Modelling personal exposure to $PM_{2.5}$ in the context of integrated assessment modelling

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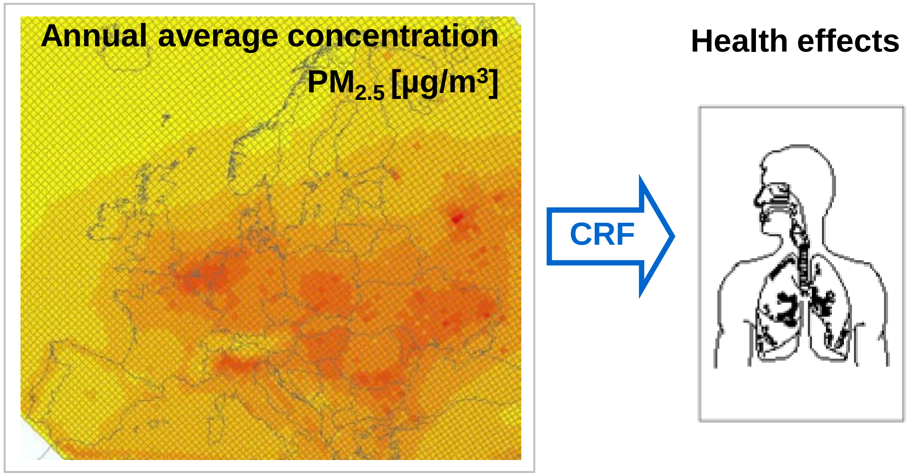
Outline

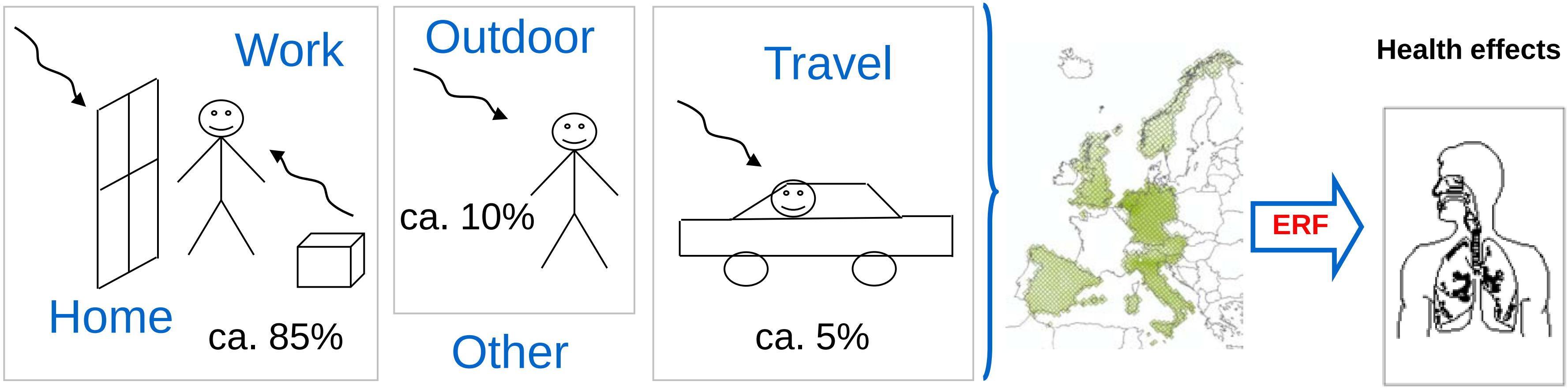
- Introduction
- Methodology
- Results
- Conclusion

Introduction

- Until now: Estimation of health effects by use of concentration response functions based on annual average concentrations



- New: Estimation of the Exposure taking into account the infiltration and the time spent in micro-environments; population subgroups



Methodology

- Concentration in different micro-environments by use of different models
- Weighed by time spent in the different micro-environments
- Urban increment for grid cells (EMEP 50x50 km^2) with cities >50,000 inhabitants
- Overall model: LAMA (TooL for Air pollution exposure Modelling and Assessment)

Parameters: country level; concentration: grid based

Concentration indoors I

- Indoor sources (homes)
  i. Background sources like small pieces of skin, dust, vacuum cleaning, cooking, candles etc.
     e.g. 1,500 µg/h (1,400 µg/h s.d.) for DE (based on Basel)
  ii. Wood burning from fireplaces or similar in areas designed for living (not basements)
     2,690 µg/h, e.g. 5% of population is using fireplaces in DE
  iii. Environmental tobacco smoke (ETS)
     13,800 µg/h (1,800 µg/h s.d.)
     e.g. 39% smoking for DE are exposed to ETS (weighted subgroup mean)

Fraction of population exposed to biomass: model TIMES; ETS source: Özkaynak et al. (1996); Background sources: Hänninen et al. (2004); Biomass source strength: McDonald et al. (2000) + Sternhufvud et al. (2004); Fraction of population exposed to ETS: CPSR (1995)

Concentration indoors II

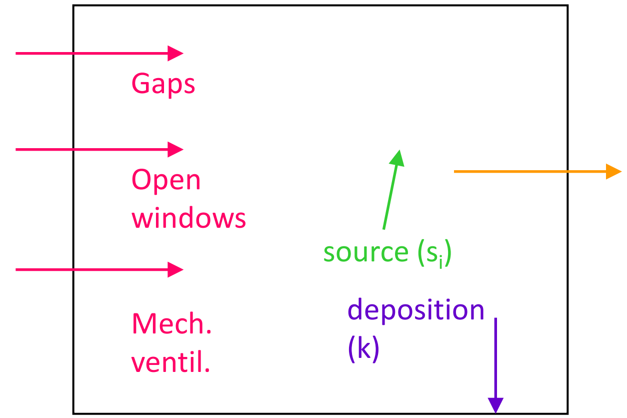
Outdoor air sources

Indoor sources

$$c_{in,ss} = \frac{p \cdot a \cdot c_{out,ss} + \frac{s_{in}}{V_{in}}}{k + a}$$

Loss indoors

Loss to outdoors



$c_{in,ss}$= indoor concentration, steady state [µg m^{-3}]

p = penetration coefficient [-]

a = air exchange rate [h^{-1}]

V_{in} = volume indoors [m^3]

k = deposition loss rate [h^{-1}]

Example of indoor concentration (DE):

$p = 1$ $a = 0.83\ h^{-1}$ $V = 310\ m^3$

$k = 0.39\ h^{-1}$ $c_{out} = 10\ \mu g/m^3$

→ $c_{in} \approx 25\ \mu g/m^3$

Model: Based e.g. on: Koutrakis et al. (1992); V and fraction of population exposed to biomass: model TIMES; p, k and ETS source: Özkaynak et al. (1996); a and background sources: Hänninen et al. (2004); biomass source strength: McDonald et al. (2000) + Sternhufvud et al. (2004); fraction of population exposed to ETS: CPSR (1995)

Concentration travel

- Concentration when travelling: no distinction is made yet between modes of travelling as the time-use data does not allow for this
- Traffic enrichment factor: 2.48 (2.13 s.d.)*

Example of concentration during travel:

$$c_{out} = 10\ \mu g/m^3 \rightarrow c_{travel} \approx 25\ \mu g/m^3$$

* Average of different studies

Urban increment

An adaptation of the model developed by Torras Ortiz et al. (2011) is used:

$$C_{i\ urban} = \varpi_i + \phi_i \frac{E_{iUE}}{A_{UE} \cdot u_{avg}} + \gamma\ C_{i\ rural}$$

where

C_i urban = Urban increment of pollutant i.

