

# Urban air pollution from solid fuel burning in Ireland – a different path taken

**John Wenger**

*University College Cork, Ireland*

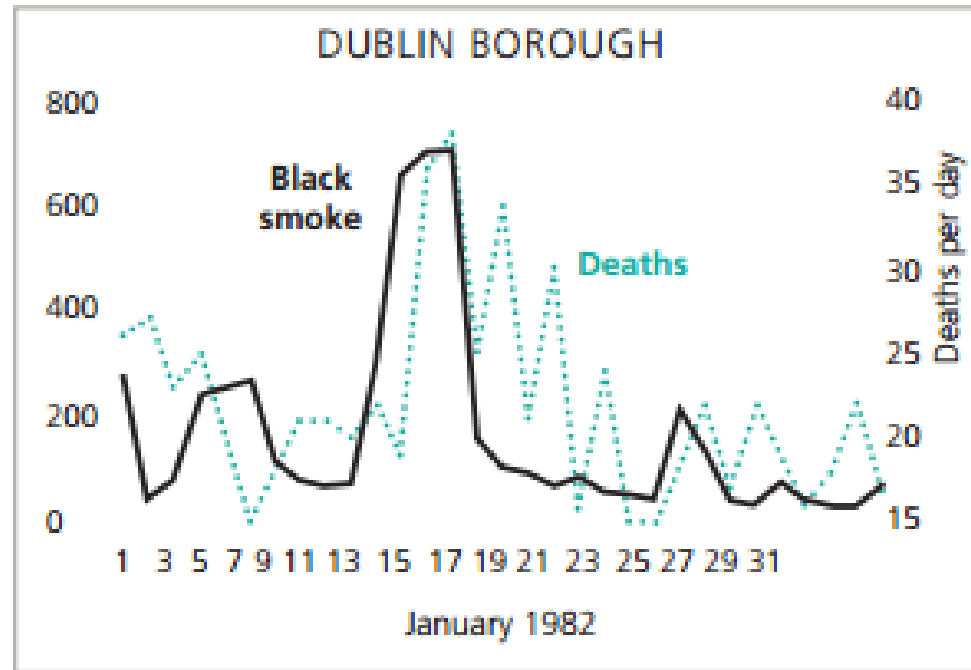
Email: [j.wenger@ucc.ie](mailto:j.wenger@ucc.ie)

web: <http://www.ucc.ie/en/crac/>

# Dublin Smog 1982

## Mortality in a General Hospital and Urban Air Pollution

Ian Kelly and Luke Clancy,  
Irish Medical Journal, 1984, 77, 322-4



- Cold weather, temperature inversion, low wind speeds
- Very high levels of black smoke and sulphur dioxide
- Number of deaths per day doubled during the smog event and remained high for days afterwards

# Dublin Smog 1980s

## The New York Times

### Dublin Journal; Fair Is City but Foul Is Air When Smog Creeps In

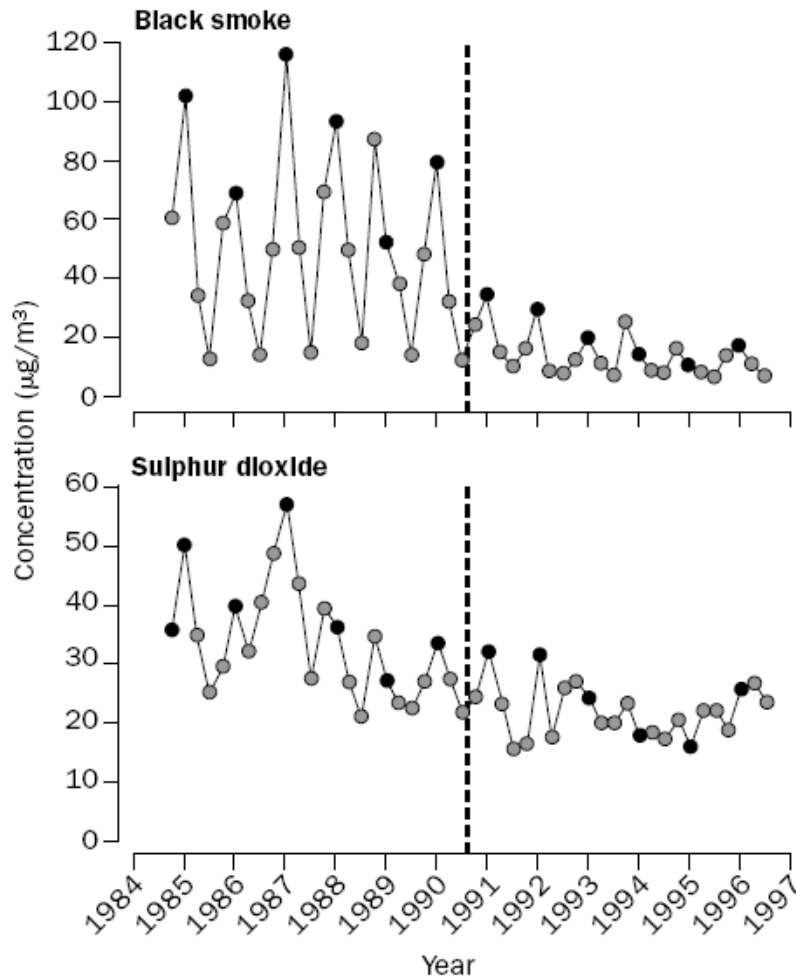
By SHEILA RULE, Special to the New York Times  
Published: January 18, 1989

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.



Dublin city centre, Friday 25  
November 1988, 2pm

# Ban on Bituminous Coal in Dublin



1<sup>st</sup> September 1990

70% reduction in black smoke

34% reduction in sulphur dioxide

On average per year:

116 fewer respiratory deaths

243 fewer cardiovascular deaths

Figure 1: Seasonal mean black smoke (upper) and sulphur dioxide (lower) concentrations, September 1984–96

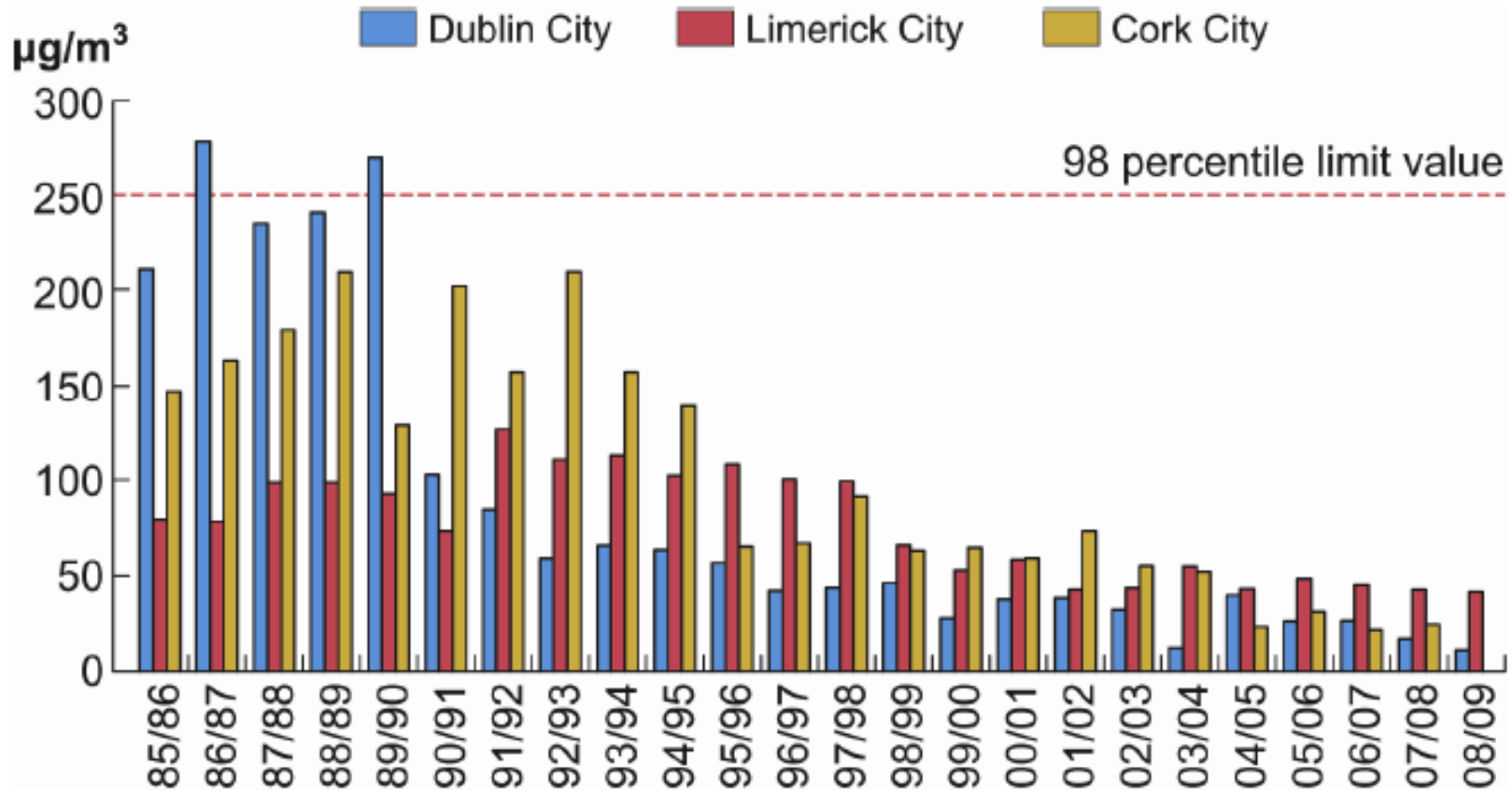
Vertical line shows date sale of coal was banned in Dublin County Borough. Black circles represent winter data.

Clancy et al., Lancet 2002

# Extension of Smoky Coal Ban

- 1990 Dublin
- 1995 Cork City
- 1998 Arklow, Drogheda, Dundalk, Limerick City, Wexford Town

# Trends for Black Smoke



- Significant reductions after ban

Dublin 1990

Cork 1995

Limerick 1998

# Extension of Smoky Coal Ban



- 1990 Dublin
- 1995 Cork City
- 1998 Arklow, Drogheda, Dundalk, Limerick City, Wexford Town
- 2000 Celbridge, Galway City, Leixlip, Naas, Waterford City
- 2003 Bray, Kilkenny, Sligo, Tralee
- 2011 Athlone, Carlow, Clonmel, Ennis
- 2013 Greystones, Letterkenny, Mullingar, Navan, Newbridge, Portlaoise

Significant reductions in Black Smoke observed in all cities and towns after the ban (up to 2000)

(Goodman et al, *J. Air & Waste Manage. Assoc.* 2009, **59**:207–213)

