URBAN BENZO(A)PYRENE CONCENTRATIONS IN AIR: A MODELLING STUDY AND VALIDATION

M. Kaasik[1], M. Maasikmets[2], R. Kiss[3], M. Pindus[1], K. Kasak[1], K. Soosaar[1]

[1] University of Tartu, Tartu, Estonia
[2] Estonian Environmental Research Centre (EERC), Tallinn, Estonia
[3] Võru State Upper Secondary School, Võru, Estonia

EUROPEAN BaP-PAH PROBLEM

- Improving the detection limit of air quality monitoring equipment, it has been found that the European target value, annual average 1 ngm^{-3} in PM_{10} fraction for benzo(a)pyrene (BaP), a carcinogenic PAH, is exceeded for 20% of people in the EU.
- BaP is responsible on about 370 lung cancer incidents in the EU each year.
- 84% of BaP in the EU is emitted from residential heating.
- BaP concentrations in air are the highest in the CEE countries, e.g. Poland, Romania. Insufficient data on the Baltic countries so far. (Guerreiro et al., 2015)

BaP IN TARTU CITY

- Tartu is the second largest city in Estonia, about 100 000 inhabitants, 3100 houses on firewood heating (Figure 1).
- Daily averages are measured from PM_{10} filters episodically since 2013 (Figure 2).
- Measurement-based annual average concentrations up to 1.9 ngm^{-3}, with clear indication of higher concentrations in heating season.

Figure 1. Wood-heated multi-flat houses (A) and family houses (B) in Tartu (Google street view).

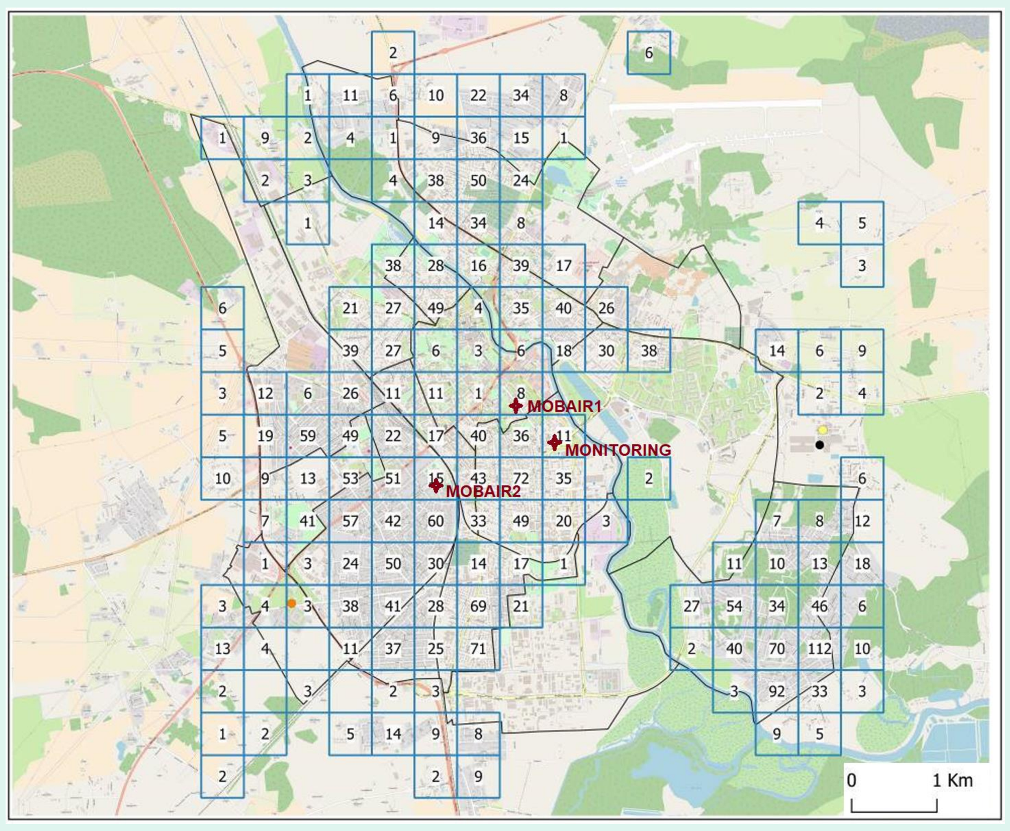

Figure 2. Map of Tartu city. Numbers of wood-heated houses are indicated in each 0.5 km square. Stars indicate the positions of a permanent air quality monitoring station and two sites, where episodic measurements were made with Mobair mobile station. The stations are operated by Estonian Environmental Research Centre (EERC).

