

Real-Time PTR-MS Monitoring of VOC Breakthrough Profiles to Estimate the Working Adsorption Capacity of Domestic Filter Materials

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INTRODUCTION

Recirculating range hoods use activated-carbon filters to reduce cooking odours and VOCs. Nitrogen adsorption on shredded filter samples characterizes accessible surface area and pore structure, but it does not show how the carbon is distributed on its supporting mat or how the complete filter performs under flow. We therefore measure the working adsorption capacity of intact filter cartridges by monitoring the outlet concentration of methyl ethyl ketone (MEK), a model VOC, in real time with PTR-MS. We then compare this capacity with the pore measurements to examine how both material properties and filter architecture relate to performance.

MATERIALS & METHODS

SAMPLES: Six homogeneous reference mats and 18 industrial filters with different architectures.

CNR-IBE Laboratories | Dynamic adsorption test

Calibrated MEK flow generator with LCU

Original filter sample

Output MEK gas analysis by PTR-MS

The Liquid Calibration Unit (LCU) generates MEK gas at a known inlet concentration ($C_i = 1000 \text{ mg/m}^3$). The gas passes through the filter in its original cartridge; proton-transfer-reaction mass spectrometry (PTR-MS) continuously measures outlet MEK concentration (C_{out}).

Polytechnic University of Turin | Surface and pore analysis

Shredded filter in porosimeter

N₂ adsorption at 77 K

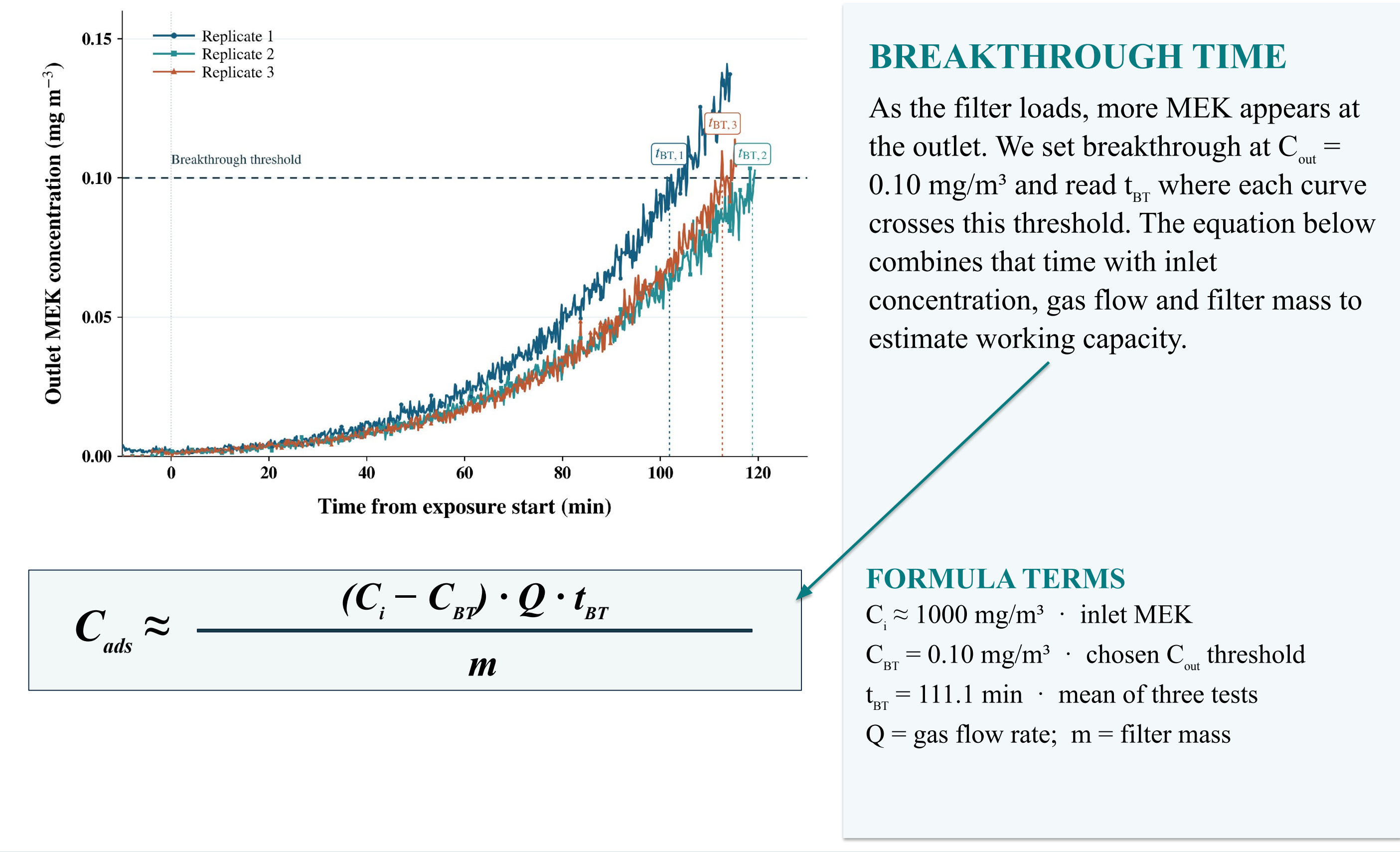
Isotherm → SSA & pore volumes

The filter is shredded and placed in a porosimeter, where it adsorbs N₂ at 77 K. Its uptake at different relative pressures produces an adsorption isotherm. A Brunauer–Emmett–Teller (BET) fit gives the monolayer capacity used to calculate SSA. Near-saturation uptake estimates total pore volume; a t-plot estimates micropore area and volume.

