

Assessment of microplastic particle exposure in indoor football halls by correlative microscopy

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Motivation

Inhalative exposure to **micro- and nanoscale plastics (MNPs)** requires specialized particle analysis. This is critical in **indoor environments** such as polymer-processing workplaces, where aerosols mix with urban and environmental particles. Identifying a **specific aerosol fraction** (e.g. inhalable MNPs) demands both **morphological and chemical characterization** [1]. Conventional **scanning electron microscopy (SEM)** fails for polymers: polymer particles cannot be accurately identified or quantified within complex matrices. **EM-based elemental analysis (EDS/EDX)** is insufficient, as many polymers share similar elemental compositions.

Methodology

We applied a **correlative SEM–Raman method** to **classify, identify, and quantify** indoor aerosol particles. **Custom software** controls both microscopes, applies **AI-based particle recognition**, and records coordinates [2]. **SEM at low beam energy** provides high-resolution images of particles; candidates are pre-selected based on **size**. **Raman analysis** reveals chemical composition, enabling clear **MNP differentiation**. Combining **air sampling data, filter evaluation, and SEM–Raman analysis** allows estimation of **airborne concentrations** of size- and substance-defined particles.

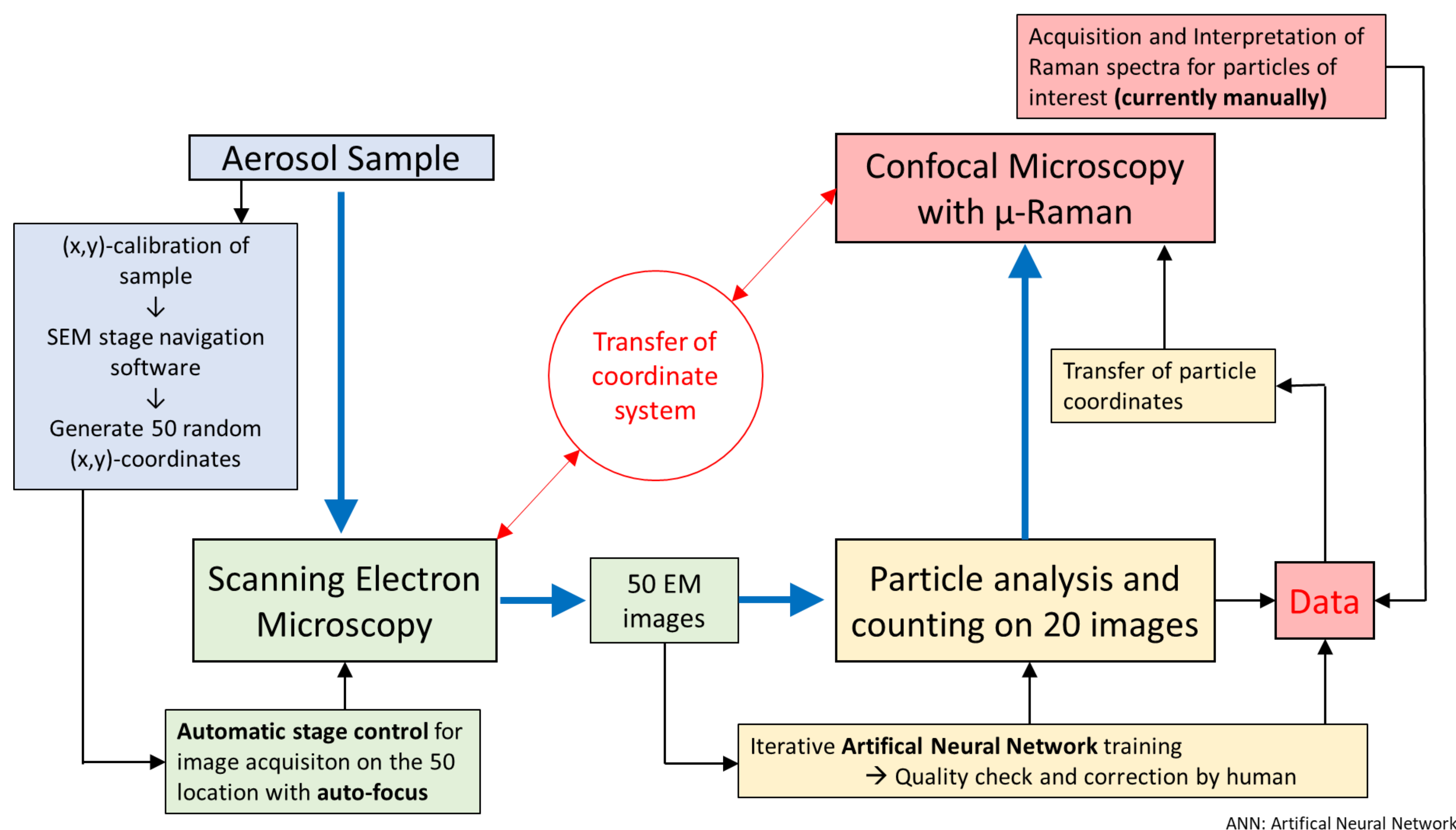
Scenario: Norwegian Indoor football halls with different artificial turf filling materials



