How Health-Predictive are Routine Air Monitoring Data?
Hanns Moshammer, Uhyg, MUW

Currently the European Union is contemplating an update of the air quality guidelines. In order to aid the decision making process WHO Europe has submitted and has been granted a project with the telling (?) acronym of "REVIHAAP". In that project WHO has brought together leading European experts on air pollution health effects to review the evidence regarding health effects of air pollution. This year (2013) the project team has submitted its first "final" report answering a first set of questions. Maybe not surprisingly the experts conclude that the older WHO statements on air pollution health effects are (mostly) still valid and the evidence base has been broadened and deepened.
Especially regarding the issue of ultrafine particles and/or particle numbers they state:
"*There is increasing, though as yet limited, epidemiological evidence on the association between short-term exposures to ultrafine (<0.1 µm) particles and cardiorespiratory health as well as the central nervous system.*" (p.6), and:
"*Although there is considerable evidence that ultrafine particles can contribute to the health effects of particulate matter, for ultrafine particles, measured by the number of particles, the data on concentration–effect functions are too scarce to evaluate and recommend an AQG.*" (p.22)
One might expect that the latter statement will not encourage EU authorities to embark on a the adventure of implementing a new monitoring network for particle numbers.
Producing a huge amount of data that cannot be anchored to limit- or guideline values and the meaning of which cannot be explained to concerned citizens will not help to solve any problems for policy-makers but likely add more difficulties.
It really seems to be a dead end or a vicious circle: Not enough data to allow sound interpretation of new data - no incentive to generate new data - lack of information - no sound interpretation - etc..
I joined university in 2000. Before that I had worked in public health making use of limit values and health effects studies when I had to give expert advice on (mostly small scale) environmental and health impact assessments in administrative processes. I had then gained a very good feeling of the meaning and appropriateness of limit values especially for gaseous pollutants. For many projects - both industrial and infrastructure related - NOx turned out to be the most restrictive and stringent parameter. Regarding particles Austrian limit values where then still based on Total Suspended Particles (TSP), but EU had already introduced the concept of PM10, even if this concept originally designed in the US was there already replaced by PM2.5.
European legislators then seemed to believe that the newly proposed PM10 target (daily mean of 50 µg/m³) would be easily achieved. Maybe they reasoned that PM10 is TSP "minus all the coarse particles" and would thus show considerably lower figures. That might have been true in former times when really large amounts of (very) coarse particles where emitted without any filtering or other cleaner technology. It soon turned out that PM10 is not so much different from TSP as PM2.5 is not much different from PM10. With the EU being slow with the introduction of stricter emission control regulations member states in fact faced unexpected problems with the new limit values for PM10 that they had not really anticipated before.
With this background it is not surprising that policy-makers in Europe are not keen on new metrics. But are these new metrics necessary? For a scientist and especially for an epidemiologist good exposure data are essential. But what is the meaning of "good" in that

respective?
When I moved to university the introduction of PM10 was in full swing. In Austria the Academy of Sciences had proposed a large national project that brought together federal and regional air protection agencies, technical universities and medical faculty to study particulate pollution in Austria (Austrian Project on Health Effects of Particles, AUPHEP). When I joined this 2-year project was already running. So I got my hands on a huge set of data without much own hard preparatory work. In principle there were two annual measurement campaigns at two measuring sites each, so 4 data series in total. Usually side to side to an existing monitoring station a wide range of measurement technologies of particles were tested. The standard technique of daily filter samples (for PM10, PM2.5, and PM1) were included and from two sampling series part of these filters were analysed for chemical composition. In parallel more continuous methods like TEOM and ß-gauge were implemented, but also particle number (CPC) and - at least for a limited period of time at two monitoring stations - also active surface using a corona discharger. From the routine monitoring stations gaseous pollutants and TSP were available. Regarding the health effects routine data, mostly on a daily basis, (e.g. mortality or hospital admissions) were available but also some panel studies were performed in children from schools and kindergartens close to the monitoring stations.
I had the opportunity to study some health effects with data from Vienna and from Linz. Surprisingly particle numbers were neither good predictors of health effects nor were they strongly correlated to other pollution measures. This was different in Graz where particle numbers and especially NOx were highly correlated but unfortunately I did not have access to health data from Graz then. But anyhow later we could show that NOx (or rather NO2) was highly predictive of health effects (daily mortality from various causes) in Graz. So why introduce a new pollution metric that is highly sensitive to spatial and temporal variability? Will it ever be possible to get meaningful information out of particle numbers?
For my research I usually need data that are representative of the exposure of a large and well defined population. Routine health data (like mortality data) are usually available on a daily basis for political units like districts or cities. Air monitoring data should best reflect these temporal and spatial specifications. From panel data (e.g. repeated spirometry in a sample of asthmatic children) I learned that rather short term changes (e.g. hourly of half hour means) are crucial. From a public health point of view long term (e.g. annual) concentrations might be much more relevant. But for the study of short-term reactions to understand (patho)-physiological mechanisms a much higher temporal resolution is necessary. I often found that nitrogen oxides are not only good proxies of fresh and toxic incineration particles but that these gaseous pollutants also serve well in predicting health effects. Of course with changes in emission scenarios NOx might lose their superb proxy status. But for the time being they not only have the advantage of health relevance but also of very long and consistent observation periods and hence data series.
The regulator and often also the epidemiologist would also need pollution metrics that are indicative of the pollution source. Chemical composition might be more informative than number or even size of particles, but indeed this is not exactly my field of expertise.
I would really love to additionally have data on particle number or even better, I suppose, on particle surface. But with the currently prevailing emission scenarios I can manage well with existing proxies that can eventually be enhanced by simple “distance to source” measures. As a citizen I would prefer money to be put in pollution reduction rather than more advanced pollution monitoring. I do understand that particle numbers are essential for emission control. I

