Contribution of Solid Fuel Burning to PM$_{2.5}$ in Residential Areas of Ireland

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The smog creeps menacingly through doors and windows here. It attacks throats and lungs. It sometimes invades Dublin to such a degree that night appears to fall by midday.
Ban on Bituminous Coal in Dublin

1st September 1990

70% reduction in black smoke

34% reduction in sulphur dioxide

On average per year:
116 fewer respiratory deaths
243 fewer cardiovascular deaths

Clancy et al., Lancet 2002
Extent of Bituminous Coal Ban 2015
WE'RE CALLING FOR CLEAN AIR
FOR ALL

Urgent action is needed to ensure clean air for all, not just for some
25 years on .... Estimated that 9,000 lives saved since Dublin smoky
coal ban in 1990 - but thousands more are lost each year throughout
the country
Phil Hogan: I want smoky coal to be banned within the next 3 years

Smoky coal is already banned in 27 towns and cities around the country, but now the Minister for the Environment says he wants to see it nationwide.

MINISTER FOR THE Environment Phil Hogan has said he wants to see a ban on smoky coal throughout the country within the next 3 years.

Smoky coal was banned in seven more towns around the country – Greystones, Letterkenny, Mullingar, Navan, Newbridge, Portlaoise and Wicklow – on 1 May, bringing to 27 the total number of towns and cities which have already banned the fuel.

The government has brought in a number of measures to discourage people from using fossil fuels, including a carbon tax on solid fuels which began last Wednesday.

Phil Hogan pointed to research which found that the smoky coal ban resulted in up to 350 fewer deaths every winter since being introduced in Dublin in 1990. The ban was in response to severe episodes of winter smog which resulted from the widespread use of smoky coal.

“The health benefits in areas where the ban is already in place are well documented and an all-Ireland ban is the next phase I anticipate in this area,” he said. “The burning of solid fuel for residential heating makes a disproportionate contribution to air pollution.”

The ban has clearly been effective in reducing air pollution with proven benefits for human health and our environment and has led to improved quality of life in cities and towns where the ban applies.

“I am convinced of the health benefits from an all Ireland ban on smoky coal and these benefits should be extended to all citizens through such a ban.

He made the comments as he announced a major new study which will measure air pollution caused by people burning solid fuel – such as coal and peat briquettes – in their homes.

The study, which is a joint piece of research between Northern Ireland and the Republic, will look at possible policy options to reduce pollution from solid fuel as well as the potential environmental and human health benefits.

“North-South cooperation in this area provides an opportunity to further improve air quality for the citizens of this island both North and South,” Phil Hogan said.

Read: Bad news for fossil fuels: cost of coal and briquettes to rise today >
Solid Fuels for Residential Heating in Ireland

Bituminous (Smoky) Coal

“Smokeless” Coal

Wood

Sod Peat (Turf)

Peat Briquettes
Source Apportionment of Particulate Matter in Urban and Rural Residential Areas of Ireland

(SAPPHIRE)

1 April 2014 – 31 March 2016

http://www.ucc.ie/en/crac/research/sapphire/
Monitoring Locations

- Outside the Smoky Coal Ban Area (pop. < 15,000)
- No natural gas supply
- High usage of solid fuels (coal, peat/turf & wood)

- Killarney, Co. Kerry (Nov & Dec 2014)
- Enniscorthy, Co. Wexford (Jan & Feb 2015)
Monitoring Location: Killarney
Monitoring Location: Killarney

- Site is located on the western side of the town, in the grounds of the Community Hospital in a residential area.
Monitoring Location: Killarney