Air sampling used **polycarbonate (PC) track-etched membrane filters** (800 nm pores). Filters were **gold-sputter coated** (≥ 60 nm) to reduce surface charging and suppress PC crosstalk in **SEM–Raman analysis**.

Sampling Strategy: **Lab blanks, field blanks, and outside samples** were taken. **Indoor filter samples** collected ambient particles for differentiation of **urban aerosols vs. indoor MNPs**. All samples were **blinded** to ensure unbiased analysis.

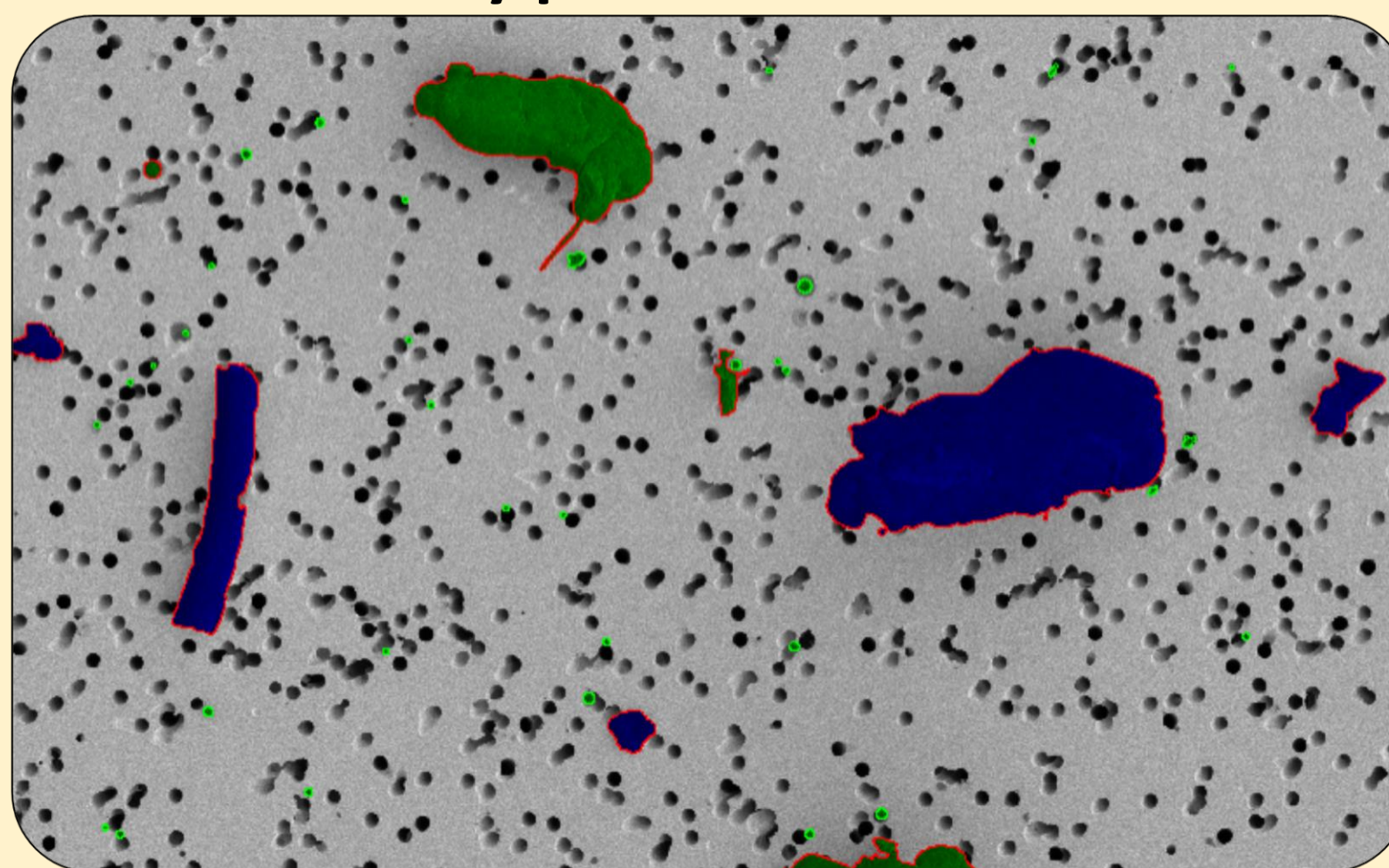
Analyzing Process: Correlative microscopy combining SEM imaging, AI and Raman spectroscopy