# Extent of Bituminous Coal Ban 2015

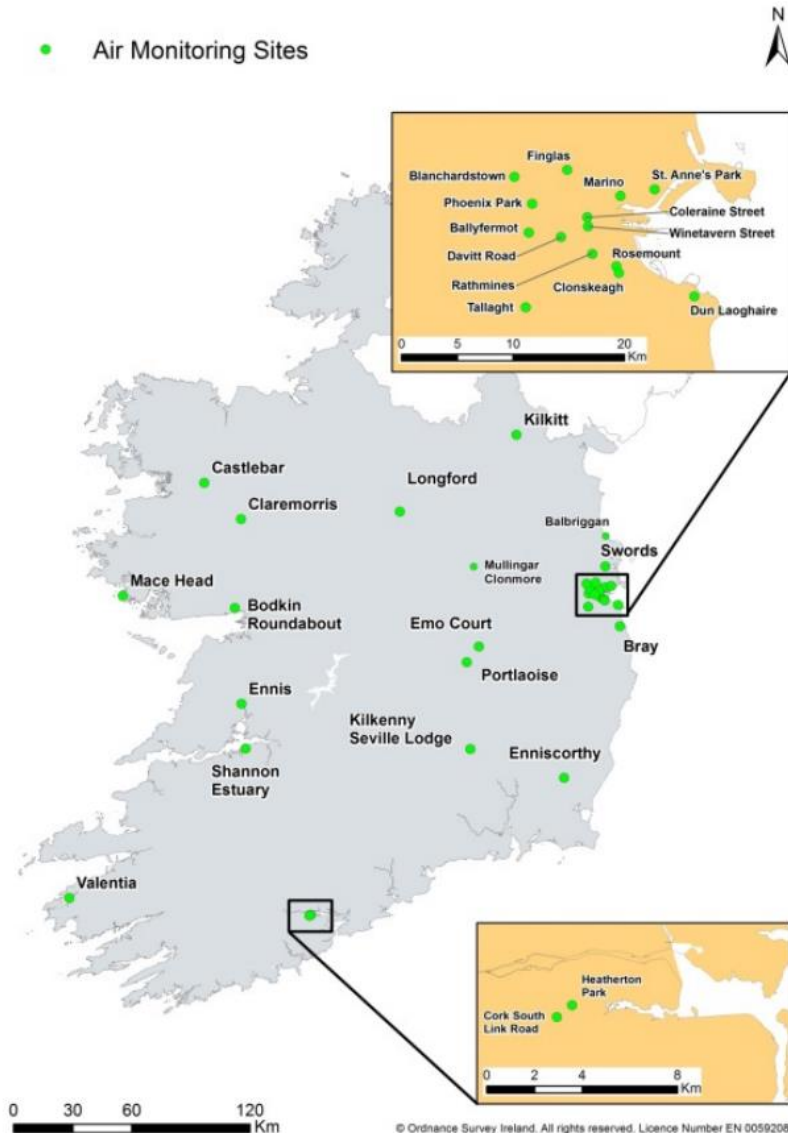
## Legend

-  Smoky Coal Ban Specified Area
-  Smoky Coal Ban Specified Area with effect from 01 May 2013





# PM Monitoring Sites in Ireland

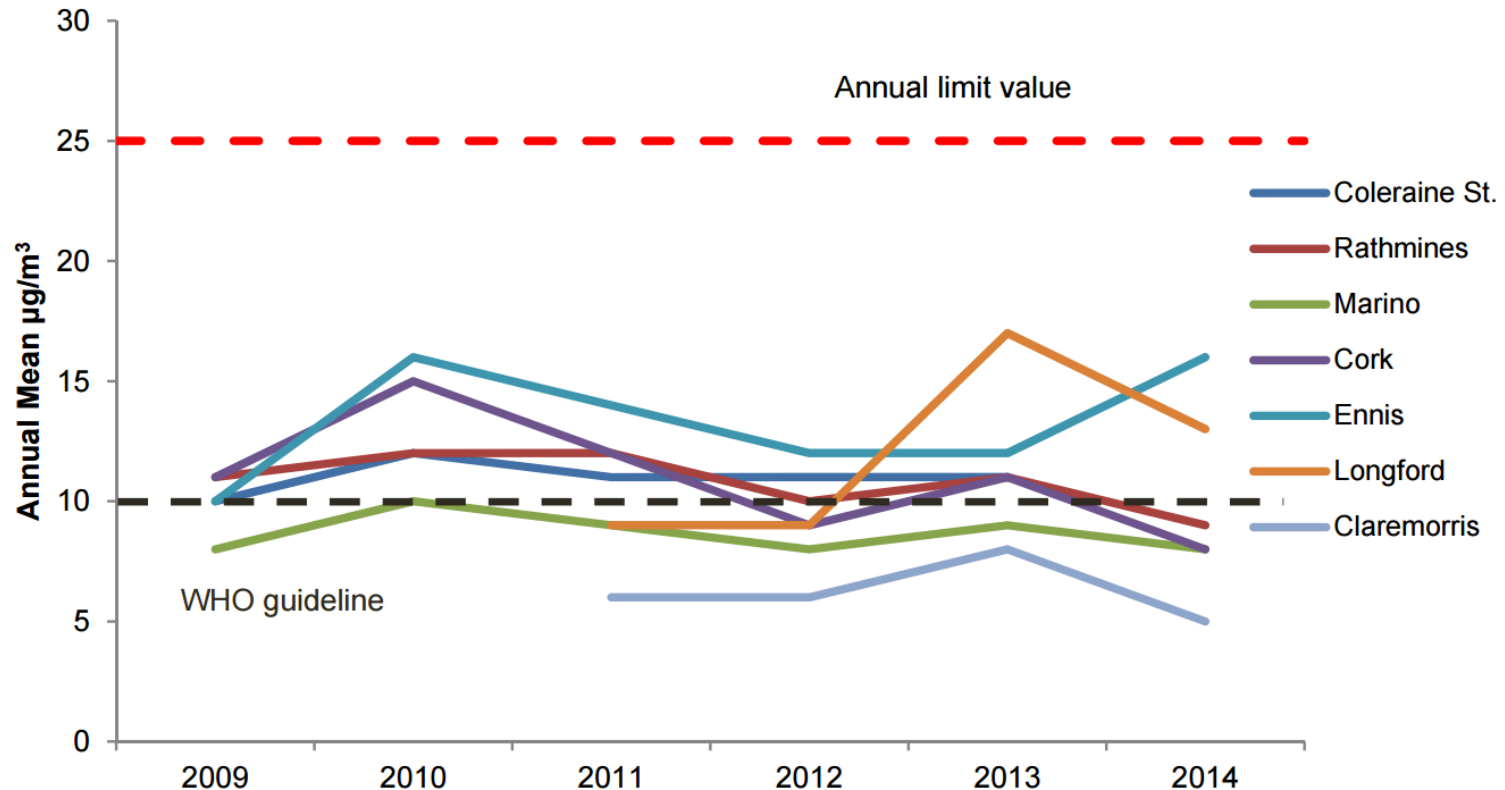


EPA Air Quality Report  
2014

PM monitored at many  
locations

Daily average values for  
concentration ( $\mu\text{g}/\text{m}^3$ )

# EPA Air Quality Report 2014



- PM<sub>2.5</sub> levels are below EU annual limit value BUT above WHO Clear Air Quality Guidelines
- Highest PM levels are in small towns NOT the cities

# The Burning Question

- What is the contribution of residential solid fuel burning to PM levels in towns where the Ban on Bituminous Coal is not in place?



# Solid Fuels for Residential Heating in Ireland



Bituminous (Smoky) Coal



"Smokeless" Coal



Wood



Sod Peat (Turf)



Peat Briquettes



**UCC**

Coláiste na hOllscoile Corcaigh, Éire  
University College Cork, Ireland



# Source Apportionment of Particulate Matter in Urban and Rural Residential Areas of Ireland (SAPPHIRE)

**1 April 2014 – 31 March 2017**

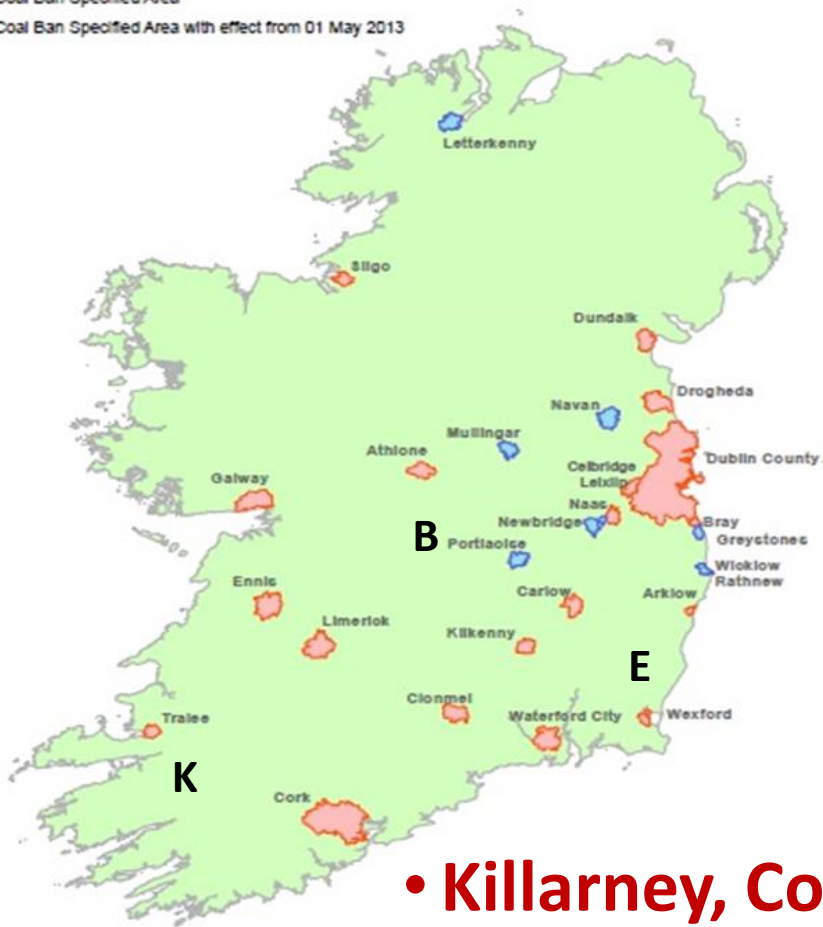
<http://www.ucc.ie/en/crac/research/sapphire/>



# Monitoring Locations

## Legend

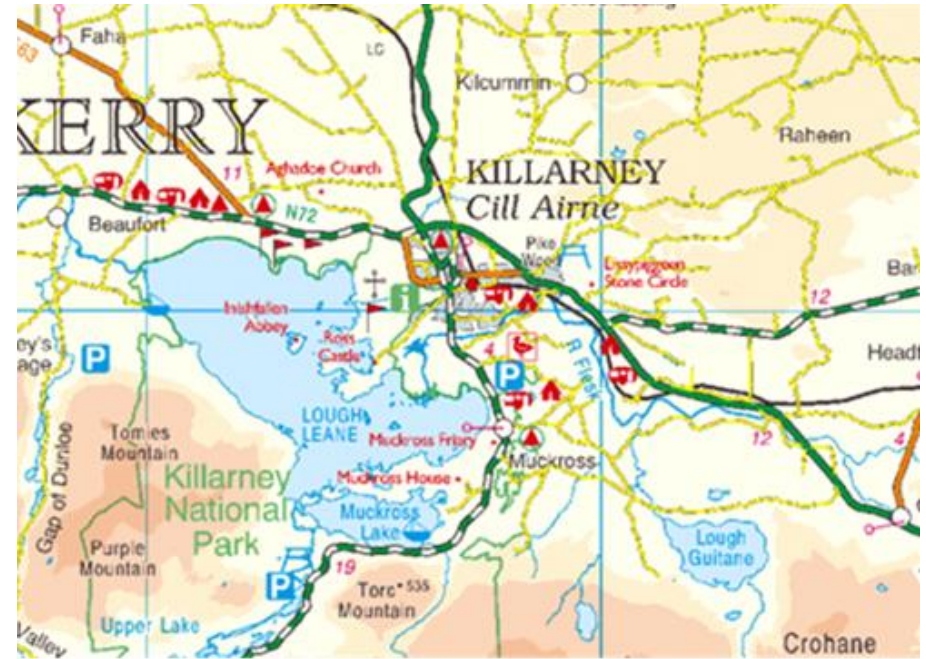
- Smoky Coal Ban Specified Area
- Smoky Coal Ban Specified Area with effect from 01 May 2013



- 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)**
- **Birr, Co. Offaly (Nov & Dec 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



