Potential systematic biases in the treatment of LCP

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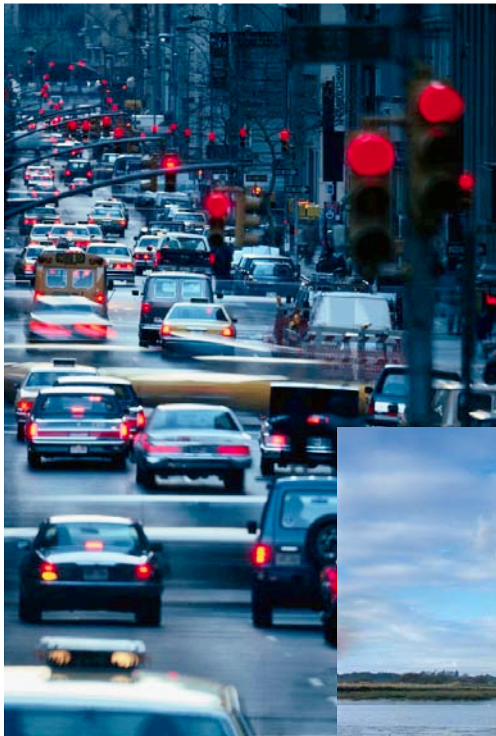
LCP have different source and location characteristics compared with other source types



Outline

> Key differences between high-level and low-level sources

> Results from CASES and NEEDS (EcoSense)

  – Implications for sectoral contribution to exposure

> Relative toxicity of particulate components; implications for quantification of effects of LCP emissions

> A simple model for building differential toxicity into GAINS

> Recommendations

Use of EcoSenseWeb to assess effects differences between high and low-level emissions

