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Near Real-time Monitoring of Diesel Exhaust Particulate (DEP)

30th April 2015

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Introduction

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- **What is Diesel exhaust particulate (DEP)?**
  - Constituent of diesel engine exhaust emissions, alongside, CO, CO_2, NO_x, aldehydes, PAHs
  - 2 main components, organic carbon (OC) and elemental carbon (EC)
  - Nanoscale particles which agglomerate into clumps and chains
- **Why monitor DEP?**
  - IARC classify it as a definite human carcinogen
  - More specific and correlated with diesel engine exhaust emissions than the other main constituents.

Elemental Carbon

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- EC is favoured as a marker for DEP
  - Thought to be highly specific to diesel exhaust
  - Other carbon sources can be removed by size selection at the inlet
  - Some evidence that the nanoscale physical nature of the particles are a cause of observed health effects

Established methods

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- The standard method is codified in EN14530:2004 and NIOSH method 5040.
- The methods are not equivalent but incorporate the same key stages.
  - Sample on to quartz fibre filters with cyclonic samplers,
  - Heat the filter to temperature 1, measure the evolved CO_2 = OC.
  - Increase the temperature, measure the evolved CO_2 = EC

Established methods

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- Being a carbonaceous soot DEP is black, therefore the degree of staining can be used to quantify exposure.
- Historically, for on-site monitoring the “blackness” of sample filters has been measured using the Bosch meter.
- Blackness can be converted to EC.

Previous work at HSL

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- Alternatives to the Bosch meter
- 3 techniques analogous to measuring "blackness"
  - Difference gloss meter (DR-Lange)
  - Scanner/photo software
  - OT21 transmissometer (Magee Scientific)
- Filters collected form
  - Mobile crane exhaust
  - Ambient air in a mine
- All 3 methods could replace the Bosch meter. In principle any optical technique could be used.

Previous work at HSL

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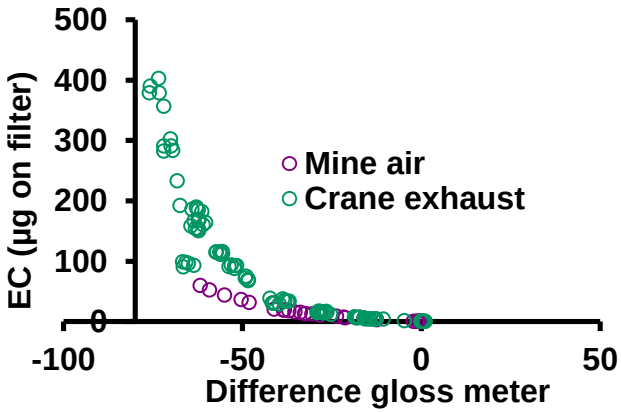
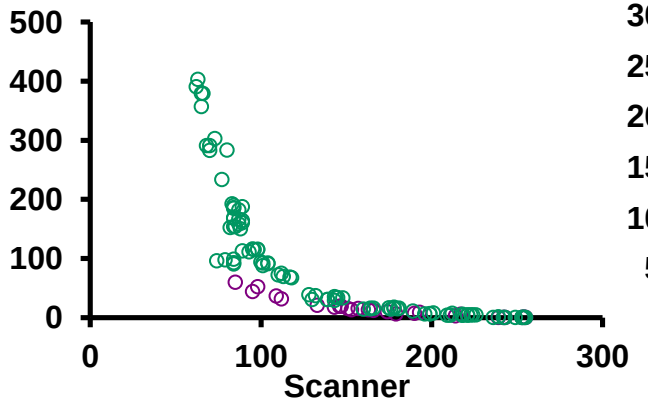
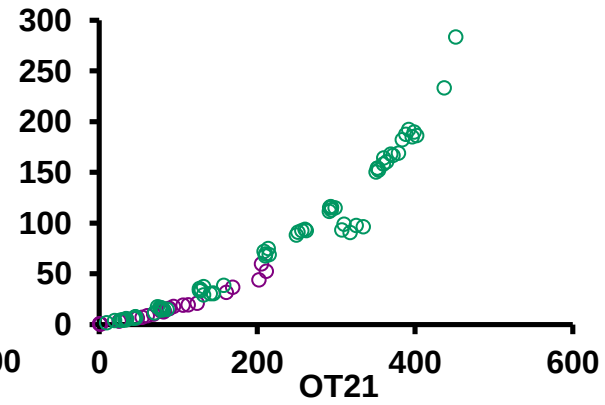
- Charts were prepared showing the correlations between each instrument and EC.
- Functions were derived to convert the instrument results to EC.
  - Difference gloss meter $EC = 10^{(-0.0244x + 0.3196)}$
  - Scanner (greyscale) $EC = 10^{(-0.0065x + 1.9672)}$
  - OT21 transmissometer $EC = 10^{(0.2x - 0.0795)}$







