A Nano-size Particle Sampler using a Differential Mobility Analyzer

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Ikegami-shincho

Contents

- Objective
- Differential mobility analyzer
- PAH analysis using direct injection GC-MS
- Field sampling
- Results

Objective

- Differential mobility analyzer (DMA) extracts aerosol particles ranging from 1 to 1000 nm in diameter.
- It is advantageous that DMA can be operated at normal pressure condition, because volatile or semi-volatile PAHs are unstable at low pressure.
- We tested twin custom-made DMAs as nano-particle samplers.
- DMA sampling flow-rate was increased up to 4 l/min to increase sample mass.

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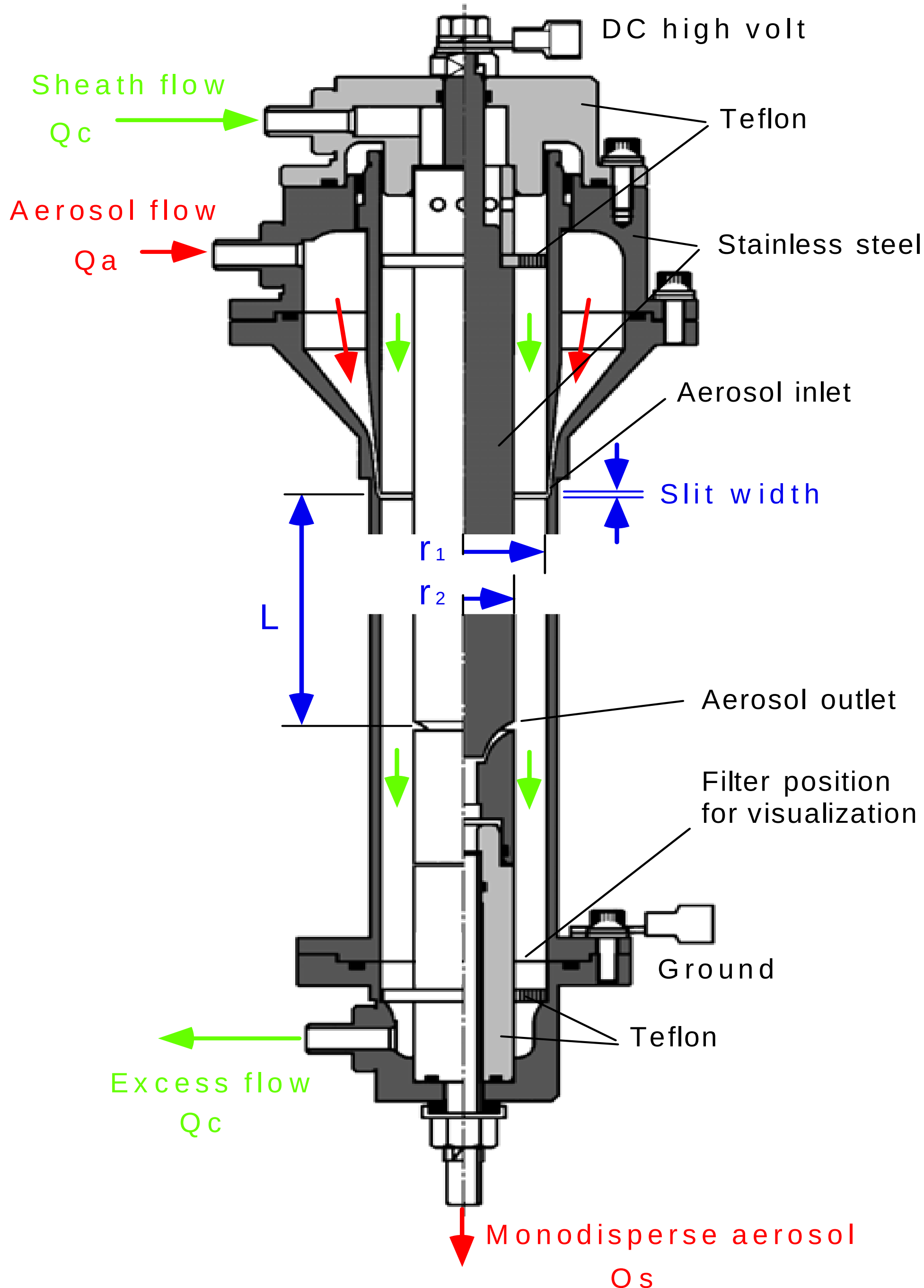
Specification of DMA

Electrode length
L: 40 cm

Electrode radius
r_1: 2.5 cm
r_2:1.5 cm

Applied voltage
V: 0 – 10000 V

Sheath flow rate
Qc: 3 – 30 L/min



Size classification theory of DMA

Electrical mobility of particle; Z_p

$$Z_p = peC_m/(3\pi\mu d_p) \qquad (1)$$

d_p: diameter, *p* :number of charge, *e* :elementary charge, μ :viscosity,

Cm: Cunningham's correction factor

Size classification theory of DMA (cont.)

