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Reference aerosols for PTI PN counters

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Particle quantification for PTI

Particle emissions in exhaust gases from motor vehicles are progressively being determined with number-based measuring instruments. Since July 2023 the measurement of the number concentration in the exhaust at the tailpipe is mandatory during periodical technical inspection in Germany [1]. For this purpose several measurement devices based on the technology of either condensation particle counters (CPC) or diffusion charge particle counters (DC) were developed. These measuring devices require periodic calibration against a reference system employing test aerosols.

Influence of particle size

Due to the fact that the signal from DC-detectors correlates to the aerosol length concentration but not to the number concentration, it depends on the particle size. Therefore, the test aerosols required for calibration have to be well-defined in terms of size distribution, particle shape and material. All required properties are specified in the "AU-Geräte Kalibrierrichtlinie" (German exhaust emission test equipment calibration guideline [2]). Typically, these test aerosols are produced by Collison-type atomizers employing saline solutions and a subsequent dilution by particle free air. Under field conditions the humidity of the diluted test aerosol has to be controlled to prevent the abrupt increase of particle size at the deliquescence point [3]. This effect is illustrated in Fig. 1 and 2.

Deliquescence effect

Salt particles adsorb water from the surrounding gas if the humidity exceeds a material-specific critical humidity (NaCl 75,5% r.H.). This process runs until the liquid and the gas phase are at equilibrium. Therefore, droplets are formed from solid particles spontaneously at this humidity, as illustrated in Fig. 1 (black data points). Due to the particle size dependence of DC-detectors their signal also increases abruptly at the deliquescence point, as shown in Fig. 2. The opposite process, turning a droplet into a solid particle proceeds at much lower humidity values, in the depicted data at about 55% r.H. (efflorescence point). Due to the hysteresis between 55% r.H. and 70% r.H. the status of the aerosol (liquid droplets or solid crystals) depends on the status before dilution. A droplet will remain liquid until the humidity falls below 55% r.H., a solid particle will turn into a droplet if the humidity exceeds 70% r.H.

How to prevent the effect during calibration?

For the correct function of DC-sensors the deliquescence effect has to be prevented by these measures:

- **Dilution by dry air** requires a membrane dryer or a diffusion dryer, which are challenging in terms of handling and regeneration under field conditions.
- **Drying the aerosol before dilution** well below 55% r.H. enables to generate stable aerosols with solid particles up to 70% r.H.
- **Drying the inlet flow** of the DC-sensor or heating the complete sensor.

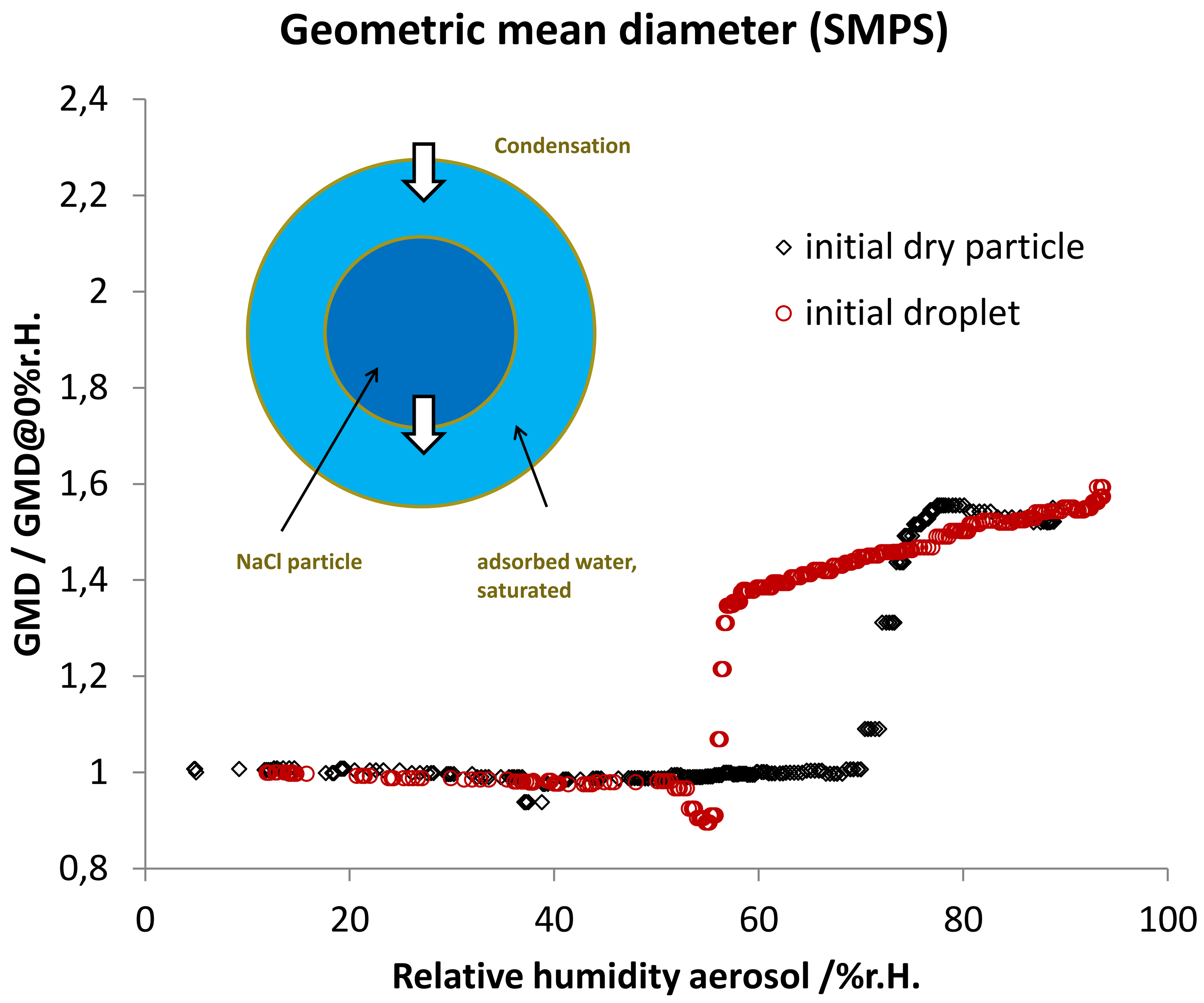

Fig 1.: Geometric mean diameter of NaCl aerosol particles/droplets as a function of gas humidity