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## Instrumentation

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Parameter(s) measured</th>
<th>Temporal resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosol time-of-flight mass spectrometer (TSI model 3800)</td>
<td>Single particle size and chemical composition (100-3000 nm)</td>
<td>1 min</td>
</tr>
<tr>
<td>Scanning mobility particle sizer (TSI model 3081)</td>
<td>Particle number concentration (10-800 nm)</td>
<td>3 min</td>
</tr>
<tr>
<td>Optical Particle Sizer (TSI model 3330)</td>
<td>Particle number concentration (300-10000 nm)</td>
<td>3 min</td>
</tr>
<tr>
<td>TEOM (Thermo Electron model RP 1400a)</td>
<td>PM$_{2.5}$ mass concentration</td>
<td>30 min</td>
</tr>
<tr>
<td>Thermal-optical carbon analyser (Sunset Inc. model 3rd generation)</td>
<td>Elemental and organic carbon mass concentrations</td>
<td>2 hr</td>
</tr>
<tr>
<td>7-Wavelength Aethalometer (Model AE33, Magee Scientific)</td>
<td>Black Carbon concentration</td>
<td>1 min</td>
</tr>
<tr>
<td>High volume sampler (Digitel model DHA 80)</td>
<td>Collection of particulate matter (PM$_{2.5}$)</td>
<td>6 hr</td>
</tr>
<tr>
<td>$\text{NO}_x$ analyser (Teledyne T200)</td>
<td>NO and $\text{NO}_x$ mixing ratio</td>
<td>1 min</td>
</tr>
<tr>
<td>$\text{O}_3$ analyser (Teledyne T400)</td>
<td>$\text{O}_3$ mixing ratio</td>
<td>1 min</td>
</tr>
<tr>
<td>Weather station (Casella 'Nomad')</td>
<td>Wind speed, wind direction, relative humidity, air temperature, rainfall, pressure, solar irradiation</td>
<td>5 min</td>
</tr>
</tbody>
</table>
• **PM$_{2.5}$** up to 10 times higher during evening hours
• Strong diurnal pattern
Elemental and Organic Carbon (EC/OC)

- Strong diurnal pattern
Elemental and Organic Carbon (EC/OC)

- Majority of PM$_{2.5}$ during night-time pollution events is carbonaceous aerosol
• Low wind speed – local emissions dominate
• High wind speed – regional sources dominate
What is ATOFMS?
Aerosol
Time-Of-Flight
Mass
Spectrometry

Single Particle Mass Spectrometry

Aerodynamic lens
(transmission of particles in range 100-3000 nm)

Sizing Region
(2 sizing lasers 532 nm)

Ionization laser
(266 nm)

Positive and negative
time-of-flight mass spectrometers
Mass Spectra: Solid Fuel Combustion

Assigned on the basis of combustion experiments:

- **COAL** → EC & some potassium, sulfate dominates negative spectra
- **PEAT** → EC & OC fragments, some potassium
- **WOOD** → Potassium dominates positive spectra
Mass Spectra: Other Particle Types

Sea salt characteristics:
→ sodium & chloride peaks, no EC

Traffic characteristics:
→ calcium & phosphate (lubricating oil), some EC

Ammonium/amine characteristics:
→ ammonium, trimethylamine, OC, large sulfate peak in negative spectra
- Each source category made up of several particle types
Particles from solid fuel burning
80% of PM$_{2.5}$

Particle Numbers

SAPPHIRE Killarney: ATOFMS Composition
Particle Numbers

Particles from solid fuel burning
77% of PM$_{2.5}$

Particle Mass

SAPPHIRE Killarney: ATOFMS Composition
Mass Concentration

ATOFMS: Source Contribution to PM$_{2.5}$

Particle Numbers

Coal 19%
Peat 31%
Wood 27%
Amines 6%
Sea salt 12%
Other 1%

Particle Mass

Coal 18%
Peat 30%
Wood 26%
Amines 16%
Sea salt 4%
Na (Combustion) 3%
Traffic 1%
Others 0.4%
• Missing mass due to regional sources — organic aerosol, ammonium sulfate?
Source contributions (% of TEOM PM$_{2.5}$)

Particles directly emitted from solid fuel combustion
= 66% of measured PM$_{2.5}$

ATOFMS Mass (% of TEOM PM$_{2.5}$)

- Peat: 26%
- Coal: 16%
- Wood: 22%
- Amines: 14%
- Sea salt: 4%
- Unidentified: 14%
- Na (Combustion): 2%
- Other (Combustion): 0.3%
- Traffic: 0.7%
Preliminary Source Apportionment

- PMF ME-2 using ATOFMS particle classes, EC-OC, SMPS, OPS, NOx, Aethalometer

- 5 factors identified
- Primary emissions from solid fuel burning = 52% of PM$_{2.5}$ but no separation by fuel type
Aethalometer (AE-33)

- Fossil fuel (FF) contribution higher than biomass burning (BB) at night!
Fuel Burning Experiments

- Peat is very similar to wood → contributes to BB
- Coal has significant absorption across the wavelength range → contributes to FF
Fuel Burning Experiments

- Derived alpha values are currently being used to develop our own model
Summary and Perspectives

- Residential solid fuel burning contributes up to 60-70% of PM$_{2.5}$ in Killarney.

- Similar results from Enniscorthy: also likely replicated in tens of small towns across Ireland.

- Peat, coal and wood all contribute: Extending the smoky coal ban may not deliver improvements in air quality.

- ATOFMS can separate contributions from coal, peat and wood, but not easy to deploy on a routine basis.

- Aethalometer source apportionment model under development.
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