Ricardo
Energy & Environment onment

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$PM_{2.5}$ / PM_{10} Ratio & $PM_{2.5}$ Network

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Overview

$PM_{10}/PM_{2.5}$ Ratio:

- Background
- Methodology
- Results
- $PM_{2.5}$ Network

Background - $PM_{2.5}$ & PM_{10} Objectives in Scotland

The Scottish Government published[1] its intentions to the change of the annual mean objective for Particulate Matter (PM) in line with the WHO guidelines:

- Annual Mean PM_{10} objective from 18 μg m^{-3} to 20 μg m^{-3}
- Annual Mean $PM_{2.5}$ objective from 12 μg m^{-3} to 10 μg m^{-3}

	Guideline (μg m^{-3})
$PM_{2.5}$ annual mean	10
$PM_{2.5}$ 24h mean	25
PM_{10} annual mean	20
PM_{10} 24h mean	50

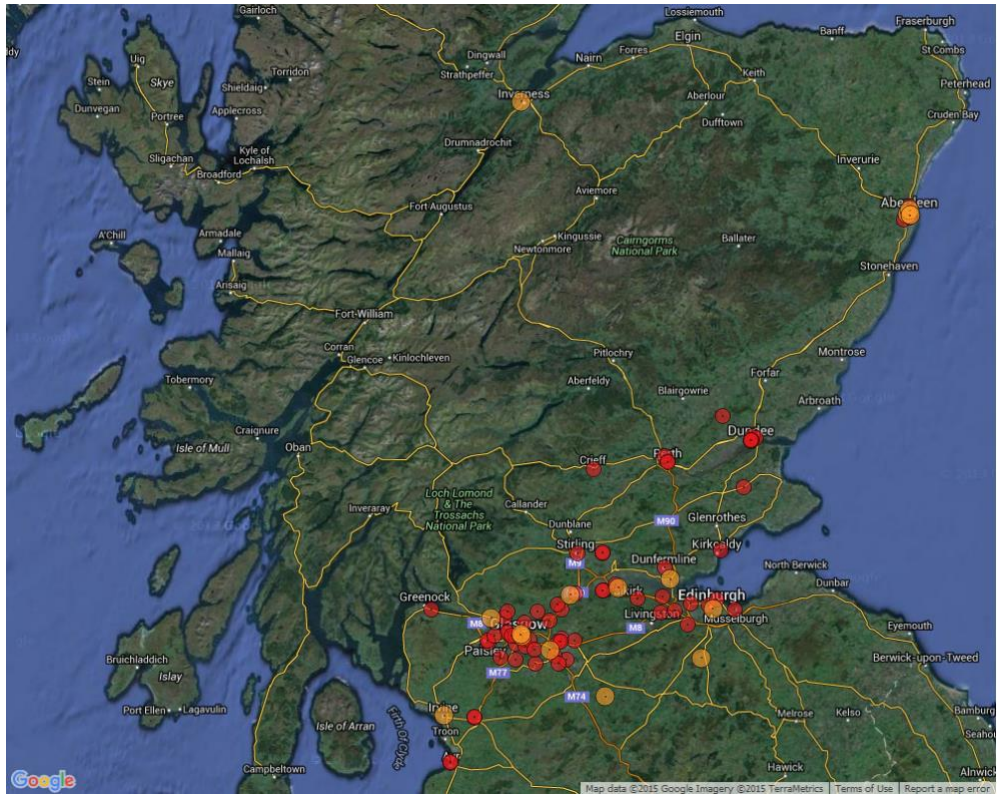
World Health Organization guidelines for particulate matter (PM)

[1] Scottish Government (2015) Cleaner Air for Scotland : Scottish Government, St. Andrew's House, Regent Road, Edinburgh EH1 3DG. Available athttp://www.gov.scot/Resource/0048/00488493.pdf (Accessed: 21/03/16.

$PM_{2.5}$ & PM_{10} Network in Scotland

- Currently they are 15 $PM_{2.5}$ & 73 PM_{10} SAQD sites.
- The vast majority around central belt and so well distributed in relation to population density
- Perhaps with exception for $PM_{2.5}$ in & around Perth / Dundee
- Recent $PM_{2.5}$ proliferation almost 2x since 2014.