E_{iUE} = Total emission of pollutant i within the urban entity in tons.

A_{UE} = Urban entity area in km^2.

u_{avg} = Urban entity average wind speed in m/s.

$C_{i\ rural}$ = Rural background concentration of pollutant i in $\mu g/m^3$

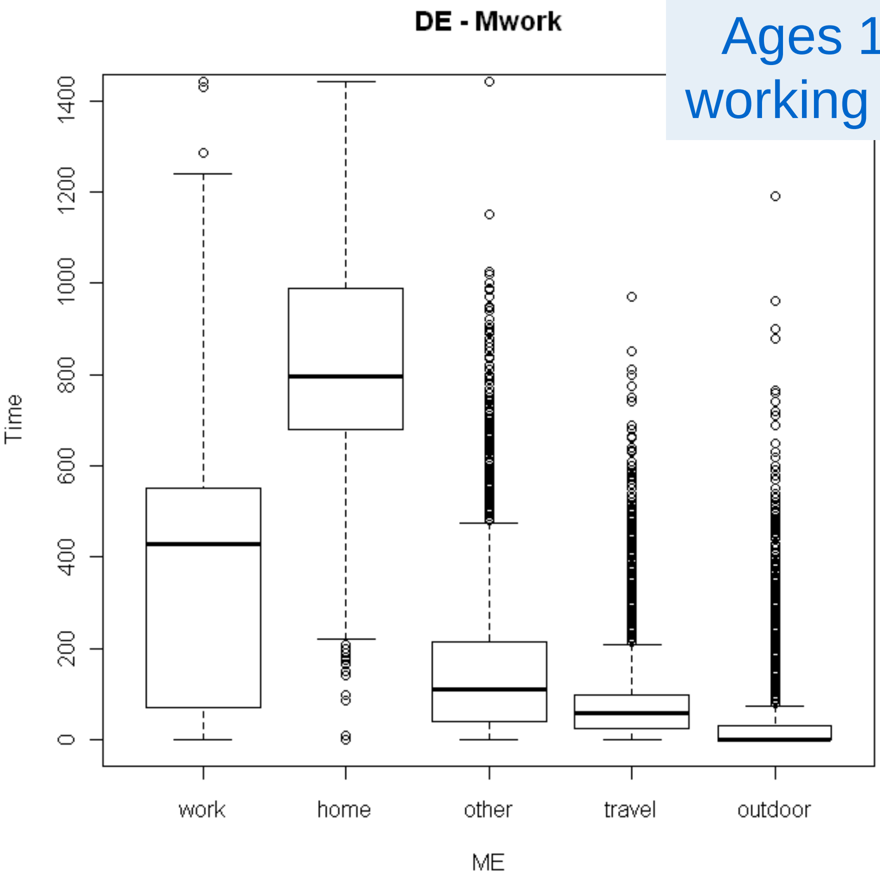
ω_i, φ_i, and γ_i = Multiple-regression parameters for pollutant i.

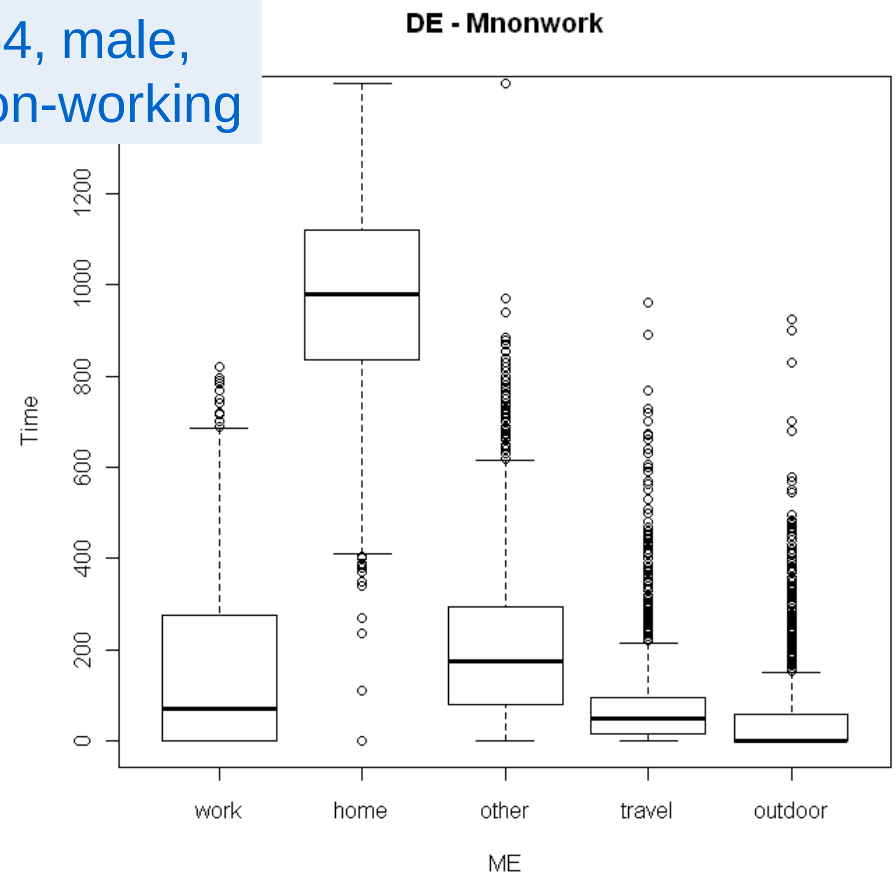
Due to the lack of detailed urban emissions data, a straightforward application of the model described above was not feasible for estimating the PM urban increment for cities outside Germany. Alternatively, a hierarchical clustering analysis was carried out to transfer the urban increment values to other European cities.

Torras Ortiz, S. et al. (2011). "A modelling approach for estimating background pollutant concentrations in urban areas" paper submitted for publication.

Time use data MTUS (example Germany)

Ages 15-64, male, working / non-working





Multinational Time Use Study, Versions World 5.5.3, 5.80 and 6.0 (released October 2010). Created by Jonathan Gershuny and Kimberly Fisher, with Evrim Altintas, Alyssa Borkosky, Anita Bortnik, Donna Dosman, Cara Fedick, Tyler Frederick, Anne H. Gauthier, Sally Jones, Jiweon Jun, Aaron Lai, Qianhan Lin, Tingting Lu, Fiona Lui, Leslie MacRae, Berenice Monna, José Ignacio Giménez Nadal, Monica Pauls, Cori Pawlak, Andrew Shipley, Cecilia Tinonin, Nuno Torres, Charlemaigne Victorino, and Oiching Yeung. Centre for Time Use Research, University of Oxford, United Kingdom.

