Validation and comparison of methods of measurement of the condensable fraction of aerosols emitted by residential wood combustion appliances and boilers

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Key words : domestic heating using biomass, atmospheric emissions, aerosol sampling and measurement

Summary

•20/20/20 target for Europe, i.e. to decrease the emissions of greenhouse gases by 20 % and to increase the use of renewable energy to 20% by the year 2020, will lead to an increased use of biomass combustion, e.g. using wood logs and wood pellets/Air Quality Directive (2008/50/EC) lies down stringent requirements on maximum levels of particulate matter in the ambient air. Solid fuel burning appliances and boilers produce particulate matter emissions which are of concern to authorities and the public.

•A part of ambient air particles initially emitted as semi-volatiles (SVOCs, condensable fraction), and volatile organic compounds (VOCs) contribute to primary organic aerosols (POA) by condensation as the flue gas cools down, or secondary organic aerosols (SOA) due to photochemical oxidation into the atmosphere.

•Contribution of condensable fraction to emission depends on quality of the combustion; the poorest the quality of the combustion, the highest its contribution to the emissions.

•Different particle sampling procedures used to characterize emissions from residential wood combustion. Depending on the sampling method chosen, the condensable fraction will be taken into account or not.

• Two methods of measurements including the condensable fractions have been adapted from existing ones and compared to existing standards (US EPA 5H, Dilution tunnel) and to each other. The first one consists of collecting the condensable fraction using cold impingers filled in with isopropanol (IPA) and placed after a heated filter collecting the solid fraction. The second one consists of diluting the aerosol using a portable dilution device (porous tube) and combine it to online mass measurements using a tempered oscillating mass balance (TEOM) initially designed for ambient air mass measurements.

Introduction

- **Growing use of biomass as renewable energy :**
  Domestic sector is a strong contributor to PM emissions at European and National levels
  Ambient air fine PM peaks of concentration are observed in areas where wood burning domestic heating systems are heavily used

- **Wood domestic heating aerosol emissions characteristics:**
  ▪Ultrafine aerosols, high contribution of the condensable fraction especially under bad combustion conditions;
  ▪Condensable phase highly contributes to fine PM ambient concentrations;
  ▪Organic gaseous compounds (OGC) is a tracer of condensable phase and indicator of the quality of combustion

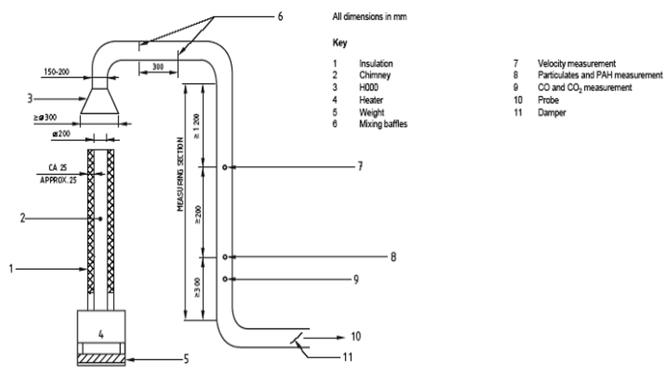
- **Different methods used to quantify TSP**
  ▪Results dependant on methods used: condensables not necessarily taken into account
  ▪Reliable methods of determination of condensables are necessary (emission inventories, impact on air quality,etc.)

Material and methods

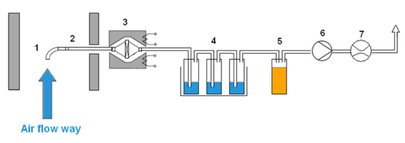
SP[1] (solid)	TSP : Heated filter 160°C
SPC[1] (solid and condensable) - IPA	TSP : Heated filter 160°C combined with cold (<20°C) impinger filled in with isopropanol
DT[1]-Filter	TSP (mass) : Dilution tunnel sampling using filter
PRD-TEOM	TSP (mass) : portable dilution device (porous tube) online mass measurements using TEOM (tapered element oscillating microbalance)
OGC (organic gaseous compunds)	FID measurement

DT (dilution tunnel)-filter method based on NS 3058-2[2]