am sure that there should be research programs investigating health-effects related to particle numbers. But I am not convinced the time is ripe to establish particle numbers as an additional parameter in a European routine monitoring network: A very broad coverage would likely be very costly and just some very few stations would not be informative enough.

Routine Air Monitoring Data

Are they Health-Predictive?

Hanns Moshammer, Uhyg, MUW

When I was still young…

- I've got to have a reggae on my LP
  - (Wilfried Scheutz, "Make-up" 1980)

- I want to talk about ultrafines!

WHO Europe

- Review of evidence (e96762-final.pdf)
- REVIHAAP 2013
  - There is increasing, though as yet **limited, epidemiological evidence** on the association between short-term exposures to ultrafine (<0.1 μm) particles and cardiorespiratory health as well as the central nervous system. (p.6)
  - Although there is considerable evidence that ultrafine particles can contribute to the health effects of particulate matter, for ultrafine particles, measured by the number of particles, the **data on concentration-effect functions are too scarce** to evaluate and recommend an AQG. (p.22)
- Yes, but...

Devil‘s Circle

- We have no data
- We cannot assess data
- No need to monitor data
- We have no data (...)

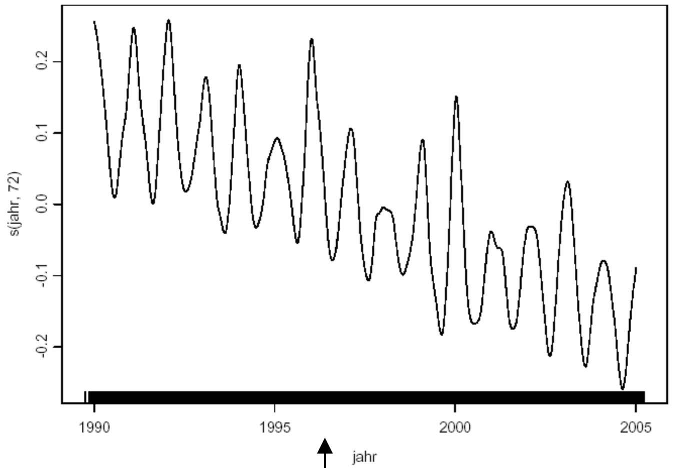
- Is this true?

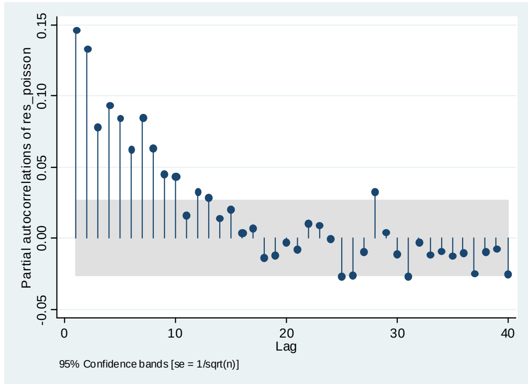
Epidemiologist's Needs I

- Small individual effects
- Confounding factors
- Chance variation

- Large data-sets (e.g. population of one whole city)
- Health data available ("let's say!")
- Exposure data? Spatial/temporal variability?