RWE
The energy to lead

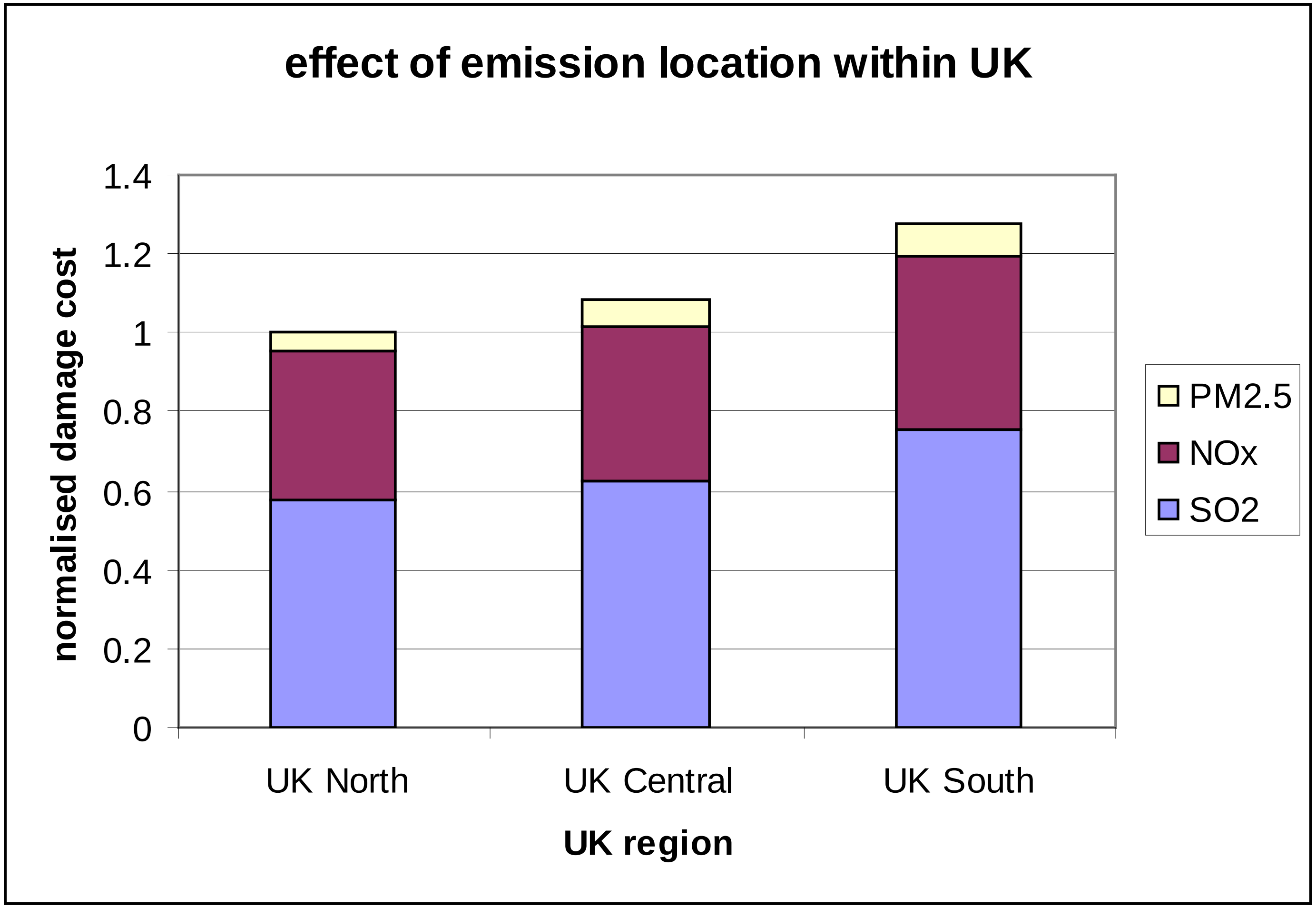
EcoSenseWeb

- On-line tool encapsulating the outputs from EU funded CASES and NEEDS Projects , written by IER – Stuttgart University
- Allows calculation of external costs of emissions
  - human health, crops, building materials and ecosystems impacts via 'impact pathway' approach
  - SO_2, NO_x, primary particulates, NMVOC, NH_3, dioxins, heavy metals. Also can include damage assessment due to emission of radio nuclides and greenhouse gases
- based on pre-calculated EMEP perturbative Source-Receptor matrices
  - 76 pre-defined 'sub-regions' as sources
  - the EMEP 50km x 50km European grid as receptor
- Separate S-R relationships for high-level (SNAP 1) and low-level sources