Dilution applied using none filtered ambient air;
Dilution ratios between 1:10 to 1:20 (controlled using a combustion gas as tracer)
Particles collected on a filter under ambient conditions (temperature, humidity);
Combined mass determination of solid and condensed phases collected



SPC –IPA (solid plus condensable method) hot filter combined to cold impinger (IPA) sampling based on US EPA 5H[3] and EN TS 15439[4]



SPC-IPA method simplified version of US EPA 5H (water collection combined to DCM extraction replaced by IPA collection) and compared to DT method (EAC 2011[5])

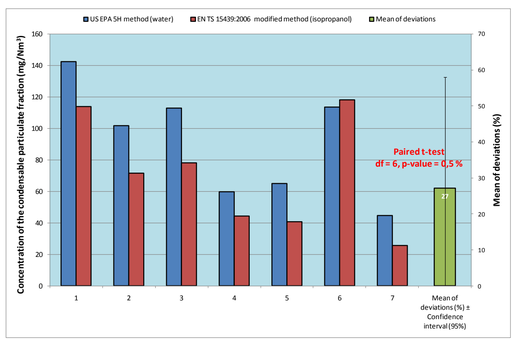
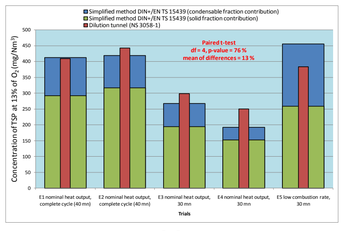
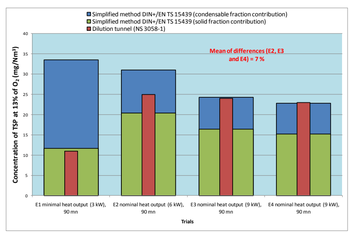


Figure 1: Comparison of results obtained from simultaneous measurements performed with US EP 5H and SPC-IPA method



(a)

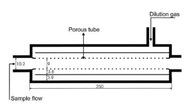


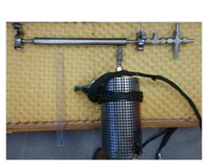
(b)

Figures 2 (a and b): Comparison of results obtained from simultaneous measurements performed with DT-filter and SPC-IPA method

PRD-TEOM: Portable dilution device (porous tube) coupled with online mass measurement method using TEOM

Dilution ratios between 30 and 60 (controlled using a combustion gas as tracer)
Online mass determination (access to combustion profiles)
Particles collected on a filter under ambient conditions (temperature, humidity);
Combined mass determination of solid and condensed phases collected





Results

•**Methods correlations**

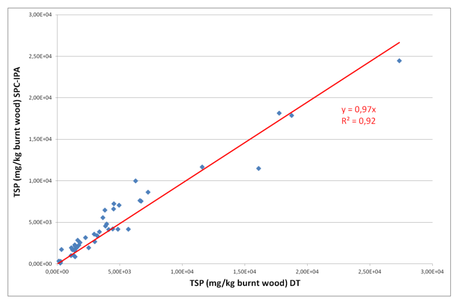


Figure 3: SPC-IPA / DT comparison

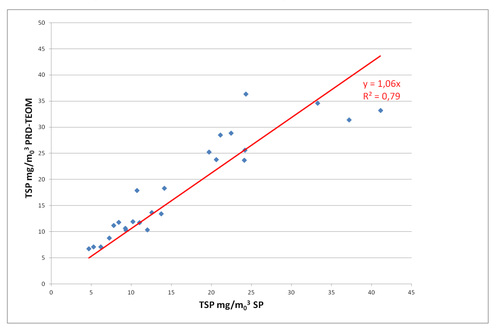


Figure 5: PRD-TEOM / SP comparison TSP and OGC< 50 mg/m$_0^3$

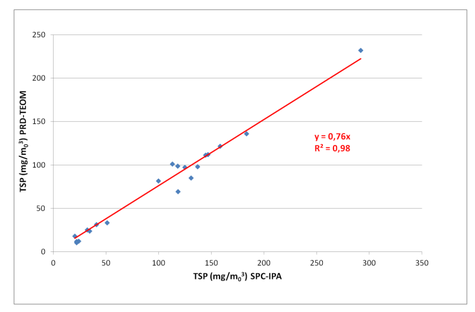


Figure 4: PRD-TEOM / SPC-IPA comparison (TSP > 20 mg/m$_0^3$ and OGC > 80 mg/m$_0^3$)

