration and Ventilation Centre, Brussels Belgium. 2016.

FROM:

Logue JM, Klepeis NE, Lobscheid AB, Singer BC. Pollutant Exposures from Natural Gas Cooking Burners: A Simulation-Based Assessment for Southern California. Environmental Health Perspectives. 2014;122(1):43-50.

Why $PM_{2.5}$?



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webinar
2019.05.23

Iain Walker

webinar
2019.05.23

Catherine O'Leary

Empirical and theoretical investigations of fine particle emission from cooking

Catherine O'Leary
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Outline

1. Laboratory
2. In-situ
3. Regulation

University of Nottingham
UK | CHINA | MALAYSIA

Section 1

Measuring emissions from cooking

University of Nottingham
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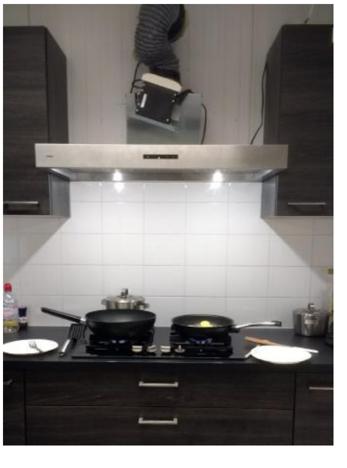
Measuring $PM_{2.5}$ emission rates from cooking complete meals

Laboratory tests with TNO to investigate:

1. Uncertainty in emissions from cooking full meals
2. Factors effecting emissions
3. Potential reduction of using a typical cooker hood



O'Leary C, de Kluizenaar Y, Jacobs P, Borsboom W, Hall I and Jones B. (2019) *Investigating measurements of fine particle ($PM_{2.5}$) emissions from the cooking of meals and mitigating exposure using a cooker hood.* Indoor Air 29(3): 423-438.

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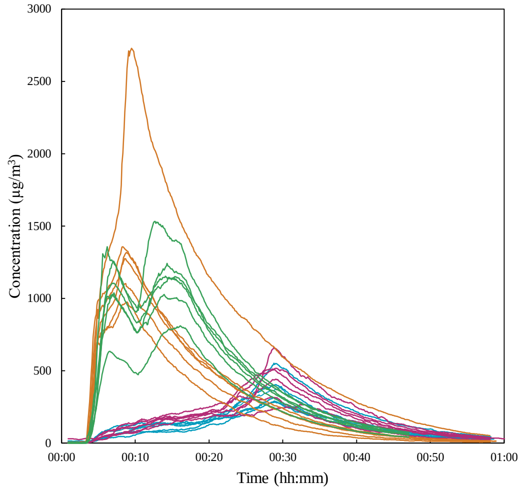
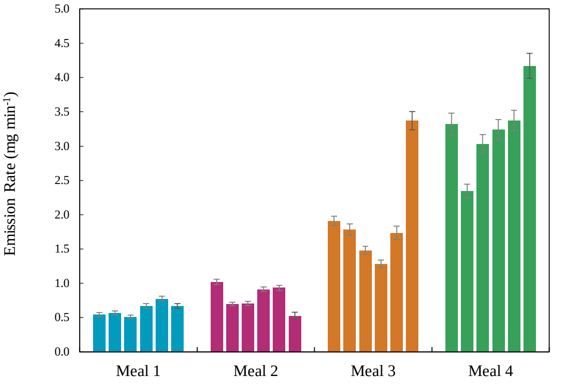
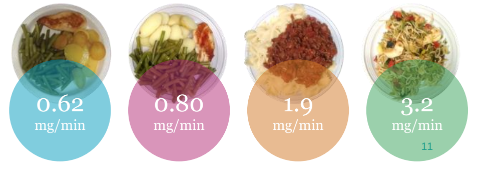
Emission Rates







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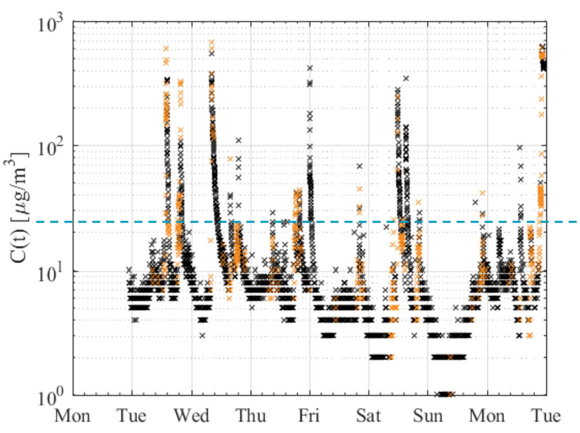
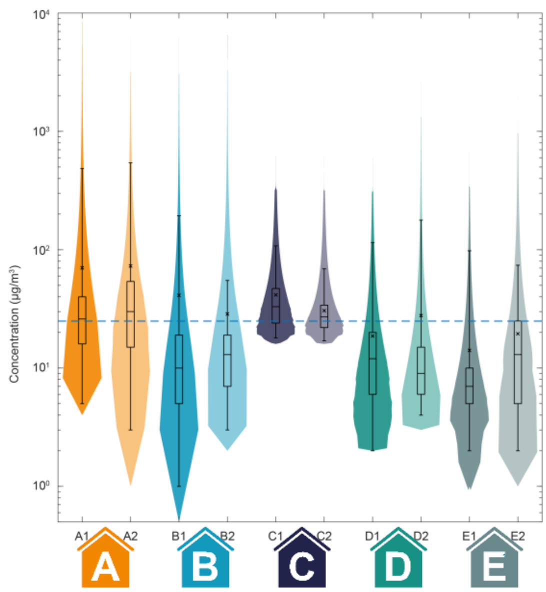
Section 2

In-situ

Example Test Set Up

Preliminary Results





Section 3

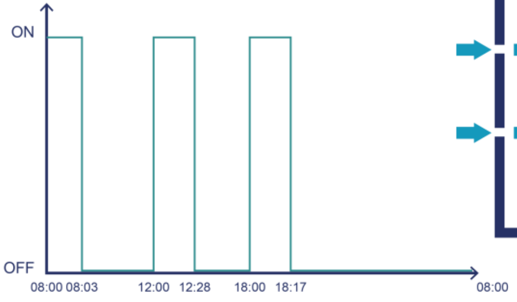
Regulation

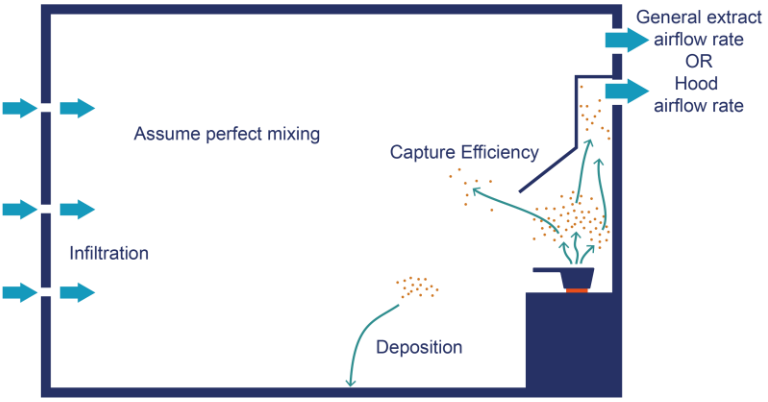
Kitchen ventilation efficacy

1. Predict internal concentrations in UK kitchens
2. Identify ventilation efficacy
3. Using a tried and tested modelling approach
4. Augmented to assess uncertainty
5. Sensitivity analysis to test relative importance of inputs

Model Kitchen

Models winter conditions
(no windows)





Model inputs

Conditions:

1. 3 cooking periods/day
2. Toasting for first meal (short duration)
3. Other meals use emission rates from full meals (longer)
4. Variable spacing
5. Kitchen volumes taken from the English Housing Survey (2009 data)
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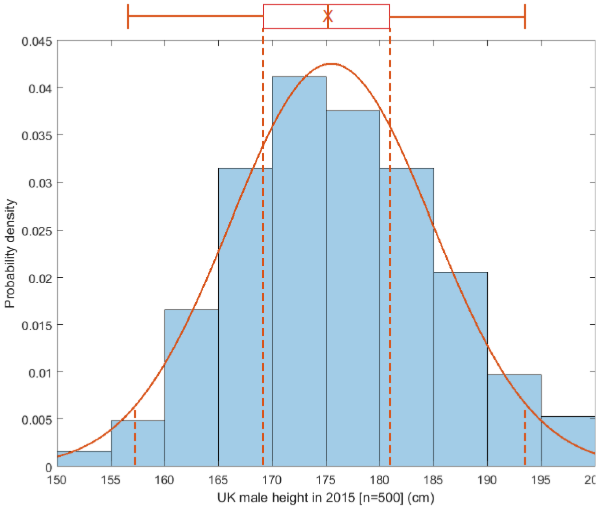
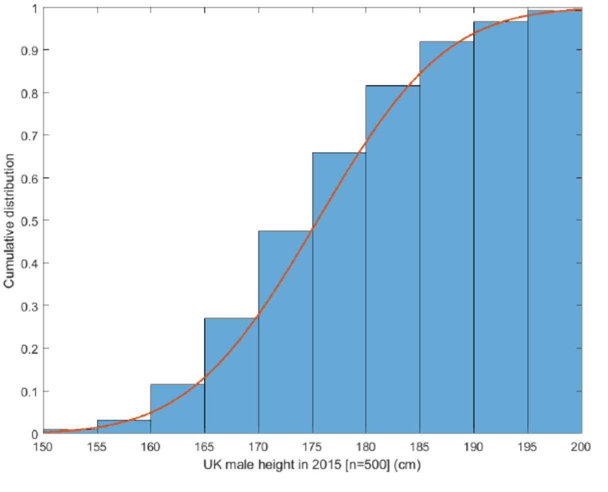
Model inputs

Initial scenarios:

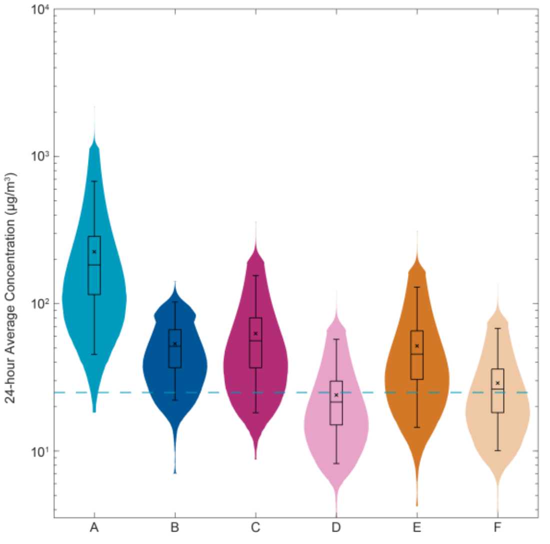
1. Infiltration only - baseline
2. Constant 13l/s mechanical extract
3. Intermittent 60l/s using extractor fan (away from stove)
4. Cooker hood 30l/s with 50% capture efficiency (arbitrary)
5. Intermittent flow for
    1. meal only
    2. meal plus 10 minutes
6. Compare against WHO $PM_{2.5}$ daily mean threshold

Monte Carlo Methods





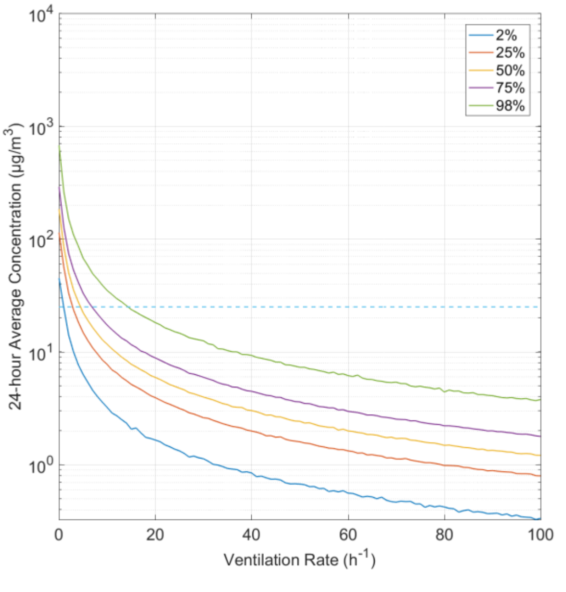
Predicted Average concentrations



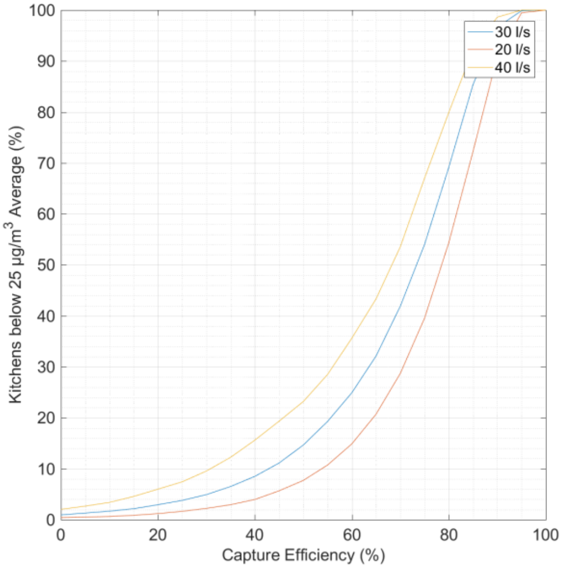
A. Infiltration only
B. Constant Mechanical Extract Ventilation at 13 l/s
C. 60 l/s intermittent general extract ventilation, only during cooking
D. 60 l/s intermittent general extract ventilation, during cooking plus 10 minutes after
E. 30 l/s intermittent extract through a cooker hood with CE 50% only during cooking
F. F - 30 l/s intermittent extract through a cooker hood with CE 50% during cooking plus 10 minutes after

WHO 24-hour guideline 25 μg/m³

Setting Constant Ventilation Rate



Setting Ventilation Requirements



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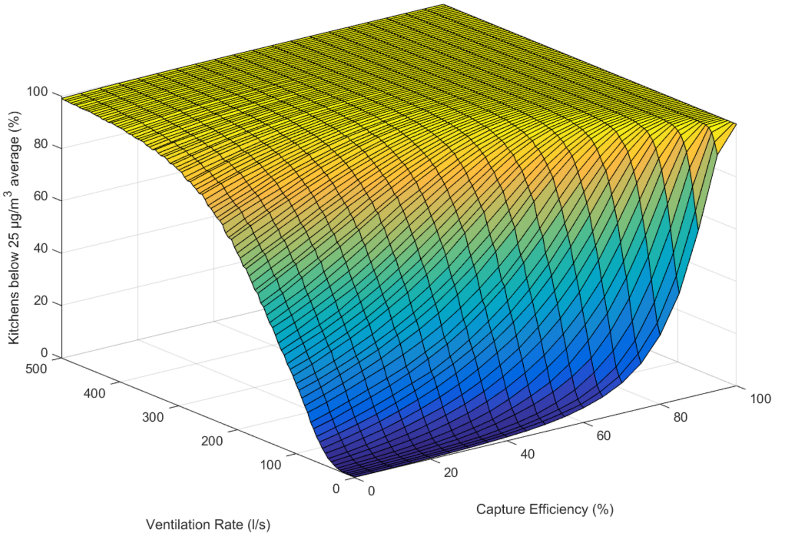
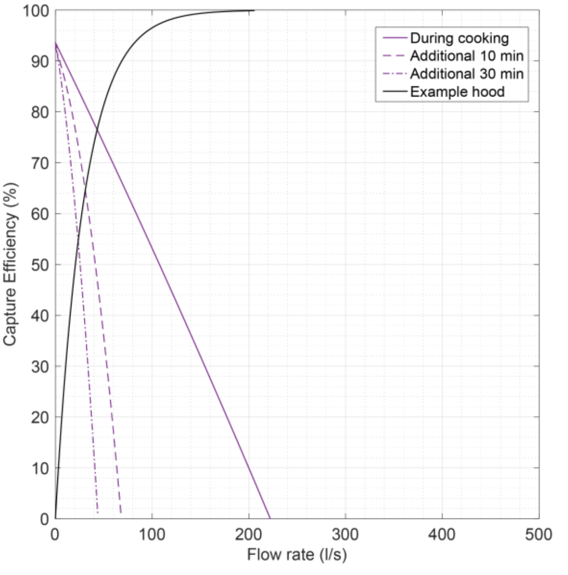
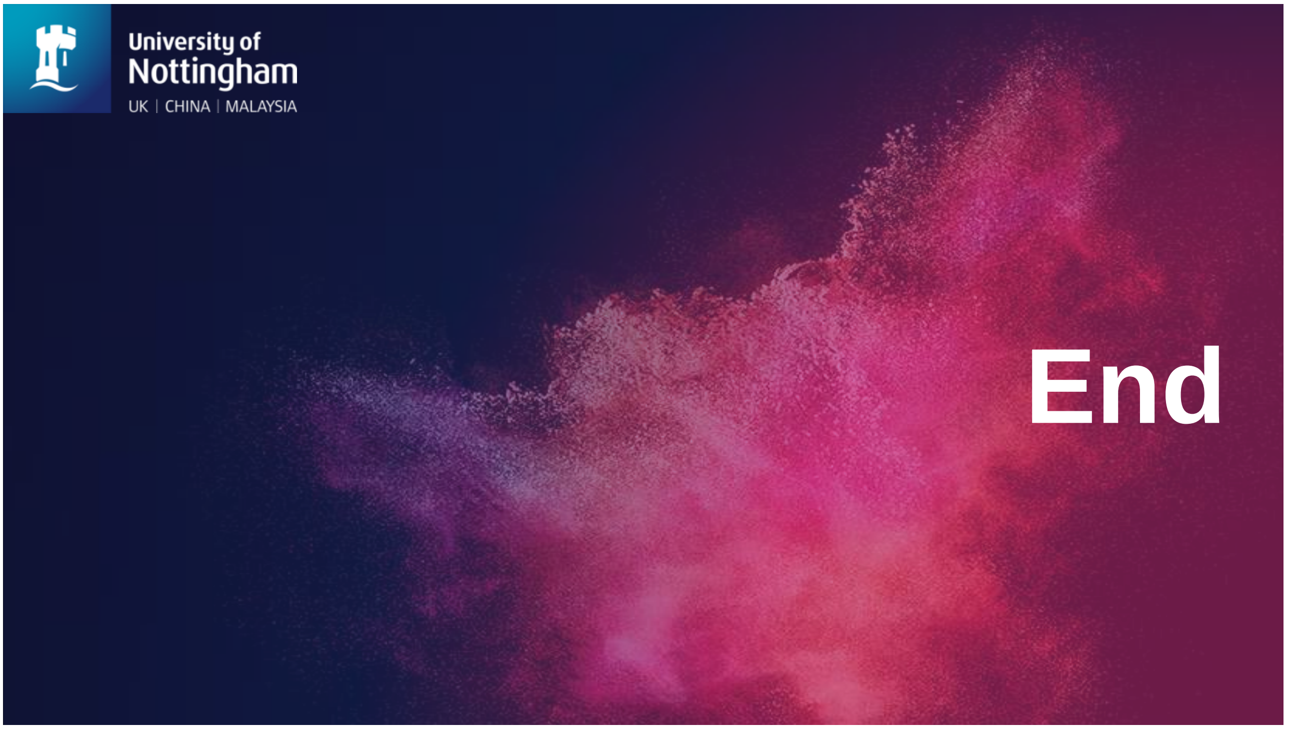