EcoSenseWeb application – low versus high emissions

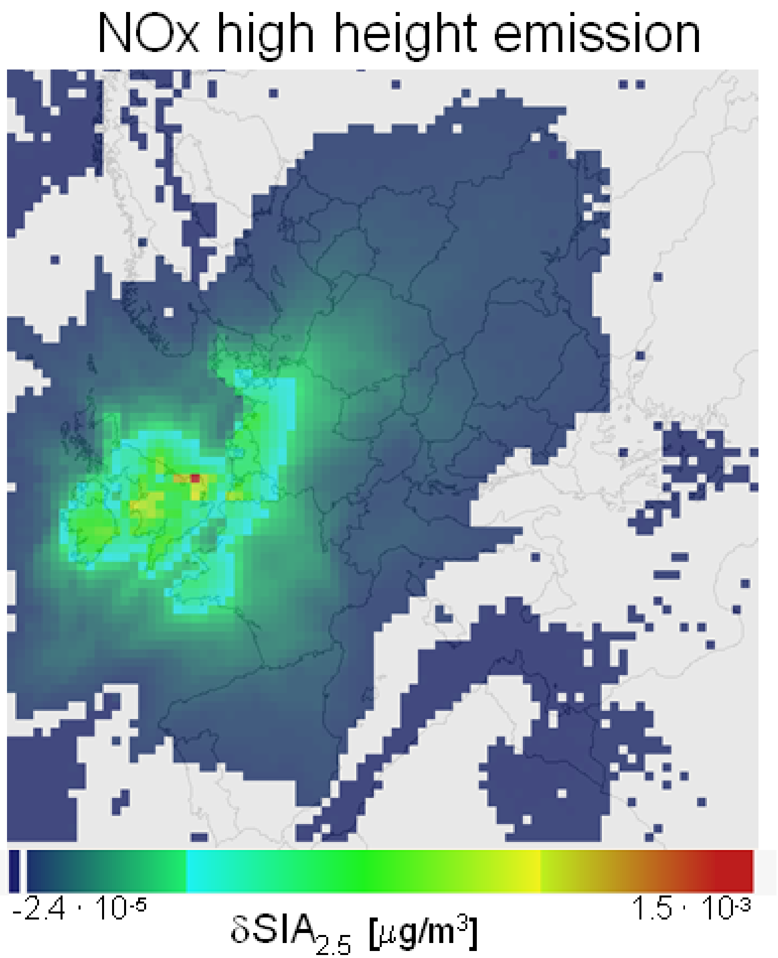
- EcoSenseWeb has been used to examine the external damage costs of unit emissions of SO_2 and NOx from a particular region in the south of the UK
- Case study 1: locational sensitivity
  - Additional emissions from north of UK
  - Additional emissions from south of UK
- Case study 2: source height sensitivity
  - additional emissions from high level sources
  - Additional emissions from low-level sources
- Case study 3: differential toxicity sensitivity
  - Influence of relative toxicity of different particulate components
    - 0.5 nitrates, 0.7 sulphates, 1.3 primary PM

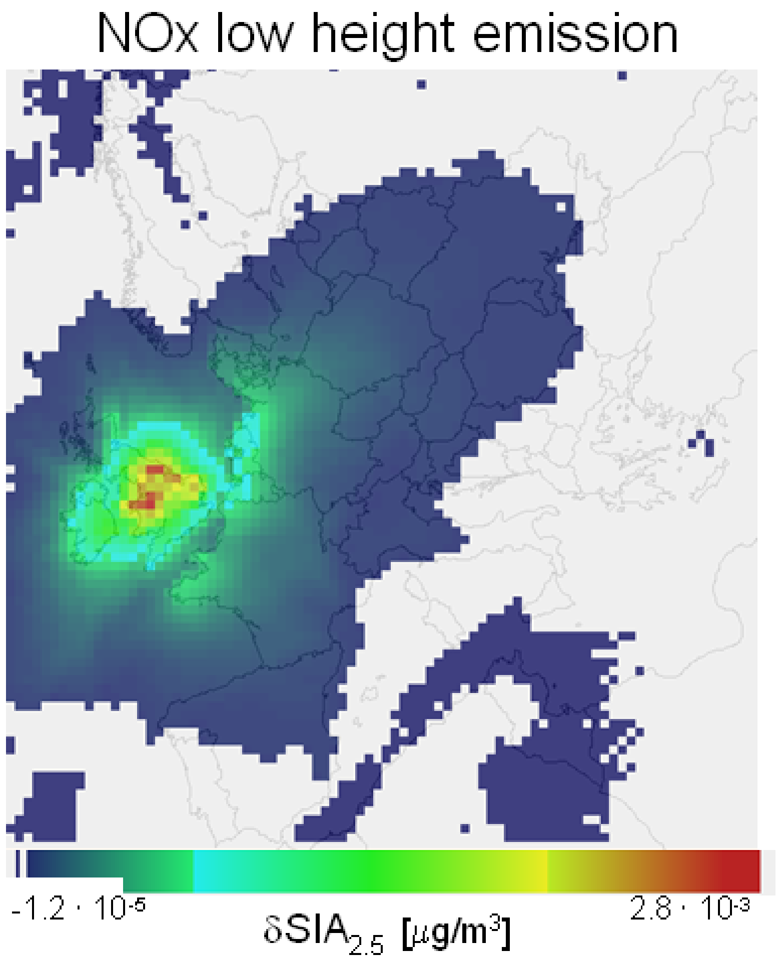
Case study 1: Influence of source region



