Brake wear - An important source for atmospheric copper

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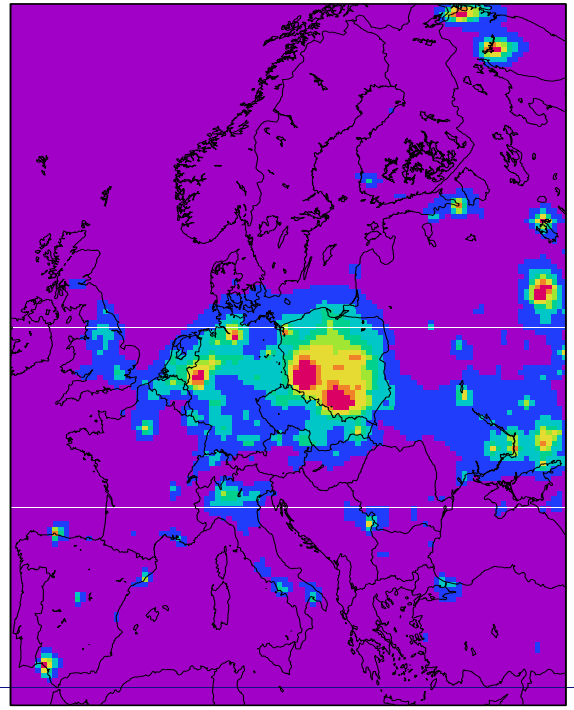
TNO | Knowledge for business

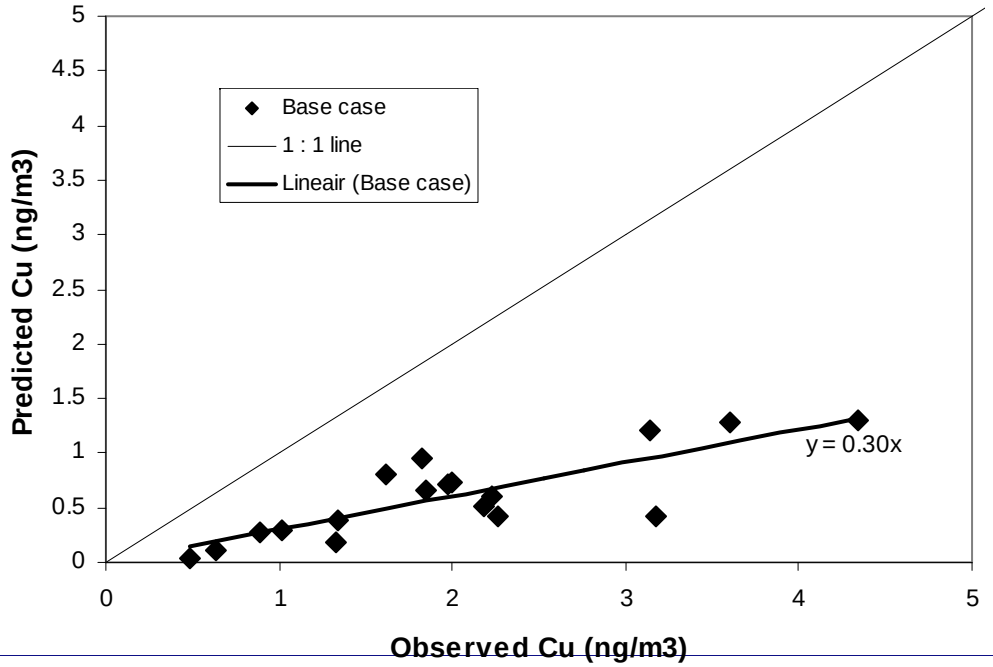
Why copper?

- Interesting case
- It’s toxic
- It has the highest bio-availability of all transition metals
- Causes the formation of reactive oxygen species leading to oxidative stress in your lungs.

