Mercury Emissions from UK Coal Fired Power Plants

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The Joint Environmental Programme of the Electricity Supply Industry

- The main objective of the JEP is to understand and increase knowledge of the environmental science and impacts associated with the production of electricity from, natural gas, biomass, gasoil and coal fired power plants.
- The JEP develops a work programme each year the purpose of which is:
  - To inform the industry’s response to developing environmental issues, policies and legislation.
  - Offering supporting technical material for environmental permitting, consent and licensing applications and specific discussions with the UK regulatory bodies concerning power station regulation.
  - Offering supporting material member companies on policy and legislative developments.
Introduction

- Mercury (Hg) is a global pollutant that affects human & ecosystem health
- Emitted from mining, coal combustion and various process operations
- Regulated on a global scale (Minamata Convention)

What do we need to measure in flue gas?
- Total mercury $Hg^T = Hg^0 + Hg^{2+} + Hg^P$ (elemental + oxidised + particle bound)
- $Hg^P << (Hg^0 + Hg^{2+})$
- Vapour phase Hg sufficient for coal fired plant with modern control technology

What is emitted?
- Depends on abatement technology
  - ESP only: $Hg^0$ and $Hg^{2+}$
    $Hg^{2+}$ is water soluble
  - ESP + FGD: mostly $Hg^0$
  - ESP + FGD + SCR: mostly $Hg^0$
- $Hg^0 \rightarrow Hg^{2+}$ enhanced by the SCR catalyst

Mercury regulation in Europe

- Industrial Emissions Directive (IED) does not specify Emission Limit Values (ELVs) but ‘For combustion plants firing coal or lignite, the emissions of total mercury shall be measured at least once per year.’

- Large Combustion Plant Best Available Techniques Reference document (LCP BREF) – BAT Conclusions applicable from 17 August 2021:

<table>
<thead>
<tr>
<th>Combustion plant total rated thermal input (MWth)</th>
<th>BAT-AELs (μg/Nm³)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New plant</td>
<td>Existing plant (¹)</td>
</tr>
<tr>
<td></td>
<td>coal</td>
<td>lignite</td>
</tr>
<tr>
<td>&lt; 300</td>
<td>&lt; 1–3</td>
<td>&lt; 1–5</td>
</tr>
<tr>
<td>≥ 300</td>
<td>&lt; 1–2</td>
<td>&lt; 1–4</td>
</tr>
</tbody>
</table>

(¹) The lower end of the BAT-AEL range can be achieved with specific mercury abatement techniques.

The BAT-associated emission level (BAT-AEL) for mercury emissions to air from the combustion of solid biomass and/or peat is < 1–5 μg/Nm³ as average over the sampling period.

Top-of-range BAT-AELs generally applicable in England & Wales

Continuous monitoring required unless Hg emissions deemed to be ‘sufficiently stable’
Expected Hg emissions

- Default average Retention Factors are defined by Eurelectric for E-PRTR (pollution inventory) reporting for large Pulverised Coal (PC) boilers in Europe

<table>
<thead>
<tr>
<th>Species</th>
<th>Plant Configuration</th>
<th>Retention Factor (R)</th>
<th>Emission (1 - R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg</td>
<td>ESP + FGD</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>ESP + SCR + FGD</td>
<td>0.85</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Electrostatic Precipitator (ESP) only: R = 0.5
All UK PC fired utility boilers have wet Flue Gas Desulphurisation (FGD). One 2 GW_e plant additionally has Selective Catalytic Reduction (SCR) which enhances Hg capture.
Actual Hg emissions – field trials

JEP field trials

- Four separate units at different sites (designated A to D) using the mercury wet chemistry standard reference method (EN 13211) for flue gas Hg in 2012 and a fifth site using the Ontario-Hydro Method in 2010
- Extended sampling durations (1 to 3 hours) to improve the uncertainty of the reference method
- Coal Hg content measured to assess overall Hg Retention Factors using a mass balance approach Coal sampling was either from the PF feed lines (bone dry) or the mill inlet feeders (‘as received’)
- Total of 33 individual test measurements with averages reported below
- Coal chlorine content also measured since this affects Hg$^0$ oxidation to soluble Hg$^{2+}$