The ratio of SO2:NOx:PM emissions are those of a 'typical' coal-fired power station

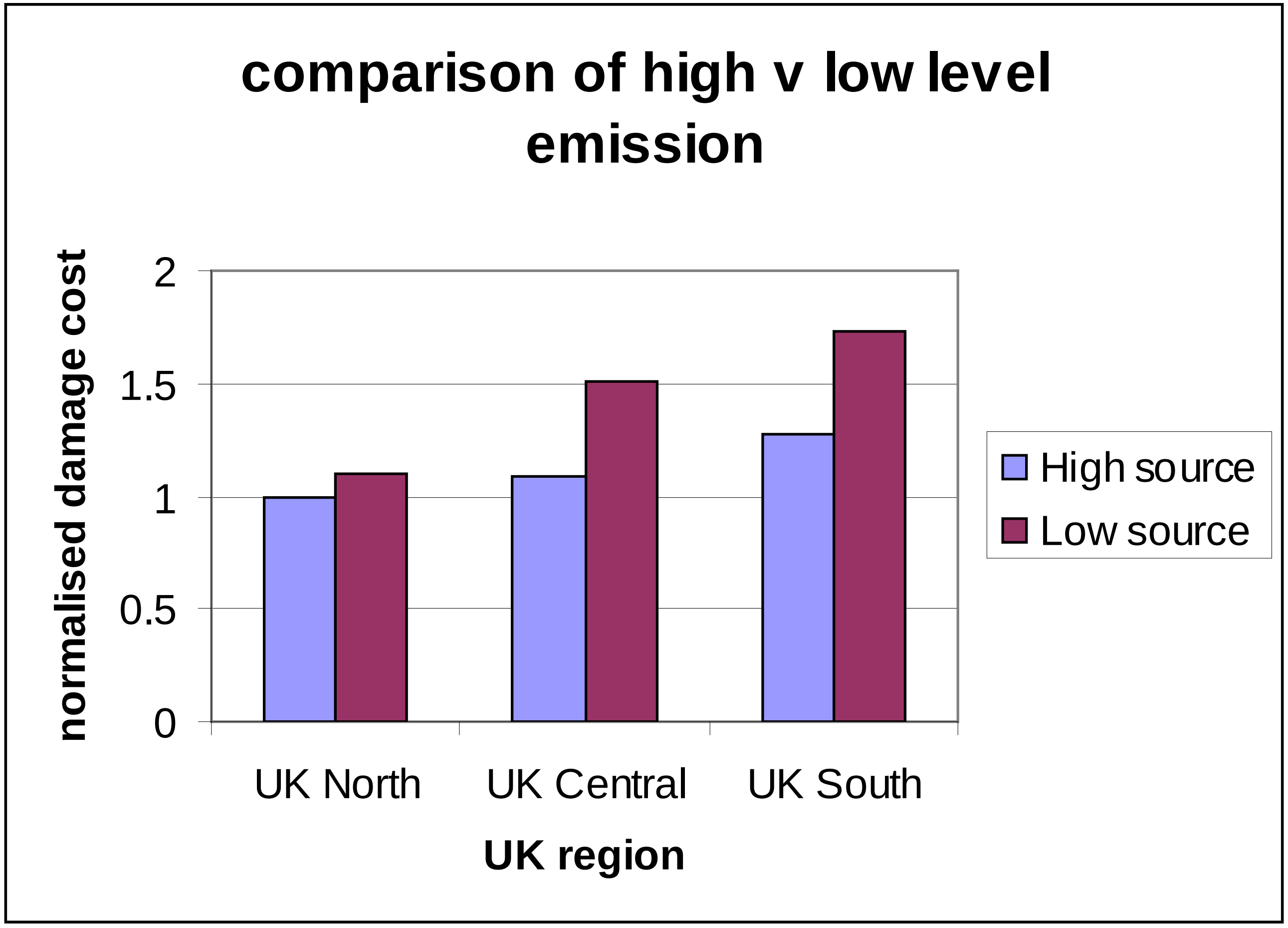