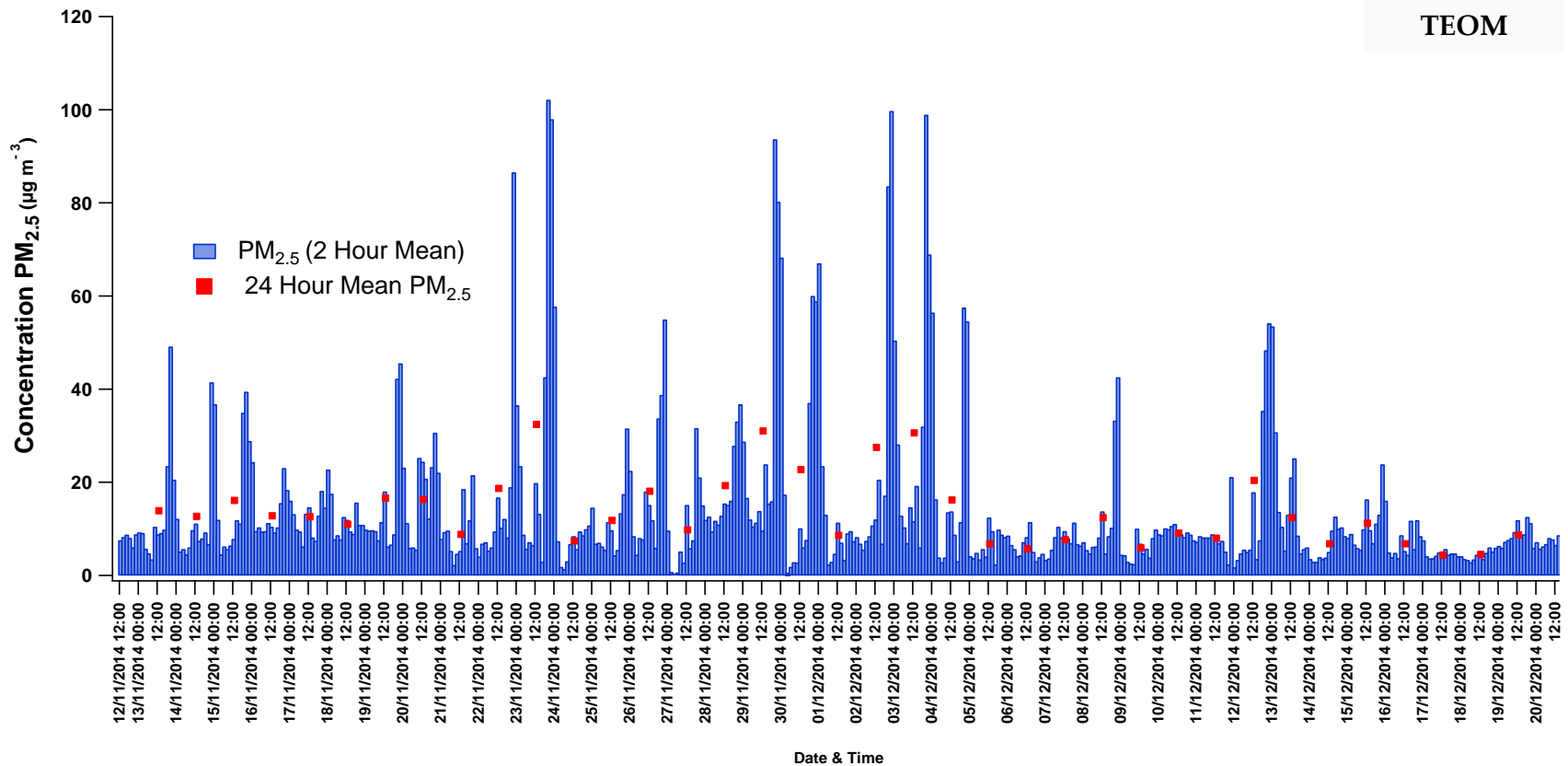


# Monitoring Location: Killarney

- Site is located on the western side of the town, in the grounds of the Community Hospital in a residential area

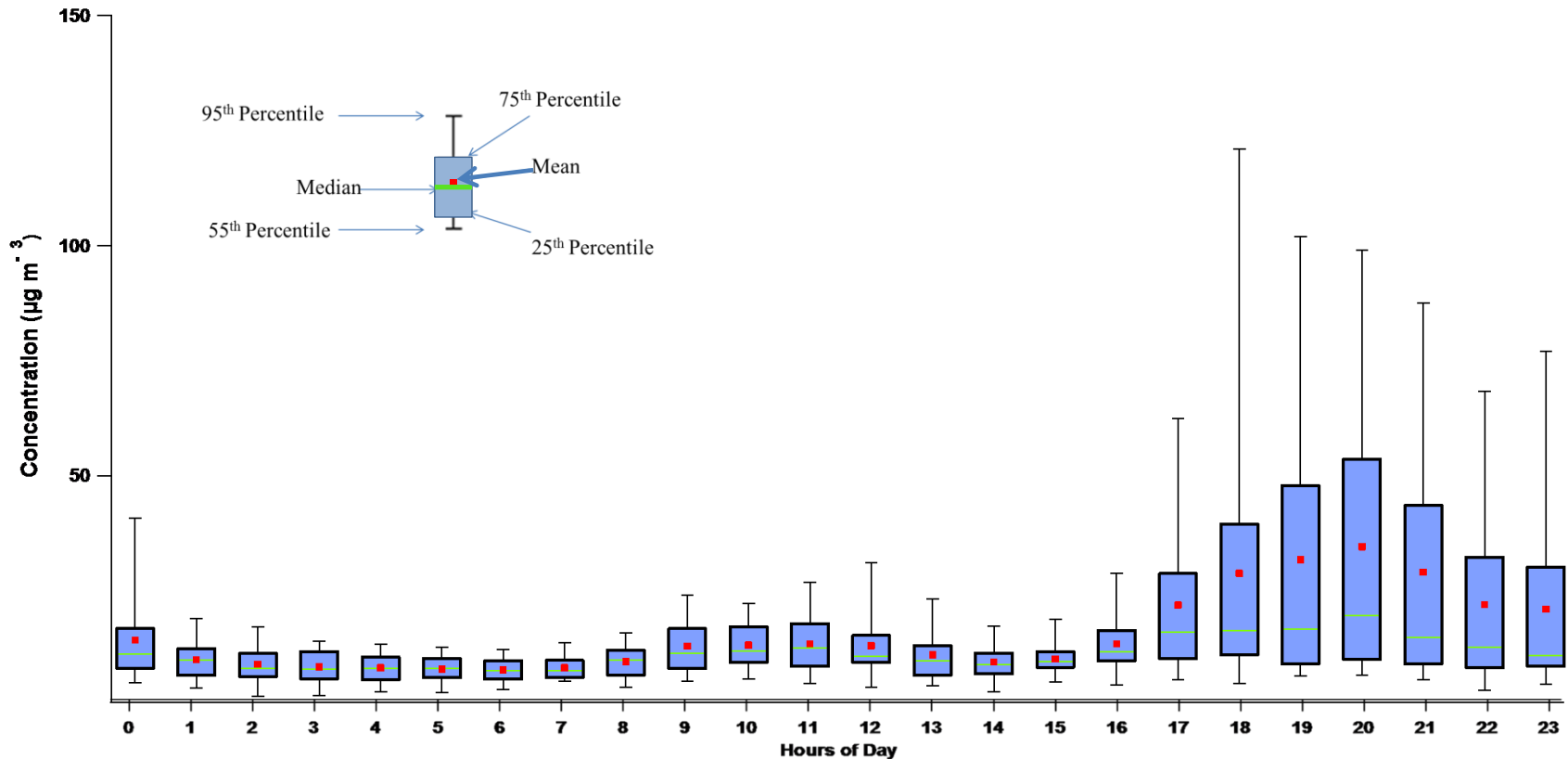


# PM<sub>2.5</sub> mass concentration



- Highest levels observed when wind speed is low

# PM<sub>2.5</sub> hourly variation



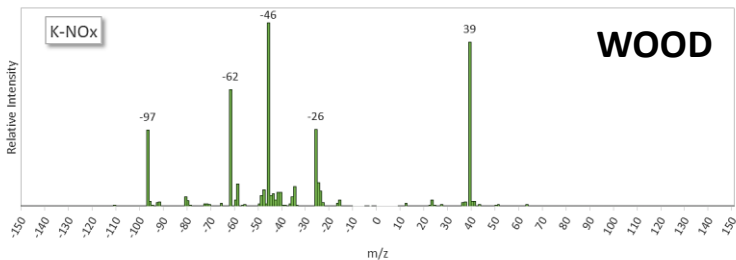
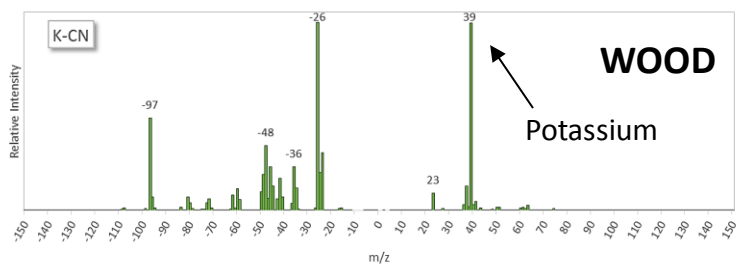
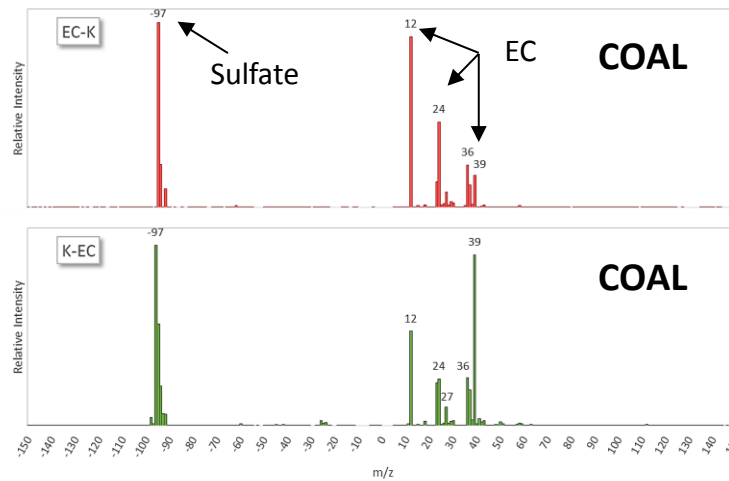
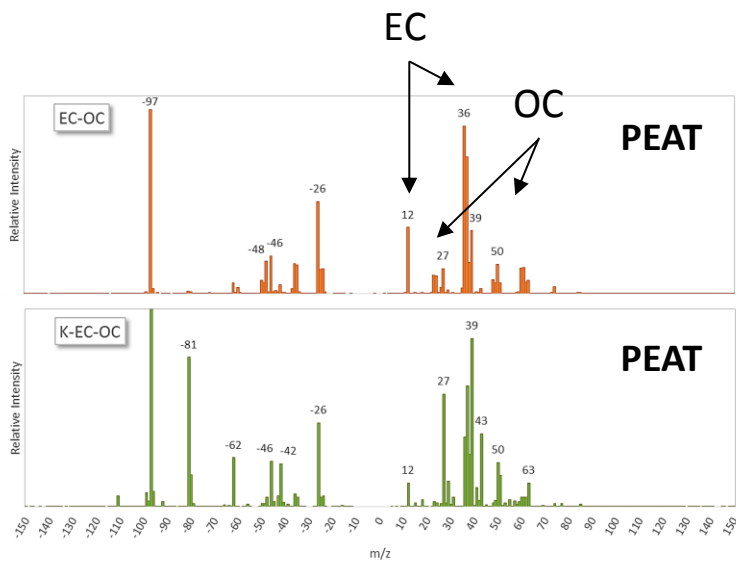
- Strong diurnal pattern
- PM<sub>2.5</sub> up to 10 times higher during evening hours