<table>
<thead>
<tr>
<th>Plant</th>
<th>Cl %</th>
<th>Hg$_{FUEL}$ μg/kg</th>
<th>Hg$_{IN}$ μg/m$^3$</th>
<th>Hg$_{OUT}$ μg/m$^3$</th>
<th>Retention %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0.01%</td>
<td>119</td>
<td>13.7</td>
<td>2.0</td>
<td>86%</td>
</tr>
<tr>
<td>B2</td>
<td>0.02%</td>
<td>63</td>
<td>6.7</td>
<td>2.2</td>
<td>67%</td>
</tr>
<tr>
<td>C3</td>
<td>0.22%</td>
<td>77</td>
<td>7.9</td>
<td>1.7</td>
<td>76%</td>
</tr>
<tr>
<td>D4</td>
<td>0.24%</td>
<td>201</td>
<td>21.8</td>
<td>1.1</td>
<td>95%</td>
</tr>
<tr>
<td>E5</td>
<td>-</td>
<td>186</td>
<td>20.0</td>
<td>1.7</td>
<td>90%</td>
</tr>
</tbody>
</table>

|       |     | 116               | 12.4              | 1.7               | 83%         |

- Emitted Hg was low (1.1 - 2.2 μg/m$^3$) across a wide range of average fuel Hg contents (63 - 201 mg/kg)
- Retention Factors varied from 67% to 95%, consistent with the assumed RF of 75% for ESP+FGD
- Retention was higher than might be expected due to the relatively high carbon-in-ash content at UK sites
Actual Hg emissions – field trials – individual test results

Mercury flue gas concentration (µg/m³)

Annual BAT-AEL 4 µg/m³
Actual Hg emissions – CEMS trial

- Mercury variation across a six-week period using speciating CEMS (PS Analytical)
- Emissions dominated by Hg\(^0\) as expected (Hg\(^{2+}\) mostly absorbed in the FGD unit)
- Emissions consistently within BAT-AEL when firing coal Hg in the range 45 to 174 μg/kg
- Highest Hg emission coincides with highest coal Hg based on limited fuel sampling – daily average Retention Factor ≥ 0.8 (0.7 on a single day when firing very low Cl coal)
Actual Hg emissions – Retention Factors

• Retention Factors mostly ≥ 0.75 (Eurelectric) noting the uncertainties in the coal Hg analysis and the flue gas analysis which explains much of the scatter within each data series.

• Linear fit – forced through zero - gives only a coarse indication of performance since retention is not just a function of coal Hg content and other factors are important, especially coal Cl content and carbon-in-ash content.
Retention Factor prediction for individual units

- Interactive Process Optimization Guidance (iPOG™) available from the United Nations Environment Programme (UNEP)
- Fuel Evaluation Tool (FET) developed by Uniper for fuel assessment in order to assist with fuel procurement and operations planning (tuned to UK utility boiler design)
UK Compliance approach

- Measure coal Hg and report monthly averages on a quarterly basis against the Hg limit
- Maintain annual average coal Hg below a threshold equivalent to the BAT-AEL using assumed Retention (R)
- Combinations of high Hg and ultra-low Cl content are undesirable but are unusual in the current basket of coals (post-2015) but coal Cl content also reported
- Measure and report flue gas concentration and associated Retention Factor annually to check that plant performance is stable (taking into account the combined uncertainty of the flue gas and fuel analyses)

<table>
<thead>
<tr>
<th>Plant configuration</th>
<th>Annual BAT-AEL μg/m^3</th>
<th>Retention Factor, R</th>
<th>Coal Annual Hg μg/kg_{ar}</th>
<th>Coal Annual Hg μg/kg_{dry}</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP</td>
<td>4.0</td>
<td>0.50</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>+ FGD</td>
<td>4.0</td>
<td>0.75</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td>+ SCR</td>
<td>4.0</td>
<td>0.85</td>
<td>230</td>
<td>270</td>
</tr>
</tbody>
</table>
UK mercury reporting

- Fuel management approach with quarterly reporting of coal analysis against annual coal Hg limit
- Mass emissions reporting is based on coal Hg and assumed or plant specific Retention Factor
- Report flue gas concentration and associated Retention Factor annually to check that plant performance is stable (taking into account the combined uncertainty of the flue gas/fuel analyses)
Summary

• Work sponsored by the Joint Environmental Programme of the Electricity Supply Industry has demonstrated that:
  • Mercury capture at UK coal fired power plant (utility boilers) is consistent with European Retention Factors that are used for Pollution Inventory reporting
  • Measured mercury emissions are consistent with the LCP BREF BAT-AEL of 4 μg/m³ when firing coals within an acceptable range of coal mercury content
  • UK compliance with the LCP BREF is based on coal mercury reporting against an annual coal mercury limit
  • Sufficiently stable operation is demonstrated by an annual flue gas mercury test that is used to check the plant mercury Retention Factor (when operating > 500 h/yr)
  • Compliance reporting is based on quarterly reporting of monthly coal Hg content along with the annual flue gas test results and a calculated Retention Factor
  • UK Coal Closure Programme requires all coal fired plant to close by October 2024 so the above measures are in place for intermittent operation of the remaining plant
Uniper: Engineering for the Energy Evolution

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