Equation for „personal“ exposure

Sum: micro-environments

Filtration

Time fraction

Outdoor concentration

Indoor sources

Urban increment

Time fraction

Sum: diaries

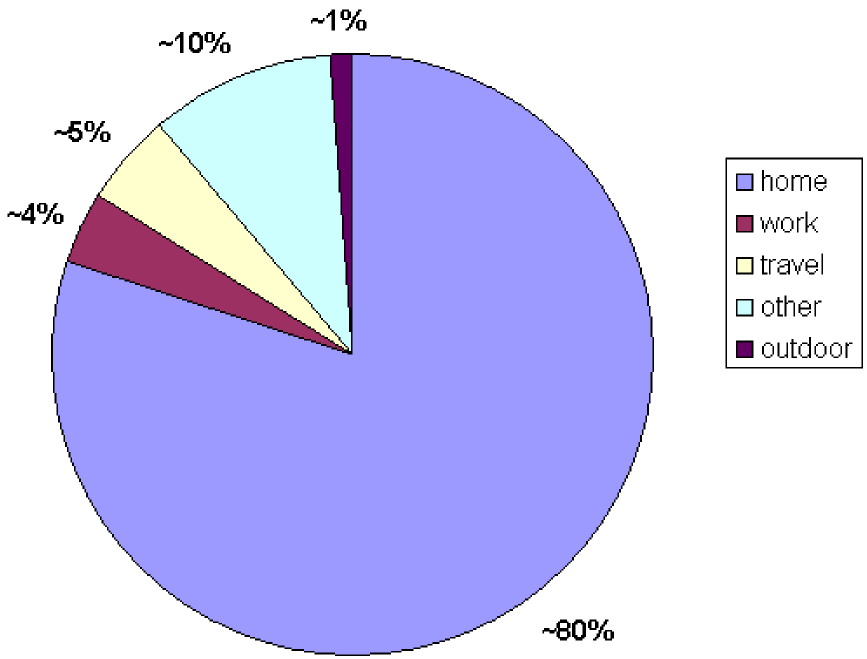
$$E_{i,g} = \frac{\sum_{d=1}^{q_g} \sum_{j=1}^{m} \left(f_j t_{d,j} \left(c_{out,i} + c_{urb,i} \right) + c_{in|s,j} t_{d,j} \right)}{q_g}$$

diaries of a subgroup

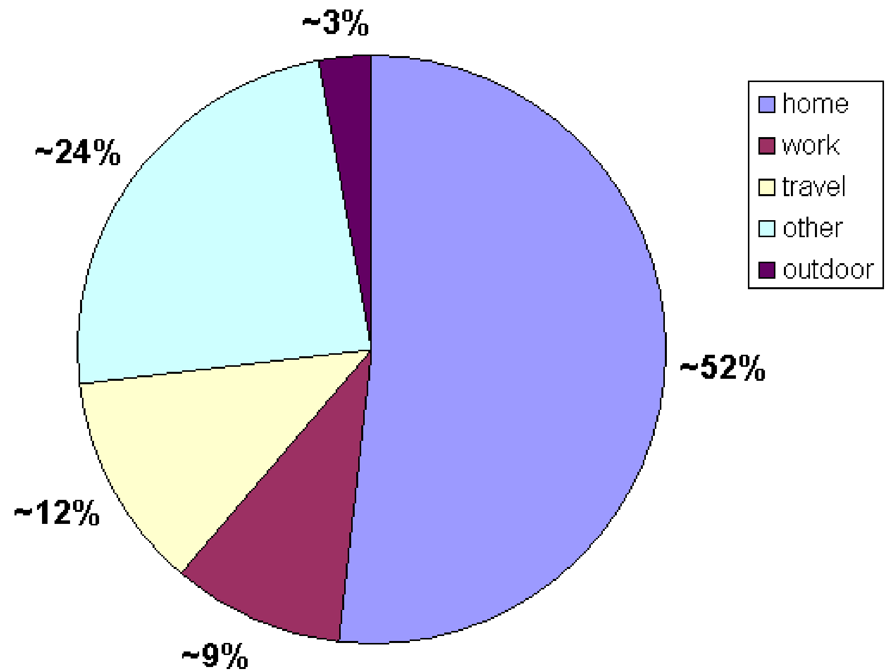
$E_{i,g}$ = exposure of a subgroup g in grid cell i [µg m^{-3}]	F0-14
d = individual diary of subgroup g g = subgroup	M0-14
q = # of diaries per subgroup g	F15-64_work
f_j = infiltration or traffic enrichment factor	M15-64_work
j = microenvironment m = # microenvironments	F15-64_non-work
t = time fraction spent in a microenvironment j	M15-64_non-work
i = grid cell	F65+
c_{urb} = urban increment for cities in grid cell i [µg m^{-3}]	M65+

Exposure in micro-environments

Percentage of personal exposure to PM2.5 experienced in micro-environments (DE)



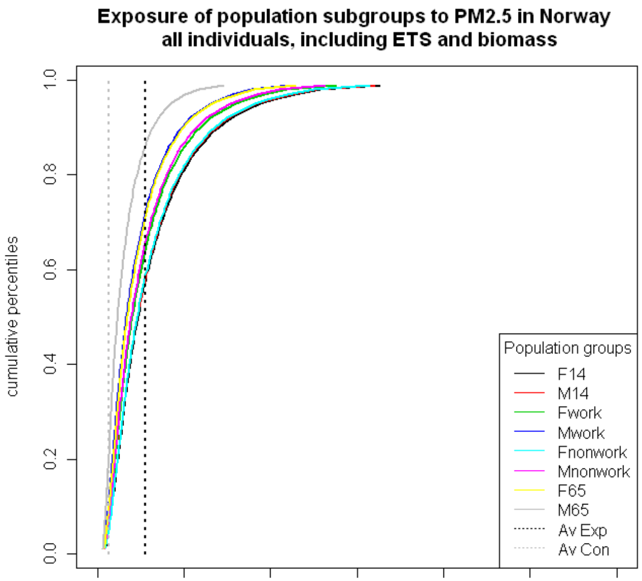
Percentage of personal exposure to PM2.5 experienced in micro-environments (DE)