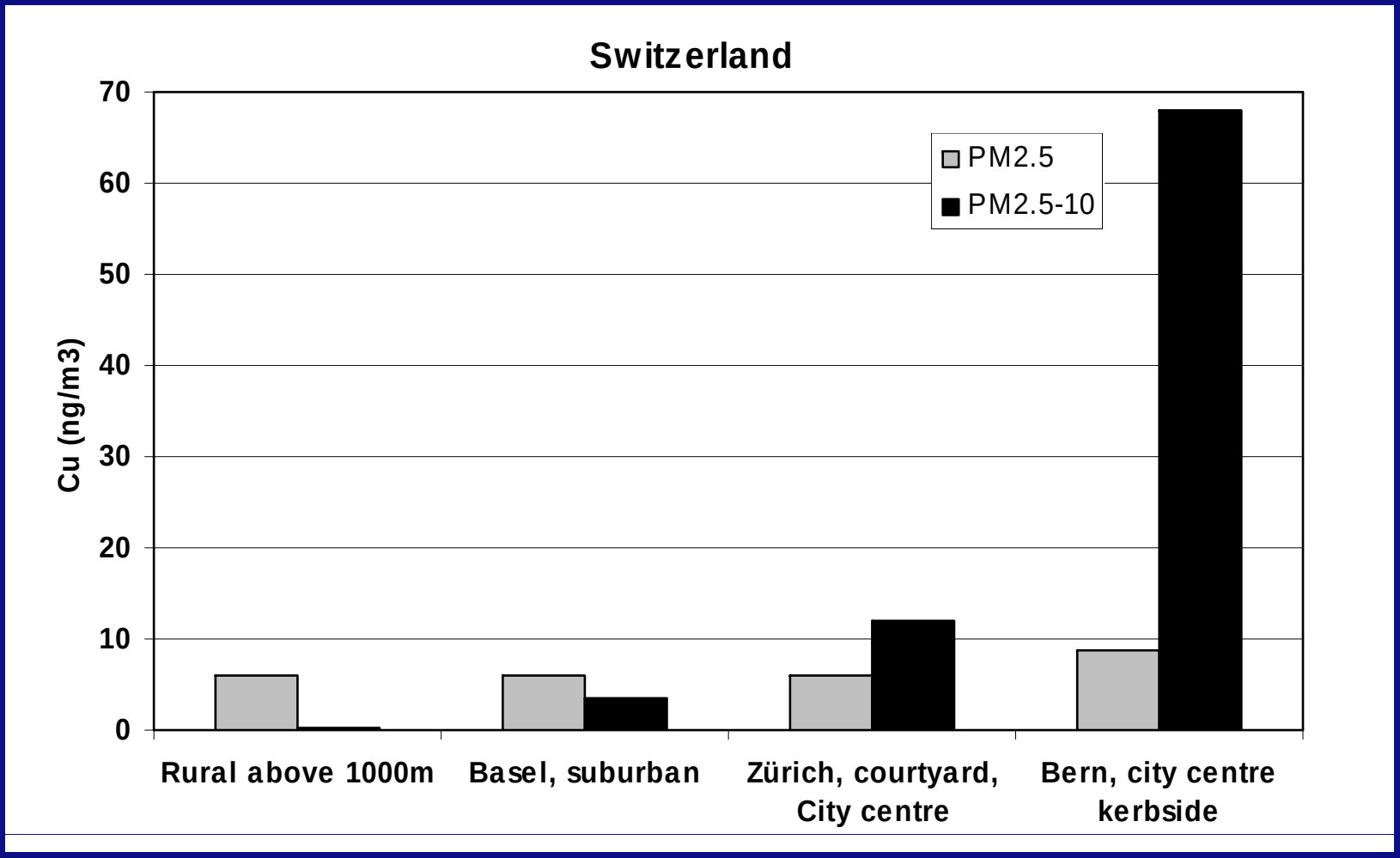
Background

Current knowledge, expressed in emission databases and models, is not able to explain the ambient concentrations of many heavy metals.





Brake wear: is it really a candidate?