Required combination of capture efficiency and flow rate





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2019.05.23

Catherine O'Leary

webinar
2019.05.23

Willem de Gids

webinar
2019.05.23

Thanks for joining us!

Benjamin Jones (University of Nottingham, UK)

Iain Walker, LBNL, USA(LBNL, USA)

Catherine O'Leary (University of Nottingham, UK)

Willem de Gids (VentGuide, NL)

Maria Kapsalaki (INIVE, BE)

Valérie Leprince (INIVE, FR)

Evaluating Cooker Hood Effectiveness

Dr. Iain Walker
Lawrence Berkeley National Laboratory
Berkeley USA

Cooking & burners emit air pollutants

CO_2 & H_2O

NO,NO_2, HONO, Formaldehyde

Ultrafine particles

Ultrafine particles, NO_X

Ultrafine particles

Formaldehyde

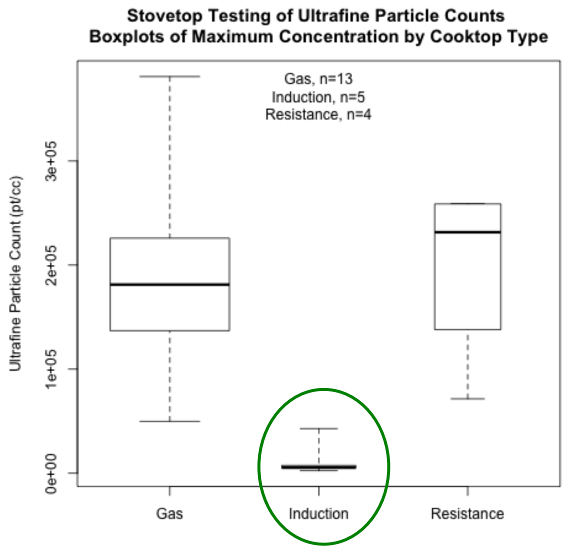
Acetaldehyde

Acrolein

$PM_{2.5}$

PAH

Induction cooking emits less Ultrafine Particles



When is a cooker hood not a cooker hood?

If it blows hot greasy air in your face… it is NOT a cooker hood

It must vent to outside

When is a cooker hood not a cooker hood?

Downdraft has no "hood"

How can you tell if a cooker/range hood works well?

The effectiveness of range hoods at capturing cooking pollutants is called capture efficiency

Performance Metric – Capture Efficiency

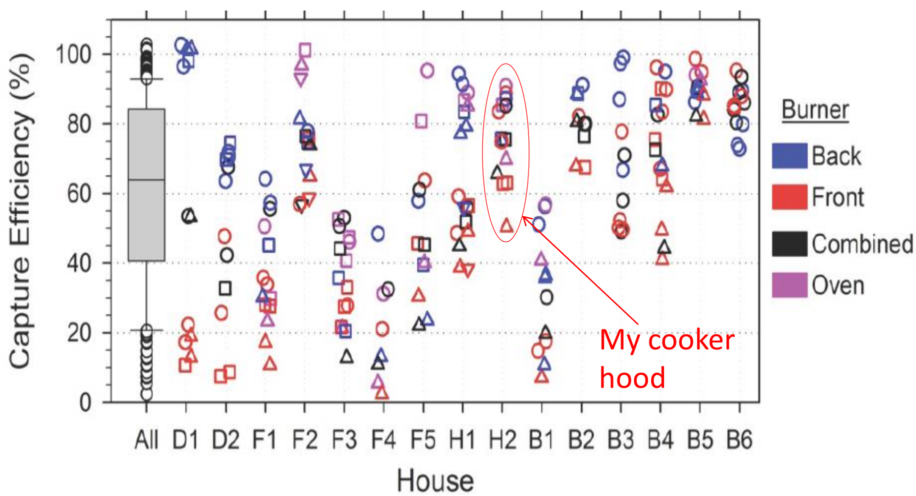
- Capture Efficiency (CE) is the fraction of pollutants generated by cooking that are exhausted by the cooker hood
- Cooking plume seeded with CO_2
  - From gas burner or deliberate injection
- CO_2 measured in outside air (C_i), room (C_c) & exhaust air (C_e)