# Aerosol Time-of-Flight Mass Spectrometer



- Measures chemical composition of single particles in real-time
- Uses a mass spectral fingerprint for different sources
- Enables monitoring of particles from various sources continuously

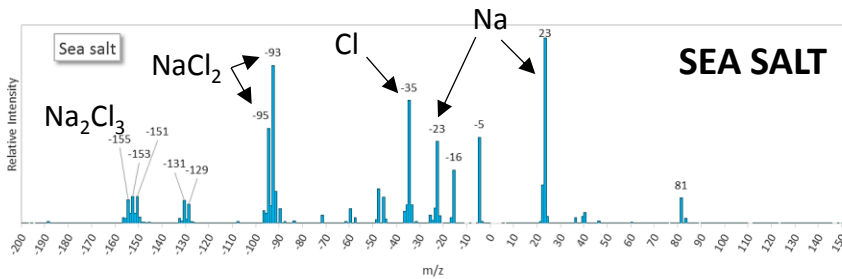
# “Fingerprints” of Solid Fuel Combustion



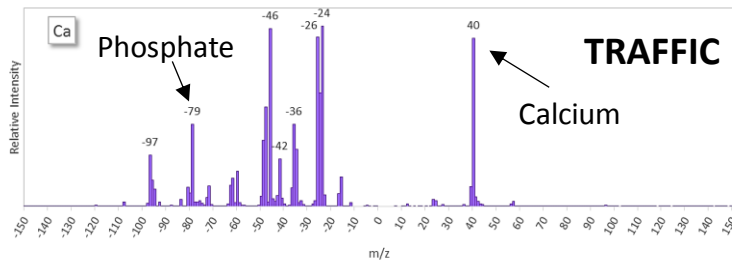
Assigned on the basis of combustion experiments

- COAL** → EC & some potassium, sulfate dominates negative spectra
- PEAT** → EC & OC fragments, some potassium
- WOOD** → Potassium dominates positive spectra

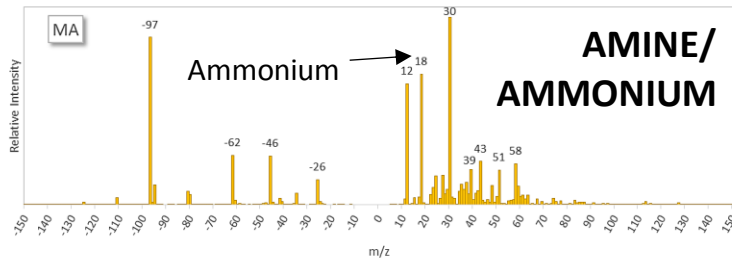
# Mass Spectra: Other Particle Types



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

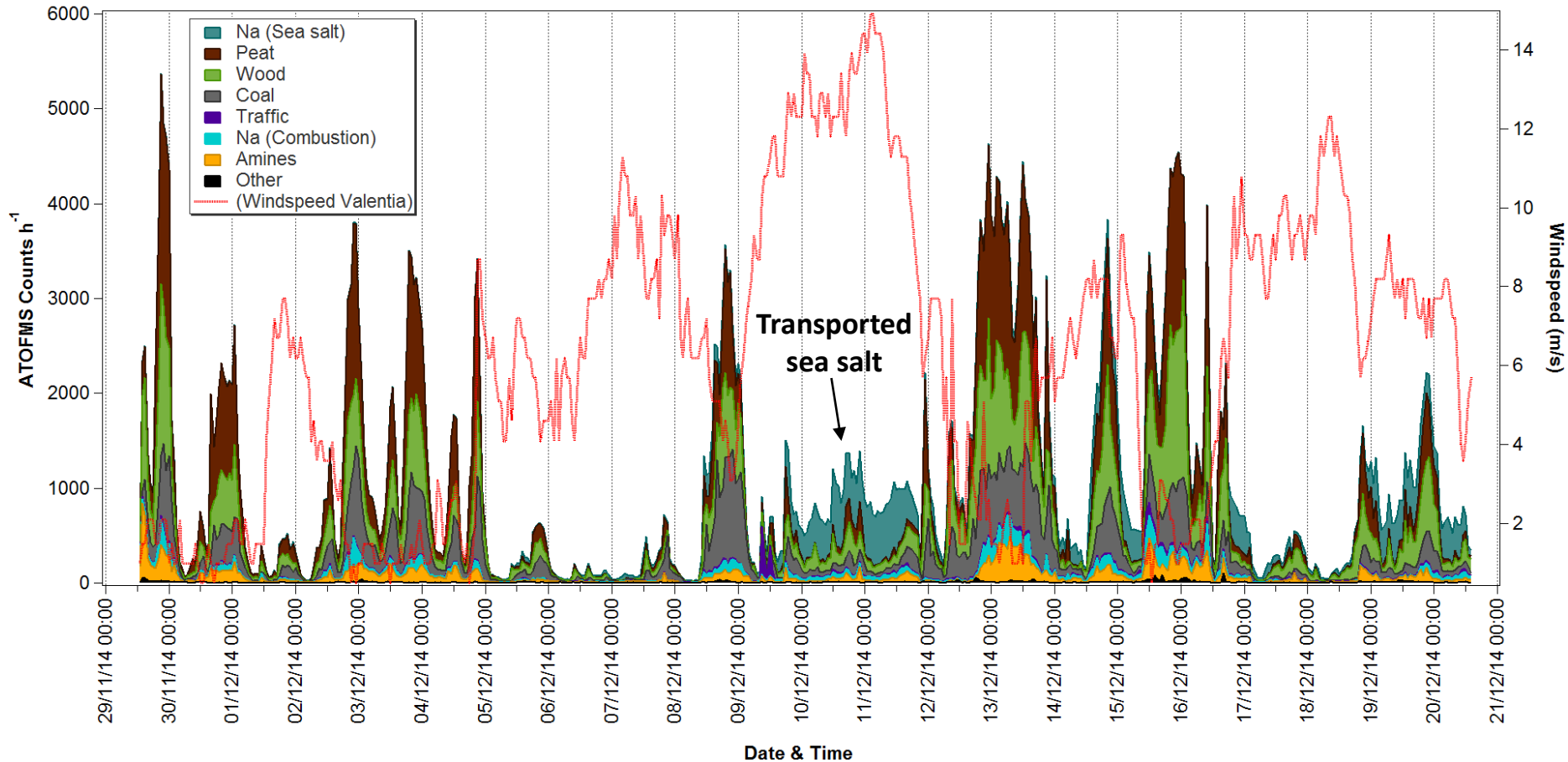


Traffic characteristics:  
→ calcium & phosphate (lubricating oil), some EC



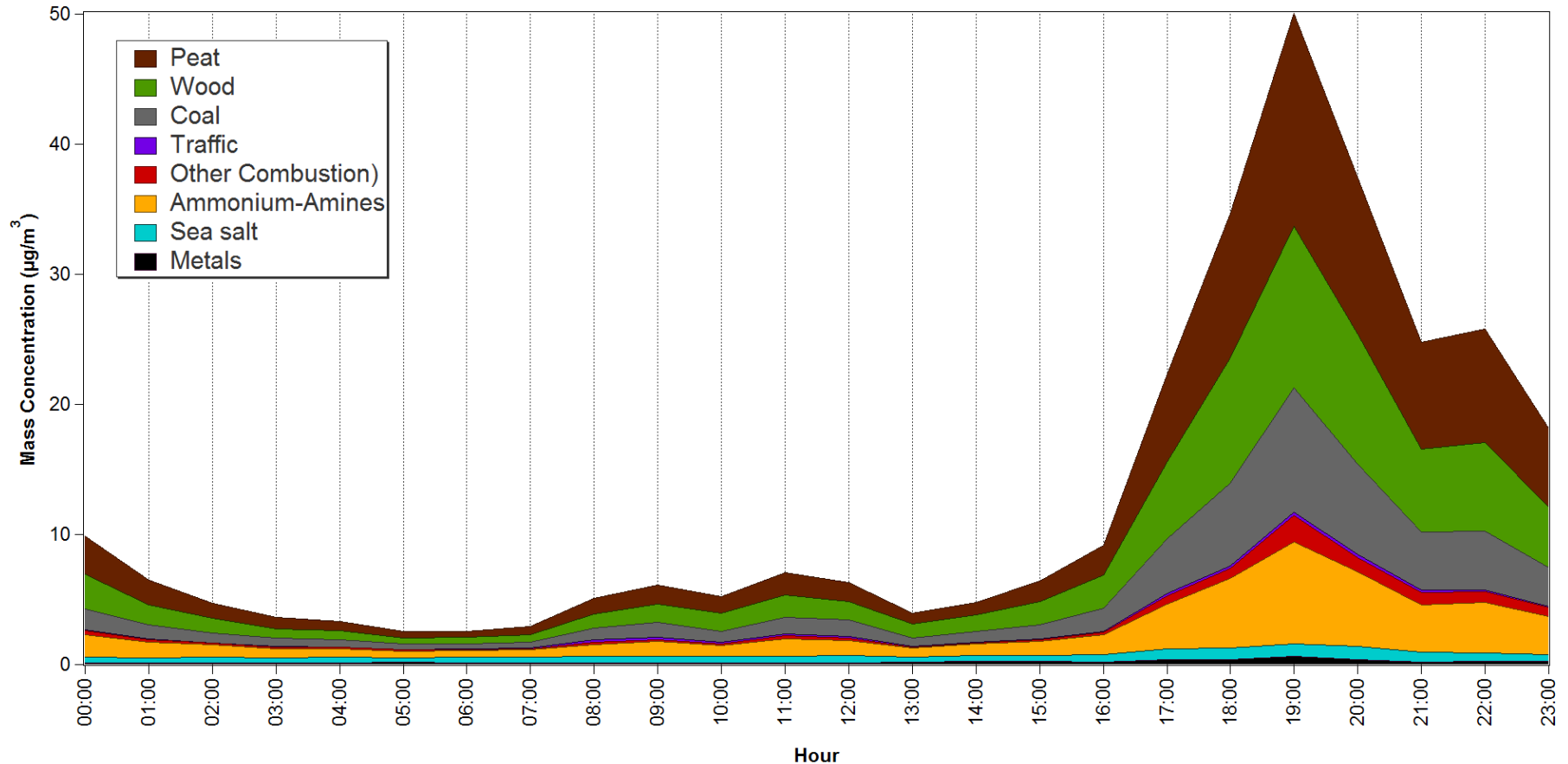
Ammonium/amine characteristics:  
→ ammonium, trimethylamine, OC,  
large sulfate peak in negative spectra

