Spatial and size distributions of ultrafine particles in the port and city of Rotterdam, Netherlands

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Introduction: Ultrafine Particles (UFP)

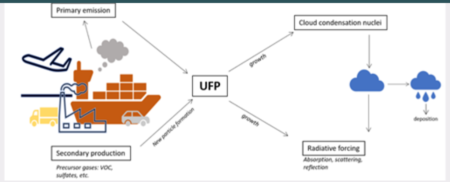
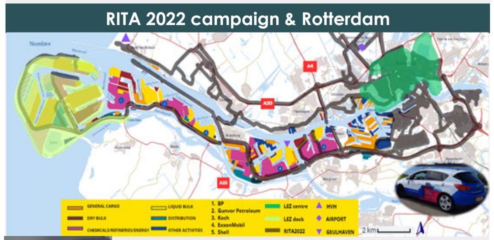


Figure 1: **Ultrafine Particles (UFP)** are defined as particles with a diameter of **100 nm** or less and are primary emitted by **industry and traffic** affecting the air quality on a regional scale. Additionally, UFPs form through condensation of atmospheric precursor gases. UFPs then grow through **coagulation** or **condensation** leading to the act as CCN, changing cloud formations and radiative forcing.

Currently, no monitoring networks exist to measure levels of UFPs in the Netherlands, which makes scientific research regarding health effects and spatial distribution difficult and has a detrimental effect on effective regulatory policy development.

RITA 2022 campaign & Rotterdam



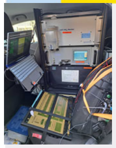


Figure 2: Measurements of the **UUAQ car mobile platform** during the RITA2022 campaign (**PM, UFP, BC, CO_2, NO_2**). Route and industries are classified. The Port of Rotterdam is Europe's **largest seaport** and with a population of **663,900** in 2023, the second most populated city in the Netherlands. Rotterdam is strongly influenced by prevailing **westerly winds** and experiences a temperate maritime climate.

TNO emission inventory

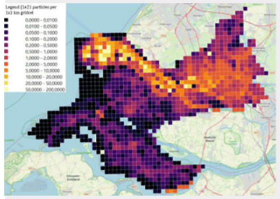


Figure 3: **Emissions** over the year **2019** in Rotterdam and surrounding municipalities. Spatial distribution over a **1x1 km grid**. There is uncertainty in emission factors causing this inventory to be prone to over- or underestimation. We **validated** the emissions with the RITA2022 UFP concentrations.

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Research objectives

1. Identify **hotspots** and distinguish UFP sources by examining **spatial patterns**.
2. Provide insight into the accuracy of **relative strengths** of UFP **sources** in Rotterdam by comparing spatial patterns of **particle number concentrations** and the estimated **emissions inventory**.
3. Investigate the importance of **particle growth** by mapping particle size distribution along a transect, and **loss to coagulation scavenging** by examining the **correlation between UFP and $PM_{2.5}$**.

Sources – Growth – Loss

Sources: Spatial patterns

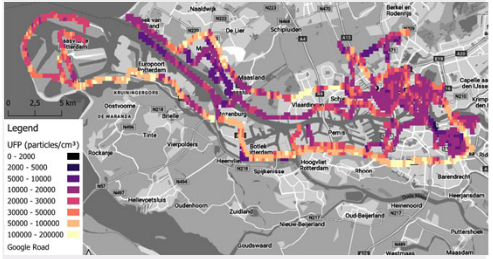

Figure 4: **Average** UFP concentrations averaged to a **200x200m grid**. Spatial patterns show highest levels of UFP on **highways** (A15 & A20) and along a **provincial road** (N223).

Figure 5: **Zoom-in** on TNO emissions inventory Rotterdam showing expected elevated UFP levels at the port area, airport and dock.