$$CE = \frac{C_e - C_c}{C_e - C_i}$$

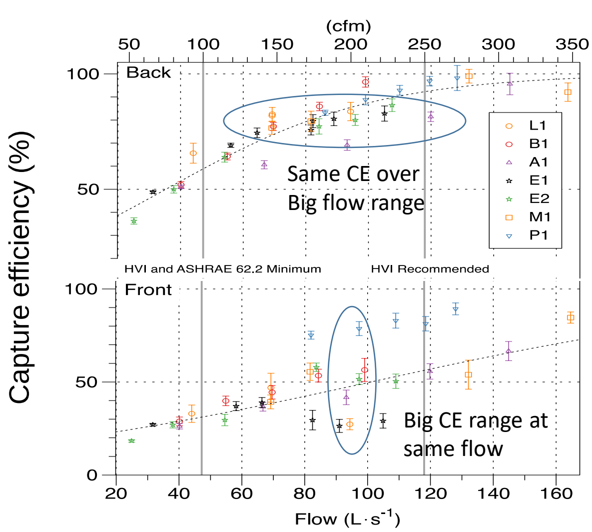
Studies of cooker hood performance

In homes

Big range of range hood performance in homes



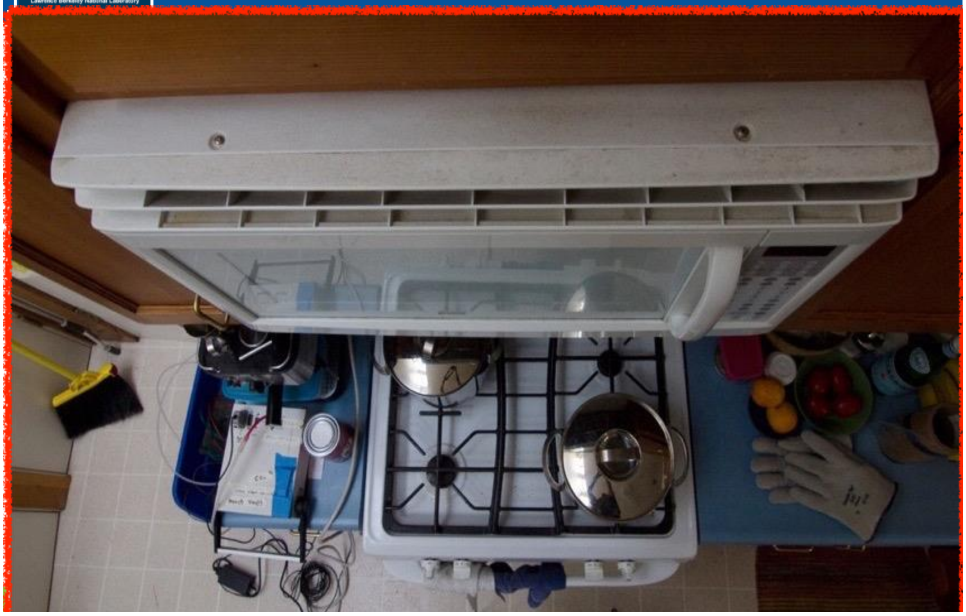
Big range of performance in the under controlled lab testing



What is important:

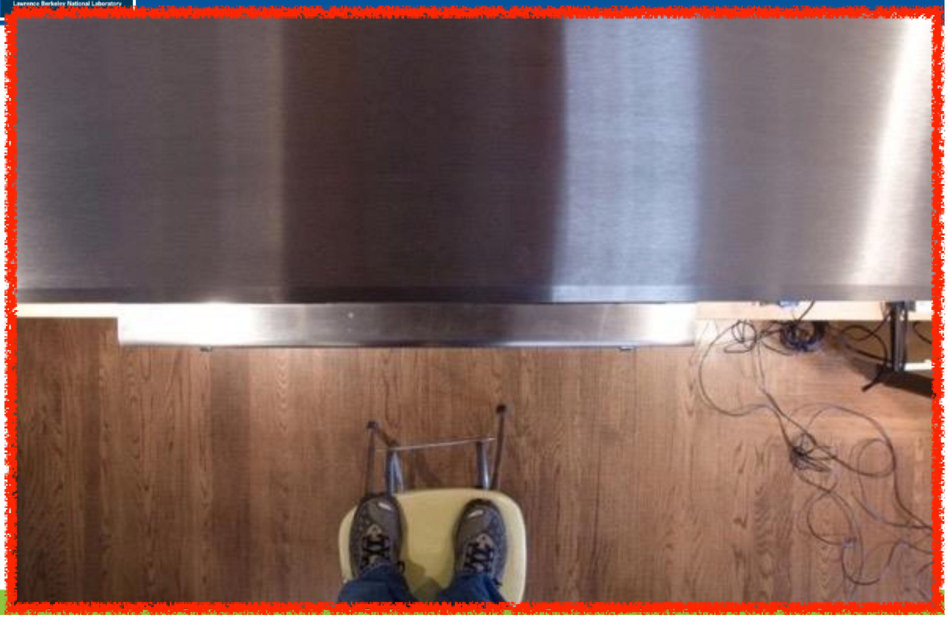
1. Air flow: more = better
2. Geometry:
   - Back burner capture better than front
   - Coverage of burners
   - Hood shape and air inlet design
3. Industry needs a rating

Bad coverage = poor capture



Typical coverage = OK for back burners

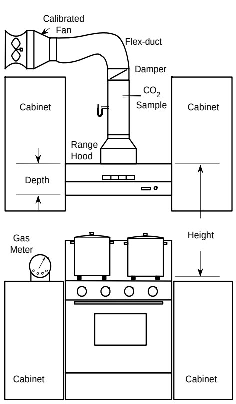
Good coverage = good capture



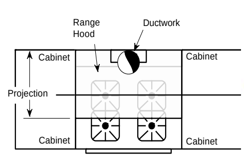
Standardized testing

Uniform test chamber & cooktop/countertop

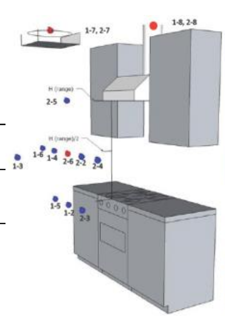
2.3m x 4.6 m floor plan



View

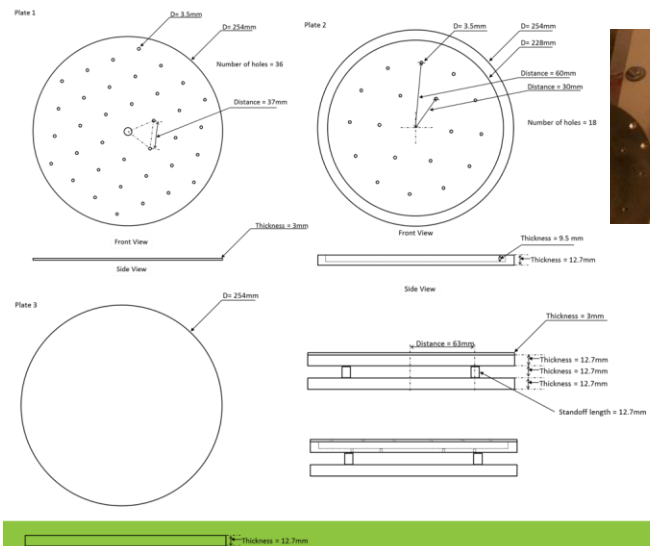


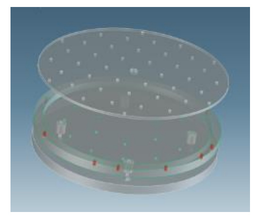
Plan



Standardized testing

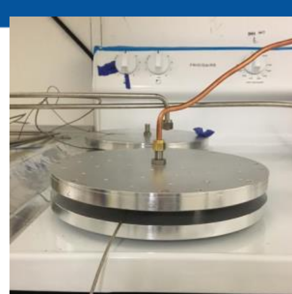
Tracer gas emitter plate





Standardized testing

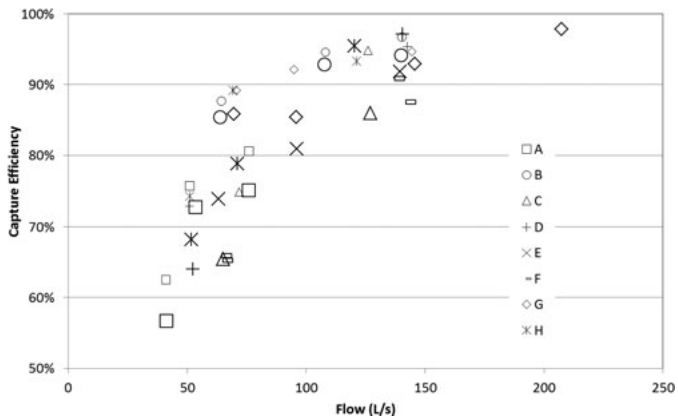
Standard emitter plate



Standard temperature and power input to plume

- A typical cooking event: 160 C and 600W per burner
- 2 Front burners

Standardized testing results



Repeatability typically +/- 0.5 CE
Worst case +/- 1.4% CE

ASTM test method + Ratings

This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: E3087 – 17

Standard Test Method for
Measuring Capture Efficiency of Domestic Range Hoods[1]