# ATOFMS Particle Number



- Each source category made up of several particle types

# Hourly variation of particle sources

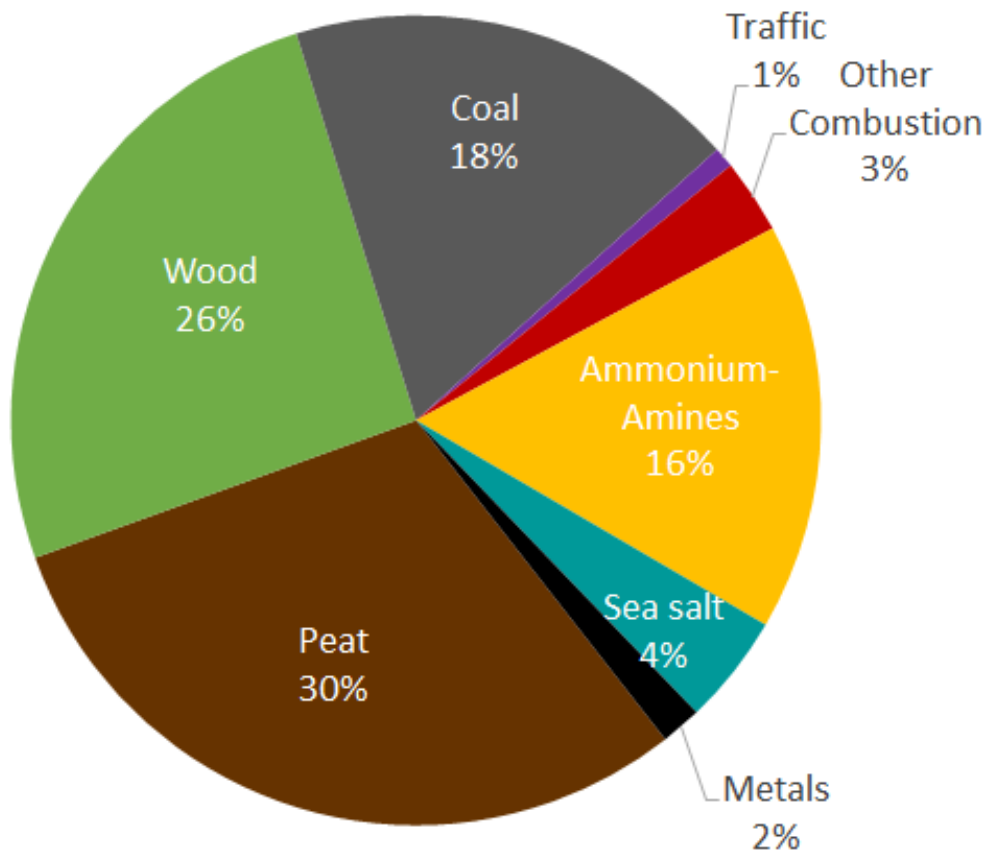


- Very clear evening peak in averaged mass concentration:  
peat ( $16 \mu\text{g}/\text{m}^3$ )      wood ( $12 \mu\text{g}/\text{m}^3$ )      coal ( $10 \mu\text{g}/\text{m}^3$ )



# Source Contribution to PM<sub>2.5</sub>

SAPPHIRE Killarney:  
ATOFMS Composition  
Mass Concentration



**77% of PM<sub>2.5</sub> from solid fuel burning**

# Summary and Perspectives

- Local sources account for 70-90% of  $PM_{2.5}$  in Cork City. Traffic accounts for ~20%; solid fuel burning 50% in winter.
- Residential solid fuel burning contributes 70-90% of  $PM_{2.5}$  in Killarney/Enniscorthy/Birr in winter
- This situation is likely replicated in tens of small towns across Ireland.

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## Nationwide ban on smoky coal due within the next year

Alan Kelly says ban in Dublin, introduced in 1990s, has saved more than 8,000 lives



A file image from 1988 showing Pauline O'Hara (left), Mrs Bridget O'Hara (centre), and Mrs Mary Nolan who protective masks distributed yesterday by local GP, Dr Conor O'Hanlon, in a protest at Government inactivity over smog levels in Dublin. A smoky coal ban was introduced in the city in 1990. Photograph: The Irish Times

Olivia Kelly

Topics: Alan Kelly | Mary Harney | Dublin City Council | Environmental Protection Agency | University College Cork

Mon, Sep 28, 2015, 15:37

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Michael Viney



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Michael Viney | The Wexford lake in autumn is a prime staging post for thousands of Ireland's migrating swallows, house martins and sand martins

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# Summary and Perspectives

- From a health and environment perspective it makes sense to support a nationwide ban on smoky coal
- But, how well will it work, particularly in areas where gas is not available?
- Peat and Wood also produce similar amounts of  $PM_{2.5}$
- A ban on smoky coal may not deliver the expected improvements in air quality
- Other strategies should also be investigated...

# Acknowledgements



Ian O'Connor



Eoin McGillicuddy



Jovanna Arndt



Gary Fuller



Stig Hellebust



Paul Buckley



John Sodeau



Eleonora Nicolisi

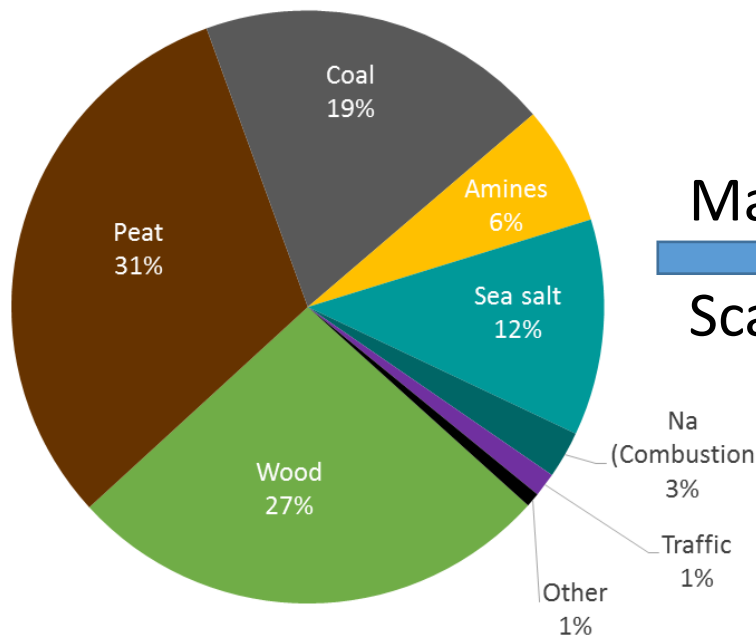
# Extra Slides

# ATOFMS: Source Contribution to PM<sub>2.5</sub>

## Particles from solid fuel burning

**80% of PM<sub>2.5</sub>**

SAPPHIRE Killarney:  
ATOFMS Composition  
Particle Numbers

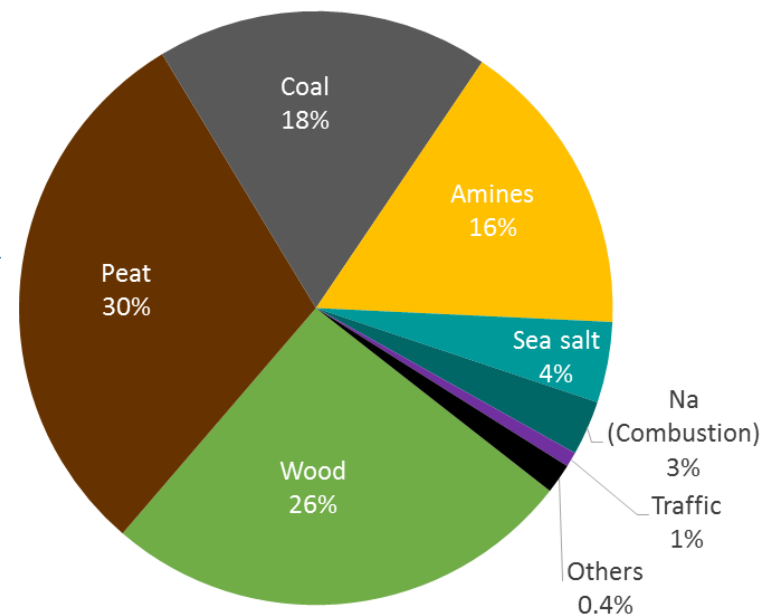


**Particle Numbers**

## Particles from solid fuel burning

**77% of PM<sub>2.5</sub>**

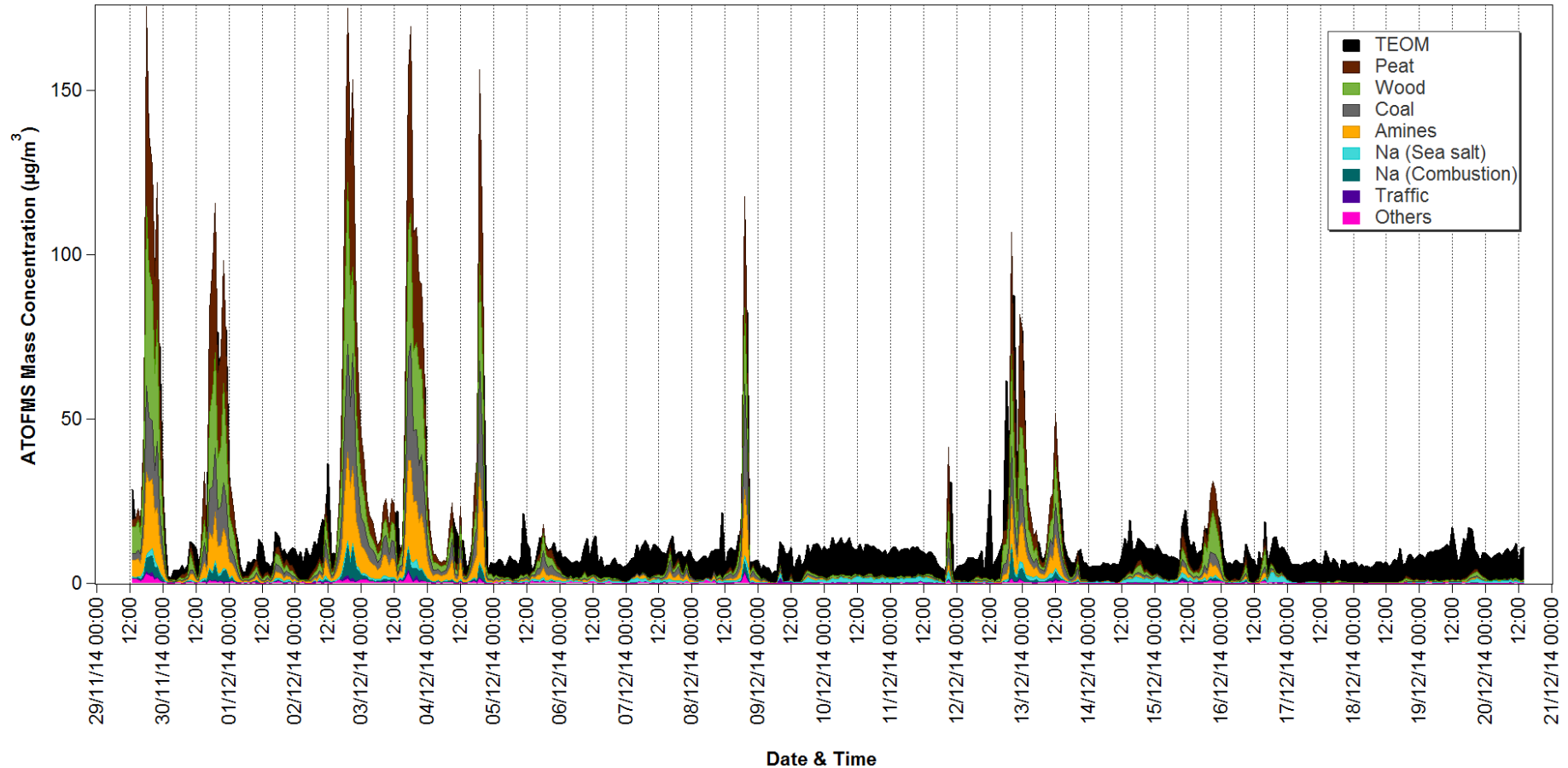
SAPPHIRE Killarney:  
ATOFMS Composition  
Mass Concentration