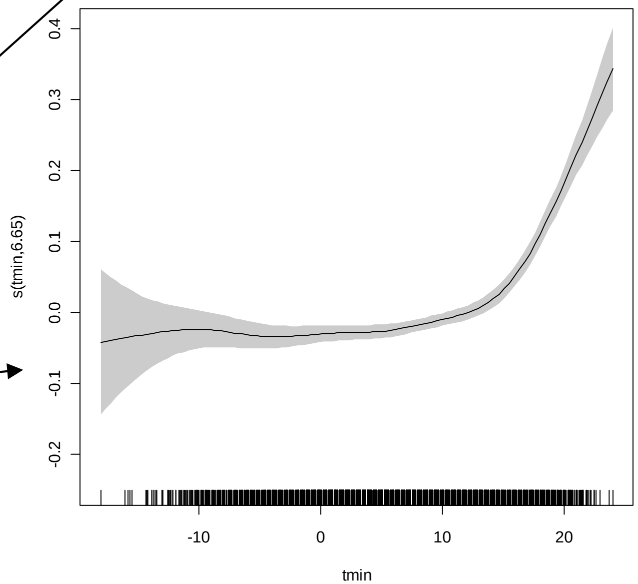
Fine dust and daily mortality



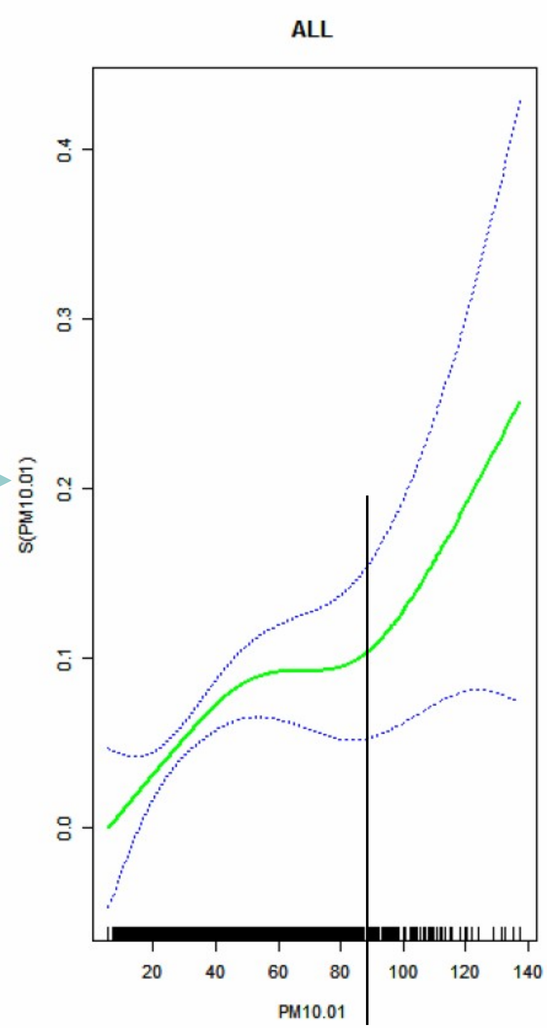


Long-term trend and seasons

Autocorrelation Temperature



(e.g. Graz)