This standard is issued under the fixed designation E3087; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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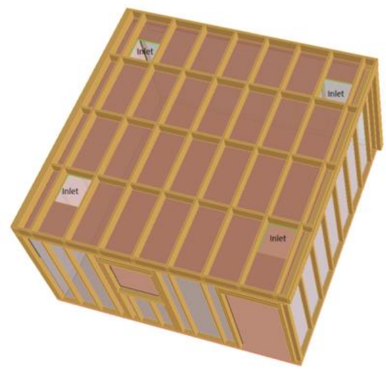
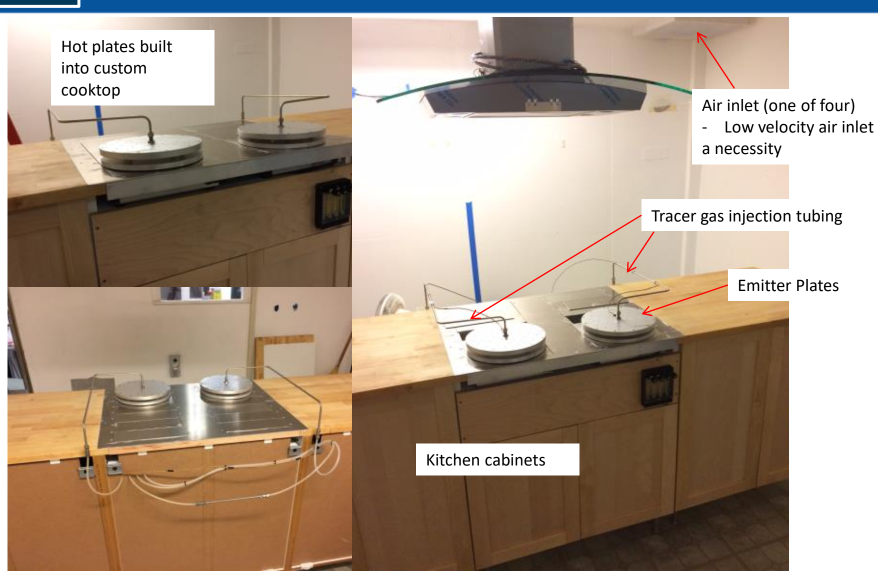
Certified Ratings in Air Delivery, Sound and Energy for Accurate Specifications and Comparisons

Island/downdraft Test Chamber

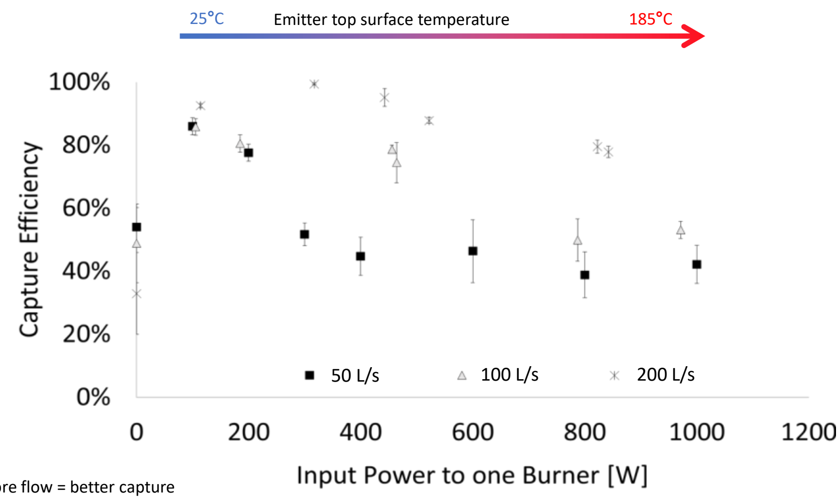
Well sealed
Multiple air inlets with diffuser screens
Double size of wall-mount test chamber



Island Hood In Test Chamber



Preliminary Island Results



More flow = better capture
Less variability above 400W

Kitchen venting: What to look for

- Good coverage
- CE ratings coming soon (>80%CE)
- Flow >100 L/s
- Quiet
- Shortest path to outside for ducting
- Follow manufacturers installation recommendations for mounting height
- Use an induction cooktop

Simple advice:
- Cook on back burners
- If too noisy on high use it on low – much better than doing nothing

Empirical and theoretical investigations of fine particle emission from cooking

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Section 1

Measuring emissions from cooking

Measuring $PM_{2.5}$ emission rates from cooking complete meals

Laboratory tests with TNO to investigate:

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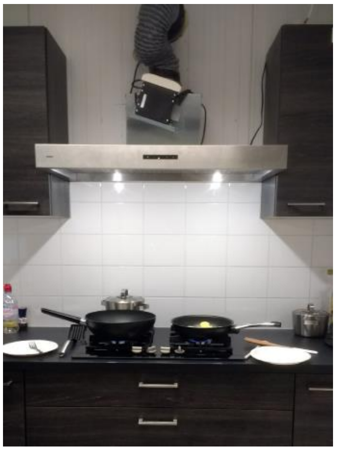

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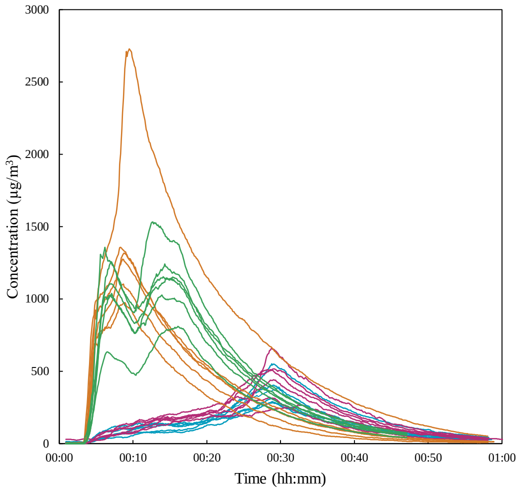
Emission Rates



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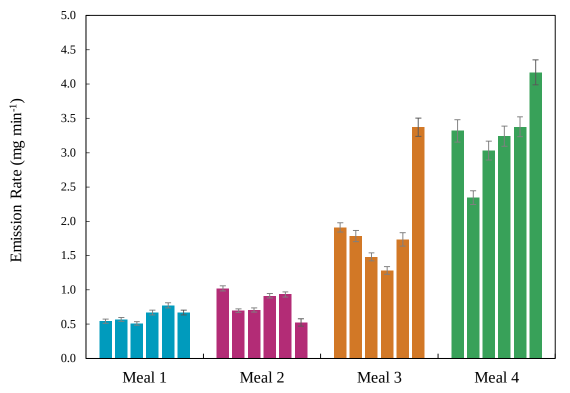

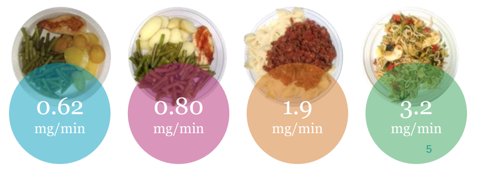

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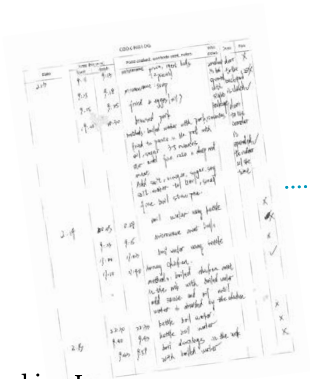
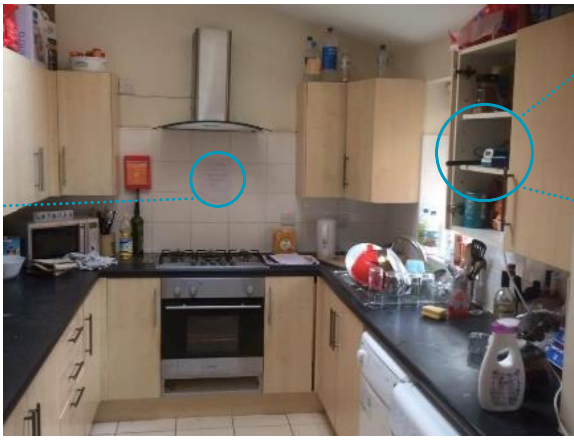
Section 2