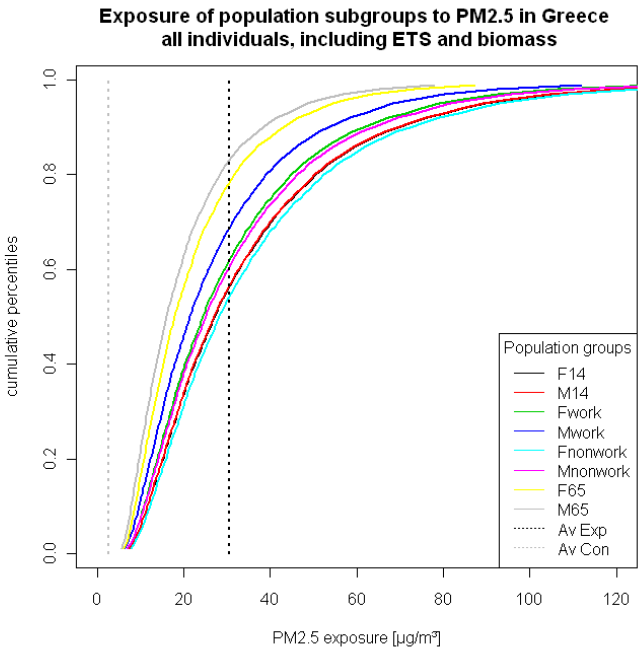


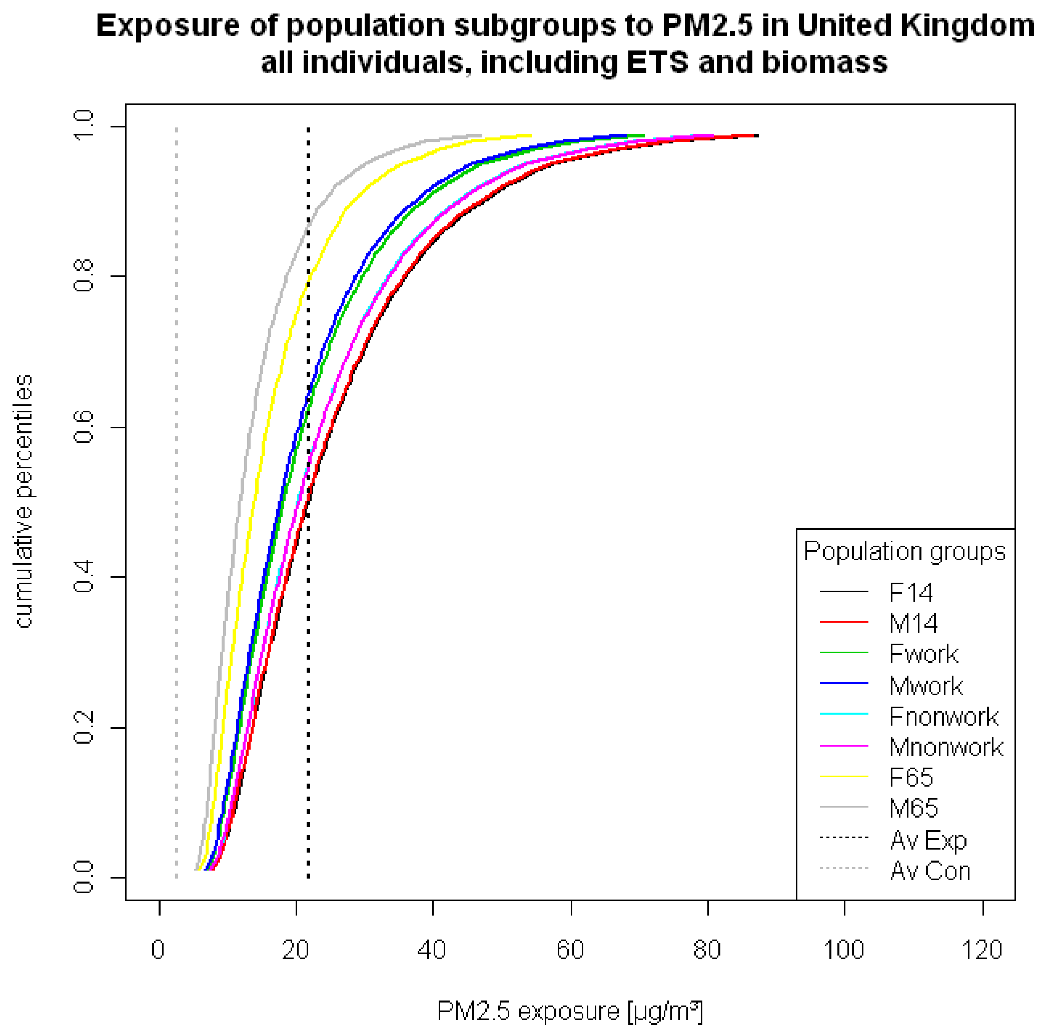
Without indoor sources

Exposure of subgroups

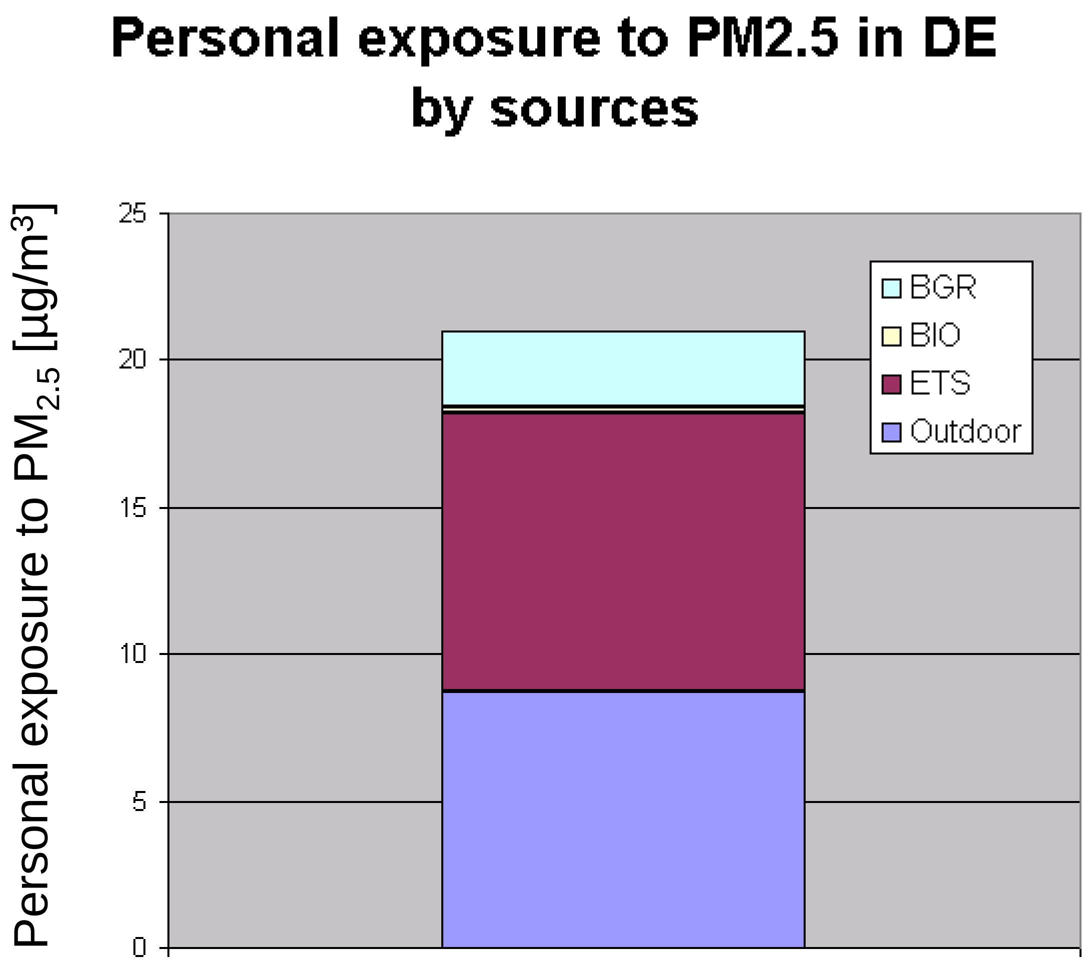
Preliminary results!!!







