Introduction: Nitrogen Oxide (NOx) Emissions

- Nitrogen Oxide (NOx) Emissions consist of Nitrogen Monoxide (NO) + Nitrogen Dioxide (NO2)
- NOx is in many urban areas the most problematic air pollutant
- Effects: health (asthma, allergies, heart diseases), acid rain, ozone production, change in atmospheric oxidation capacity
- Traffic is the main source (up to 80%) of NOx, especially diesel engines
- Busses contribute up to 30%, a significant part
- NOx real driving emission data for busses are sparse
- NOx emissions are not controlled over lifetime
- Regular real driving emission measurements would help to investigate high emitters and defective emission systems

ICAD NOx Instrument

- NOx Plume Chasing measurements require a mobile instrument with resolution and response time of max. few seconds and high accuracy (<5ppb)
- The new optical ICAD NOx device (Airyx GmbH) fulfills perfectly the criteria
- It is combined with an IR CO2 sensor (K30, Sensair)
- Oxidation of NO by O2 to NO2
- Direct optical NO2 measurement (represents NOx) by characteristic absorption structures (ICAD principle)

NOx Real Driving Emission (RDE) Measurement with Plume Chasing

\[ E_{NOx} = E_R \times EC_{O2} \]

- Correct background concentration of NOx and CO2 (measured when no vehicle is driving in front or at traffic lights)
- Calculate from the measured \( E_R \) = NOx/CO2 ratio the NOx emission \( E_{NOx} \) [mg/kWh]
- Use known CO2 Emission \( E_{CO2,\text{new}} \times 10^3 \) [mg/kWh] (assumes engine efficiency of 40%)
- Each vehicle investigated several minutes to cover different driving properties and derive realistic emission values
- Derived emission accuracy 10-20% (investigated with PEMS inter-comparisons)

NOx Real Driving Emissions of Public Buses (urban traffic)

Heidelberg/Mannheim (Germany) - 49 busses

- Older busses until EURO V show very high emissions
- Especially EURO V (incl. EEV – Enhanced Environmentally Friendly) are much above emission norm, also relative new busses
- EURO VI show typically very low emissions (strong improvement), emissions are close to EURO norm (on average 663mg/kWh)
- Individual EURO VI busses show very high emissions and are likely not correct working / defective emission systems
- Observed emissions are similar for different transport companies and cities
- Average Emissions of all investigated busses are on average ~1500mg/kWh (EURO IV level)

Reutlingen (Germany) - 22 busses

EURO Emission Norm

- EURO Norm define allowed emissions in EU
- Emissions are tested from the manufacturer in the lab, since EURO VI also by RDE (Real Driving Emissions)
- Total emission is a combination from typ. urban, country and highway driving modes (since EURO VI urban driving is more relevant)
- No guarantee for low emissions in urban areas

- To achieve low EURO V and VI standards → SCR catalyst is used
- AdBlue* (urea solution) form ammonia (NH3) which react with NOx to mainly nitrogen (N2) and water (H2O)
- Precise and dynamic AdBlue® injection is required

Conclusions

- ICAD NOx instrument allow easy NOx emission investigation with plume chasing principle
- NOx Real Driving Emissions in urban areas of busses until EURO V are very high (per passenger still low in comparison to cars)
- Especially EURO V (incl. EEV) and partly EURO IV busses show emissions much above EURO norm
- Low emissions for EURO VI busses, close to Emission Norm (per passenger much lower than for cars)
- Some EURO VI busses with high emissions are likely non correct working / defective emission systems → they can easily be identified with plume chasing measurements
- Upgrade of all busses (above 2000mg/kWh) to current EURO VI RDE level → reduction of total urban bus emission by ~80%
- Thus an upgrade of existing bus fleet could significantly improve urban air quality (up to 25%)