Case study 2: effect of emission height





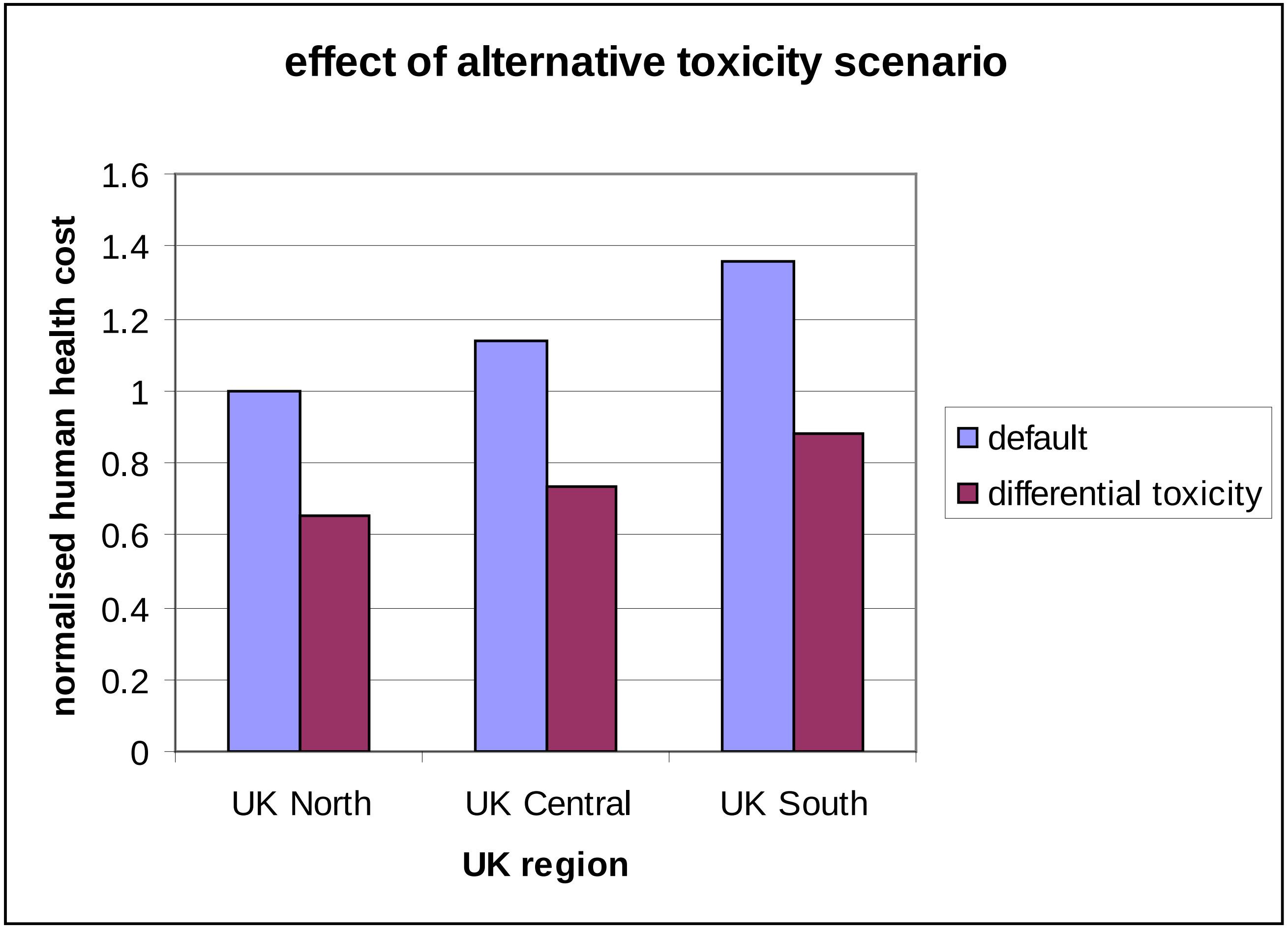
(Note different scale in 2 plots)