RESULTS

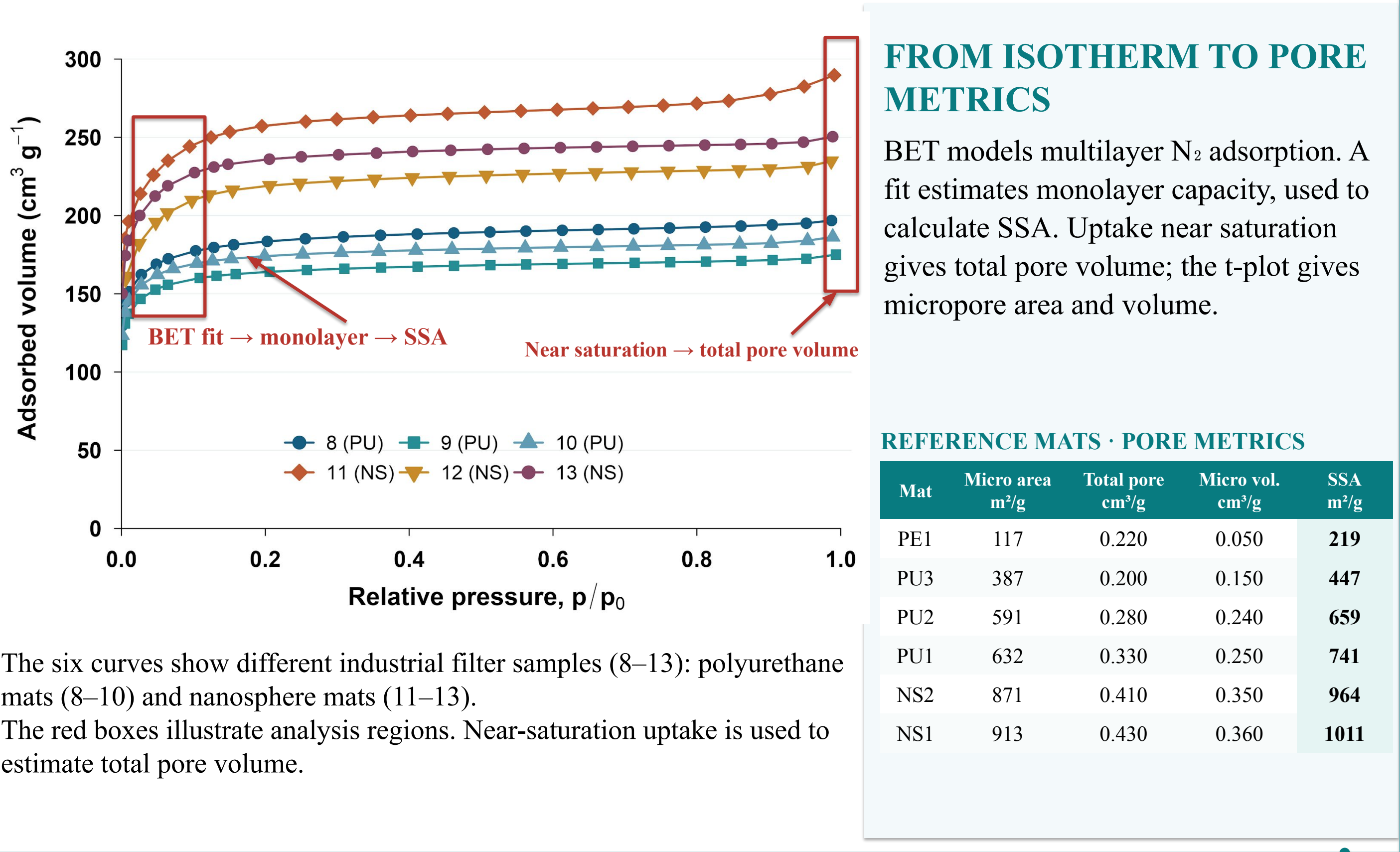
A | Breakthrough time (t_{BT}) and working capacity (C_{ads})

Example: PU3 filter sample, three replicate tests · outlet MEK concentration over time