All $PM_{2.5}$ with PM_{10} sites (yellow) and PM_{10} sites (red)



$PM_{2.5}$ / PM_{10} Ratios - Methodology

The $PM_{2.5}$ / PM_{10} ratios were investigated using the following:

- Current and historical concentration data from the SAQD.
- Mobile monitoring of PM within the AQMAs around Scotland.
- Pollution Climate Mapping (PCM) maps.
- Enabling the use of PM_{10} data to:
  - estimate $PM_{2.5}$ concentrations where only PM_{10} monitoring exists, and
  - review the impact of changes to the objectives.

This information helped understand the change in the objectives on:

- AQMAs across Scotland.
- Need for expansion of the $PM_{2.5}$ network.

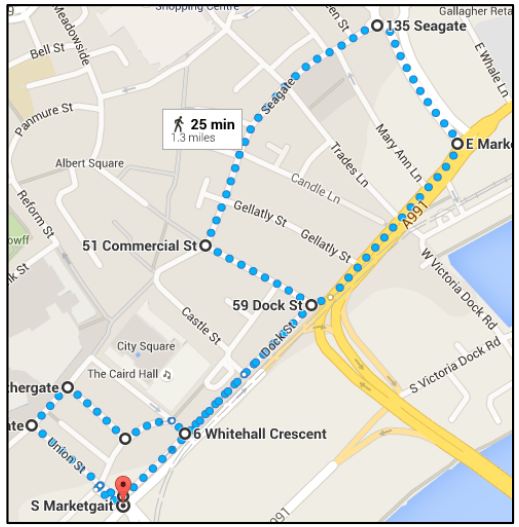
SAQD Data

- Historically, $PM_{2.5}$ and PM_{10} was only monitored at AURN sites.
- Local authorities started to monitoring $PM_{2.5}$ in 2014.
- Currently 15 sites monitoring both $PM_{2.5}$ and PM_{10} – 7 AURN and 8 LA.

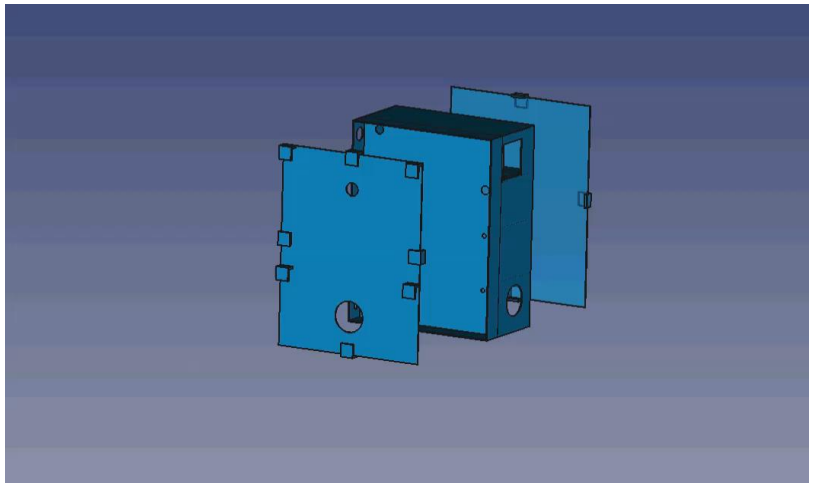
Monitoring Site	Instrument Type(s)
Aberdeen Errol Place	FDMS
Aberdeen Market St 2	FIDAS
Aberdeen Union St	FDMS
Auchencorth Moss	FDMS / Partisol
Edinburgh St Leonards	FDMS
Glasgow High St	FDMS
Glasgow Townhead	FDMS
Grangemouth	FDMS
Falkirk Banknock	FIDAS
Fife Rosyth	FIDAS
Inverness	Partisol
North Ayrshire Irvine High St	FIDAS
South Lanarkshire Lanark	FIDAS
South Lanarkshire Uddingston	FIDAS
West Dunbartonshire Clydebank	FIDAS

Mobile Monitoring

- “Historic” mobile monitoring collected during 2014 used.
- Mobile monitoring exercises carried out in 2014/15.
- Colocations carried out with reference analysers.
- 24 days in total.