In-situ

Example Test Set Up



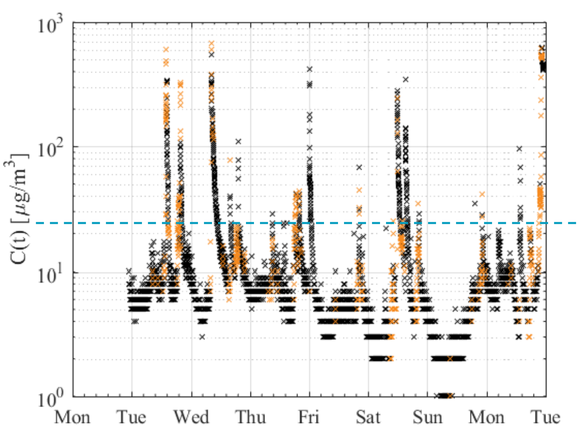
Cooking Log

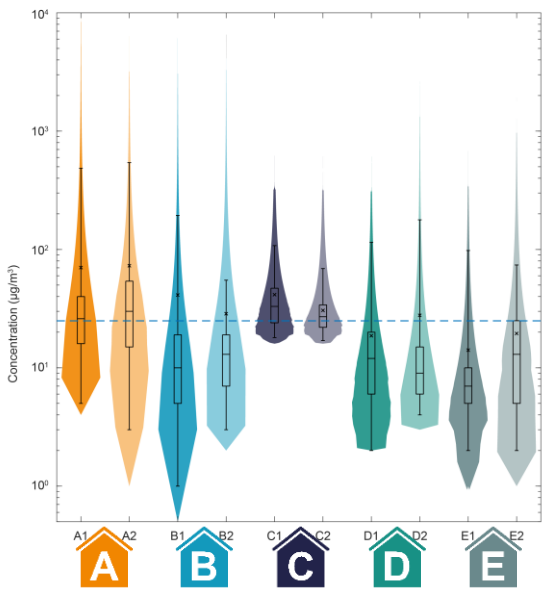


$PM_{2.5}$

Temperature
Relative
Humidity
CO
CO_2

Preliminary Results





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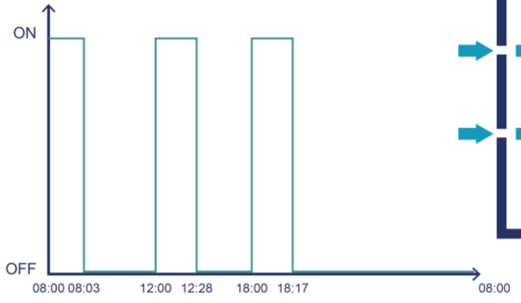

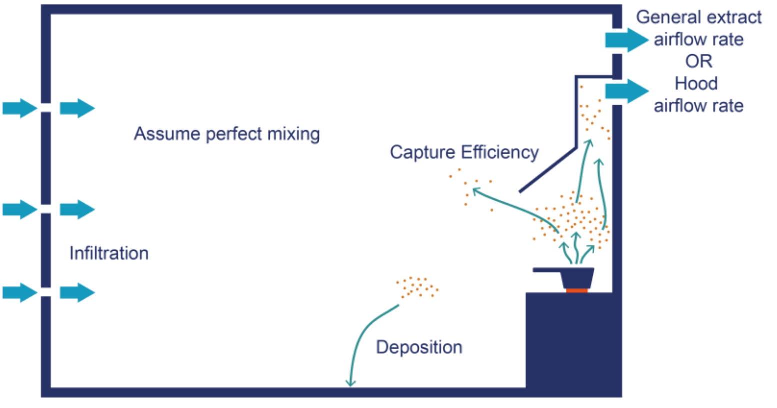

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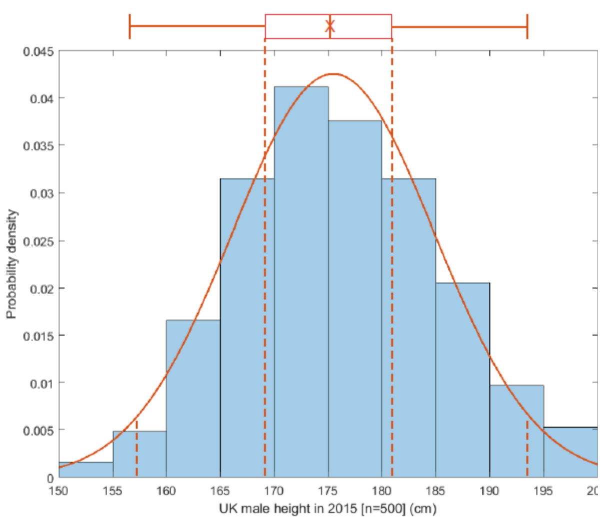

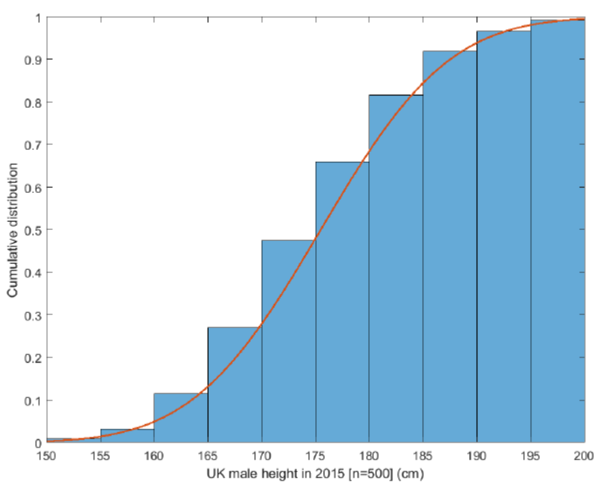

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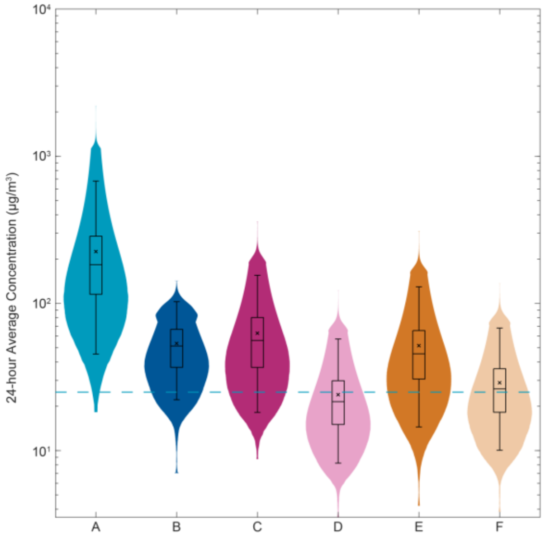
Predicted Average concentrations



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WHO 24-hour guideline 25 µg/m³

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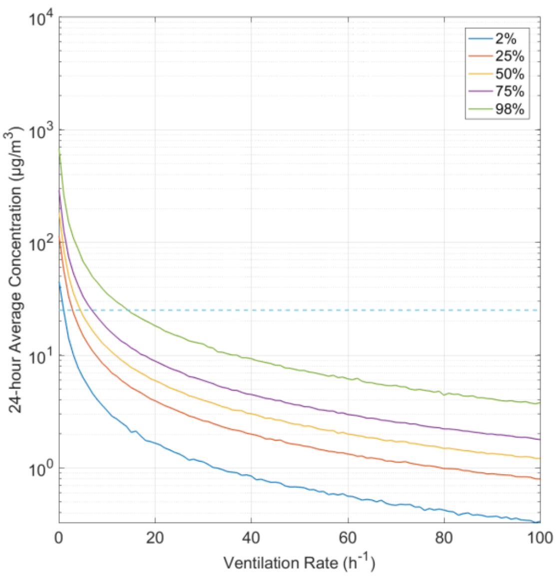
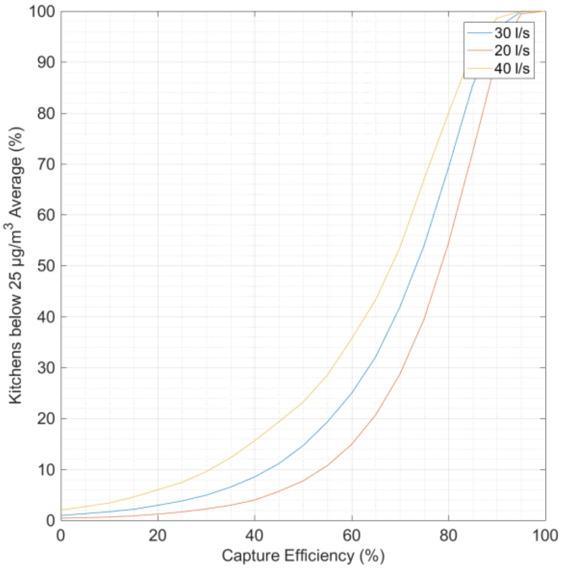
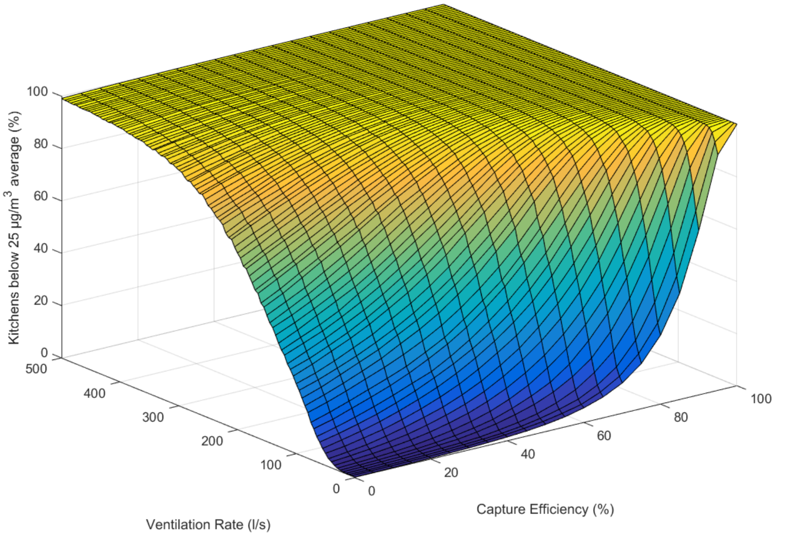
Setting Constant Ventilation Rate