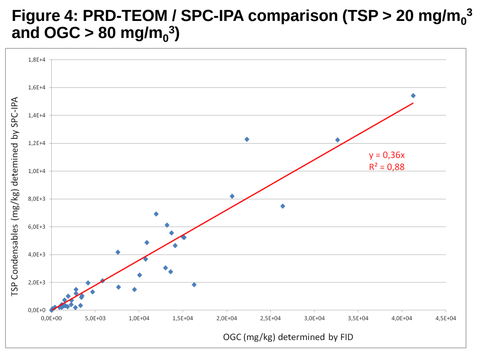


Figure 6: Condensable by SPC / OGC by FID

•**Applications**

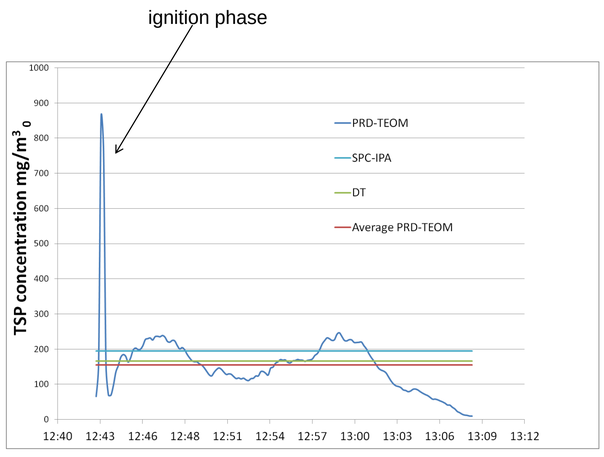


Figure 7: Example of an emission profile observed using PRD-TEOM

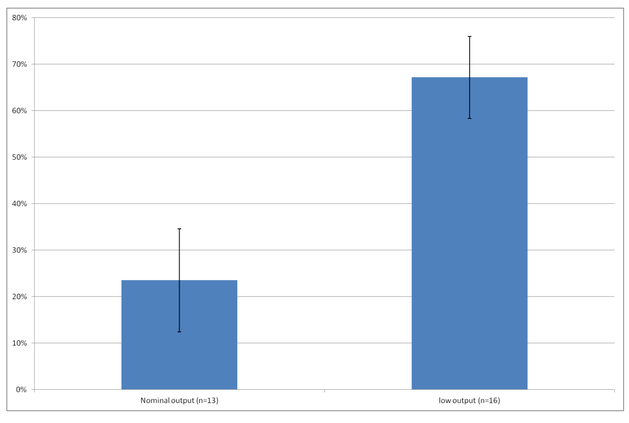


Figure 8: Contribution of the condensable fraction determined by SPC-IPA method, under different combustion conditions

Conclusions and perspectives

•**Good correlations and agreement are observed between SPC-IPA and DT methods (Figure 3)**
•**PRD-TEOM correlates :**
  •with SPC-IPA at high concentrations of TSP and OGC, with an underestimation of about 25% (Figure 4)
  •with SP at low concentrations of OGC (condensables close to LOQs) (Figure 5)
•Strong dependency is observed between OGC and condensable fraction of TSP (Figure 6) i.e gap between measurement on the hot matrix or after dilution

•**SPC-IPA : Reliable and quite simple approach to determine solid and condensable fractions separately**
  •Emission factors determination, with contribution of condensable much higher when appliance used in low output (Figure 8)
  •Input data for modelling of air quality
  •Evaluation of reduction techniques, impact on solid fraction may not be not enough, impact on condensable may also be necessary

•**PRD-TEOM: direct and reliable determination of mass**
  • combustion profiles accessible (Figure 7)
  • Perspectives: Possibility to combine PRD dilution to other ambient air technique for aerosol characterisation like aethalometer for black carbon measurements

References

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2 NORSK STANDARD, NS-3058 (1994), Enclosed wood heaters, smoke emission
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5 EAC 2011, CEM 2011 Definition and evaluation of a new method for the characterization of particulate emissions from domestic combustion devices using biomass

Acknowledgment :
French environment and energy management (ADEME), French Ministry of environment