**Particle Mass**

Mass  
Scaling

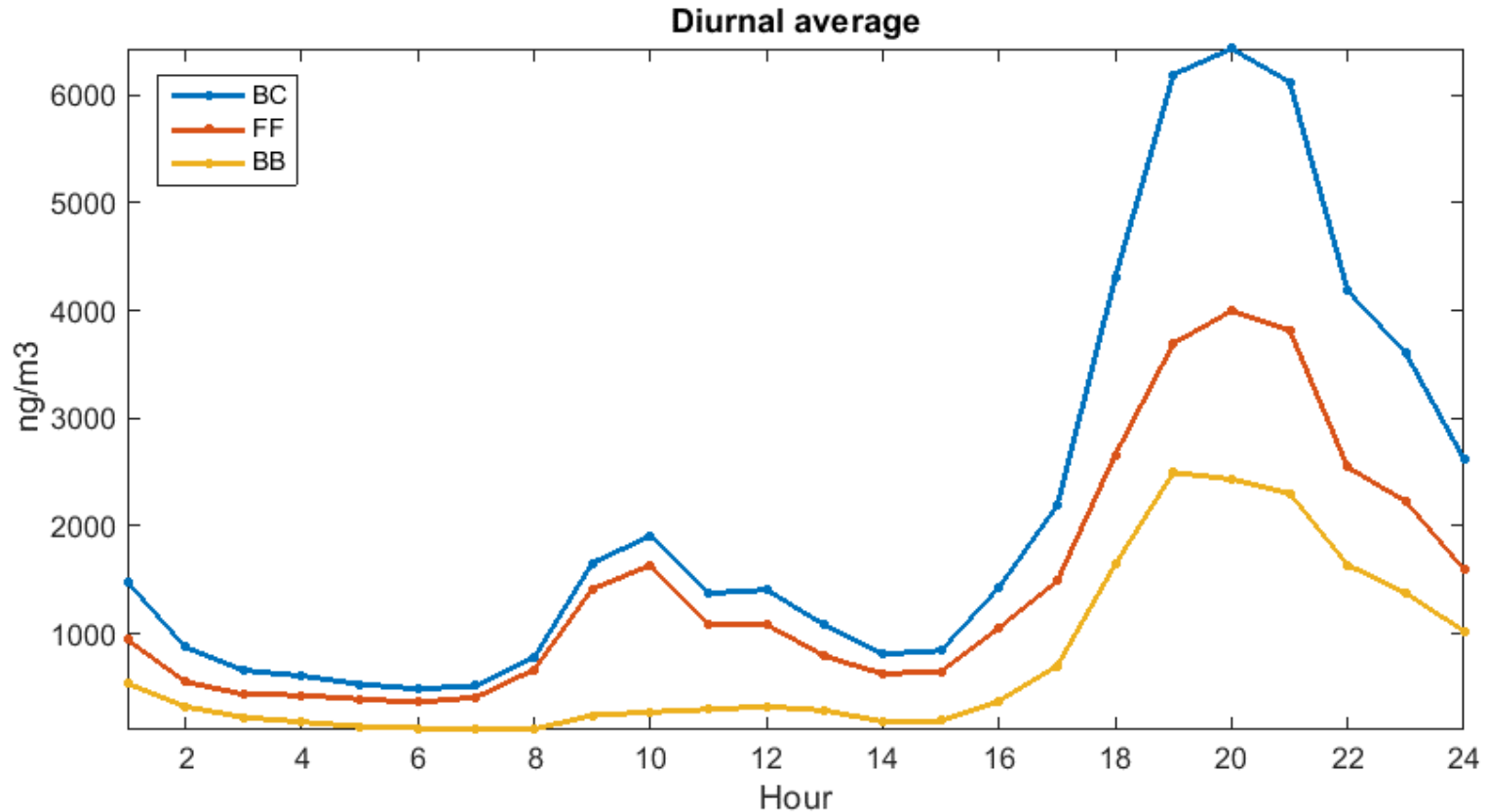
# ATOFMS Particle Mass vs TEOM



- Missing mass due to regional sources – organic aerosol, ammonium sulfate?

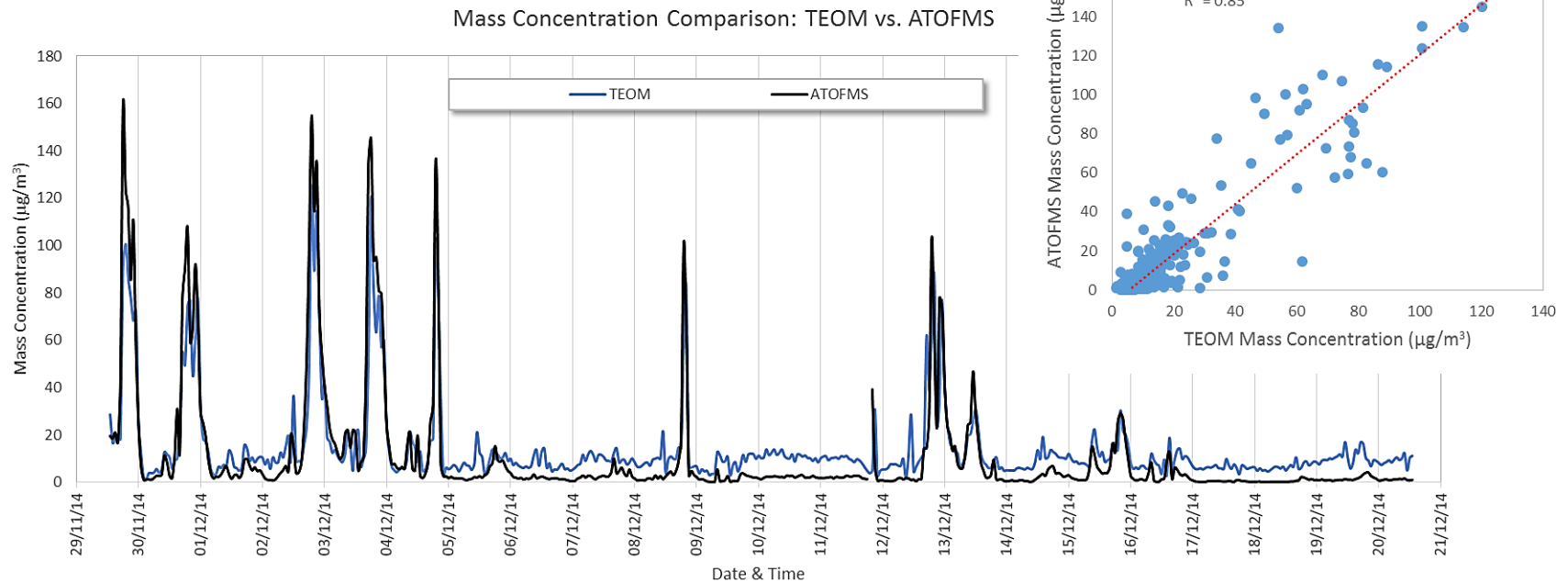


# Aethalometer (AE-33)



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

# ATOFMS vs. TEOM Mass





Dochoireil, Páirtí agus Rialtas Áille  
Department, Community and Local Government



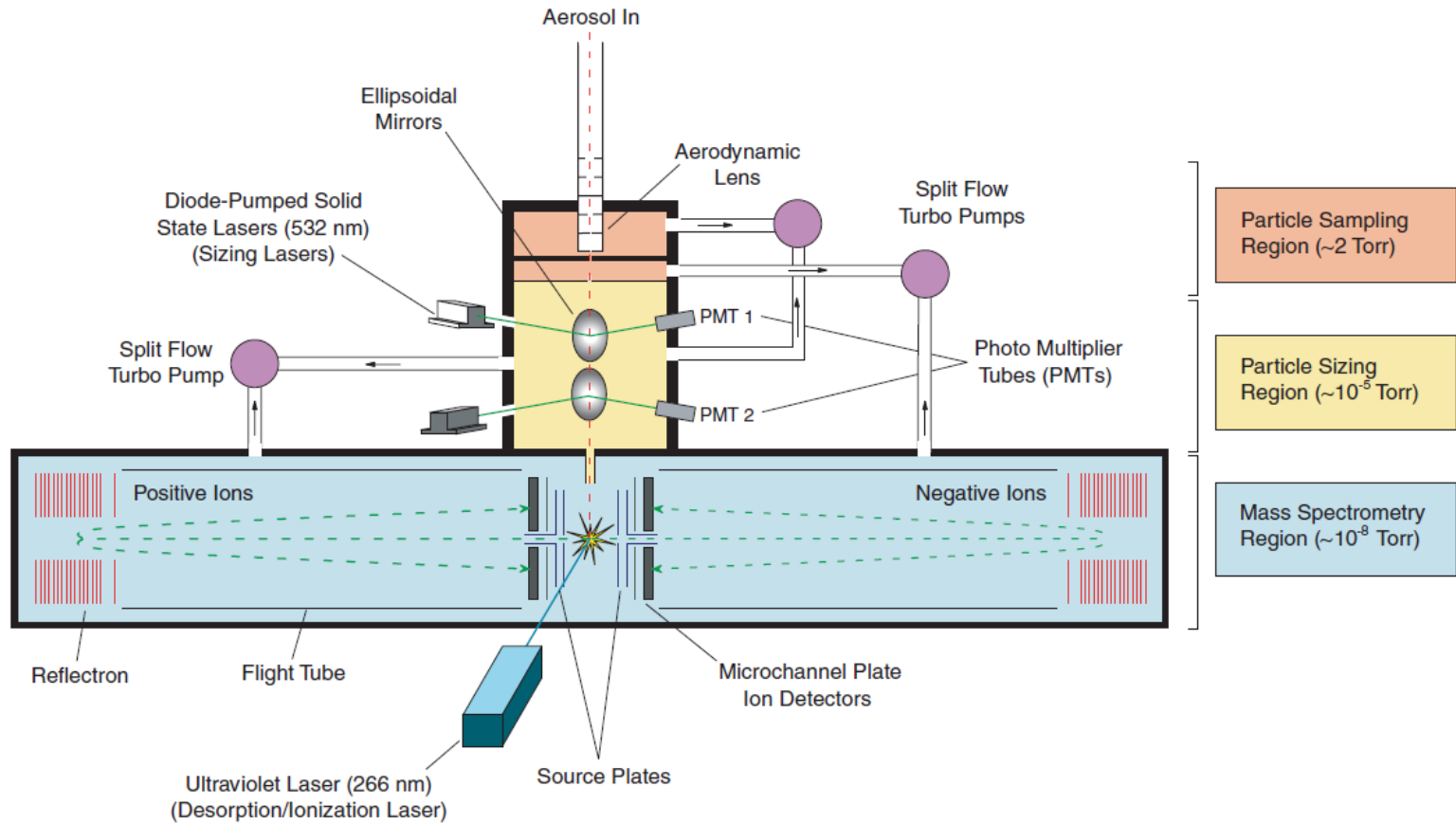
## Delivering Cleaner Air

Smoky Coal Ban Regulations –  
Review and Public Consultation

April 2012

Fuels	Particulate Matter		NO <sub>x</sub>	SO <sub>x</sub>	B[a]P
	PM <sub>10</sub>	PM <sub>2.5</sub>			
	Relative to Home Heating Oil				
Smoky Bituminous Coal	125	52	1	11	513
Anthracite (Smokeless Coal)	13	4	2	12	10
Smokeless Solid Fuel	29	8	1	11	95
Peat	132	55	1	6	513
Wood	141	109	1	0	693
Home Heating Oil (Gas oil)	1	1	1	1	1
Natural gas	0	0	1	0	0

# ATOFMS Schematic



# Well Documented Health Effects of PM

Short term (hours, days) exposure

- respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms

Long term (months, years) exposure

- mortality from cardiovascular and respiratory diseases and from lung cancer

PM<sub>10</sub> and PM<sub>2.5</sub> are classified as air pollutants and limits on their concentration form part of EU legislation on air quality

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# WE'RE CALLING FOR CLEAN AIR FOR ALL

**04 DEC 2014**

By THE ASTHMA SOCIETY OF IRELAND

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**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**

# A Hot Topic!

## 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.

May 6 7:30 AM 8,694 Views 90 Comments Share 23 Tweet 28 Email 20

**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.



Phil Hogan  
Image: Sasko Lazarov/Photocall Ireland

“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.