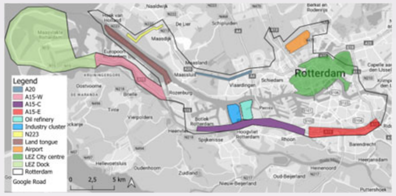

Figure 6: Selected focus areas in Rotterdam based on spatial patterns in concentrations and emissions. Note that the A15 is separated into 3 sections due to potential differences in vehicle traffic.

Concentrations vs. Emissions

We can use **concentration measurements** to validate **emissions** spatial patterns if we assume that when we observe a concentration hotspot – under conditions of roughly constant UFP lifetime and boundary layer height – these should be a similarly located hotspot in emissions.

Therefore, we compare the relative contribution of the concentration and emissions in the polygons represented in Figure 6.

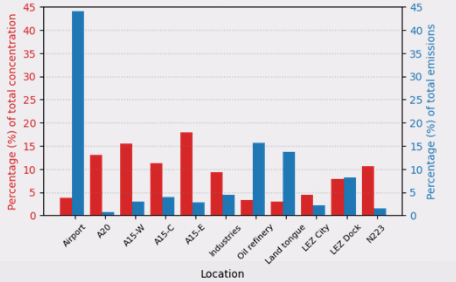

Figure 7: Percentage contribution to total concentrations (red) and emissions (blue); see area designations on the map in Fig. 6.

The **airport** area shows larger share of predicted emissions than concentrations, but data was sparse, and thus potentially not representative flight activity. **Highways** show larger share in concentrations than emissions, suggesting that automotive and freight vehicle traffic may be a larger source of UFP than captured in emissions factors.

We note there is a **potential bias in on-road sampling** versus spreading over a 1 km² emission inventory.

Growth: Growth rate along cycled transect

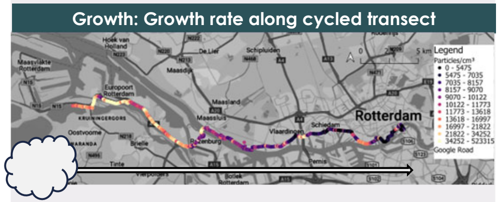

Figure 8: Cycled transect along the port area, during a day with westerly winds (9. May 2023). Measurements were made using a **Partector 2 Pro**. A gradient appears in the particle number concentration following the transect from West to East. We apply a simple growth rate model to this "**particle plume**" to check if we can observe particle growth through coagulation along the transect.

Growth rates

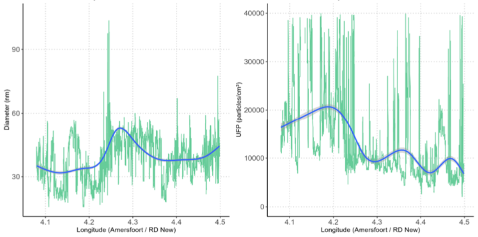

Figure 9: **Peak particle diameter** and **UFP number concentration** along the west-to-east the transect. Transect shows non-monotonic growth, while particle number concentrations show a decrease.

Analysis with measured windspeed resulted in an inferred overall growth rate of **2.6-3.8 nm/hr**, consistent with previous research in mid-latitude urban environments of 1-18 nm/hr (Holmes, 2007) & 1-20 nm/hr (Kulmala et al, 2004)

Loss: Can we observe UFP loss to $PM_{2.5}$?

UFP loss to $PM_{2.5}$ through coagulation leads to a decrease in UFP number concentration as they merge with larger particles and join the $PM_{2.5}$ fraction.

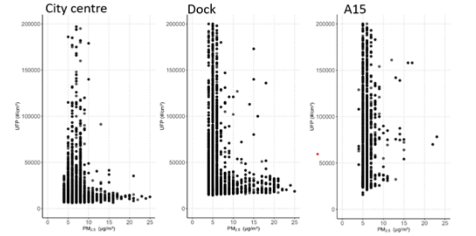

Figure 10: Anti-correlation between UFP and $PM_{2.5}$ for the city center and dock and could indicate particle loss due to coagulation. A15 shows the abundance of UFP on highways.

Acknowledgements

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