- The concentration of BaP was anticorrelated with temperature, revealing impact of heating. Exponential regression fits better (Figure 3A).
- Carbon monoxide, another product of incomplete combustion appeared a considerable proxy for BaP (Figure 3B).
- BaP in air was less correlated with $PM_{2.5}$, R^2=0.21.
- Linear regression on carbon monoxide was marginally improved (R^2=0.46), when adding concentration of nitrogen oxide (in ppb) as the second independent variable to carbon monoxide (in ppm):

$$[BaP]=-1.76+14.0[CO]-0.043[NO]$$

- BaP and CO concentrations were found higher with southern and western winds (from residential heating areas) and NO concentrations with eastern winds (from a busy street crossing).

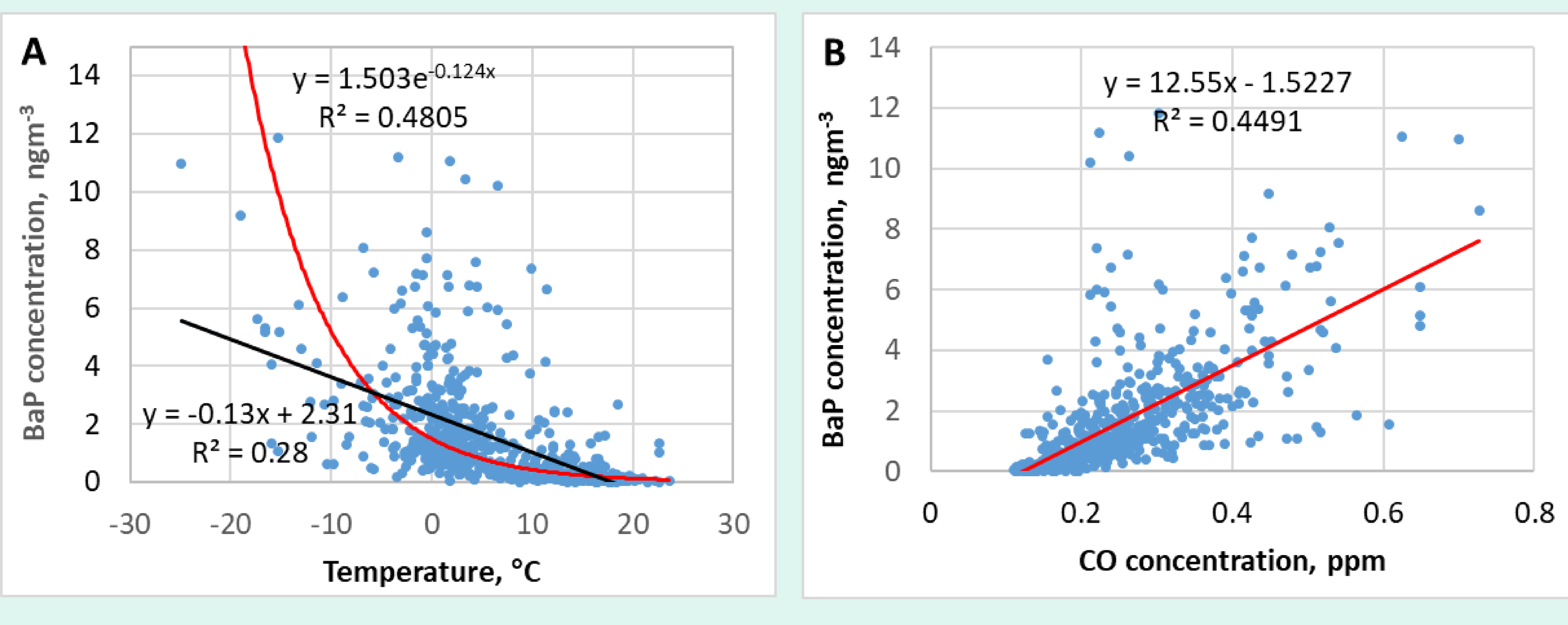

Figure 3. Regression graphs of BaP concentration on outdoor (A) temperature and (B) concentration of carbon monoxide. Daily averages in permanent monitoring station, 2014–2017.