Revision of Traffic Copper emissions

- Copper brake wear emission =

Vehicles travel distance (km)
X
Mass loss/distance (kg/km)
X
Mass fraction to air (kg/kg)
X
Substance concentration (kg/kg)

Revision of Traffic Copper emissions

- Copper brake wear emission =

PM10 emission factor for brake wear

Vehicles travel distance (km)
X
Mass loss/distance (kg/km)
X
Mass fraction to air (kg/kg)
X
Substance concentration (kg/kg)

Copper content of brake pads and linings

Copper content (% wt)	Remarks	Reference
1.5-2.7	HDV- Volvo	Westerlund (2001)
0.01	HDV-Scania	Westerlund (2001)
11.8	New passenger cars (1997) – front	Westerlund (2001)
9.2	New passenger cars (1997) - rear	Westerlund (2001)
7.2	Old[a)] passenger cars-front	Westerlund (2001)
5.1	Old[a)] passenger cars-rear	Westerlund (2001)
1.5 - 14.2	based on various references	Luhana (2005)
4.4	based on 40 percent of sales in US in 2000	Brake Pad Partnership, 2001
7.5	Non-asbestos Organic	Recalculated from Garg et al. 2000
7.1	Non-asbestos Organic	Sanders et al. 2003
0.6	Semi-metalic	
3.5	Low-Metallic	
10	European assessment	van Hyfte (2005)

- Copper content of total brake wear particles is variable (1-14%).
- We use a low (5 %) and high (10 %) case to represent the range of available compositions.

Example: Copper emissions for traffic in Albania

Exhaust emissions				
Fuel	Consumption	Revised emission factor		Revised Emission
	(TJ)	mg Cu/kg fuel	(kg Cu/TJ)[a)]	Kg/yr
Diesel	9490	0.01	0.000231	2
Gasoline	5600	0.05	0.001116	6
Total Cu emission from road transport fuel combustion (exhaust)t				***8***
Brake wear emissions				
vehicle_type	mileage	EF Brakewear		Emission Brake wear
	(10^6 km)	low	high	low	high
		mg Cu /km		Kg/yr	
HDV	1166	1.35	2.7	1574	3148
PC	2020	0.3	0.6	606	1212
MC	75	0.15	0.3	11	23
Total Cu from brake wear				**2191**	**4383**
Motor oil burning emissions				
vehicle_type	mileage	EF Cu Motoroil		MotorOil burning	
	(10^6 km)	mg Cu/km		Kg /yr	
HDV	1166	0.00144		1.7	
PC	2020	0.00144		2.9	
MC	75	0.00144		0.1	
Total Cu emission motor oil burning				***5***	

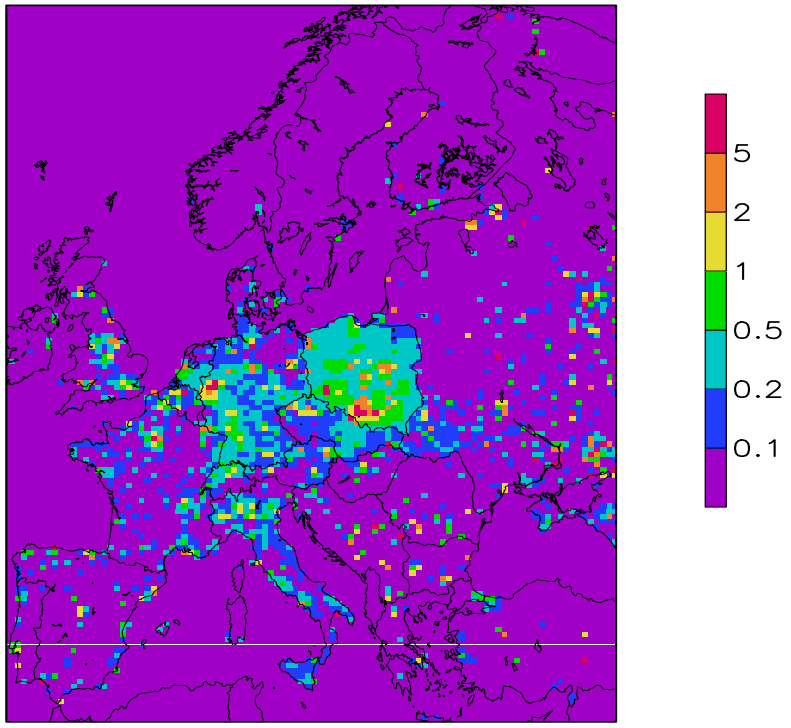
New emission totals (Tonnes/yr) for UNECE Europe