Exposure of different sources



Exposure response functions

- Concentration response functions (CRFs) for $PM_{2.5}$ based on outdoor air background concentration, do not capture the health effects from indoor sources
- CRFs can be scaled to exposure response functions (ERFs) based on the relationship between background concentrations and personal exposure to $PM_{2.5}$ experienced indoors from outdoor sources (dividing by 0.7)
- Assume that these ERFs can be applied to estimate the health effects of $PM_{2.5}$ from indoor and outdoor sources

Measure „Insulation“

- Decreasing penetration, air exchange rate and deposition loss rate in homes; *Example DE*

Scenario	**Mean exposure** [µg/m^3]	**Δ DALYs**	**Δ Costs** [Mio. EUR_{2010}]
BAU (w/o BGR)	~18.7		
Insulation (w/o BGR)	~19.9	+85,600 (→ in addition)	+8,838 (→ in addition)
BAU (only outdoor)	~8.9		
Insulation (only outdoor)	~8.8	-7,130 (→ avoided)	-736 (→ avoided)

Measure „Reduce ETS“

- Reduce smoking by 50%; *Example DE*

Scenario	**Mean exposure** [µg/m^3]	**Δ DALYs**	**Δ Costs** [Mio. EUR_{2010}]
BAU (w/o BGR)	~18.7		
Reduce ETS (w/o BGR)	~13.5	-371,000 (→ avoided)	-38,300 (→ avoided)

Conclusions

- Exposure modelling provides a means of better assessing mitigation measures with direct effects on exposure (e.g. changes in barriers between outdoor and indoor micro-environments)
- Indoor sources constitute a large part of the total exposure, especially ETS
- Largest part of the exposure experienced at home
- Distinguishing between subgroups of similar behaviour gives bigger differences than age, gender and working status

Scenario development

- Developed scenarios on EU level for the projects HEIMTSA / INTARESE
    i. Distinguish between old, new and renovated houses with different assumptions for air exchange rate and penetration
    ii. Include also changes in dwelling volume and use of biomass for space heating (TIMES model, Markus Blesl, Stuttgart)

Plans + open questions

- Enhance ETS modelling:
  1. Collect newer data (after smoking ban)
  2. Lives with smoker yes/no → active smokers/non-smokers
- Enhance biomass burning:
  1. Better distinction between appliances (fireplaces, pellets etc.) and if used for leisure or main heating purpose
  2. More information needed on emission factors to indoors and percentage of biomass usage for which purpose
- Work: indoor sources? Include non-office work
- Include different modes of traffic
- Enhance assumptions underlying the ERFs

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Thank you very much for your attention!

Acknowledgements:

INTARESE: Integrated assessment of health risks of environmental stressors in Europe (FP6- 018385)

HEIMTSA: Health and environment integrated methodology and toolbox for scenario assessment (FP6-036913)

Urban increment

- Urban population: 75% of the European population and by 2020 it will be for some countries even 90%[1]..

- For several pollutants, higher concentrations levels are commonly found within urban areas.

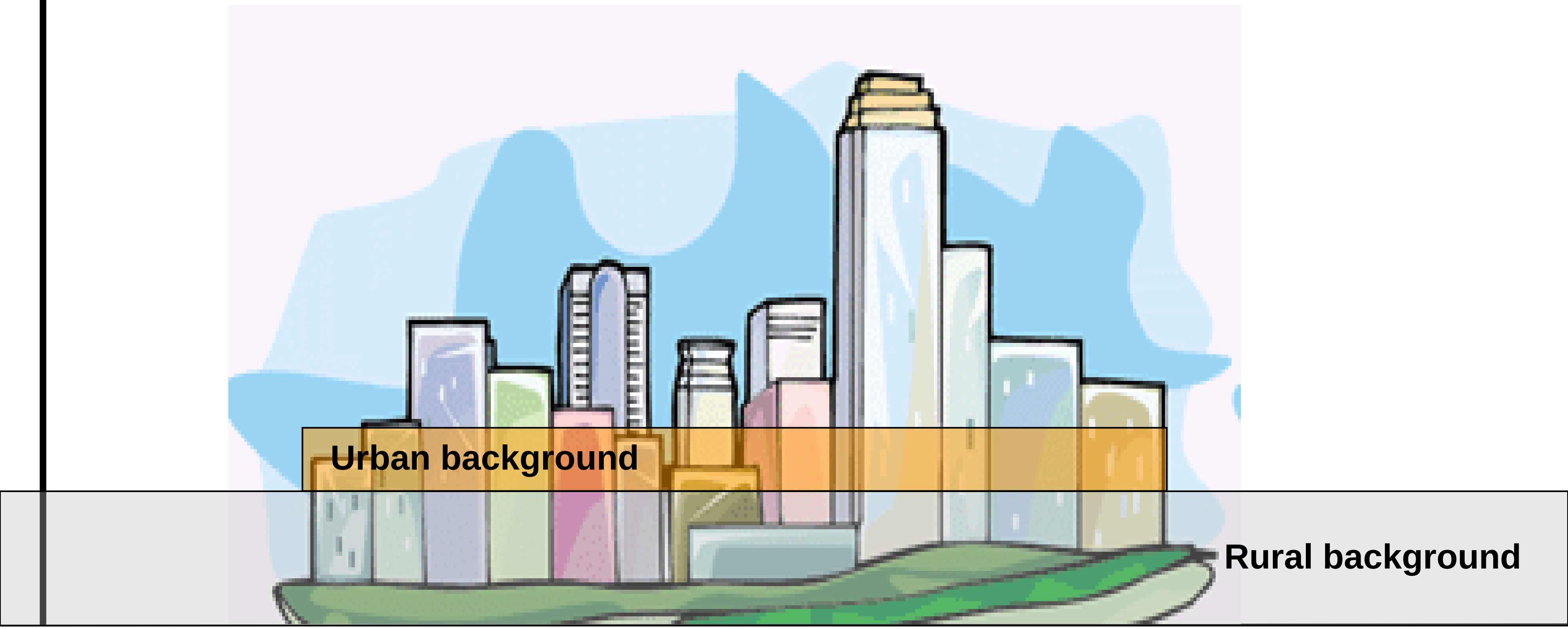
- The number of people affected by elevated pollutant concentrations is notably higher in urban areas than in rural environments.

