CARABLACK
Characterization of atmospheric emissions of black carbon in stack discharge of plants


*Presenting author
Partners and collaborations

- Project coordinated by **INERIS** (French National Institute For Industrial Environment And Risks) as part of its activities supporting French Ministry for an Ecological and Inclusive Transition (MTES) (cecile.raventos@ineris.fr)

- Partner: **CITEPA** (French Interprofessional Technical Centre for Studies on Air Pollution) responsible from French emission inventories and projections for MTES

- In collaboration with:
  - **LSCE** (French Laboratory for Sciences of Climate and Environment)
  - Industrial sites where the trials were performed

**Work supported by:**

**ADEME** (The French Environment and Energy Management Agency)
➢ Characterisation of BC in ambient air as requested by Directive 2008/50/CE
   ➔ One measurement method standardised in EU since 2017: EN 16909

➢ But absence of requirement for BC measurement at the emission of stationary sources; no emission limit value (ELVs)
   ➔ Limited emission measurement data from stationary sources
   ➔ Measurement methods rarely described: comparability of methods and results?
   ➔ No standardised methods

➢ Nevertheless inventories are established, based on EF (emission factors): 1st inventory in France carried in 2013 (CITEPA)
   ➔ Applied methods and characteristics?
   ➔ Reliability of established inventories?
   ➔ Way of improving?
Objectives and methods

➢ Identify the measurement methods of black carbon in stacks:
  ▪ Already applied for the characterisation of stationary source emissions
  ▪ Or those applied for ambient air but which could be adapted for emission
    ➔ State of the art on black carbon measurement methods

➢ Assess the different measurement methods selected during a campaign of trials on INERIS bench test:
  ▪ Implementation
  ▪ Performances
  ▪ Comparison of results obtained during measurements on a same BC/PM matrix
  ▪ Assessment of the size distribution of black carbon particles

  **NOTE:** inventories are based on BC EF (emission factors) expressed in most cases as a BC fraction in PM$_{2,5}$

  ➔ black carbon emissions are derived from: EF(BC/PM$_{2,5}$ ) x EF (PM$_{2,5}$)

➢ Measurement campaigns performed on 2 biomass boilers for heat and hot water production (capacity 3,5 and 5,5 MW): selected in a sector identified by CITEPA as an important contributor of black carbon emissions in France
The Scientific Advisory Group for Aerosols of the Global Atmosphere Watch program of the World Meteorological Organization (WMO) recommends:

**Use BC as a qualitative term** whatever the measurement method is but use:

- **Equivalent Black Carbon (EBC) when optical methods are used.** The absorption rate of the aerosol is converted in EBC with the Mass Absorption Coefficient (MAC). The MAC should be always reported.

- **EC Element Carbon when thermo-optical methods are used**
Measurement methods assessed

➢ Optical methods downstream diluter (automatic method)

➢ Thermal and thermo-optical methods
  ▪ Sampling systems implemented:
    ➢ Sampling system of total particles onto filter
    ➢ Impactor to determine size distribution: fractions PM$_{10}$ and PM$_{2.5}$
  ▪ Analytical methods tested:
    ➢ Thermal analysis: method 2-Steps developed by Cachier et al. (1989)
      NOTE: analytical conditions initially optimised for diesel BC ambient air measurement
    ➢ Thermo-optical analysis (method standardised for ambient air ➔ EN 16909 since 2017)
      Interest compared to the thermal method: optical correction of artefact due to OC pyrolysis
Measurement methods assessed

- Good repeatability of each method
- **BUT** significant differences between results from optical/thermal/thermo-optical methods (differences also observed in ambient air)

  ➔ Importance to specify the method, the protocol and the equipment used together with the results obtained

Comparison of thermo-optical and optical methods

- Relatively good agreement during trials on bench tests:
  ➔ BC(optical method)/BC(thermo-optical method) = between 0,6 and 2,8
  (average = 1,5 - median = 1,5)

- But not so good on site:
  ➔ BC(optical method)/BC(thermo-optical method) = between 0,1 and 6,2
  (average = 1,4 - median = 0,5)

- Difficulties due to lack of reference material
Lessons from trials on bench test and on site

BC is present in PM2.5 but also other fractions
Assessment of EF

- Estimation of input capacity of the boiler associated to uncertainties
- Main influencing factors for the 2 sites:
  - Measurement method used
  - PM fraction considered, especially when PM larger than 2.5 are not negligible
  
  ➔ Recommendation: improvement of the robustness of BC EF determination by performing several measurements

- Fractions $[\text{BC/PM}_{2.5}]$ of the 2 sites compared to national inventory ratio:

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
<th>National inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[\text{BC/PM}_{2.5}]$</td>
<td>$&lt; 1.5 %$</td>
<td>$&lt; 1 %$</td>
<td>10 %</td>
</tr>
<tr>
<td>$[\text{TC/PM}_{2.5}]$</td>
<td>$\approx 2 %$</td>
<td>$\approx 7 %$</td>
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BUT ⚠️ $[\text{BC/PM}_{2.5}]$ of national inventory is applied for combustion installations with a rated capacity below 50 MW, burning wood and similar waste: 10 %

➔ Include all types of wood and waste, and different size of installations
Conclusions and perspectives

➢ No measurement method interely satisfactory
  - No simple correction factor can be applied to the different methods
  - Oncoming projects to be followed:
    ➢ Feedback necessary on hybrid methods (incandescence and photo acoustic methods)
    ➢ More comparisons on emission matrices needed
    ➢ Development of a reference material

➢ Which method to be selected in case of practices harmonization?
  - Choice can be guided by:
    • The capacity to use the method rapidly: Feasibility/easiness of routine measurements?
  - Good practices to be applied:
    • Measurement repetitions

➢ Which PM fraction should we consider in emission inventories?
  - BC fraction both in PM10 and PM2.5
  - Focus just on BC emitted by fine particles in order to deal with health effects?
  - Risk of underestimation of total BC emissions if BC just estimated from a ratio in PM2.5?