Electrical mobility of particle extracted through DMA slit; Z_{pc}

$$Z_{pc}=\{Qc+(1/2)(Qa-Qs)\}\,ln(r_1/r_2)/(2\pi VL) \qquad (2)$$

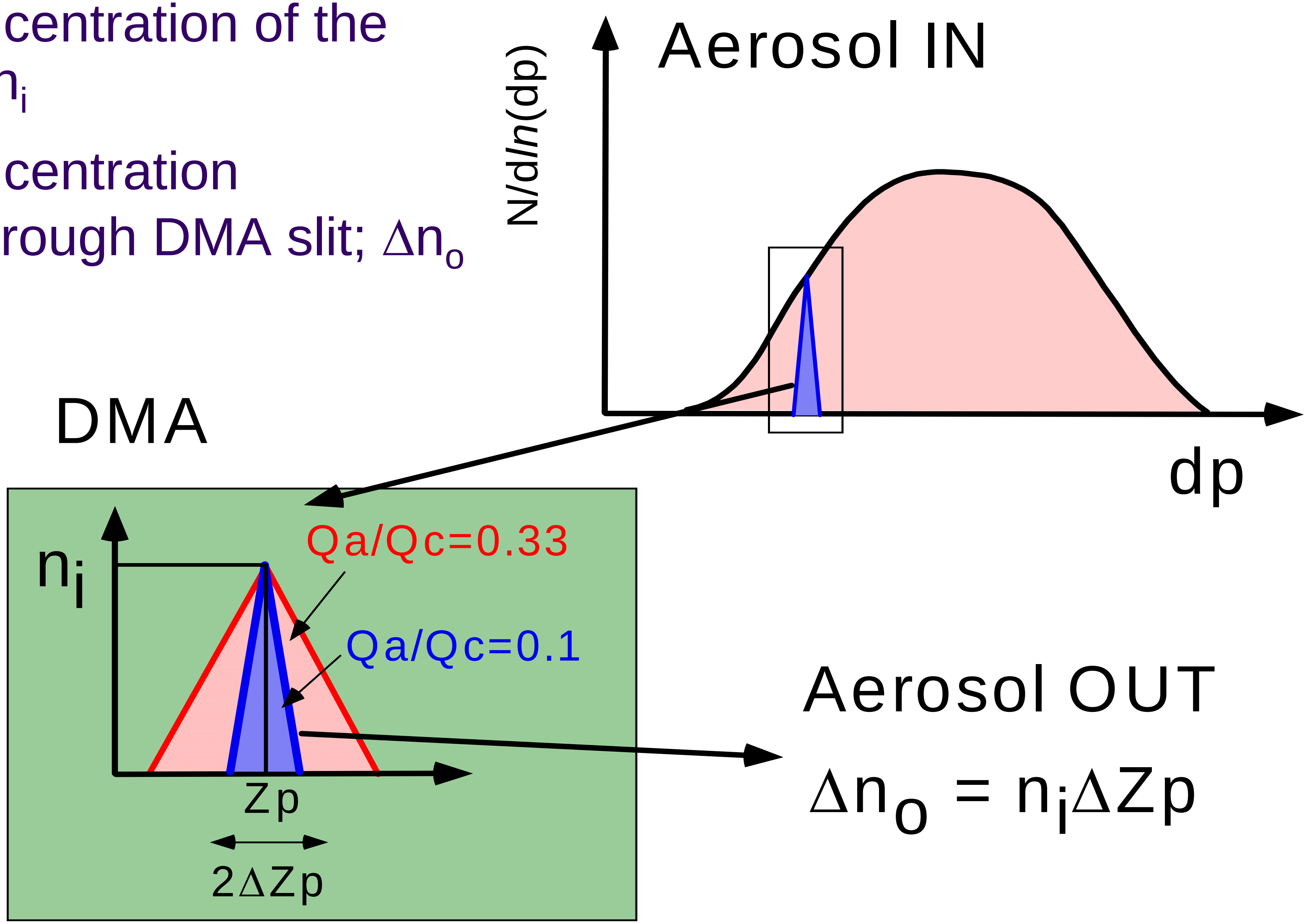
Width of the mobility spread; ΔZ_p

$$\Delta Z_p = (Qa+Qs)\,ln(r_1/r_2)/(2\pi VL) \qquad (3)$$

Aerosol concentration at DMA outlet