Mobile Sample Area	When
Glasgow City Centre	8 days in 2014
Rosyth	21/03/2014
Dunfermline	24/03/2014
Cupar	25/03/2014
Kirkcaldy	27/03/2014
Perth Central	23/05/2014
Perth Central	24/05/2014
Crieff	27/05/2014
Perth Glasgow Rd	29/05/2014
Perth Blackford	30/05/2014
Perth Crieff Rd	03/06/2014
Paisley	18/09/2015
Bearsden	25/09/2015
Edinburgh	02/10/2015
Aberdeen	14/10/2015
Broxburn	27/10/2015
East Kilbride	26/11/2015



Data Analysis - Methodology

The $PM_{2.5}/PM_{10}$ ratios were calculated using the following methods:

- Using hourly and daily means.
- Using monthly and annual means.
- Using regression analysis of hourly means.

Results - Impact of Changing PM Objectives

Changing annual mean objective for PM:

- Reducing the $PM_{2.5}$ objective from 12 μg m^{-3} to 10 μg m^{-3} increases the number of exceedances, but not substantially. However, this is based on small number of monitoring sites.
- Increasing the PM_{10} objective from 18 μg m^{-3} to 20 μg m^{-3} reduces the number of exceedances significantly
- Mobile monitoring data also indicates daily exceedances might follow the same pattern.

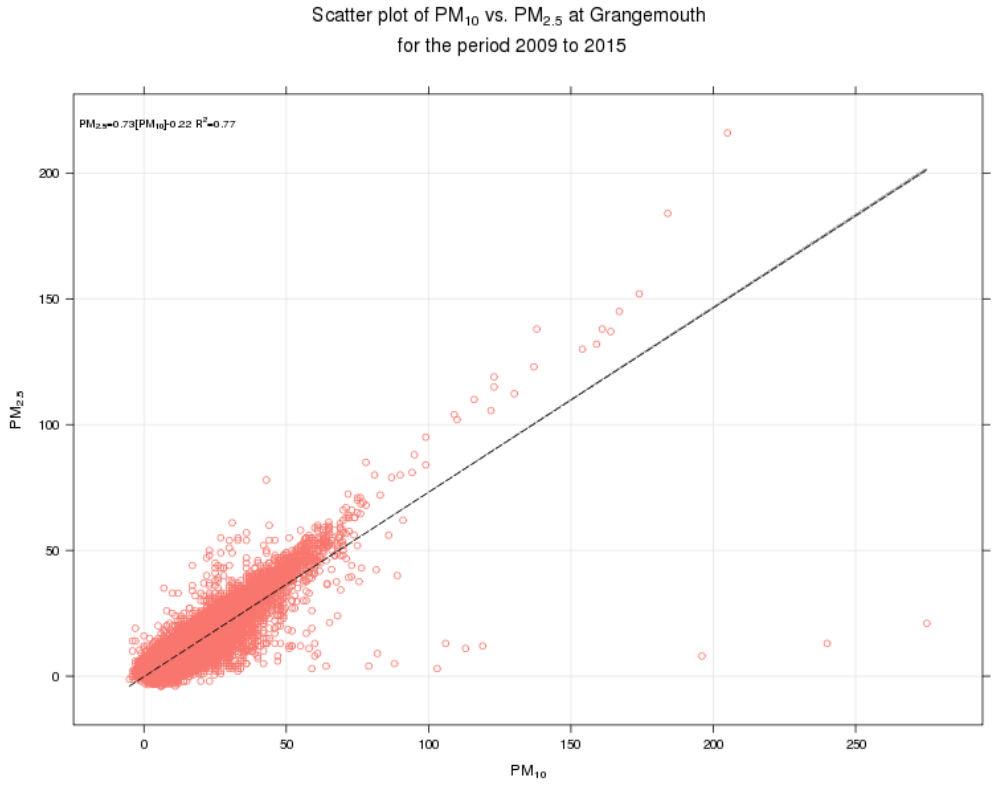
Comparing exceedances for PM of Scottish Air Quality Objectives vs WHO – Fixed Monitoring