Influence of emission height on damage cost



Same annual mass emission in all cases

Influence of changed particulate toxicity assumptions



EcoSenseWeb model results

- Average externalities for a power station located in the ‘UK – Northern region’ are found to be significantly lower than those associated to the same facility when located in the ‘UK – Southern region’ (a factor of ~30% for SO2, ~15% for NOx and about a factor two for primary particulate, the last mainly reflecting the lower population density ‘along the dispersed plume’);

- The EcoSenseWeb results, based on the EMEP Source-Receptor matrices, tend to show that the impacts from ‘low level’ emissions are significantly higher (20-40%) then those that would originate if the same amount of pollutants were emitted from a ‘high stack’, even in the case of SO2 and NOx (whose impact is mainly related to ‘long-range’ secondary particulate).

Potential improvements for integrated assessment models

- EcoSenseWeb study showed significant differences depending on where within a country the emission is made

  → Use of country-to-grid relationships could lead to errors in assessment of LCP environmental effects

- Study showed that use of different source-receptor relationships for LCP and other sectors results in significant differences in effects

  → Use of separate S-R relationships for LCP and other sources needed to ensure correct targeting of emission reductions

- Study showed that use of reasonable alternative health hypotheses for particulate toxicity results in significant differences in benefits

  → Need for sensitivity studies to alternative reasonable health hypotheses to ensure costs are targeted where they will have greatest benefits

Consistent with TFMM EuroDelta results

> EcoSenseWeb results show a similar picture to those from EuroDelta presented at last TFIAM, which highlighted the greater ‘efficiency’ of emission reduction from low level sources for effects reduction

> Policy implications are the same: if the relative environmental effectiveness of emission reductions from LCP and other sources is not correctly represented in the integrated assessment modelling, then emission ceilings may not reflect the most cost-effective way to attain environmental targets

Fine PM health impact

How might GAINS calculations be improved?

Committee on the Medical Effects of Air Pollution (COMEAP) recently-published report ‘Long-term exposure to air pollution: effect on mortality’

> ‘in the absence of clear evidence to the contrary we consider that the recommended coefficient should apply equally to all components of PM2.5’

> ‘this is not to say that all components of PM2.5 do have the same toxicity – but, rather, that there is not, at present, evidence to quantify different components differently, in a way that would gain wide consensus’

> ‘this is clearly an area that requires further study’