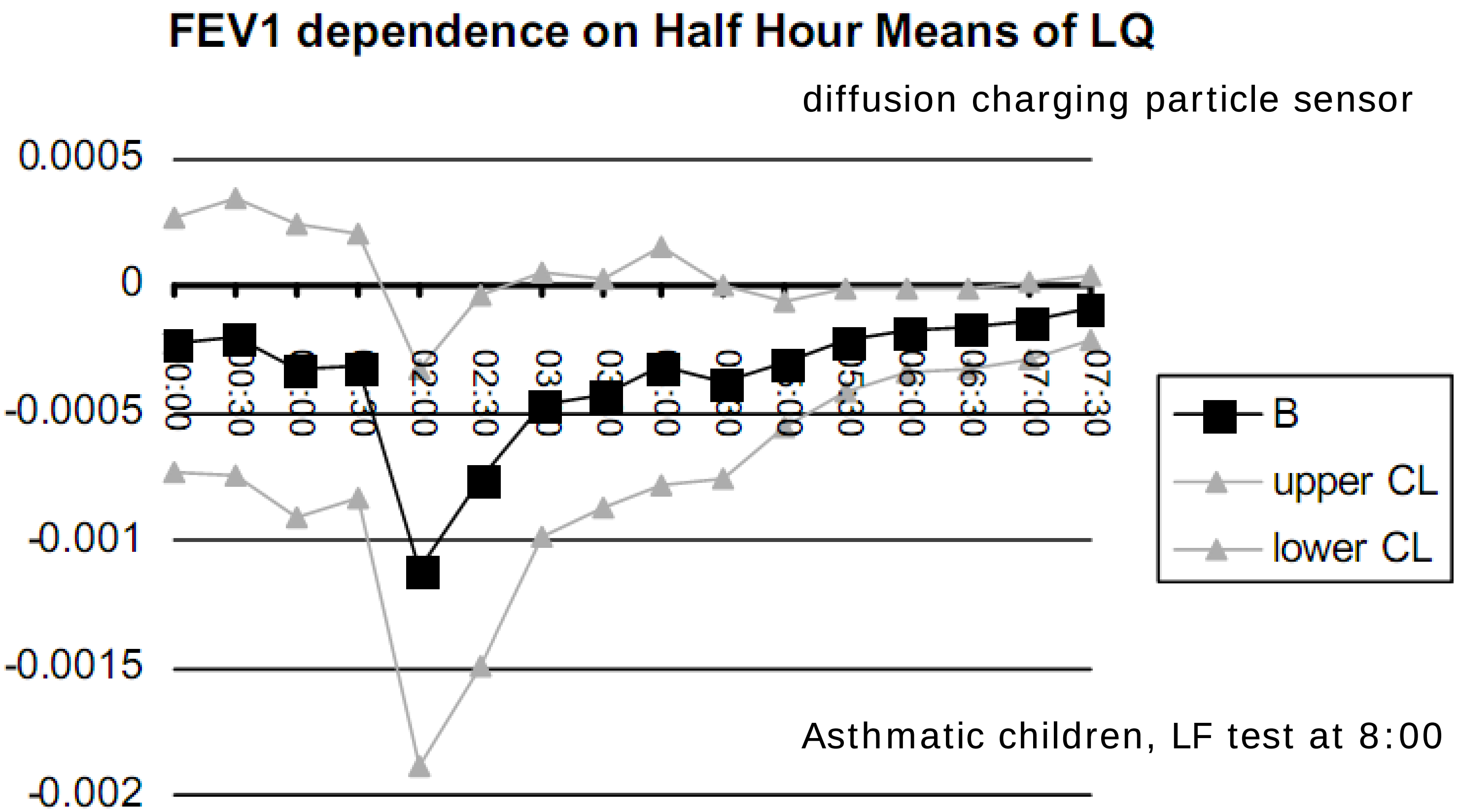
Epidemiologist's Needs II

- Spatial resolution / contrasts?
  - Health-data often only on district level
  - Mobility of persons

- Temporal resolution
  - Routine health data per day
  - Clinical effect data (panel study) in higher resolution

Particle Surface & Lung Function

H. Moshammer, M. Neuberger / Atmospheric Environment 37 (2003) 1737–1744



Public Health Needs

- Source of pollutant?
  - Composition of PM
  - Link with wind fields
  - Diurnal, weekly, and seasonal patterns
- Long-term trends
  - Representative monitoring station
  - Constant methods

Proxy data I

HEI Special Report 17
January 2010

Chapter 3: Exposure

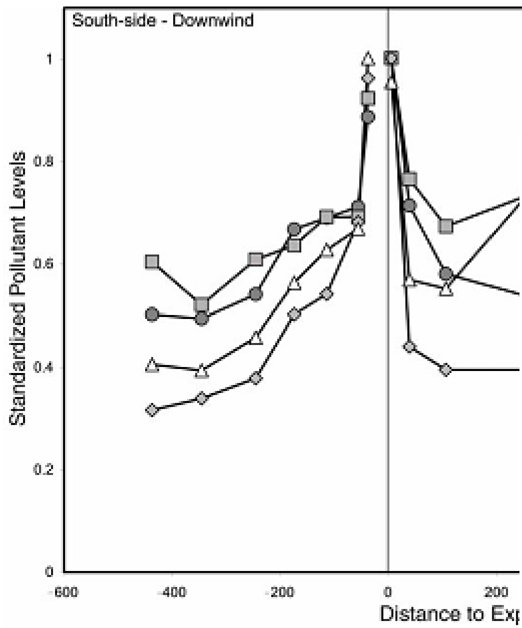


Figure 3.3. Distance-decay gradients of benzene, methyl *tert*-butyl ether (MTBE
with those observed with NO_2. All gradients decreased consistently with distanc
centrations (y axis) were normalized by dividing each pollutant by the largest val
with permission of Elsevier.)