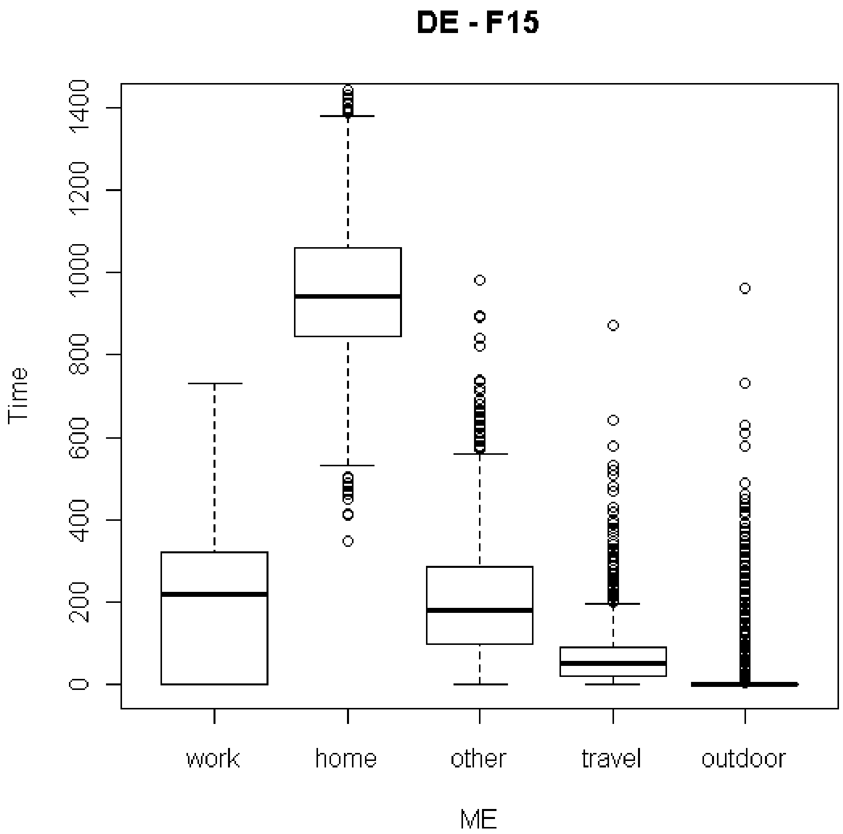
- Due to its relevance, the urban increment (i.e., the difference between regional and urban background pollutant concentrations) should be included in the analysis.

[1] Urban Sprawl in Europe. European Environment Agency, Report 2006-4

Pollutant Concentration in μg/m³

The typically higher pollutant levels in urban areas for most pollutants can be referred as urban increment, i.e., the difference between regional and urban background pollutant concentrations