Workflow for chemical substance-specific particle analysis

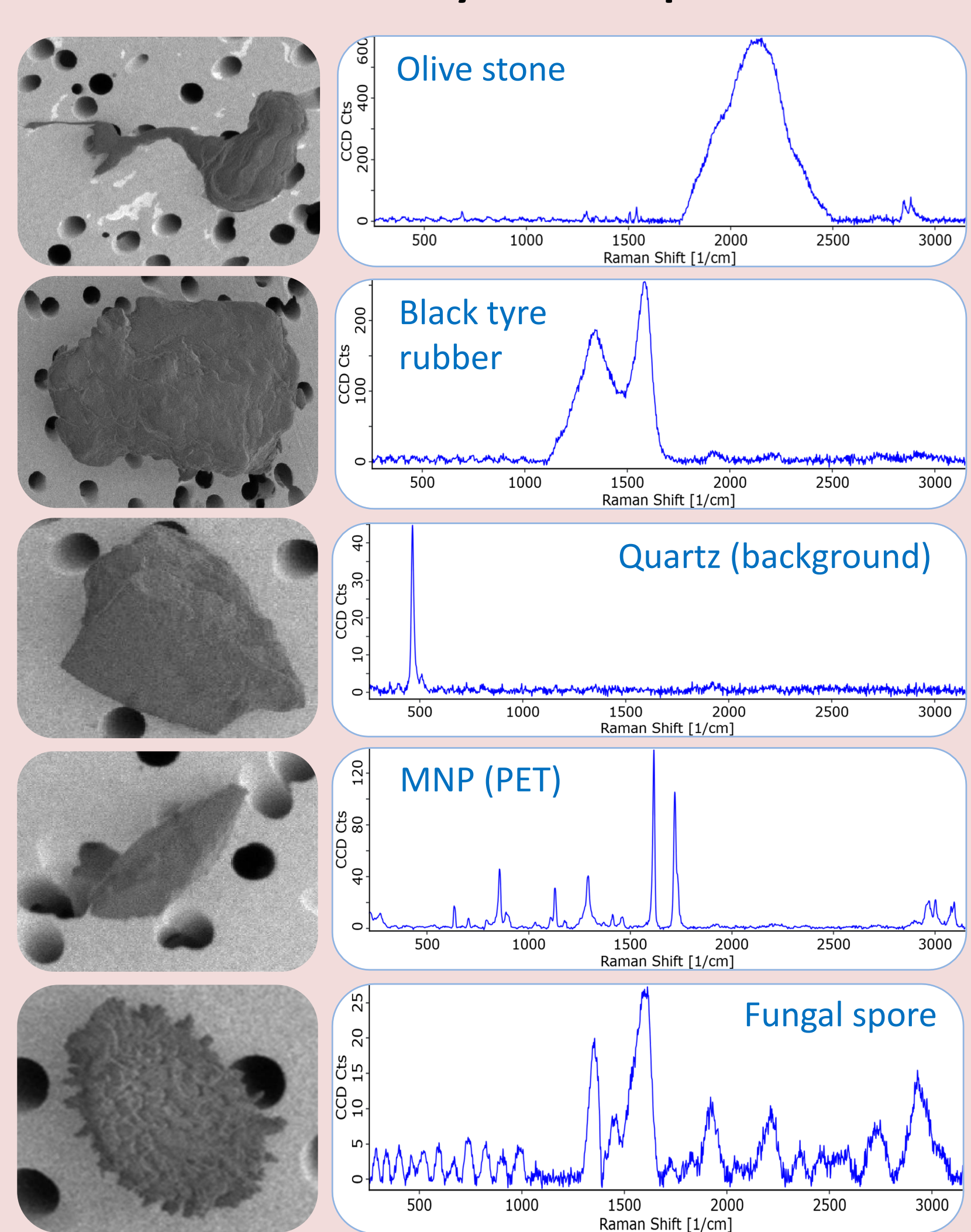
- **SEM imaging:** High-resolution, low-voltage SEM, minimizing material damage.
- **AI-based image analysis:** An **artificial neural network (ANN)** performs **semantic segmentation**, marking particle location and shape.
- **Morphology & size:** Dimensions are determined via a **segment interpretation algorithm**.
- **Coordinate referencing:** Particle positions are mapped to a **filter-specific coordinate system** using **in-house software** controlling both the **Hitachi SU8230 SEM** and **WITec Apyron RA 300 Raman microscope**
- **Selection criteria:** Particles are chosen by a **minimum projected area** equivalent to the substrate pore diameter ($> 0.6 \mu\text{m}$).
- **Chemical identification:** Selected particles undergo **correlative confocal Raman spectroscopy (532 nm)**.