Traffic-Related Air Pollution: A Critical Review of the Literature

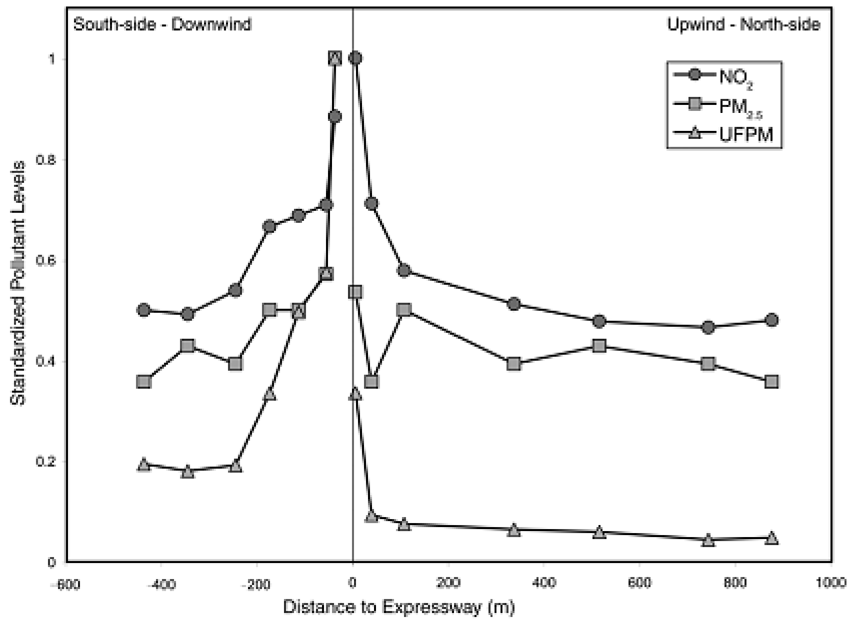


Figure 3.4. Distance-decay gradients of PM at the Bayview site in Toronto compared with those observed for NO_2. Gradients of $PM_{2.5}$ and UFPM (ultrafine particulate matter) were similar to that of NO_2. The pollutants' gradient concentrations (y axis) were normalized by dividing each pollutant by the largest value observed at a given study site. (Reprinted from Beckerman et al. 2008, with permission of Elsevier.)

AUPHEP

Correlations (all p < 0.01), daily mean values, approx. 1 year (**Graz**)

	FH1	FH2.5	FH10	TEOM1	TEOM2.5	TEOM10	TSP	CPC	O3	NO	NO2	CO	SO2
FH1		0.97	0.95	0.98	0.97	0.92	0.89	0.54	-0.37	0.77	0.59	0.79	0.74
FH2.5	0.97		0.96	0.95	0.98	0.92	0.90	0.55	-0.43	0.77	0.62	0.82	0.75
FH10	0.95	0.96		0.95	0.97	0.98	0.97	0.59	-0.39	0.81	0.67	0.81	0.76
TEOM1	0.98	0.95	0.95		0.97	0.95	0.91	0.58	-0.33	0.82	0.61	0.80	0.73
TEOM2.5	0.97	0.98	0.97	0.97		0.95	0.92	0.55	-0.42	0.78	0.61	0.81	0.72
TEOM10	0.92	0.92	0.98	0.95	0.95		0.97	0.60	-0.38	0.80	0.68	0.79	0.75
TSP	0.89	0.90	0.97	0.91	0.92	0.97		0.61	-0.37	0.80	0.67	0.77	0.69
CPC	0.54	0.55	0.59	0.58	0.55	0.60	0.61		-0.55	0.66	**0.80**	0.78	0.80
O3	-0.37	-0.43	-0.39	-0.33	-0.42	-0.38	-0.37	-0.55		-0.50	-0.63	-0.66	-0.54
NO	0.77	0.77	0.81	0.82	0.78	0.80	0.80	0.66	-0.50		0.67	0.94	0.60
NO2	0.59	0.62	0.67	0.61	0.61	0.68	0.67	0.80	-0.63	0.67		0.74	0.77
CO	0.79	0.82	0.81	0.80	0.81	0.79	0.77	0.78	-0.66	0.94	0.74		0.80
SO2	0.74	0.75	0.76	0.73	0.72	0.75	0.69	0.80	-0.54	0.60	0.77	0.80	