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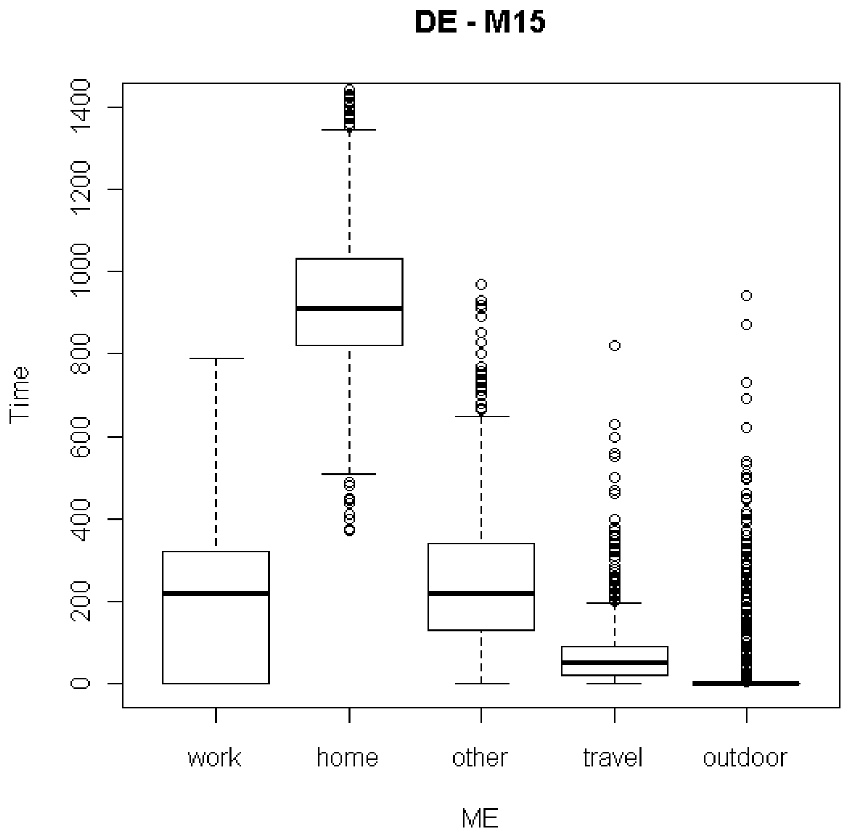
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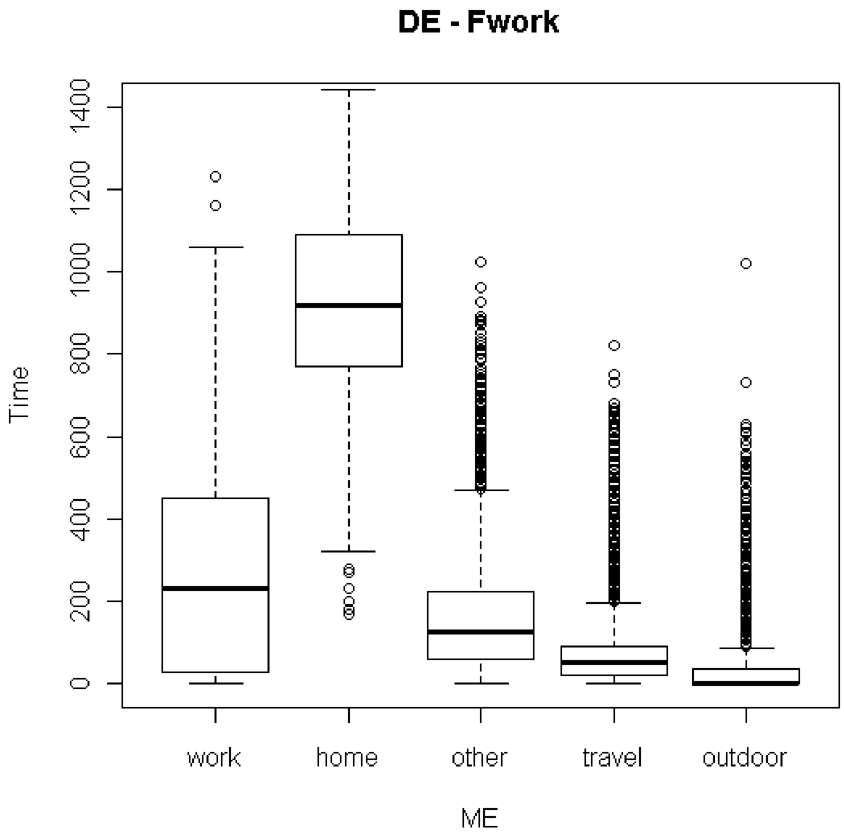
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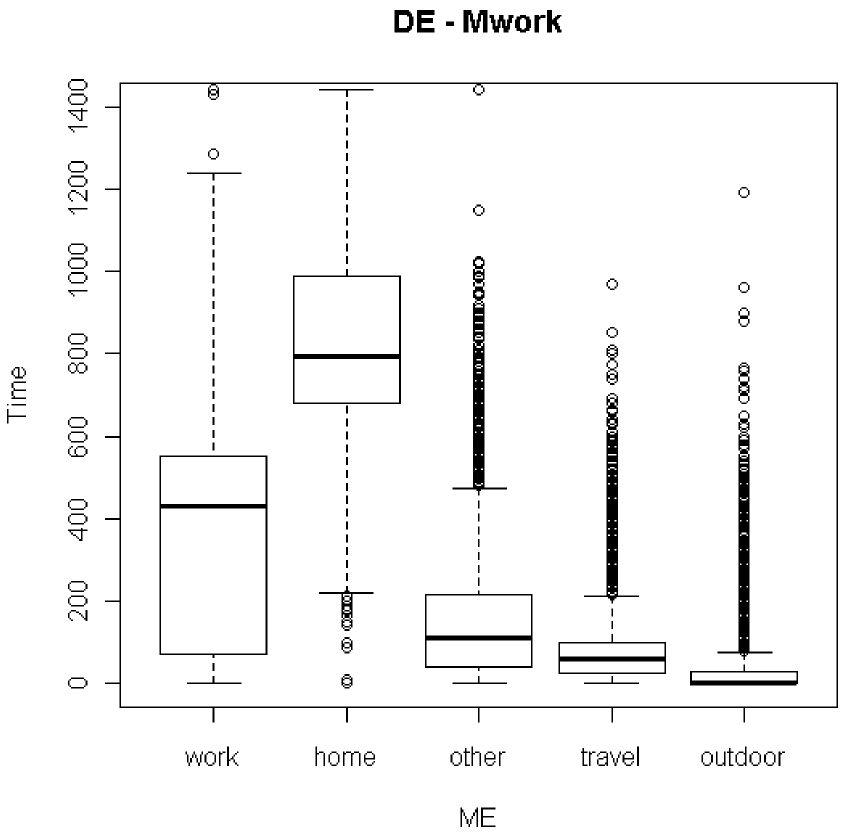
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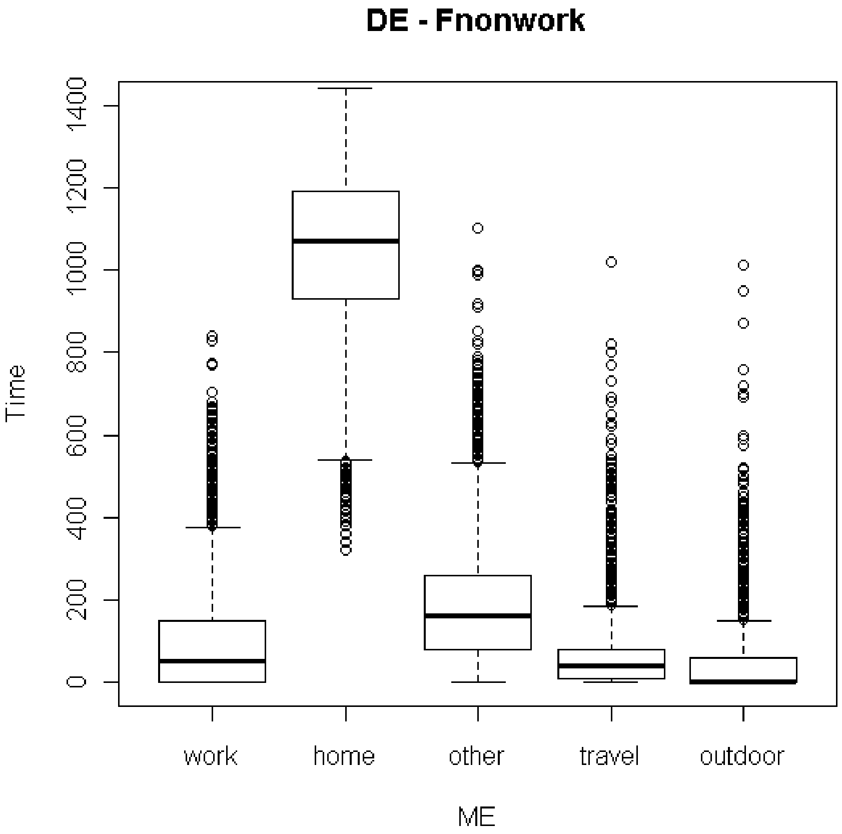
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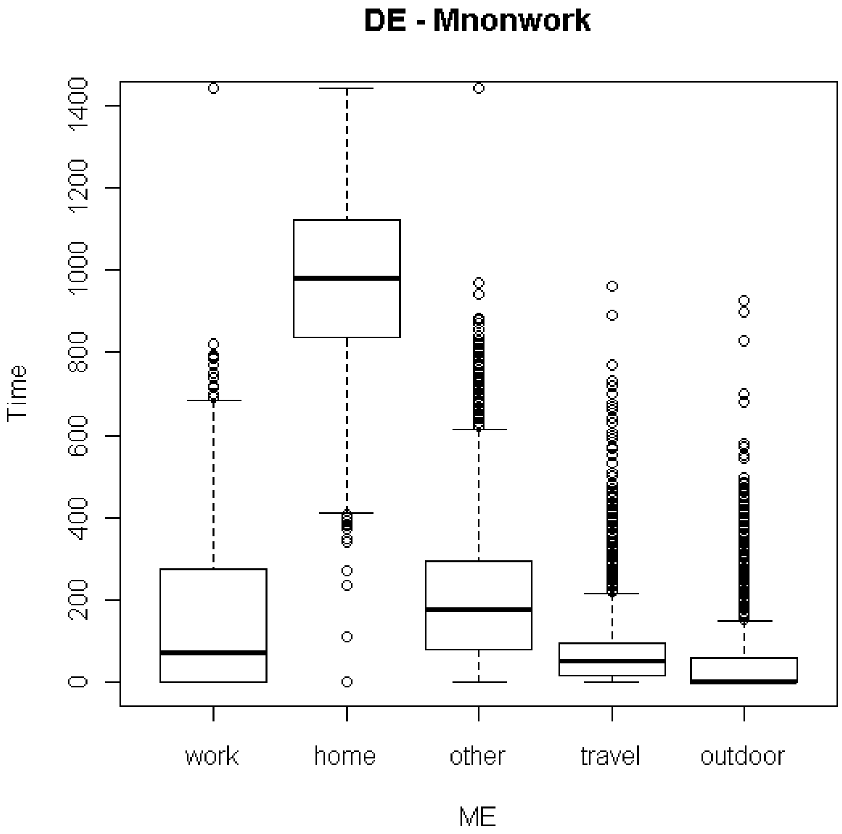
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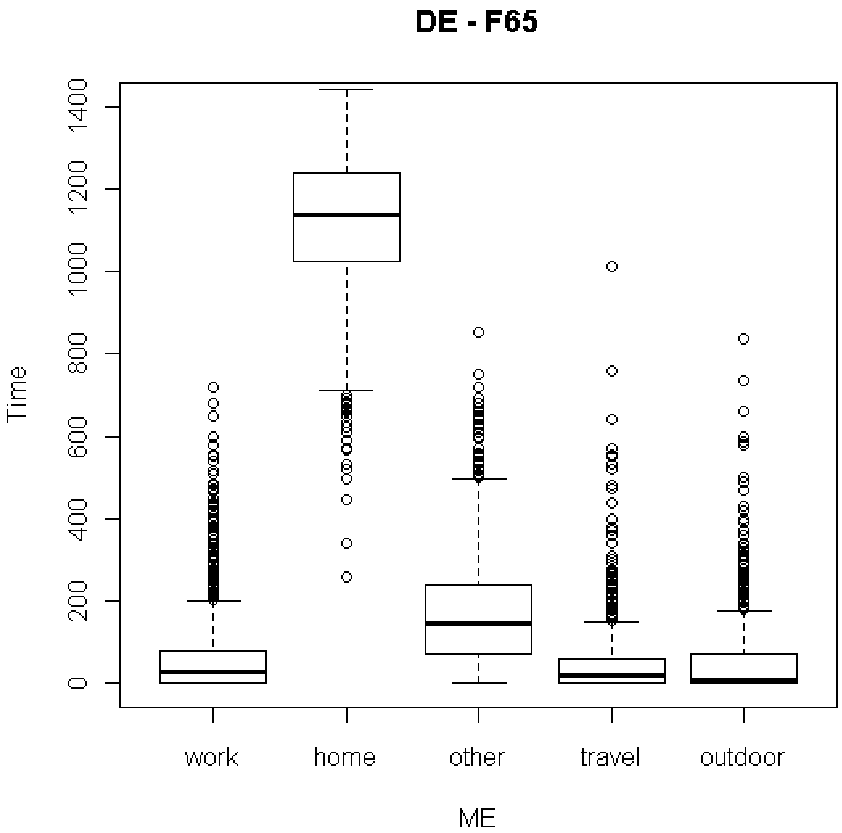
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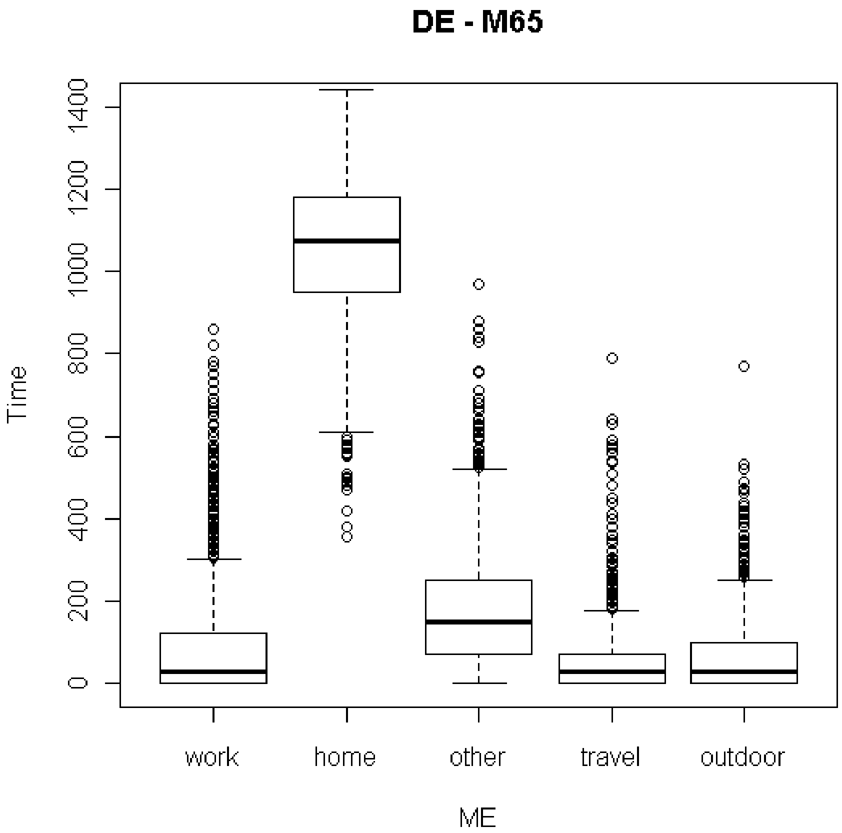
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DALYs: duration in fraction of year, DALY= weight * duration * # cases

endpoint	weight	duration	pollutantID
Bronchodilator Usage Adults and Children	0.22	0.00274	PM10
Cardiac Hospital Admissions	0.71	0.038	PM10
ChronicBronchitis	0.099	10	PM10
Infant Mortality	1	80	PM10
Lower Respiratory Symptoms Adults and Children	0.099	0.00274	PM10
Respiratory Hospital Admissions	0.64	0.038	PM10
Minor Restricted Acitvity Day	0.07	0.00274	PM25
Restricted Acitvity Day	0.099	0.00274	PM25
Work Loss Day	0.099	0.00274	PM25
Years Of Life Lost chronic. Mortality	1	1	PM25

Air pollutants – monetary values (EUR 2010)

Health End-Point	Central	per case
Increased mortality risk (infants)	4,485,731	Euro
New cases of chronic bronchitis	66,000	Euro
Respiratory hospital admissions	2,990	Euro
Cardiac hospital admissions	2,990	Euro
Work loss days (WLD)	441	Euro
Restricted activity days (RADs)	194	Euro
Minor restricted activity days (MRAD)	57	Euro
Lower respiratory symptoms	57	Euro
Medication use / bronchodilator use	80	Euro
Life expectancy reduction - Value of Life Years chronic	59,810	Euro