	Road transport				Other sources [a)]	Total	
	Exhaust	Brake wear		Burning of Motor Oil		Low	High
		Low	High				
Copper emission	**10**	**1573**	**3147**	**6**	**2386**	**3975**	**5548**

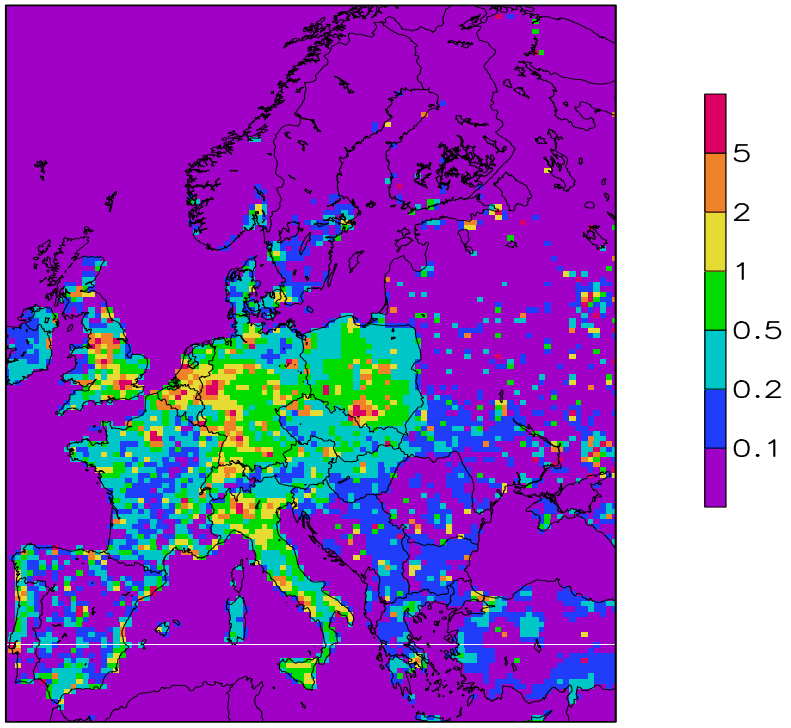
- It is assumed that PM2.5 from break wear covers 70% of the PM10 fraction.
- Emissions are spatially allocated using the traffic PM emissions as a proxy