> Recommendation is consistent with the WHO/Convention task force recommendation

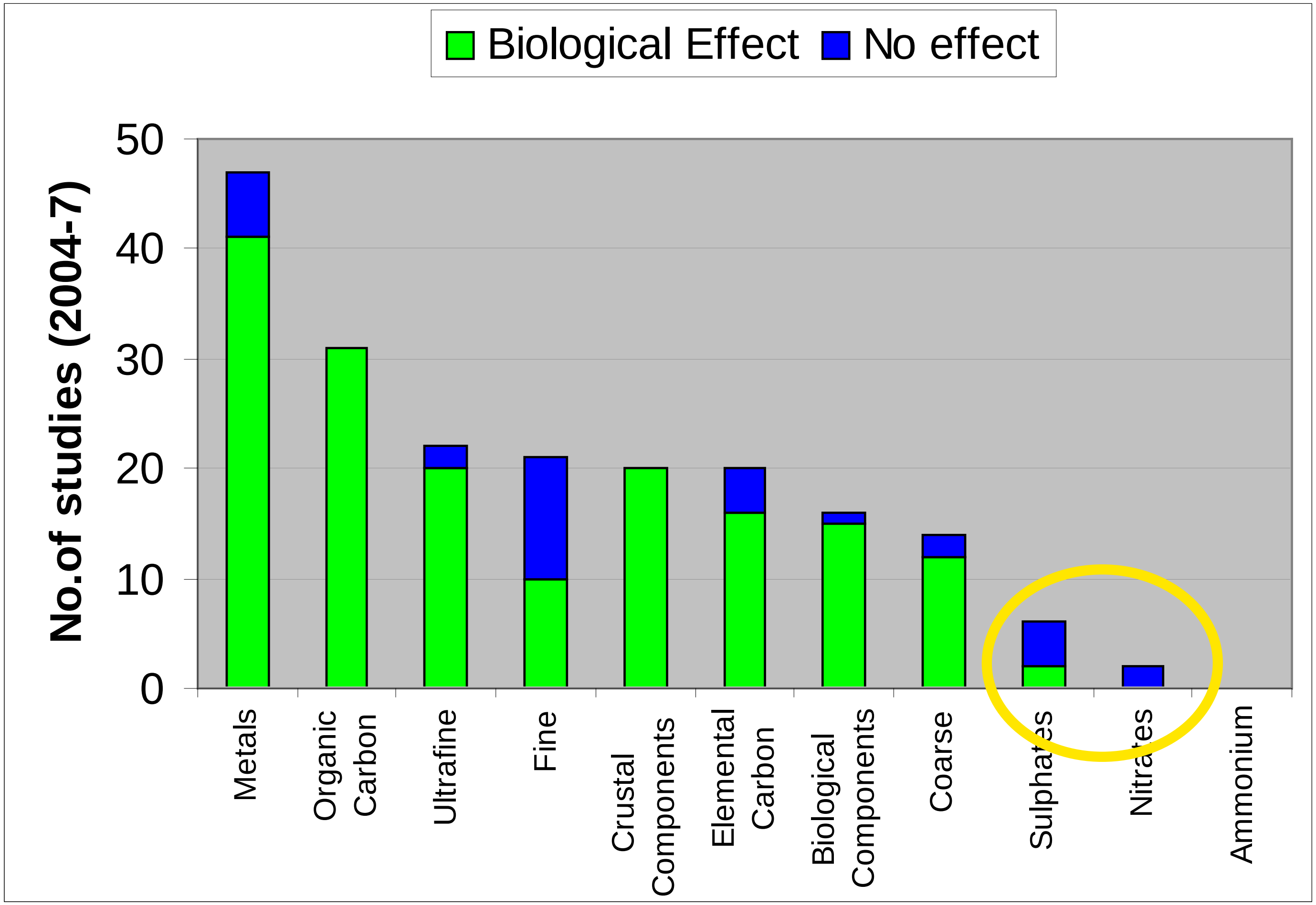
Arguments for testing the status quo

- **Prof P Hopke, COMEAP peer review comments** : '*This report continues lines of very conventional thinking with regard to the mechanisms of causality by particles. How can one really think that ammonium sulphate or ammonium nitrate will start a catastrophic chain of events leading to death?'*

- **WHO Bonn workshop, Fintan Hurley***: 'While accepting that it is currently not possible to quality precisely any differences in PM toxicity, some differential quantification is recommended, at least as sensitivity analyses… It may be unwise to wait until the evidence for differential quantification is compelling.'*

- **NEEDS comprehensive review**: *'we think that it is progressive to attempt differential quantification, including of different kinds of particles, even when the evidence to support differential quantification is limited, rather than simply use as default an assumption which is widely believed to be wrong, i.e. that, within a given size range, all particles have similar toxicity'*

Which component of particulate is toxic?



Data from Kelly F & Fussell J C, (2007).
Particulate toxicity ranking report. Kings College London, No 02/07, July 2007.