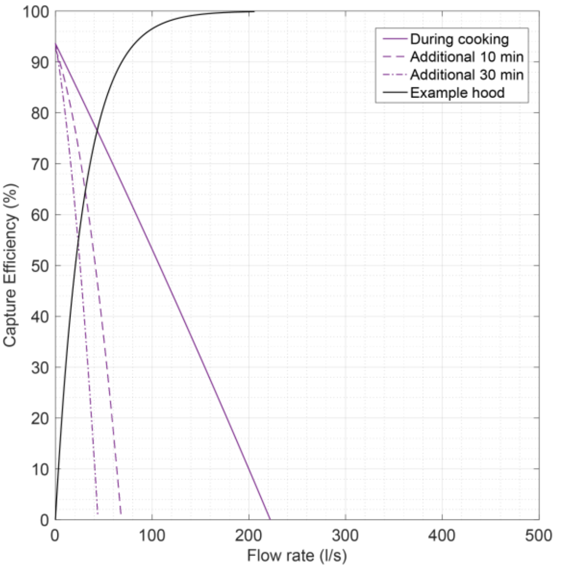
Setting Ventilation Requirements

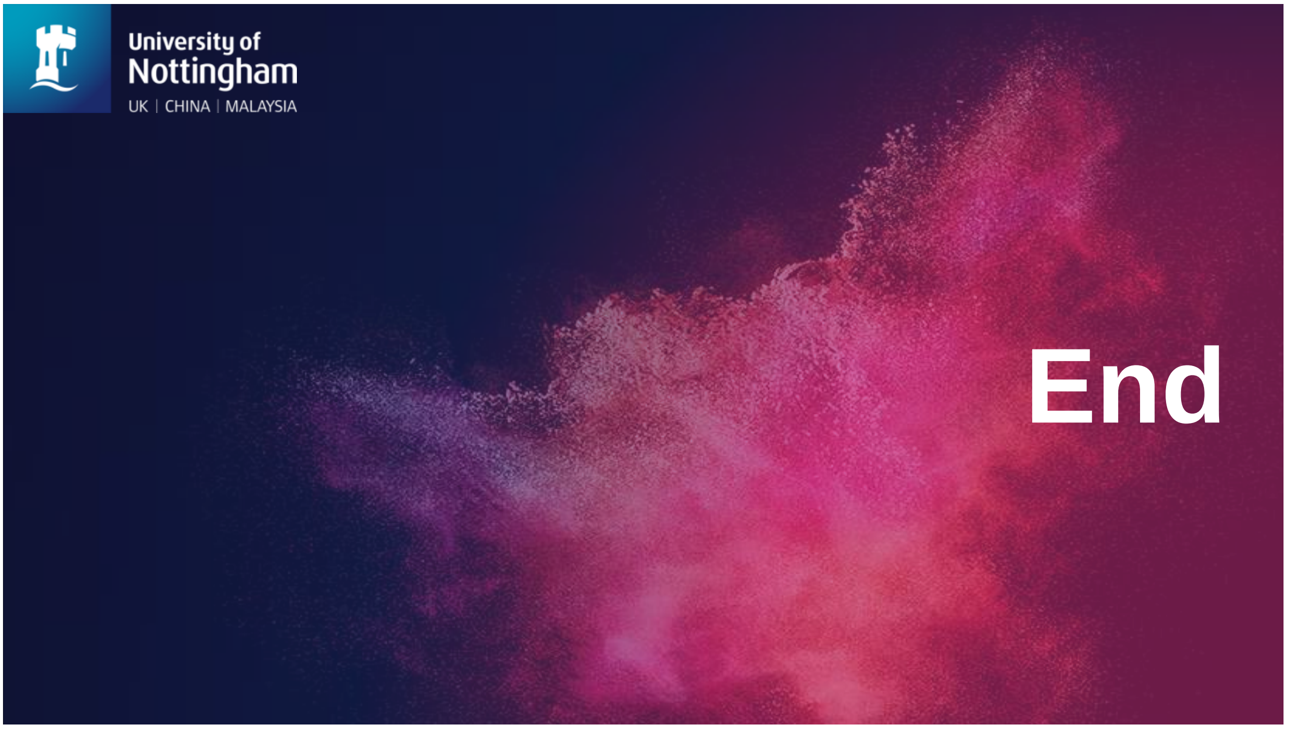


Setting Ventilation Requirements



Required combination of capture efficiency and flow rate





AIVC Webinar

AIVC

May 2019

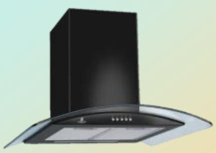
From range hood efficiency to exposure

Willem de Gids

Vent Guide

Wouter Borsboom
Piet Jacobs

TNO innovation for life

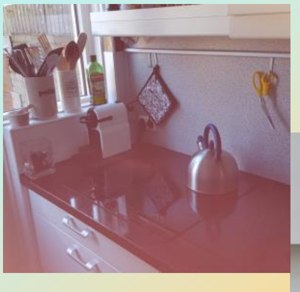


Range hood efficiency ?

It is exposure that matters !

Considerations

- For comparing range hoods as a product measuring capture efficiency satisfies
- For people finally the exposure to pollutants from cooking is more relevant
- The exposure of people
  – the hood efficiency but also the way people behave in front of the range hood plays an important role

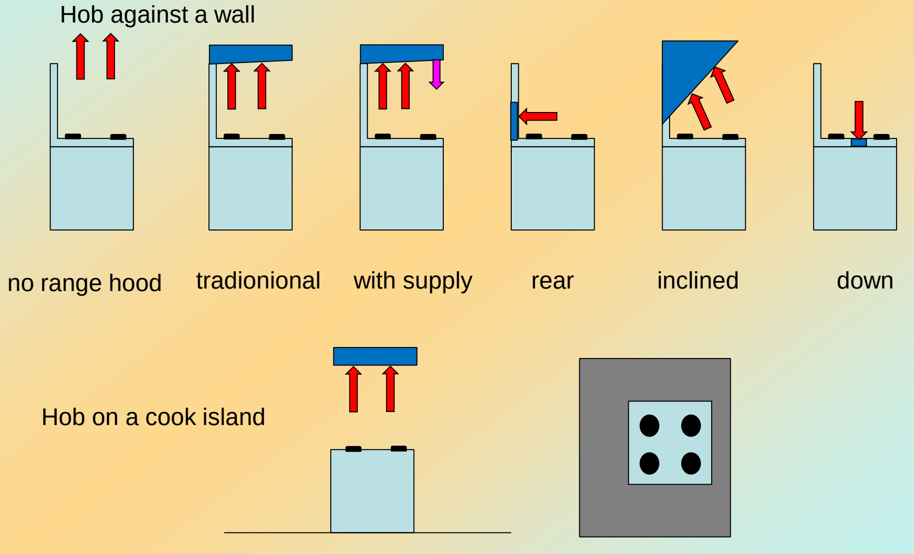


no range hood

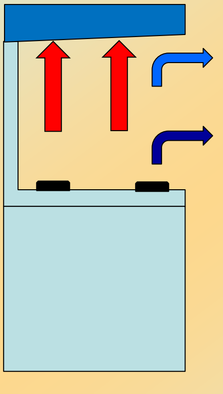
traditional range hood

recent development

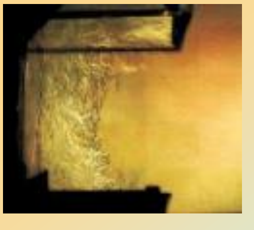
Type of cooking exhaust



Interference/disturbance due to cooking increasing the exposure



- inefficient exhaust
- smelling
- body movements
- arm movements



Interference or disturbance effect is depending on exhaust type

Efficiency including interference

CETIAT J. Simon 1984

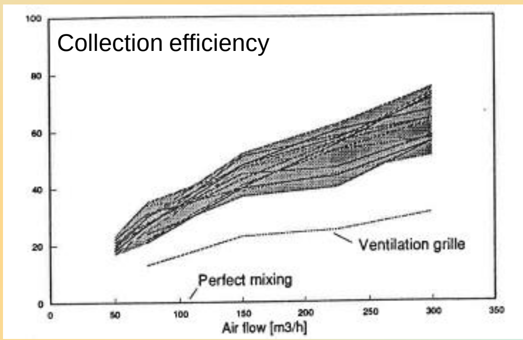
Air flow [m³/h]	With interference device	Without interference device
450	0.74	0.97
300	0.66, 0.67	0.89, 0.90
200	0.46, 0.49	0.95, 0.96

