Impact of ultrafine particle emissions from in-land ferries

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Motivation

Ultrafine particles (UFP) are particularly hazardous to human health and their UFP number concentrations are much more sensitive to recently discharged emissions than mass-based particle indicators such as PM2.5. A simulation with the urban air quality model EPISODE-CityChem [1] based on a detailed particle number emission inventory with city-wide spatial distribution, gives the chance to examine the impact of passenger ferries in Hamburg harbour as ferryboat transport is one of the main contribution sectors to UFP concentrations in port cities (total annual emissions: 0.2 x 10^{24} #/yr).

Ferry boat emissions

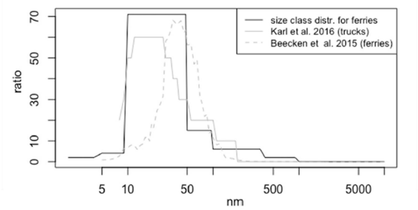

Figure 1: Emission fraction distribution of particle sizes from ferry boat emissions. For the simulations, engines of ferry boats were treated like diesel truck engines (light-grey line)

- In Hamburg: 25 vessels with diesel engines on 7 routes, 60% equipped with selective catalytic reduction unit and particle filter
- Particle number emission factor and size distribution of diesel truck engines applied in simulation

UFP measurements

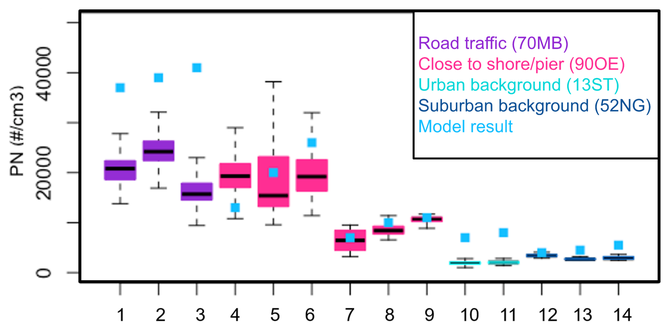

Figure 2: Measurement of UFP at four stations in Hamburg at five days during February 2021 on precipitation free days with low wind speeds for 2 hours each (1 sec values) with a TSI P-Trak Ultrafine Particle Counter. Comparison to CityChem model simulation results [1]. Correlation: r = 0.85; FAC2 = 0.79; NMB = 0.43; Normalized mean error: 50% [2]

Simulation of ferry boat contribution

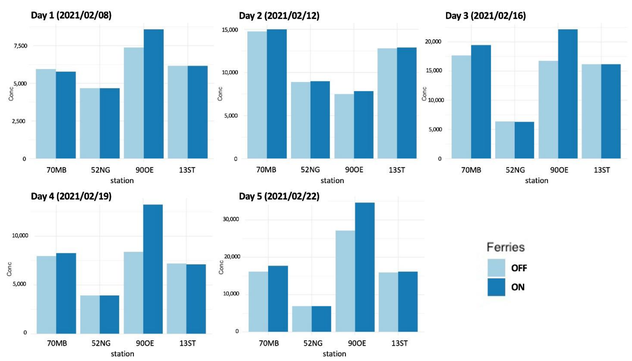

Figure 3: Contribution of ferries to UFP concentrations at the four different stations on five days. Simulation with CityChem model in two different modes: emissions from ferries on/ferries off [2].

Modelled daily average particle number concentration in particles per cm^3 in the Hamburg urban area on five days in February 2021;
Area: 30x30 km^2
Resolution: 100x100 m^2

The five-day average contribution of ferryboat emissions is 21.2% at the ferry pier station (90OE), 4% at the road traffic station (70MB) and <0.1% at the background stations (52NG, 13ST) [2]

Contribution on local scale

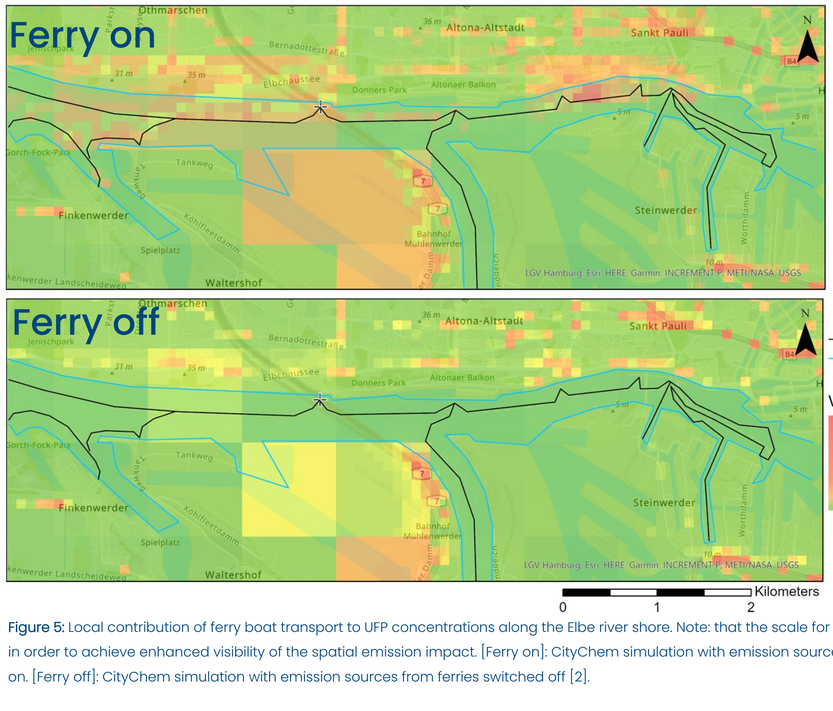

Figure 5: Local contribution of ferry boat transport to UFP concentrations along the Elbe river shore. Note: that the scale for the maps is manipulated in order to achieve enhanced visibility of the spatial emission impact. [Ferry on]: CityChem simulation with emission sources from ferries switched on. [Ferry off]: CityChem simulation with emission sources from ferries switched off [2].

Figure 4: Ferry boat of the public transportation system in Hamburg

Conclusions

1. Input data for major particle emissions sources in the city and the respective emission size distribution were provided based on existing emission data, sector-specific bottom-up calculation, and the shipping emission model MoSES [3]
2. Modelled hourly PN concentration ranges were 1.0–2.5 x 10^4 #/cm^3 in the city centre and 0.3 – 1.0 x 10^4 #/cm^3 in suburban areas
3. Particle emissions from regularly operating in-land ferryboats might present a significant contribution to inner city UFP concentrations
4. Simulation of particle numbers with the presented model system can help to capture und assess exposure to UFP in coastal cities
5. Future model simulations should cover longer periods to better understand the influence of meteorological conditions on UFP dynamics in cities

Acknowledgements

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References: 1: https://doi.org/10.5194/gmd-12-3357-2019 2: https://doi.org/10.3390/toxics10010003 3: https://doi.org/10.1016/j.aeaoa.2021.100132