Modernising & Improving

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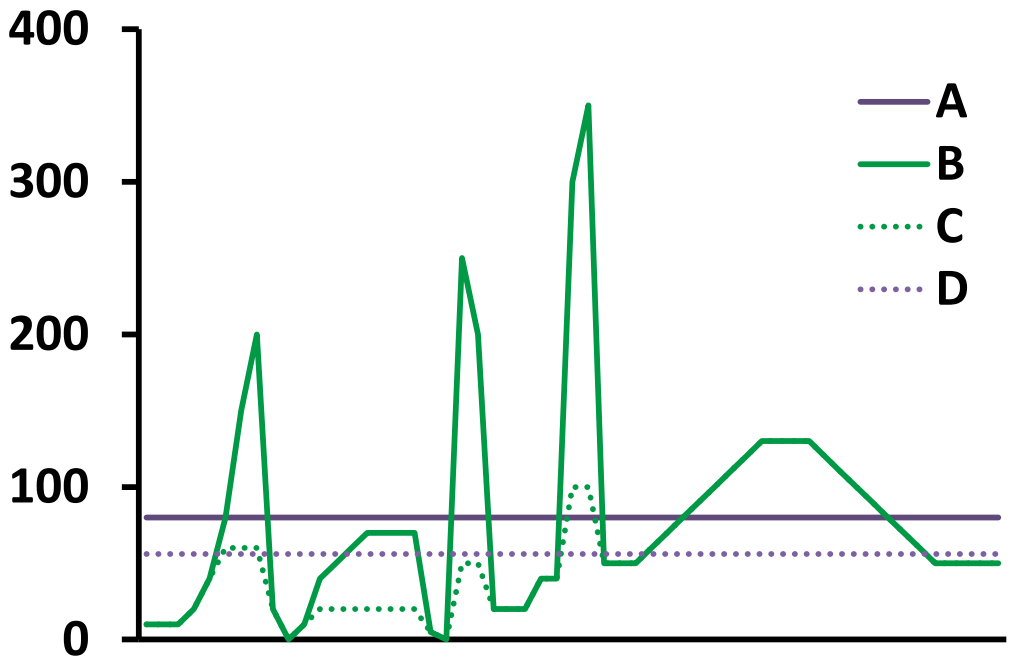
- Results post shift is good but wouldn't results during a shift be better?
  - Highlight specific exposure sources
  - Facilitate and encourage immediate interventions
  - Empower workforce



Real-time monitoring

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- Incorporate pump, sampler and measurement in one device. Several options.
  - General particle counters
    - Readily available
    - Non-specific, result is number of particles not mass of EC
  - FLIR Systems Airtec
    - Developed to replicate NIOSH 5040
    - Light absorption measurement technique
    - Result given is EC based on a calibration study
  - AethLabs AE51 microaeth
    - Developed for ambient air measurement
    - Miniaturised version of OT21 measurement technique
    - Result is Black carbon

Real-time monitoring

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- HSL has been studying the performance of the µAeth and Airtec in parallel sampling tests with filters analysed by EN14530.
- A controlled atmosphere of diesel exhaust has been prepared and measured in the laboratory.
- In addition the instruments have been tested in field trials in a variety of workplaces.
  - RO-RO ferries
  - Vehicle test station
  - Underground non-metal mines

Conclusions

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Airtec

- Advantages
  - Can sample for a full shift at high concentrations
  - On board display
- Limitations
  - Slow response time – not truly real time
  - High limit of detection, especially for short term sampling

AE51 microAeth

- Advantages
  - Low detection limits
  - Quick response
- Limitations
  - Short monitoring period at high concentrations
  - Does BC = EC?
  - Separate device required to view results in real-time

Acknowledgements/Further reading

- This work was funded by the Health and Safety Executive. Its contents, including any opinions/conclusions expressed, are those of the author alone and do not necessarily reflect HSE policy.

- HSE RR994, available from the HSE website
- Simply Scan published in the Annals of Occupational Hygiene, 2014, vol 58, 889-898
- AethLabs AE51 µAeth - www.aethlabs.com/microaeth
- FLIR Airtec - www.flir.com/airtec/