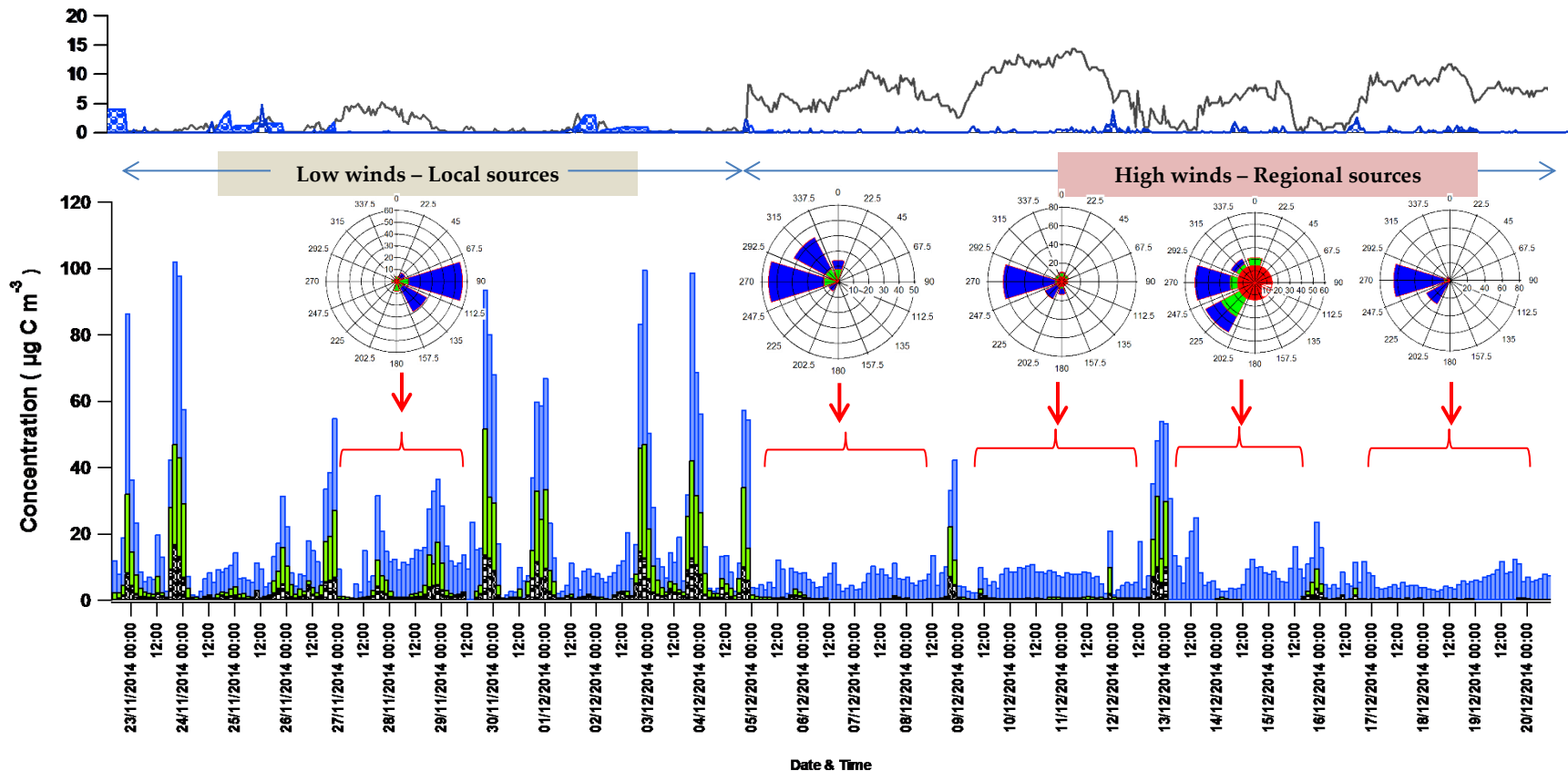
**Read: Bad news for fossil fuels: cost of coal and briquettes to rise today >**

# Instrumentation

Instrument	Parameter(s) measured	Temporal resolution
Aerosol time-of-flight mass spectrometer (TSI model 3800)	Single particle size and chemical composition (100-3000 nm)	1 min
Scanning mobility particle sizer (TSI model 3081)	Particle number concentration (10-800 nm)	3 min
Optical Particle Sizer (TSI model 3330)	Particle number concentration (300-10000 nm)	3 min
TEOM (Thermo Electron model RP 1400a)	PM <sub>2.5</sub> mass concentration	30 min
Thermal-optical carbon analyser (Sunset Inc. model 3 <sup>rd</sup> generation)	Elemental and organic carbon mass concentrations	2 hr
7-Wavelength Aethalometer (Model AE33, Magee Scientific)	Black Carbon concentration	1 min
High volume sampler (Digital model DHA 80)	Collection of particulate matter (PM <sub>2.5</sub> )	6 hr
NO <sub>x</sub> analyser (Teledyne T200)	NO and NO <sub>x</sub> mixing ratio	1 min
O <sub>3</sub> analyser (Teledyne T400)	O <sub>3</sub> mixing ratio	1 min
Weather station (Casella 'Nomad')	Wind speed, wind direction, relative humidity, air temperature, rainfall, pressure, solar irradiation	5 min



# Influence of Meteorology



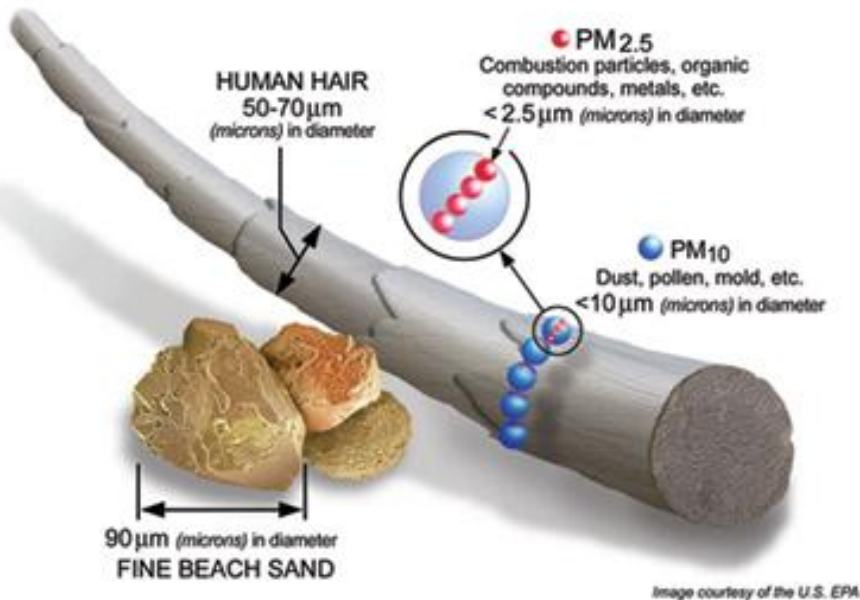
- Low wind speed – local emissions dominate
- High wind speed – regional sources dominate

# From Black Smoke to Particulate Matter

In 2005 Black Smoke standards were replaced by PM limit values in European Air Quality Directive (1999/30/EC)

**PM<sub>10</sub>** Particulate Matter with diameter less than 10 microns

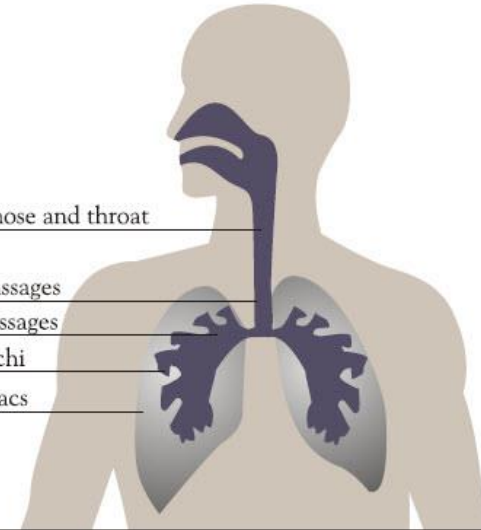
**PM<sub>2.5</sub>** Particulate Matter with diameter less than 2.5 microns



## Where airborne particulate go.

Particle Size	Effect
5.5 - 9.2 microns	Lodges in nose and throat
3.3 - 5.5 microns	Main breathing passages
2.0 - 3.3 microns	Small breathing passages
1.0 - 2.0 microns	Bronchi
0.3 - 1.0 microns	Air sacs

PM 10 refers to particulate matter that is less than 10 microns in size.



# Reducing PM levels

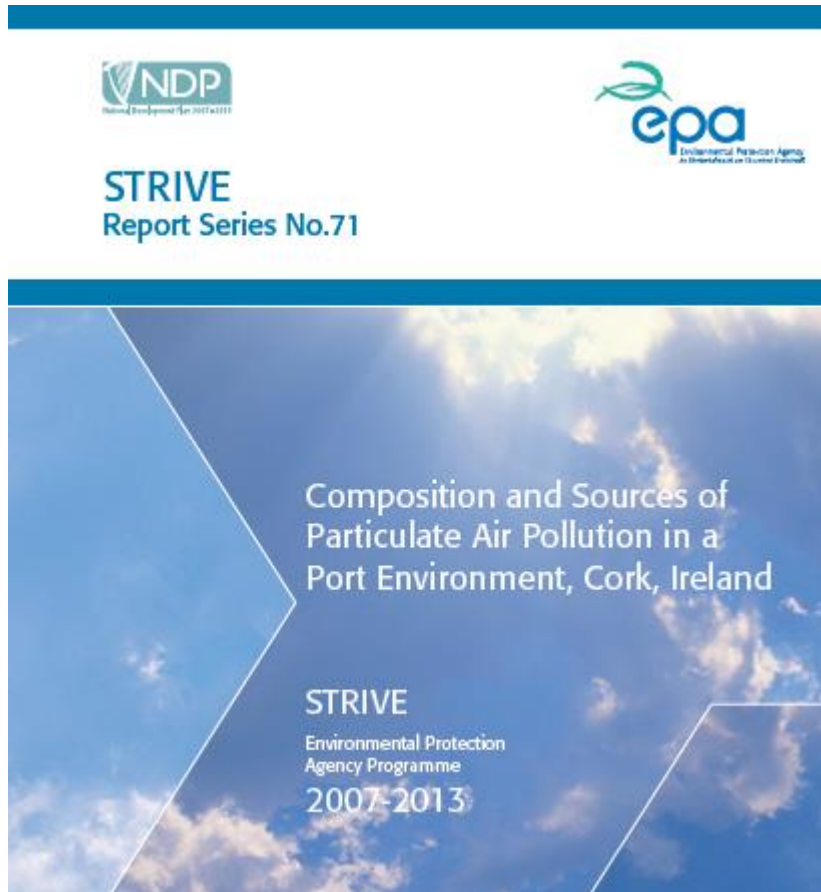
We need to know AND quantify the sources

- How much PM is from traffic?
- How much PM is from solid fuel burning?
- How much PM is from other sources?
- How do the emissions from these sources vary during the day and by season?