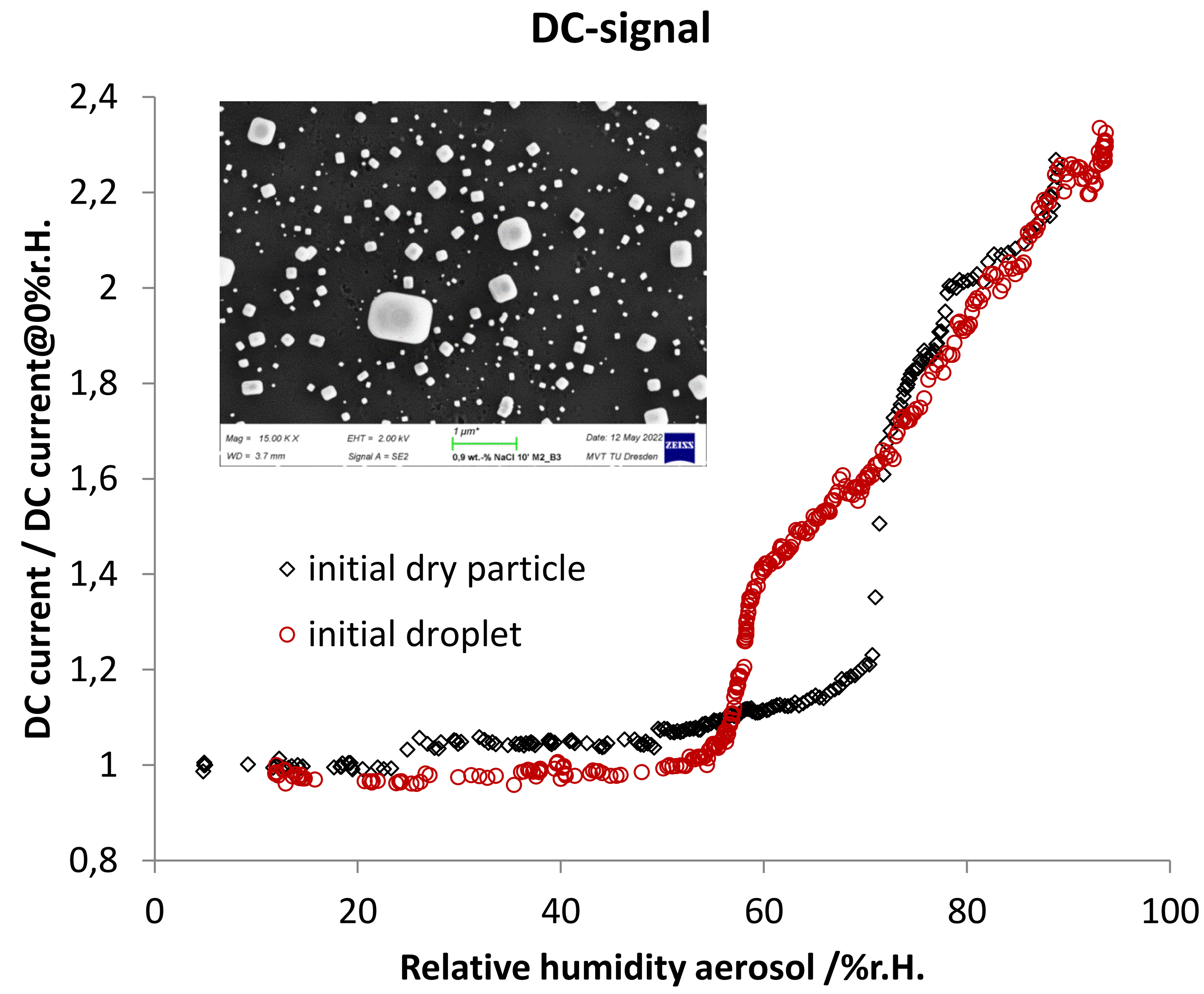

Fig 2.: Concentration signal of a DC-sensor (TSI EAD 3070A) from NaCl aerosol particles/droplets as a function of gas humidity

References

[1] Amtsblatt des Bundesministeriums für Digitales und Verkehr der Bundesrepublik Deutschland Nr.73/2023 vom 08.05.2023, Verkehrsblatt Nr.11/2023

[2] Richtlinie zur Kalibrierung von Abgasmessgeräten, die für die Untersuchung der Abgase von Kraftfahrzeugen nach Nummer 6.8.2 der Anlage VIIIa StVZO eingesetzt werden ("AU-Geräte Kalibrierrichtlinie")

[3] Hämeri, Kaarle & Laaksonen, Ari & Väkevä, Minna & Suni, Tanja. (2001). Hygroscopic growth of ultrafine sodium chloride particles. Journal of Geophysical Research. 106. 20749-20758. 10.1029/2000JD000200.