Automated particle characterization to identify particles of interest



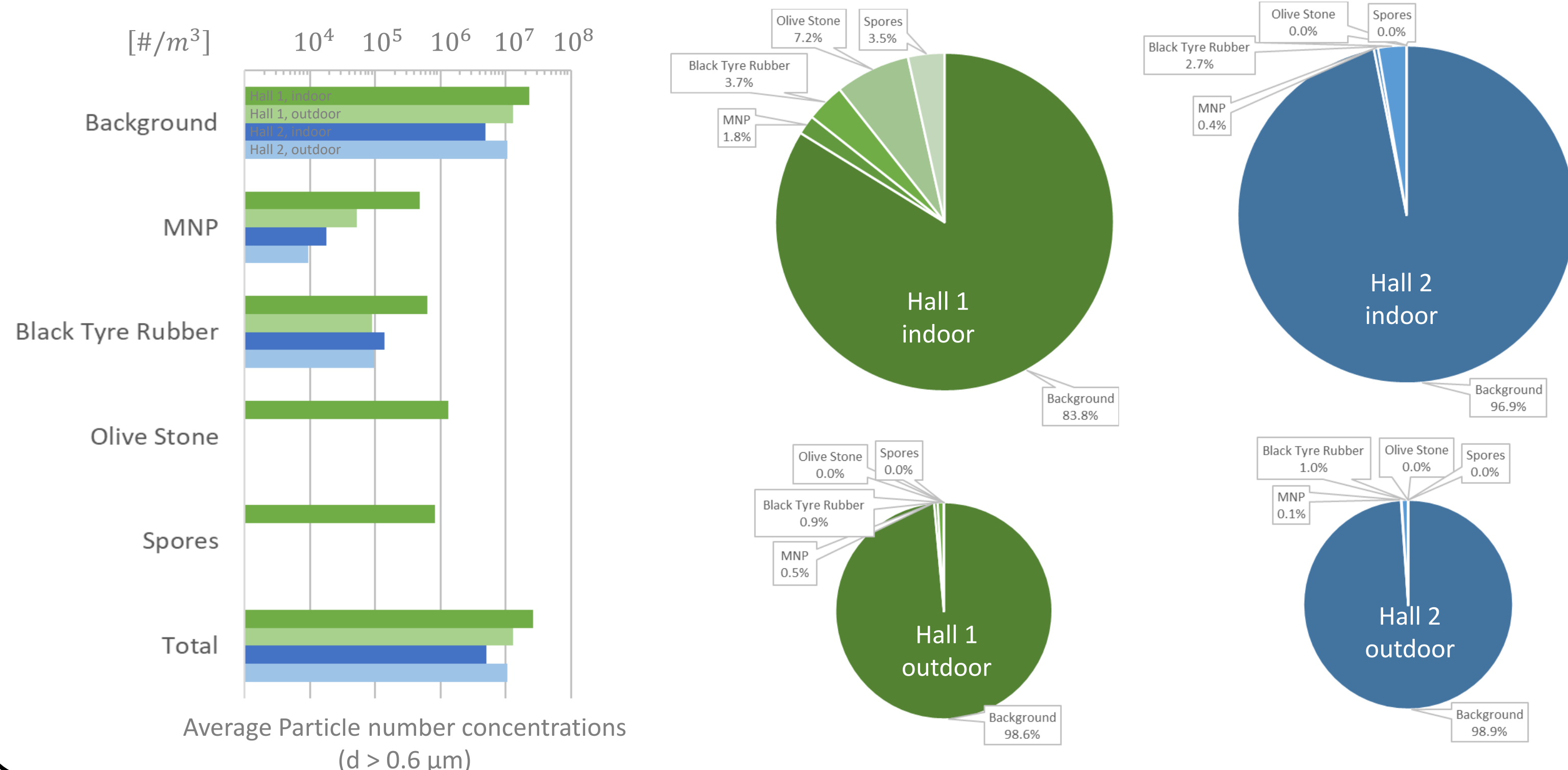
Object Recognition on SEM images by trained **ANN**, including **morphological identification & characterization**

Chemical structure identification for particles of interest by Raman spectra



As expected, we found particles of the two infill materials: **olive stone** and **tyre rubber**. Additionally, quartz sand was present both infills/halls. The **background** consisted primarily of urban particles, including **soot, minerals**, and particles of probable **natural origin**. Only a small number of particles in both indoor and outdoor samples were identified as **MNPs** (PE, PS, PET, PC, rubber). One hall contained **fungal spores**.

Extrapolated particle identity-specific results for the indoor & outdoor aerosols



Both halls had a generally **low concentration** of **airborne particles** ($d > 0.6 \mu\text{m}$). Most particles were **background** and only a **small fraction** were **MNPs**. Particles of the **turf** were also detected in the **indoor air samples**. **Black tyre rubber** transported inside from the environment and from the dataset, their release by the turf in hall 2 cannot be proven. Our research provides evidence for the **presence of fungal spores** in the olive stone turf football hall.

[1] Levermore, J.M. et al. (2020): "Detection of Microplastics in Ambient Particulate Matter Using Raman Spectral Imaging and Chemometric Analysis", Analytical Chemistry 2020 92 (13), 8732-8740

[2] Schumann, J., et al. (2019): "Automated Detection, Tracking and Characterization of Toxicologically Relevant Nanoscale Fibres in Scanning Electron Microscope Images.", IEEE International Symposium on Biomedical Imaging. ISBI 2019, April 8-11, 2019, Venice Italy IEEE, 2019