Correlations (**all but CPC:** p < 0.01), daily mean values, approx. 1 year (**Vienna**)

	FH1	FH2.5	FH10	TEOM1	TEOM2.5	TEOM10	TSP	CPC	PM2.5	PM10	O3	NO	NO2	SO2	CO
FH1		0.88	0.82	0.94	0.91	0.82	0.78	0.03	0.83	0.82	-0.22	0.37	0.48	0.44	0.61
FH2.5	0.88		0.89	0.93	0.98	0.88	0.82	0.03	0.91	0.91	-0.30	0.35	0.50	0.55	0.62
FH10	0.82	0.89		0.88	0.92	0.98	0.98	0.18	0.87	0.96	-0.32	0.53	0.63	0.52	0.70
TEOM1	0.94	0.93	0.88		0.96	0.90	0.85	0.11	0.89	0.89	-0.29	0.43	0.59	0.55	0.67
TEOM2.5	0.91	0.98	0.92	0.96		0.92	0.87	0.06	0.92	0.92	-0.33	0.43	0.58	0.54	0.68
TEOM10	0.82	0.88	0.98	0.90	0.92		0.97	0.10	0.83	0.92	-0.24	0.47	0.59	0.50	0.69
TSP	0.78	0.82	0.98	0.85	0.87	0.97		0.16	0.79	0.91	-0.25	0.49	0.60	0.48	0.69
CPC	0.03	0.03	0.18	0.11	0.06	0.10	0.16		0.26	0.25	-0.53	0.55	0.61	0.36	0.24
PM2.5	0.83	0.91	0.87	0.89	0.92	0.83	0.79	0.26		0.95	-0.50	0.54	0.68	0.58	0.72
PM10	0.82	0.91	0.96	0.89	0.92	0.92	0.91	0.25	0.95		-0.46	0.58	0.72	0.57	0.75
O3	-0.22	-0.30	-0.32	-0.29	-0.33	-0.24	-0.25	-0.53	-0.50	-0.46		-0.64	-0.61	-0.52	-0.47
NO	0.37	0.35	0.53	0.43	0.43	0.47	0.49	0.55	0.54	0.58	-0.64		0.73	0.38	0.72
NO2	0.48	0.50	0.63	0.59	0.58	0.59	0.60	0.61	0.68	0.72	-0.61	0.73		0.45	0.74
SO2	0.44	0.55	0.52	0.55	0.54	0.50	0.48	0.36	0.58	0.57	-0.52	0.38	0.45		0.35
CO	0.61	0.62	0.70	0.67	0.68	0.69	0.69	0.24	0.72	0.75	-0.47	0.72	0.74	0.35	

Proxy Data II: NO_2

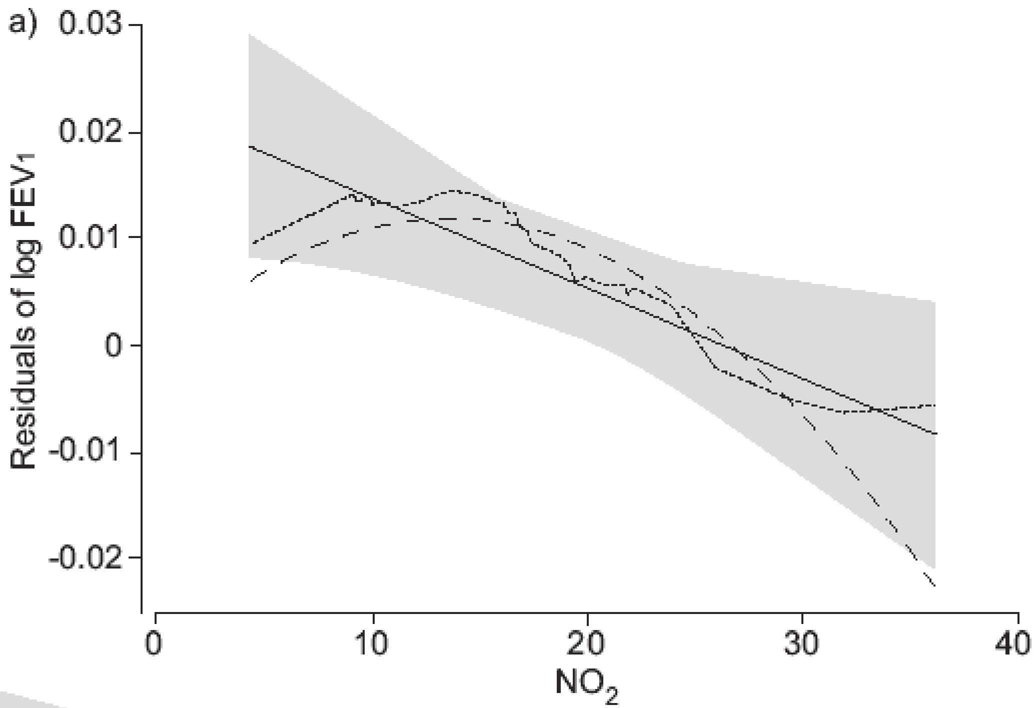
- NO_x good proxy for spatial variation of exposure to road emissions
- Will this proxy hold for all time?

