Introduction

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Pollutant behaviour

70% TIME IN HOUSES
Which pollutants matter?


FROM:

Why PM$_{2.5}$?

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
Section 1

Measuring emissions from cooking

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

Example Test Set Up

Cooking Log

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
Models winter conditions (no windows)

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)
6. Infiltration data from DOMVENT
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
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

![Graph showing the relationship between ventilation rate and 24-hour average concentration.](image-url)
Setting Ventilation Requirements

Graph showing the relationship between Kitchen below 25 ppm average (%) and Capture Efficiency (%) for different ventilation rates (30 l/s, 20 l/s, 40 l/s).

Graph showing the relationship between Ventilation Rate (l/s), Capture Efficiency (%), and Kitchen below 25 ppm average (%) in a 3D plot.
Required combination of capture efficiency and flow rate

![Graph showing capture efficiency vs flow rate](image-url)
Catherine O’Leary

Willem de Gids
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

- CO₂ & H₂O
- NO, NO₂, HONO,
- Formaldehyde
- Ultrafine particles

- Ultrafine particles, NOₓ

- Ultrafine particles
- Formaldehyde
- Acetaldehyde
- Acrolein
- PM₂.₅
- 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 CO₂
  • From gas burner or deliberate injection

• CO₂ measured in outside air (Cᵢ), room (Cᵣ) & exhaust air (Cₑ)

\[ CE = \frac{Cₑ - Cᵣ}{Cₑ - Cᵢ} \]

Studies of cooker hood performance

In the lab

In homes
Big range of range hood performance in homes

My cooker hood

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

Capture Efficiency (%)

House

Big CE range at same flow

HVI and ASHRAE 62.2 Minimum

HVI Recommended

(cfm)

Flow (L. s⁻¹)

Big CE over Big flow range

Back

Front

Combined

Burner

Back

Front

Combined

Oven
Bad coverage = poor capture

Typical coverage = OK for back burners
Good coverage = good capture

Uniform test chamber & cooktop/countertop
2.3m x 4.6 m floor plan
Standardized testing

Tracer gas emitter plate

Standard emitter plate

Standard temperature and power input to plume

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

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.

CERTIFIED HOME VENTILATING PRODUCTS DIRECTORY

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**

- Hot plates built into custom cooktop
- Air inlet (one of four)
  - Low velocity air inlet a necessity
- Tracer gas injection tubing
- Emitter Plates
- Kitchen cabinets
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
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Section 2

In-situ

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WHO 24-hour guideline 25 µg/m³

Setting Constant Ventilation Rate
Setting Ventilation Requirements

- Graph showing the relationship between capture efficiency and ventilation rate.
- The graph includes lines for 30 L/s, 20 L/s, and 40 L/s, indicating how different ventilation rates affect capture efficiency.

- Another graph illustrating the impact on dust concentration over a range of ventilation rates and capture efficiencies.

- The graphs help in understanding how to set appropriate ventilation requirements to achieve desired capture efficiencies.
Required combination of capture efficiency and flow rate
AIVC Webinar

May 2019

From range hood efficiency to exposure

Willem de Gids

Wouter Borsboom
Piet Jacobs

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
Type of cooking exhaust

- Hob against a wall
  - no range hood
  - traditional with supply
  - rear inclined down

- Hob on a cook island

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

<table>
<thead>
<tr>
<th>Air flow [m³/h]</th>
<th>With interference device</th>
<th>Without interference device</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>0.74</td>
<td>0.97</td>
</tr>
<tr>
<td>300</td>
<td>0.66, 0.67</td>
<td>0.89, 0.90</td>
</tr>
<tr>
<td>200</td>
<td>0.46, 0.49</td>
<td>0.95, 0.96</td>
</tr>
</tbody>
</table>

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 cook's blocking effective front area of 0.075 m²
- A flowrate of the range hood 50 dm³/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 dm³/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

\[ A_{exch} = \text{front area} + 2 \ast \text{side area} \]

Assume hob:
- length 0.6 m
- width 0.6 m
- Height of the above the hob 0.6 m

\[ A_{exch} = (0.6 \ast 0.6) + 2 \ast (0.6 \ast 0.6) = 1.08 \text{ m}^2 \]
Flow field around the hood

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

\[ A_{\text{exch}} = \text{front area} + 2 \times \text{side area} = 1.08 \text{ m}^2 \]

The average air velocity \( V_{\text{exch}} \) is

\[ V_{\text{exch}} = \frac{q_{\text{vent hood}}}{A_{\text{exch}}} \]

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 \( V_{\text{exch}} \)

<table>
<thead>
<tr>
<th>( q_{\text{vent hood}} )</th>
<th>( V_{\text{exch}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{dm}^3/\text{s} )</td>
<td>( \text{m}^3/\text{h} )</td>
</tr>
<tr>
<td>50</td>
<td>180</td>
</tr>
<tr>
<td>75</td>
<td>270</td>
</tr>
<tr>
<td>100</td>
<td>360</td>
</tr>
<tr>
<td>150</td>
<td>540</td>
</tr>
</tbody>
</table>

Calculation

\[ C_{\text{av kitchen}} = \frac{q_{\text{source}}}{q_{\text{vent kitchen}}} \]

\( q_{\text{source}} = (100-80) \times 1 = 0.2 \text{ g/s} \)
\( q_{\text{vent kitchen}} = 50 + 21 = 71 \text{ dm}^3/\text{s} \) or 0.071 m\(^3\)/s

\[ C_{\text{av kitchen}} = \frac{0.2}{71} = 2.82 \text{ g/m}^3 \]

\[ C_{\text{av hood}} = \frac{q_{\text{source}}}{q_{\text{vent hood}}} \]

\( q_{\text{source}} = 1.0 \text{ g/s} \)
\( q_{\text{vent hood}} = 50 \text{ dm}^3/\text{s} \)

\[ C_{\text{av hood}} = \frac{1}{50} = 0.02 \text{ g/m}^3 \]
Effect of disturbance

\[ q_{\text{dist flow}} = A_{\text{dist cook}} \cdot v_{\text{cook}} \]
\[ = 0.075 \cdot 0.5 = 0.0375 \text{ m}^3/\text{s} \text{ or } 37.5 \text{ dm}^3/\text{s} \]

\[ q_{\text{dist flow}} = 37.5 \text{ dm}^3/\text{s} \]
\[ q_{\text{v hood}} = 50 \text{ dm}^3/\text{s} \]

Assume
• that about 50% can’t be captured
• the cook moves two times to the hob

\[ \Delta C_{\text{dist}} = \frac{(q_{\text{re ent}} \cdot C_{\text{av hood}})}{q_{\text{vent kitchen}}} = \]
\[ = \frac{(0.0375 \cdot 20)}{0.071} = 1.06 \text{ g/m}^3. \]

\[ C_{\text{av kitchen}} = 2.82 \text{ g/m}^3 \]

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
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