Detailed measurements of the PM are required

- Size, concentration and chemical composition at a HIGH-TIME resolution
- Source Apportionment Modelling

# Case Study: Cork Harbour



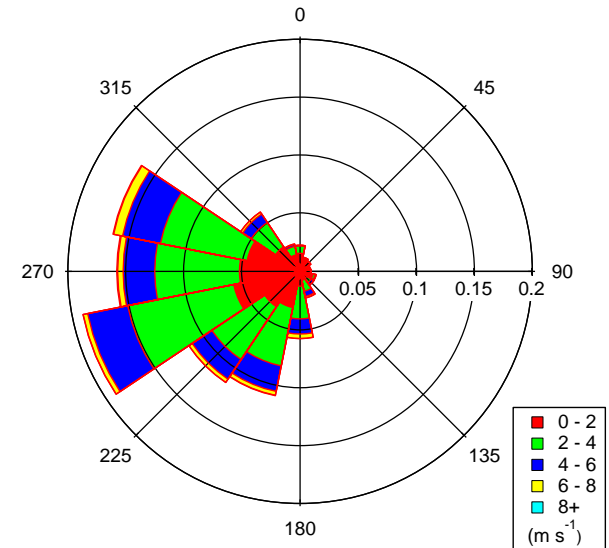
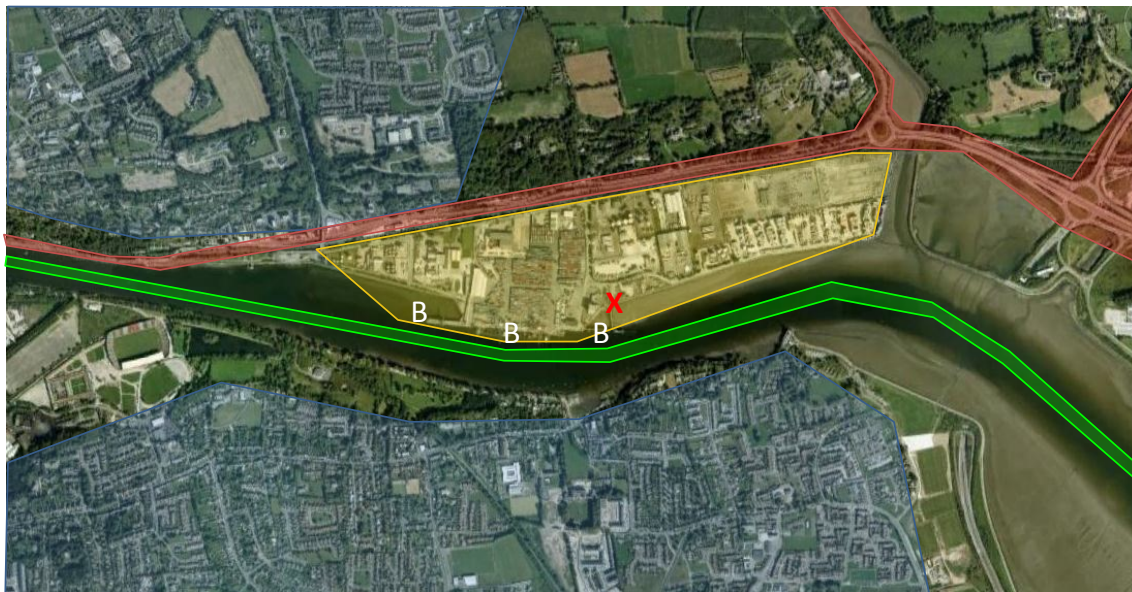
Tivoli Docks  
and Estates



- Long-term (1 year) monitoring campaigns
- Intensive (1 month) measurement campaigns

# Intensive Measurement Campaign

Tivoli Docks August 2008 and February 2009



*Healy et al., Atmospheric Chemistry and Physics 2010*

# Intensive Measurement Campaign

Tivoli Docks August 2008 and February 2009



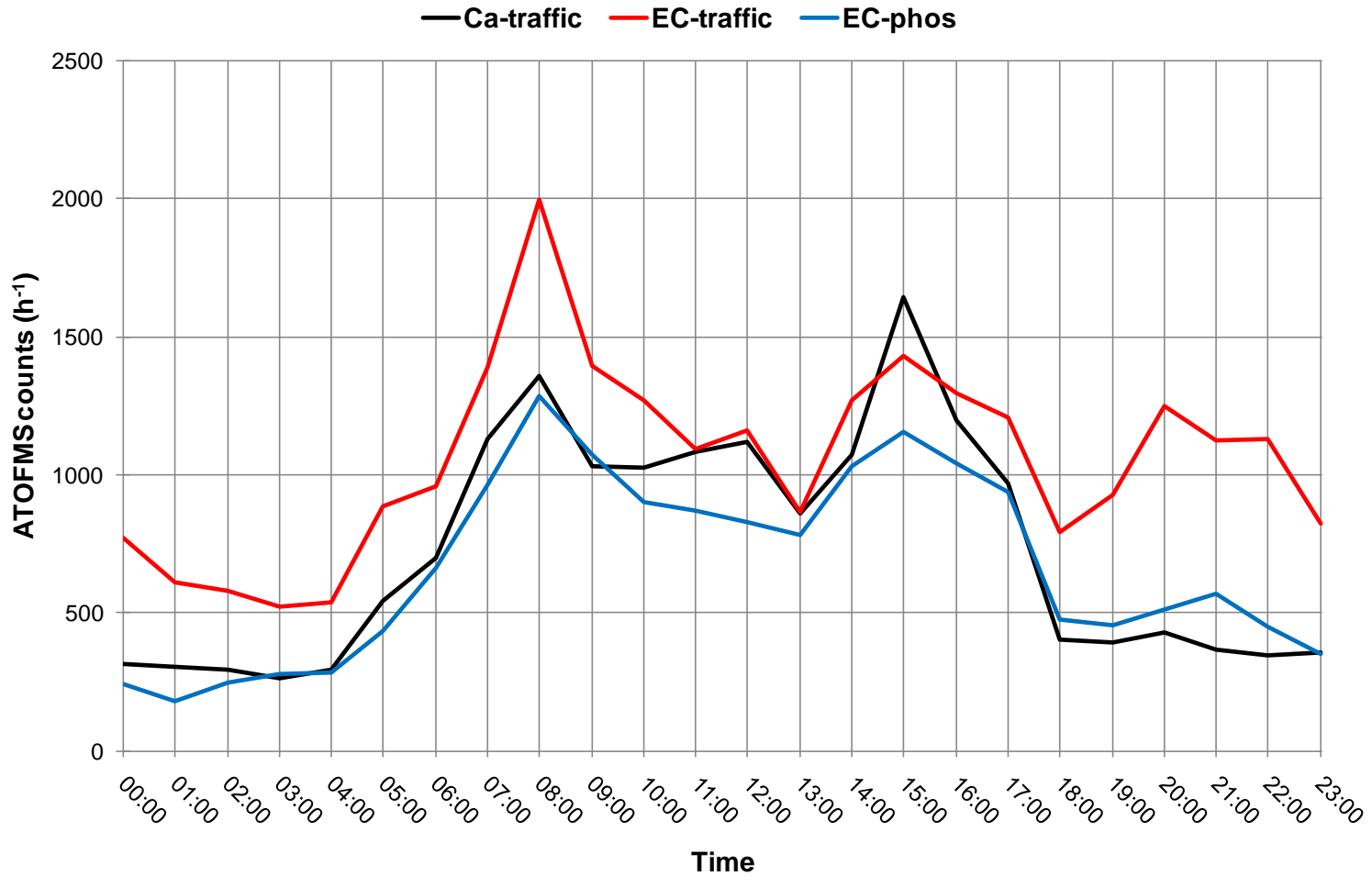
A range of state-of-the-art instruments deployed for *On-line* monitoring of particle mass, size, number and chemical composition in *real-time*

# Aerosol Time-of-Flight Mass Spectrometer



- Measures chemical composition of single particles in real-time
- Uses a mass spectral fingerprint for different sources
- Enables monitoring of particles from various sources continuously

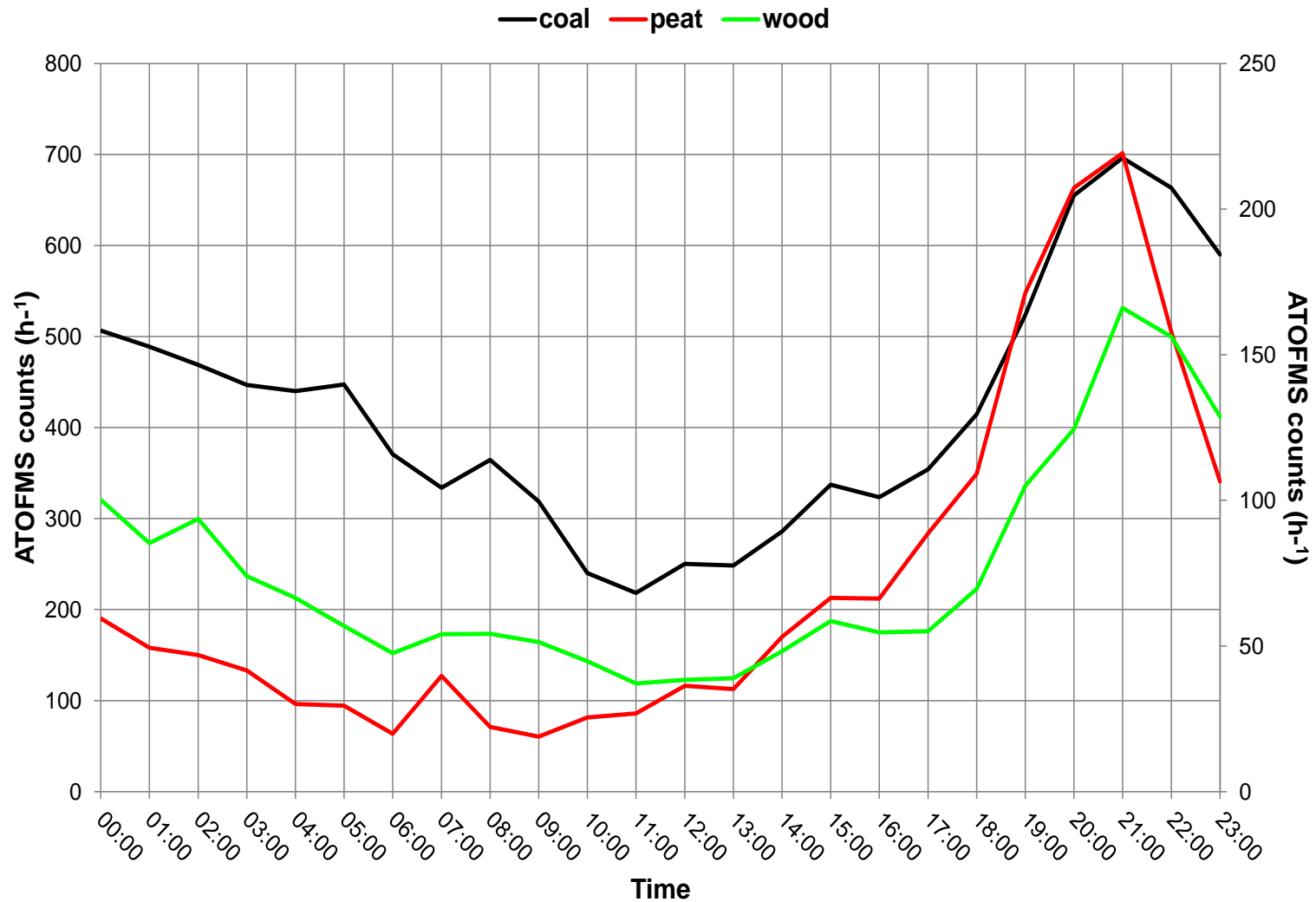
# Sources in Cork Harbour: Vehicular Traffic



*Healy et al., Atmospheric Chemistry and Physics 2010*



# Sources in Cork Harbour: Solid Fuel Combustion



*Healy et al., Atmospheric Chemistry and Physics 2010*

# Source Apportionment of PM

- State-of-the-art analytical techniques used to apportion PM mass

	PM2.5 average ( $\mu\text{g}/\text{m}^3$ )	Solid Fuel Burning %	Traffic %	Other Local Sources %	Regional Sources %
August 2008	9.7	5	23	24	26
February 2009	16.2	50	19	21	10

*Dall'Osto et al., Atmospheric Chemistry and Physics, 2013*

*Kourtchev et al., Science of the Total Environment, 2011*

*Healy et al., Atmospheric Chemistry and Physics, 2010*