- Currently a valid predictor of health effects
- High temporal resolution
- Long historic data series

Lung Function of Pupils

Even well below the limit values

Eur Respir J 2006; 27: 1138–1143



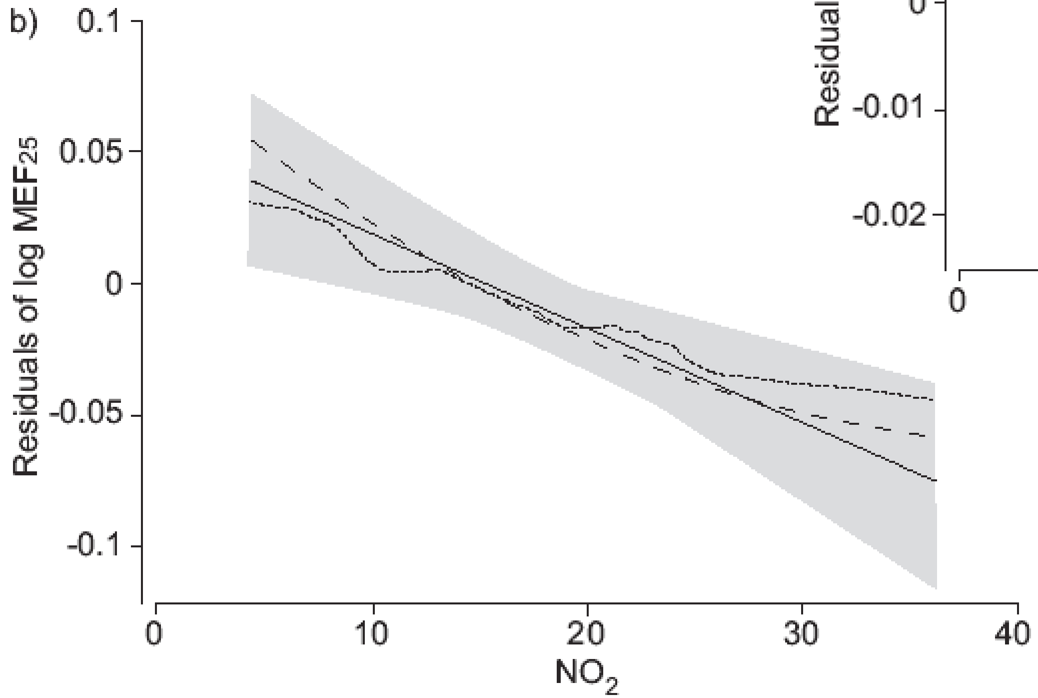


FIGURE 1. Selected outcomes for nitrogen dioxide (NO_2). Linear (——) and quadratic fit (– – – –) and LOWESS plot (········) on the residuals of the logs of forced expiratory volume in one second (FEV_1), maximal instantaneous forced flow at 25% of the forced vital capacity remaining to be exhaled ($MEF_{25\%}$) and hypothetical resistance at frequency=0 ($R(0,c)$).

Distance to roads

- Various proxies
  - Distance to “busy roads” (definition?)
  - Number of vehicles in a given distance
  - Number X Distance (log-scale)
  - Dispersion models (often NO_X-based)
- Seem to work pretty well
- Had good experience with simplest:
  - Trucks on the road in front of house

Example of some risk factors for Wheeze: Prevalence, Odds ratios and Attributable fractions