Spatial distribution of Cu emissions

Default



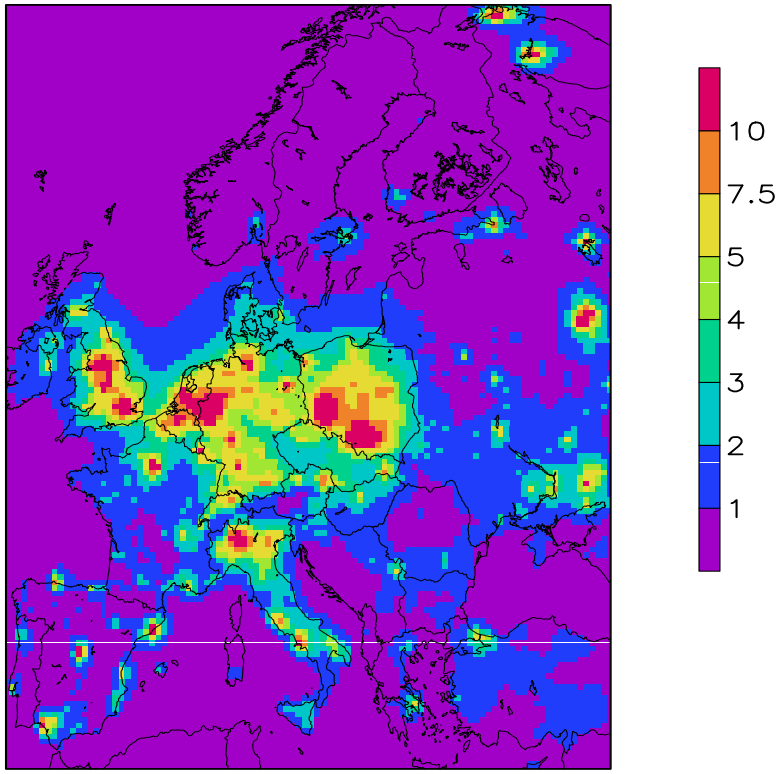
Low scenario



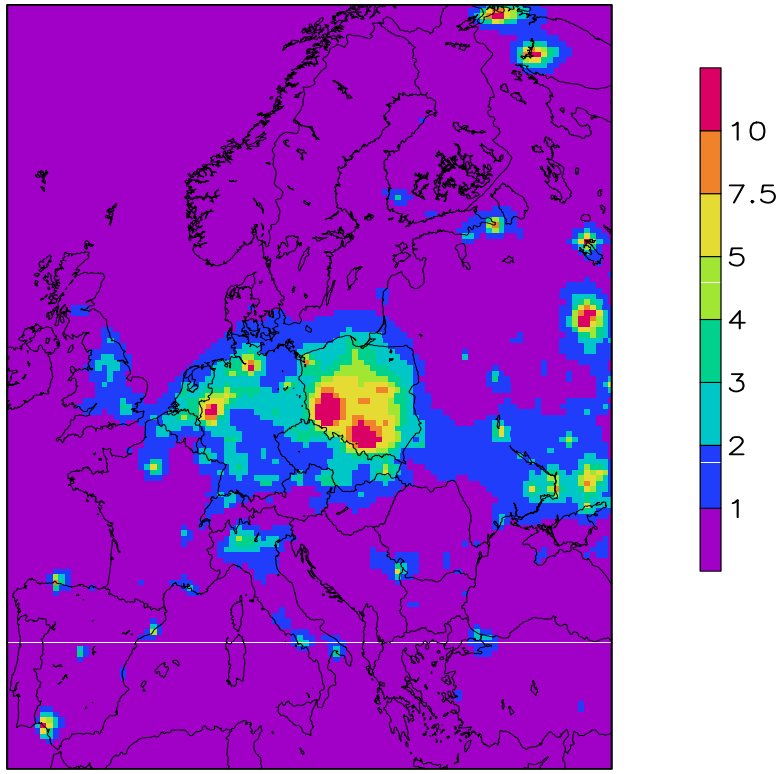
Tonne per gridcell per year

Results

New modelled field (low)