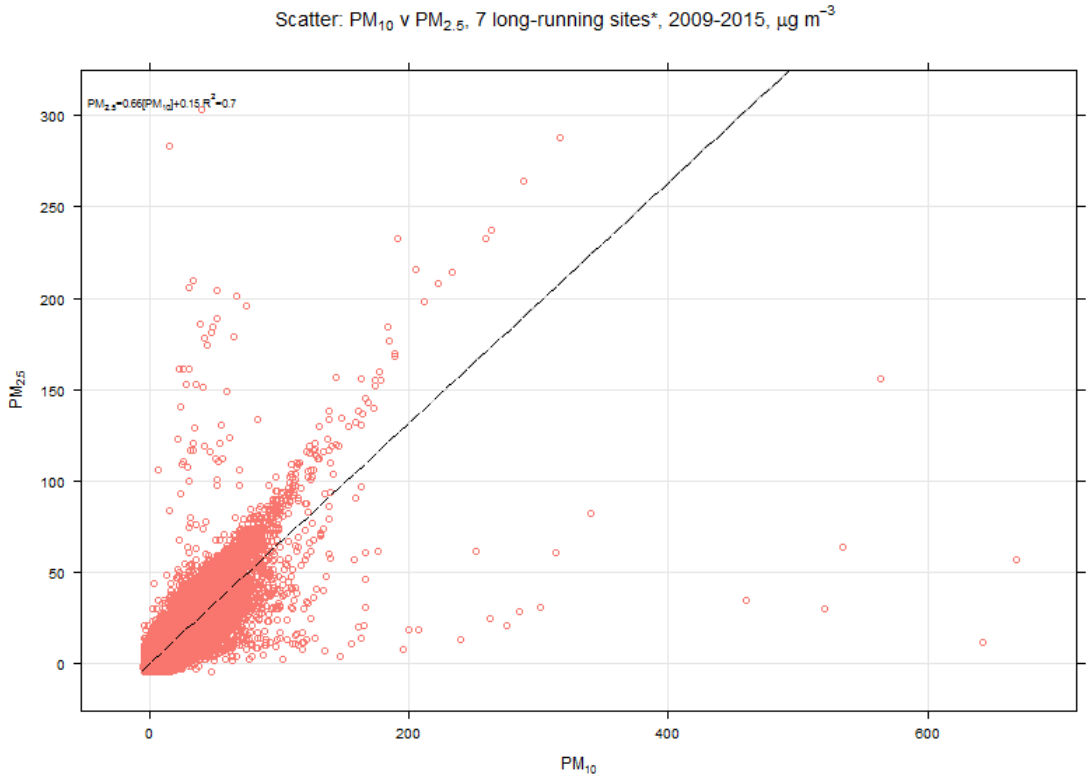
	2014	2015
Exceedances $PM_{2.5}$ @ 12μg m^{-3}	3	0
Exceedances $PM_{2.5}$ @ 10μg m^{-3}	3	1
Exceedances PM_{10} @ 18μg m^{-3}	19	11
Exceedances PM_{10} @ 20μg m^{-3}	6	1

Results - Relationship between $PM_{2.5}$ and PM_{10}

The scatter plots indicate that:

- The relationship between $PM_{2.5}$ and PM_{10} was approximately linear for most of the sites.
- However, in many cases there were clearly two or more separate 'lines' or 'groups' of points for each site, possibly reflecting different seasons, weather conditions or times when different types or sources of PM predominated.
- The correlation coefficient R^2 was > 0.7 in all cases except Aberdeen Errol Place.