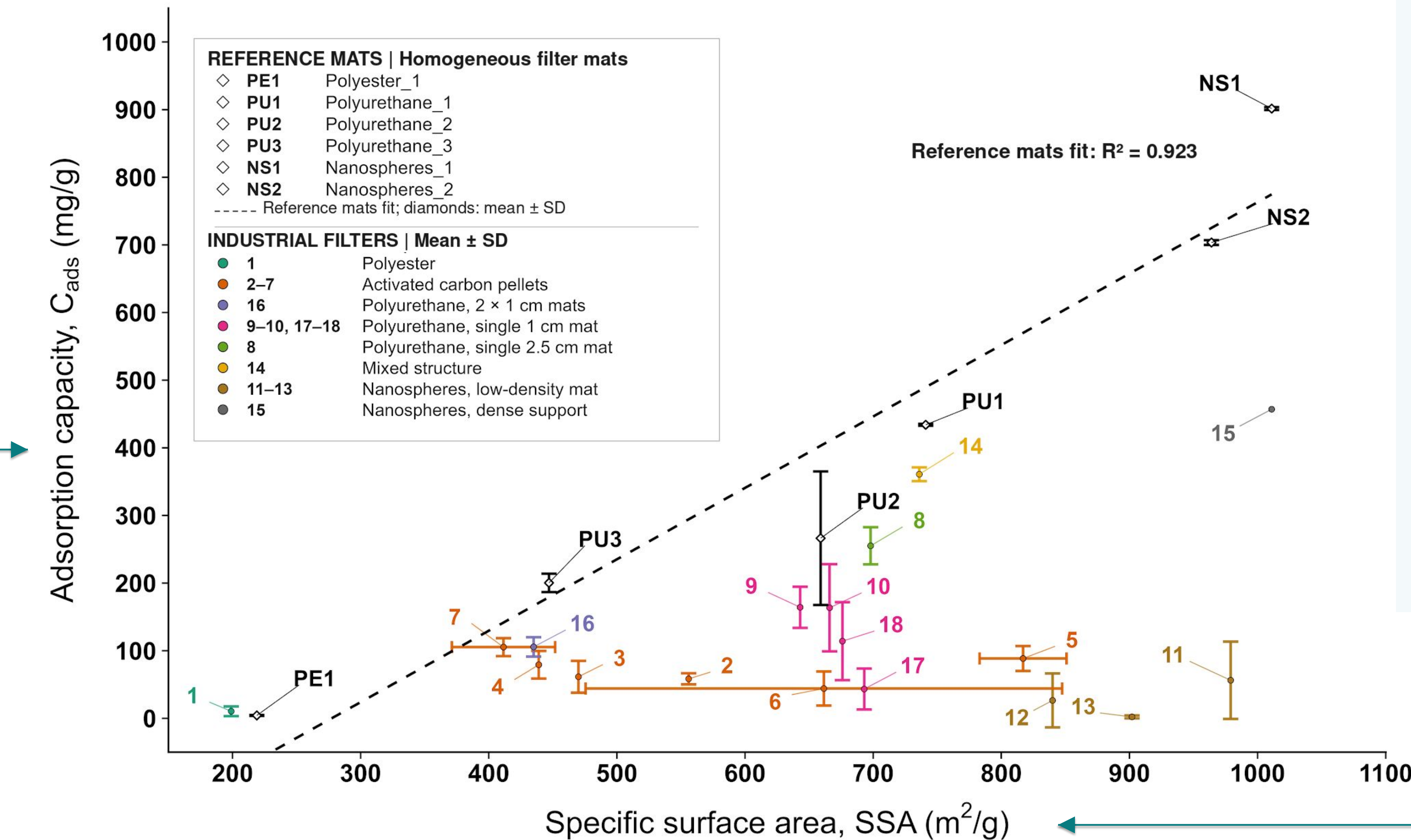
B | Specific surface area (SSA) and pore structure

Nitrogen adsorption isotherms · Industrial filters 8–13



C | Adsorption capacity (C_{ads}) versus specific surface area (SSA)

- 1 **REFERENCE MATS** Capacity rises with SSA in homogeneous mats ($R^2 = 0.923$).
2 **INDUSTRIAL FILTERS** Many have lower capacity than the reference trend at similar SSA.



REFERENCE MATS

Each reference sample represents a distinct carbon–mat configuration: one activated-carbon type on a uniform, relatively dense support. Diamonds mark sample means; error bars show ± SD. Capacity rises nearly linearly with SSA (dashed fit, $R^2 = 0.923$).

INDUSTRIAL FILTERS 1–18

Each number identifies one industrial filter; colors group filters of the same type, including products from different suppliers. At comparable SSA, their capacities are more scattered and some fall below the reference trend. Filters 11–13 contain high-SSA nanosphere carbon on sparse, perforated mats and show low working capacity.

CONCLUSIONS

- The filter material's specific surface area (SSA) alone cannot explain working capacity across filter configurations.
- PTR-MS breakthrough tests on intact filters reveal performance differences missed by pore measurements.
- Homogeneous reference mats provide an SSA–capacity benchmark; filters with different geometries can fall below it.

[1] Zatta et al. Molecules (2023), 28:7658. doi:10.3390/molecules28227658
[2] Zhang et al. Building and Environment (2022), 216:109011. doi:10.1016/j.buildenv.2022.109011