ratio in %

76

74

50

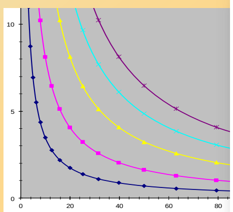


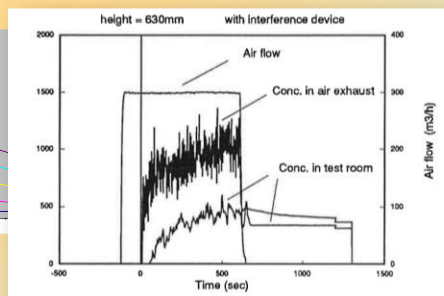
Wouters 1991

Role of ventilation in kitchen/living

Kitchen/living normally almost perfect mixed air
But in the vicinity of the hob is it not the average concentration

Exposure during
- Cooking
- Period after





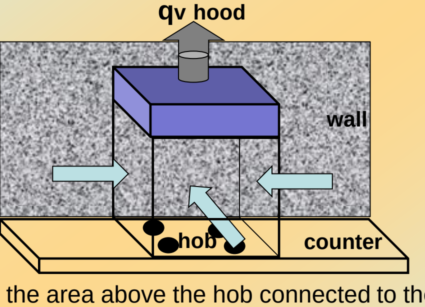
The exposure is the integration over time
of the concentration during cooking and after cooking

Effects by a moving person

Assumptions

- The cook moves twice to and from the hob
- The cook moves with a velocity of 0,5 m/s
- The cooks blocking effective front area of 0,075 m^2
- A flowrate of the range hood 50 dm^3/s
- Range hood efficiency 80%
- A source strength under the hood above the cook plate of 1 g/s
- A general kitchen exhaust rate 21 dm^3/s in addition to the flow through the range hood

Flow field around the hood



For a wall mounted range hood the area above the hob connected to the kitchen
A_{exch} = front area + 2 * side area

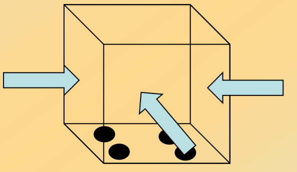
Assume hob:
length 0,6 m
width 0,6 m
Height of the above the hob 0,6 m

$$A_{exch} = \text{front area} + 2 * \text{side area}$$
$$= (0,6 * 0,6) + 2\ (0,6 * 0,6) = 1,08\ m^2$$

Flow field around the hood

For a wall mounted range hood the area above the hob connected to the kitchen

A_{exch} = front area + 2 * side area = 1,08 m^2



The average air velocity $V_{exch} = q_{vent\ hood} / A_{exch}$

$q_{vent\ hood}$		**V_{exch}**
dm^3/s	m^3/h	cm/s
50	180	4,6
75	270	6,9
100	360	9,3
150	540	13,9

It is understandable that a moving person with a walking velocity from around **0,5 m/s or 50 cm/s** , easily may disturb the average air velocity V_{exch}

Calculation

$$C_{av\ kitchen} = q_{source}/q_{vent\ kitchen}$$

q_{source} = (100-80) * 1 = 0,2 g/s
$q_{vent\ kitchen}$ = 50 + 21= 71 dm^3/s or 0,071 m^3/s

$$C_{av\ kitchen} = 0,2 / 71 = 2,82\ g/m^3$$

$$C_{av\ hood} = q_{source}/q_{vent\ hood}$$

q_{source} = 1,0 g/s
$q_{vent\ hood}$ = 50 dm^3/s

$$C_{av\ hood} = 1/50 = 20\ g/m^3$$

Effect of disturbance

$q_{\text{dist flow}} = A_{\text{dist cook}} * v_{\text{cook}}$
$= 0{,}075 * 0{,}5 = 0{,}0375\ m^3/s$ or $37{,}5\ dm^3/s$

$q_{\text{dist flow}} = 37{,}5\ dm^3/s$
$q_{v\ \text{hood}}$ is $50\ dm^3/s$
Assume
- that about 50% can't be captured
- the cook moves two times to the hob

$\Delta C_{\text{dist}} = (q_{\text{re ent}} * C_{\text{av hood}}) / q_{\text{vent kitchen}} =$
$= (0{,}0375 * 20) / 0{,}071 = 1{,}06\ g/m^3$.

$C_{\text{av kitchen}} = 2{,}82\ g/m^3$
the calculated effect of the disturbance is about 37,5 %.

Effect of disturbance on range hood configuration

- The capture efficiency differs for the different configurations
  - the inclined hood has a lower average velocity for the same extract flow as the wall mounted range hood
  - an island range hood with the same extract flow as a wall mounted range hood will be more easily disturbed because the disturbance flow will be captured in a less effective manner

The exposure to fine dust during cooking

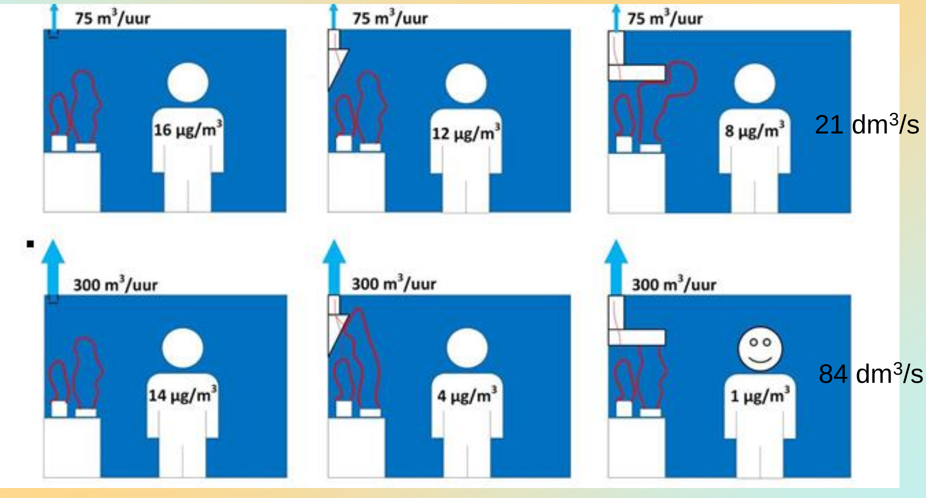
- TNO has carried out long term exposure study on persons due to cooking
- The focus was on particle fine dust $PM_{2,5}$
- Three different exhaust strategies
  - No range hood
  - Standard range hood
  - Inclined range hood
- Two different extract rates
  - Low 21 dm^3/s
  - High 84 dm^3/s

The exposure study

- Cooking a full Dutch meal for 2,2 persons causes an emission of 35 mg $PM_{2,5}$
- Dutch people: a meal is cooked on average 5 times a week
- The average daily emission is 25 mg $PM_{2,5}$
- An open kitchen/living with a volume of 96 m^3
- Cooking 10 minute emission
- Constant emission rate of 41,6 µg/s
- Dilution flow of 21 dm^3/s for the kitchen/living

Results of exposure study

no inclined standard



21 dm^3/s

84 dm^3/s

Concluding remarks

- The disturbance due to cooks is very important for their exposure
- Efficiency is an important step to compare similar types of range hoods
- For the exposure of people in kitchens the effect of disturbances have to be taken into account
- To estimate exposures it is important to account for differences in geometry, for example island and wall mounted range hoods.
- Ventilation of the kitchen can play a significant role in the exposure of the persons in the kitchen
- More research on this topic is needed:
  - Measurements of the exposure during cooking
  - Measurements of the effect of disturbances during cooking
  - The role of differences range hoods types on the exposure

Thank you for
your attention