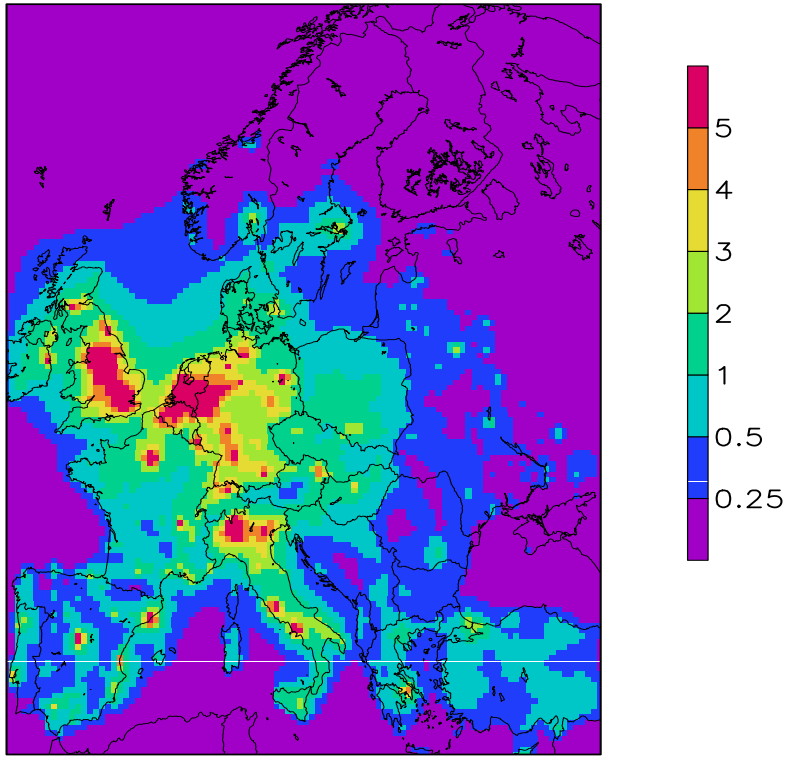


Starting point

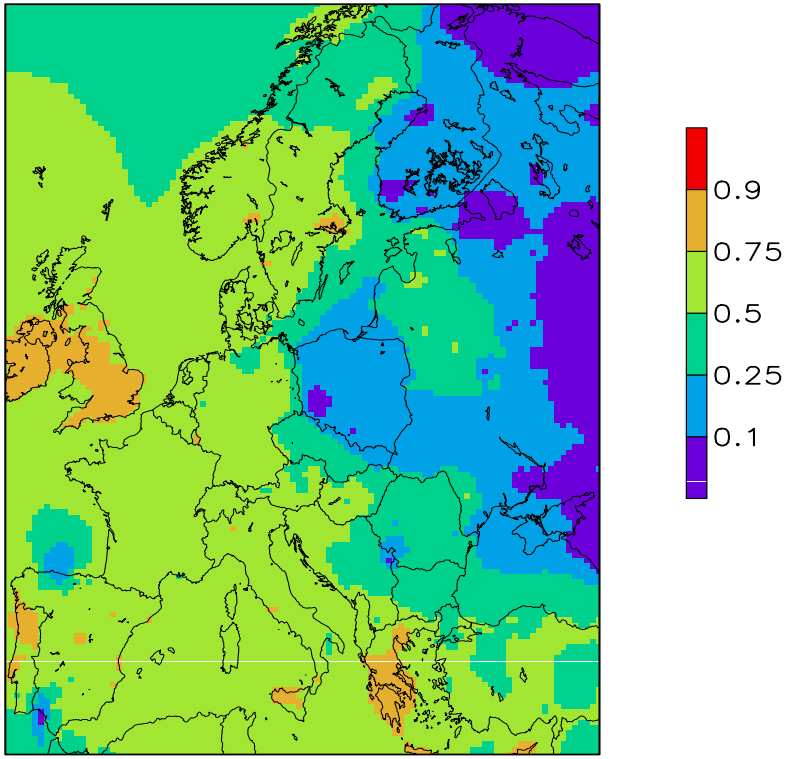


Results (low case)