Ability to cause oxidative stress

Component	Ability to cause oxidative stress and inflammation	Important sub-components
Diesel Soot	++++	Surfaces, organics, metal
Petrol Soot	+++?	Surfaces, organics, metal
Tyre dust	+?	?
Brake dust	+?	?
Natural gas particles	++?	? Organics
Point sources e.g. steel mills	+ to +++	Metals
Mineral dusts, sand, soil dust	+ to +++	Quartz
Plant debris (harvesting)	- to +++	lipopolysaccharide
Sea/road salt		
Sulphuric acid and sulphates	-	
Ammonium nitrate	-	

Donaldson K, (2006). Which particle characteristics are important in view of health effects? Presentation to COST 633 Conference, April 3 to 5, 2006, Vienna

Health impact of fine PM - toxicology

- Toxicological studies clearly show the adverse effects of carbonaceous PM, especially diesel exhaust particles (ultrafine particles):
  - genotoxicity, mutagenicity, carcinogenicity (*i.e.* PAHs, nitro-PAHs)
  - cardiovascular and respiratory diseases (oxidative stress with ROS)
- Toxicological studies do not clearly demonstrate detrimental effects of inorganic particulate matter (particularly when compared with proven effects of carbonaceous PM)
- Uncertainty on the toxicity of the black carbon alone, but black carbon UF particles responsible for adsorption of semi-volatile organic compounds (PAHs, nitro-PAHs)

GAINS/EMEP limitations in health impact calculations

> Secondary organic aerosols not taken into account

> Exposure assessment in urban areas

- the correction factor (City-Delta) is applied to the overall cell-averaged mass concentration whereas effects probably due to increased carbonaceous contribution
- the increasing mass concentration ratio [carbonaceous PM/inorganic PM] is not taken into account in health impact calculations via a higher RR value
- the RR value does not increase in the case of high fine PM mass concentration likely to be associated with a high number concentration of ultrafine particles
- Grid size: epidemiological studies typically find relevant lengthscales for elevated effects around major roads of order 50-100m, i.e. finer resolution than GAINS/EMEP

How might the GAINS relative risk treatment be improved?

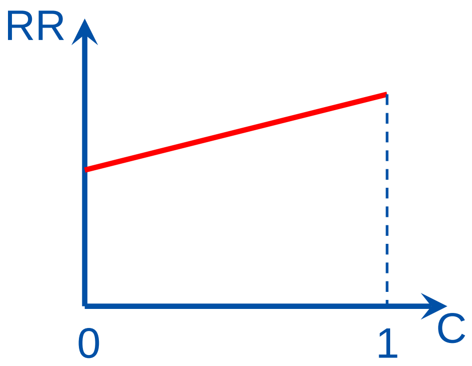
> The present uniform value of RR (1.06) is likely too high for secondary inorganic aerosol (sulphate, nitrate) and too low for carbonaceous compounds

> Simple model, easy to implement: RR value depending on the ratio

C=[carbonaceous PM] / [carbonaceous PM + inorganic PM]

> *<u>Example of 2 possible limit cases</u>:*

- *RR = 1.02 if C=0* — *No carbonaceous compounds*
- *RR = 1.20 if C=1* — *No inorganic compounds*



> In practice these limit values should be given and periodically updated by « generalist experts », e.g. from UNECE-WHO Task Force on Health (expert judgment)

Recommendations

> Policy should be based on best science

> Large combustion plants and low-level sources have different dispersion and population exposure characteristics, and these differences should be accounted for in integrated assessment approaches

  – Integrated assessment models should incorporate different source-receptor relationships for LCP and other sources

> Differential toxicity sensitivity studies for PM should be undertaken to inform emission reduction policy development

> If this is not done there is a significant risk that emission reduction policies, and the costs of emission abatement, will be targeted incorrectly and with less effectiveness

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