Results - Relationship between $PM_{2.5}$ and PM_{10}

$[PM_{2.5}] \approx 0.66\ [PM_{10}]$

Site	Equation of regression line (units µg m^{-3})	Correlation coefficient R^2
Aberdeen Errol Place	$[PM_{2.5}] = 0.48\ [PM_{10}] + 1.9$	0.56
Auchencorth Moss	$[PM_{2.5}] = 0.75\ [PM_{10}] - 1.2$	0.74
Edinburgh St Leonards	$[PM_{2.5}] = 0.67\ [PM_{10}] - 0.2$	0.70
Glasgow Centre (2009-12 only, no December data)	$[PM_{2.5}] = 0.66\ [PM_{10}] + 0.15$	0.70
Glasgow Kerbside (to end 2014)	$[PM_{2.5}] = 0.71\ [PM_{10}] + 1.6$	0.80
Glasgow Townhead (2013-15 only)	$[PM_{2.5}] = 0.73\ [PM_{10}] - 1.8$	0.80
Grangemouth	$[PM_{2.5}] = 0.73\ [PM_{10}] - 0.22$	0.77
Inverness (Partisol, daily)	$[PM_{2.5}] = 0.49\ [PM_{10}] + 0.42$	0.60
All hourly sites' data	**$[PM_{2.5}] = 0.66\ [PM_{10}] + 0.15$**	**0.70**
Average slope and intercept	**Slope = 0.66, intercept = 0.08**	**n/a**

Results - Annual Average $PM_{2.5}/PM_{10}$ Ratios

Annual average $PM_{2.5}/PM_{10}$ ratios calculated from yearly concentrations:

- A mean of 0.63 and median of 0.61
- Show a range from 0.58 to 0.71 over a seven year period.
- Ratios from 2015 within range but low at 0.58
- Likely to be a function of weather or other external conditions

Ratios							
2015	2014	2013	2012	2011	2010	2009	Mean
0.58	0.67	0.58	0.67	0.71	0.61	0.58	**0.63**

Day $PM_{2.5}$ / PM_{10} Ratios from Mobile Monitoring Study

- Overall mean ratios for all study data was 0.47.
- Lower overall mean consistent with lower monthly SAQD means during spring / summer months.
- Mean ratios from 2014 and 2015 data were the similar.
- And a range of 0.21 – 0.69.
- Again likely a function of weather, other external conditions, and sample area.

Mobile monitoring ratios were within the range seen with SAQD data, though overall means are lower than seen with SAQD data.

Mobile Sample Area	When	Mobile Ratio	Sample Size
Glasgow City Centre	8 days in 2014	0.57	2315
Rosyth	21/03/2014	0.42	581
Dunfermline	24/03/2014	0.46	574
Cupar	25/03/2014	0.37	665
Kirkcaldy	27/03/2014	0.60	562
Perth Central	23/05/2014	0.33	608
Perth Central	24/05/2014	0.53	419
Crieff	27/05/2014	0.62	533
Perth Glasgow Rd	29/05/2014	0.47	619
Perth Blackford	30/05/2014	0.63	591
Perth Crieff Rd	03/06/2014	0.31	514
Paisley	18/09/2015	0.43	430
Bearsden	25/09/2015	0.34	444
Edinburgh	02/10/2015	0.69	403
Aberdeen	14/10/2015	0.46	410
Broxburn	27/10/2015	0.62	352
East Kilbride	26/11/2015	0.21	374
	Mean	0.47	

$PM_{2.5}$ / PM_{10} Ratios - PCM

- Overall mean ratios for mapped areas in 2014 is 0.69.
- Overall mean consistent with calculated SAQD means.