DISPERSION MODELLING

To understand spatial distribution and to evaluate future scenarios.

- Tool: AEROPOL Gaussian dispersion model (Geertsema & Kaasik, 2018).
- Emission inventory: 50 kg BaP per year emitted from Tartu: 94% from residential heating, 5% from industrial boiler houses, 1% from vehicles.
- Emissions from residential heating: inventory by EERC, based on BaP emission 195 μgMJ^{-1} and 77 μgMJ^{-1} (experiments with mixed and dry wood only) and yearly heating demand 871 MJm^{-2} on average.
- Estimated yearly average emission rates Q_{avg} weighted with heating demand coefficient, depending of monthly outdoor temperature T:

$$Q = Q_{avg}(15°C - T)/(15°C - T_{avg}), \text{ if } T < 15°C$$

$$Q = 0, \text{ if } T < 15°C$$

MODELLING RESULTS

- AEROPOL model represents fairly the annual average concentrations, daily and heating season variations (Table 1, Figure 4).
- Residential heating determines the geographical distribution of BaP in Tartu (Figure 5A *vs.* Figure 2).
- The scenario with use of dry firewood only (*vs.* current expectation of mixed use of dry and wet wood) was found to be the most effective and nearly zero-cost measure for the reduction of BaP to acceptable level (Figure 5B) – how to change people´s heating habits?!

Table 1. Modelled and measured (avg.± st.dev. and correlation) BaP concentrations on daily basis

Site	Stationary monitoring station					Mobair 1		Mobair 2	
Year	2013	2014	2015	2016	2017	2015	2016	2016	2017
N (days)	60	61	60	180	292	26	148	64	150
Measured	1.88 ±2.60	1.85±2.34	1.20±1.46	1.82±2.12	1.37±1.64	2.20±2.77	1.46±1.66	1.17±1.54	1.09±1.42
Modelled	1.99±2.45	1.34±1.40	1.08±0.97	1.55±1.56	1.39±1.33	1.47±0.84	1.51±1.48	1.71±0.89	1.63±1.09
Corr.	0.67	0.53	0.44	0.51	0.79	0.67	0.67	0.58	0.63

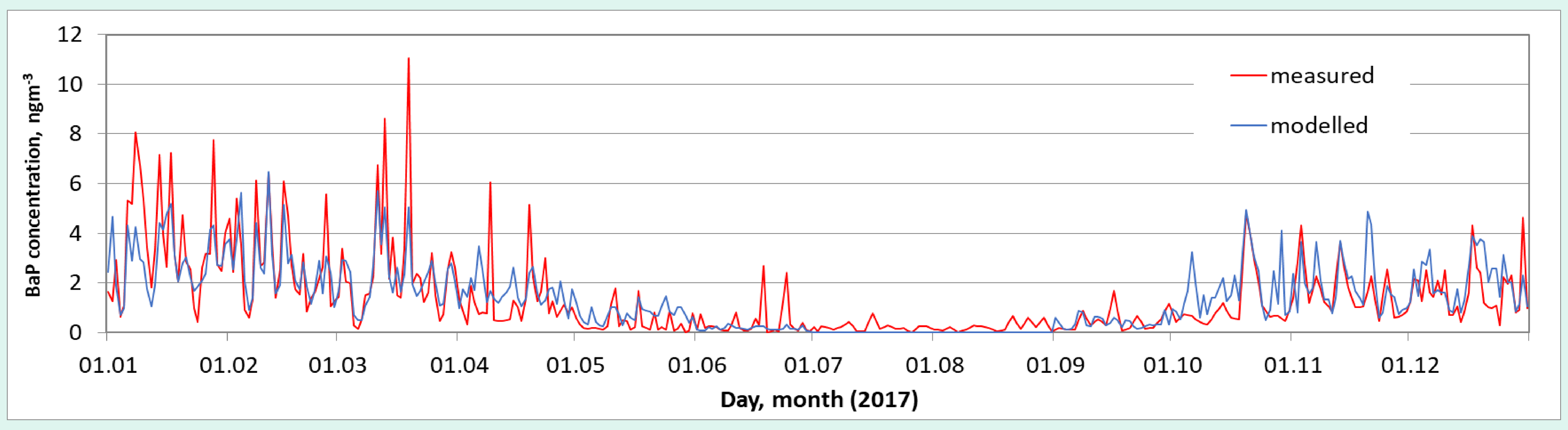

Figure 4. Comparison of daily average modelled and measured BaP concentrations in stationary monitoring station through 2017