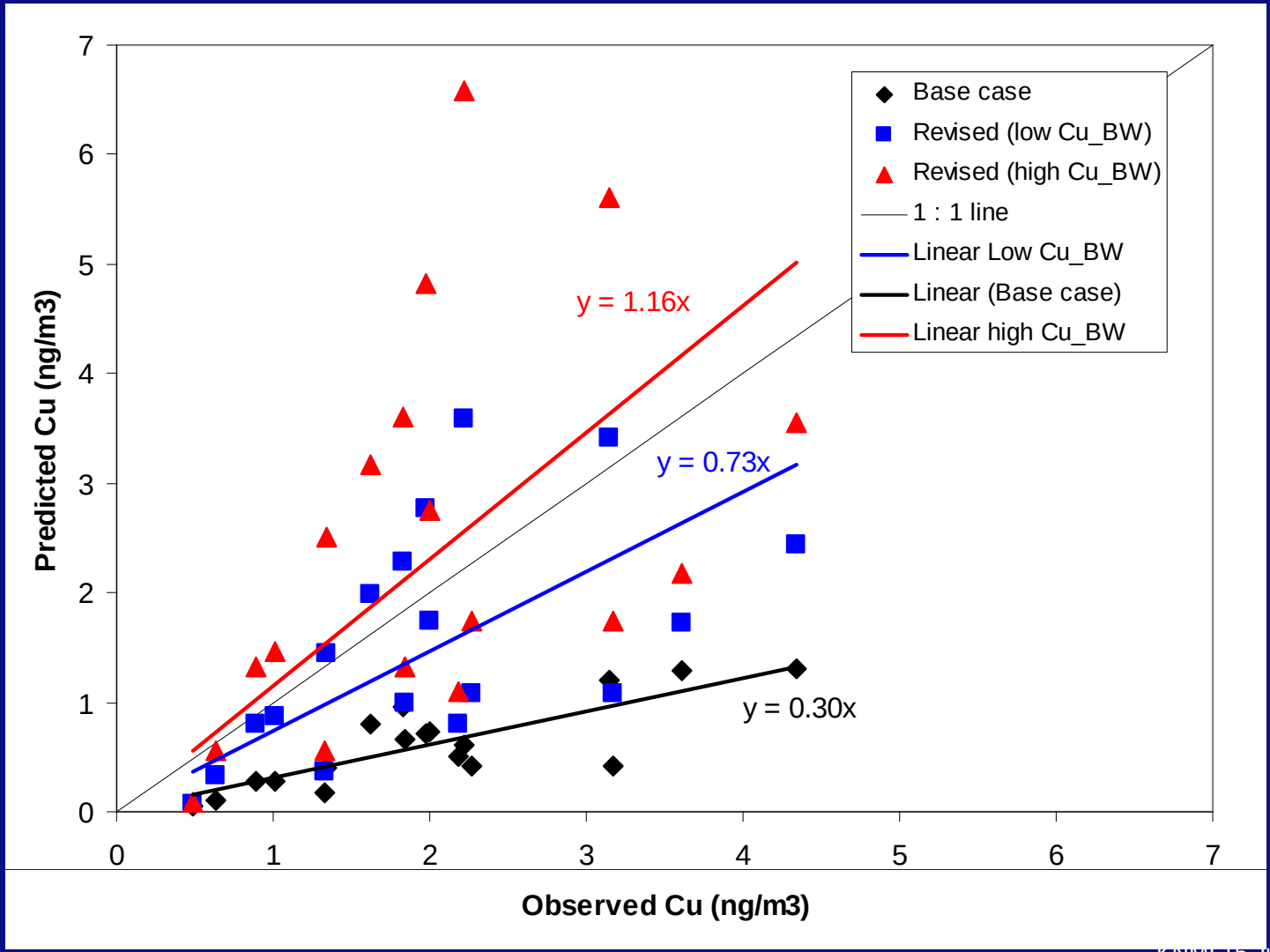
Brake wear



Fraction



Verification against EMEP data



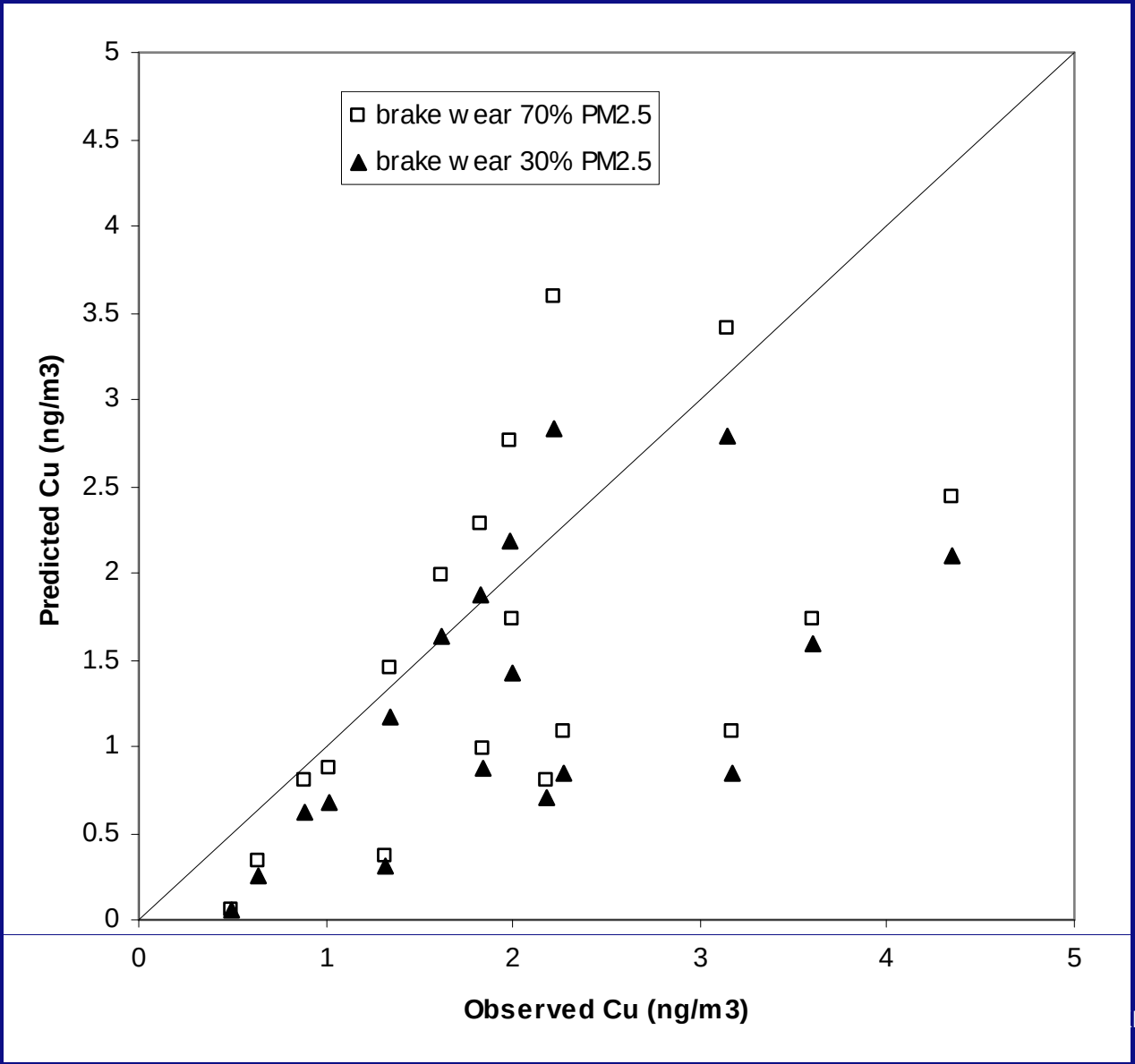
Uncertainties

- The Cu content of (average) brake lining material
- The amount of brake wear material emitted to air

Source	EF (mg Cu/Km)	
This study	0.36 (low) 0.72 (high)	Bottom up, inventory
Denier vdG 2003	0.34	Tunnel, Rotterdam, NL
Sternbeck 2002	0.17	Tunnel, Vilnius, LT

- Spatial dependancies were not accounted for.
- Size fractionation of the Cu PM10 emisssions (% PM2.5)

Influence of assumed PM2.5 fraction



Conclusions

- Brake wear is the dominating source of copper in ambient air in Western Europe.
- The revised Cu emissions are 4.0-5.5 kton/yr, which is substantially higher than the previous estimate of 2.8 kton/yr
- Uncertainty in the emission estimates is high (factor 2-3)
- The revised copper emissions from road transport are a major step towards gap closure of predicted and observed Cu concentrations in ambient air.
- Modification of brake lining composition is an important mitigation option to reduce copper exposure of the population in Western Europe