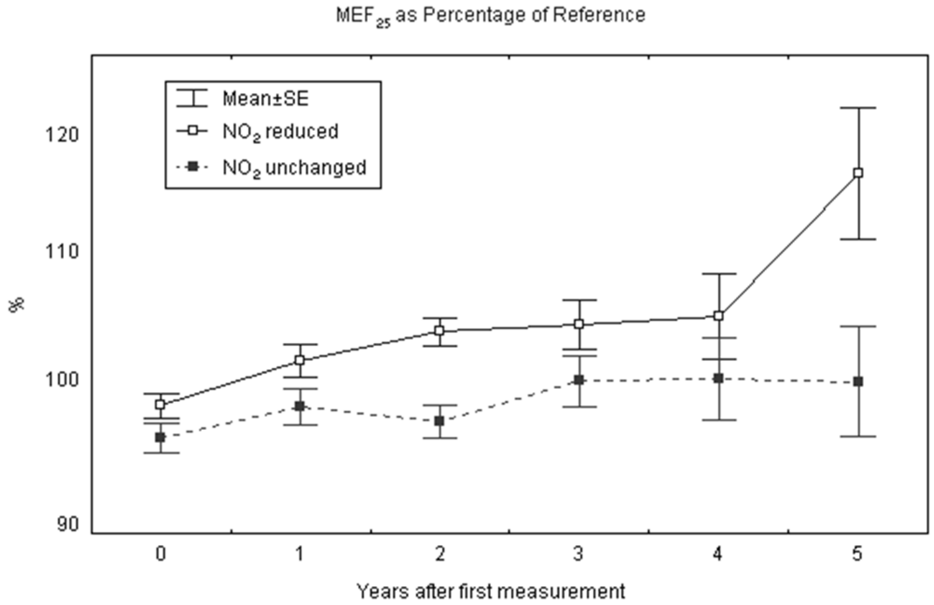
CESAR study, Tony Fletcher

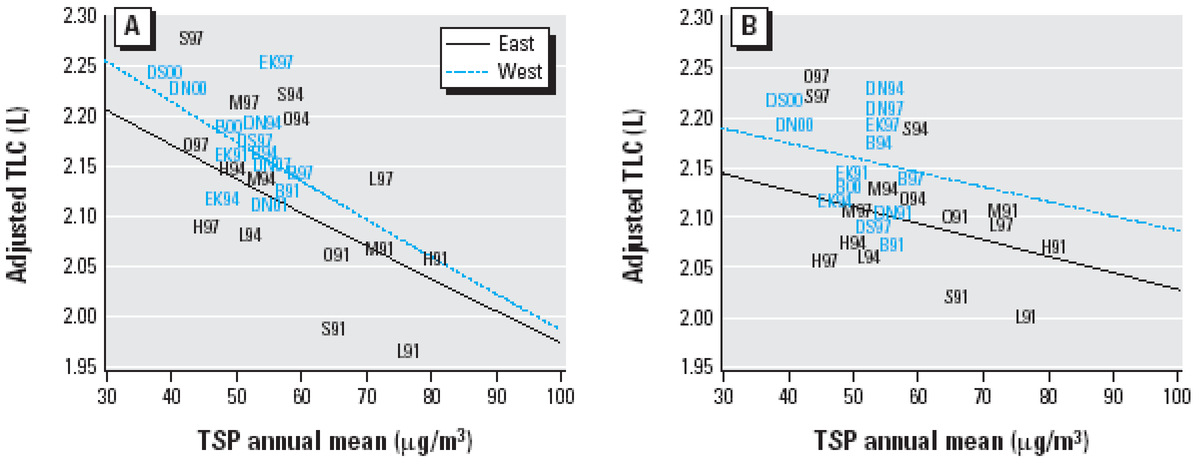
Variable	Level	Prev. %	OR	95% CI	AFs %
Air pollution	29 µg/m^3	5			
	67 µg/m^3	5 - 95	1.49	1.07 - 2.07	**11.3**
Traffic intensity	None	52			
	Light	29	1.16	1.03 - 1.31	3.0
	Medium	12	1.18	1.03 - 1.35	1.4
	Heavy	6	1.17	1.05 - 1.31	0.7
Traffic					**5.1**
Heating with Gas Oven	No	96			
	Yes	4	1.04	0.85 - 1.28	0.1
Kerosene heater	No	96			
	Yes	4	1.32	1.05 - 1.67	0.8
Indoor combustion sources					**0.9**

Air quality gets better, but…

Linz: Lung growth of children improved in districts where also NO_2 was reduced.

(ca. 3500 children 5+ from 1984 till 1990)





Heinrich et al.: Lung volume of German children (6 years), either more (A) or less (B) than 50 m from busy road.

Routine Air Monitoring Data

Thank you for your interest!

- Health-predictive and meaningful
- Rather serve as proxy
- Need for careful interpretation