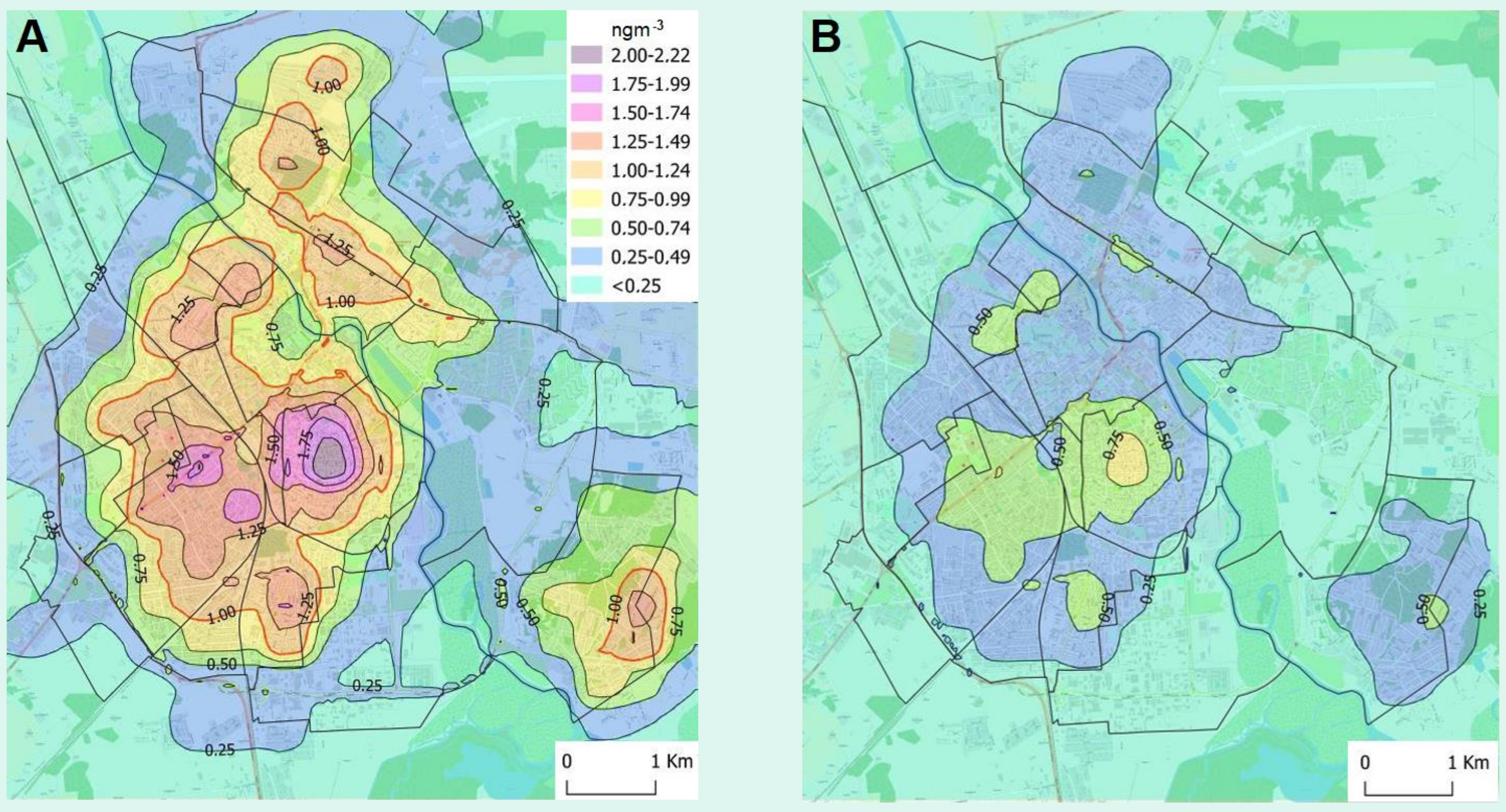

Figure 5. Map of modelled average concentrations of BaP for 2017 (A) and for future scenario with use of dry wood only in residential heating (B).

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