Local Authority	$PM_{2.5}$	PM_{10}	$PM_{2.5}$ / PM_{10} Ratio
City of Glasgow	8.25	11.53	0.72
City of Edinburgh	8.45	12.35	0.68
Fife	7.70	11.40	0.68
North Lanarkshire	7.44	10.54	0.71
South Lanarkshire	6.61	9.07	0.73
Aberdeenshire	6.94	10.56	0.66
Highland	4.67	6.87	0.68
City of Aberdeen	8.20	12.52	0.65
West Lothian	7.64	11.48	0.67
Renfrewshire	6.43	9.03	0.71
Falkirk	7.76	11.07	0.70
Dumfries and Galloway	6.15	8.45	0.73
City of Dundee	7.86	11.38	0.69
Perth and Kinross	5.65	8.00	0.71
North Ayrshire	5.61	7.82	0.72
East Ayrshire	6.21	8.56	0.73
Angus	7.03	10.40	0.68
South Ayrshire	6.02	8.33	0.72
Scottish Borders	6.88	9.64	0.71
East Dunbartonshire	6.79	9.40	0.72
East Lothian	7.68	11.19	0.69
Moray	5.72	8.11	0.71
Argyll and Bute	4.98	6.87	0.72
East Renfrewshire	6.44	9.01	0.71
West Dunbartonshire	6.13	8.46	0.72
Midlothian	7.47	10.61	0.70
Stirling	5.42	7.44	0.73
Inverclyde	5.66	7.79	0.73
Clackmannanshire	6.89	9.81	0.70
Na h-Eileanan Siar (Western Isles)	4.39	6.72	0.65
Shetland Islands	6.23	11.46	0.54
Orkney Islands	5.62	9.39	0.60
Mean	6.59	9.54	0.69

$PM_{2.5}$ / PM_{10} Ratios - Summary

- There appears to be a roughly linear relationship between $PM_{2.5}$ and PM_{10}, good enough to use to obtain an indicative estimate of annual mean $PM_{2.5}$ at a location where only PM_{10} is measured.
- Regression analysis of fixed monitoring: **$[PM_{2.5}] \approx 0.66\ [PM_{10}]$**
- Annual mean of daily mean **$[PM_{2.5}] \approx 0.63\ [PM_{10}]$**, based on 8 SAQD sites' data from years between 2009 and 2015.
- The ratio typically varies between 0.5 and 0.8.
- The ratio is only suitable to use for indicative purposes, as it varies from site to site and from year to year. However, it serves the purpose of indicating how many more $PM_{2.5}$ sites might be needed if the objective is changed.
- For 2015 alone, all sites measuring both parameters, the average ratio was 0.58.

Possible implications of changing objectives

- Increases the number of AQMAs for $PM_{2.5}$.
- Reduces the number of AQMAs for PM_{10}.
- Will have a (possibly significant) change(s) in Local Authority Air Quality Action Plans.
- Need to expand $PM_{2.5}$ monitoring network as $PM_{2.5}$ will be included within the Local Air Quality Management Regime.

Monitoring $PM_{2.5}$

- Use two analysers.
- Use an analyser that can measure both PM_{10} and $PM_{2.5.}$
- Monitor $PM_{2.5}$ instead of PM_{10} (attach sharp cut-off cyclone).
- Ratio calculations indicate that the $PM_{2.5}$ proposed annual mean objective of 10 $\mu g\ m^{-3}$ could be exceeded if the annual mean PM_{10} > 15 $\mu g\ m^{-3}$.
- Therefore, it might be appropriate to monitor $PM_{2.5}$ even if the PM_{10} annual mean objective is not being exceeded and the ratio could be used to identify priority sites for $PM_{2.5}$ analysers.
- QA of the data will be important due to the uncertainties associated with $PM_{2.5}$ at 10 $\mu g\ m^{-3}$.

Determining $PM_{2.5}$ Network Needs from $PM_{2.5}/PM_{10}$ Ratio

- The study shows it is possible to calculate $PM_{2.5}$ from PM_{10} concentrations using the $PM_{2.5}/PM_{10}$ ratio.
- That annual average $PM_{2.5}/PM_{10}$ ratio from SAQD data produced the most consistent results for this calculation.
- Also that the number of $PM_{2.5}$ SAQD monitoring sites has doubled in 2015 compared to 2014.

Given this information the $PM_{2.5}$ network may be sufficient, given the following considerations:

- Use of the $PM_{2.5}/PM_{10}$ ratio to calculate PM_{10} concentrations is used with caution, given the ratio fluctuates.
- The number of $PM_{2.5}$ monitoring sites continues to increase.
- Gaps within the network (Dundee, Perth & additional rural sites) are perhaps filled.