Aerosol concentration of the size at Z_{pc}; n_i

Aerosol concentration extracted through DMA slit; Δn_o



Aerosol concentration at DMA outlet

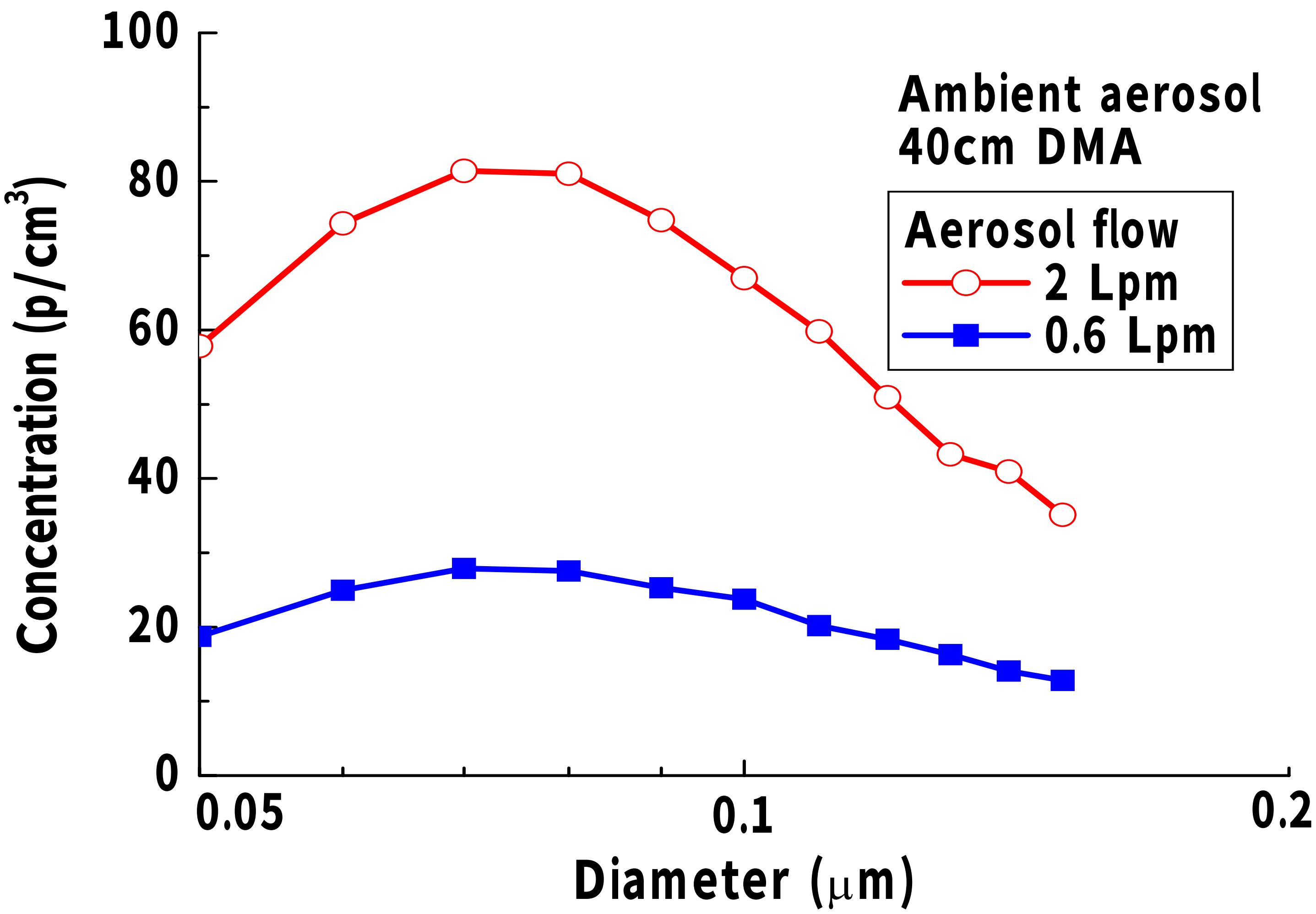
Aerosol concentration extracted through DMA slit; Δn_o
Aerosol concentration of the size at Z_{pc}; n_i

$\Delta n_o = n_i \, \Delta Z_p$ (4)

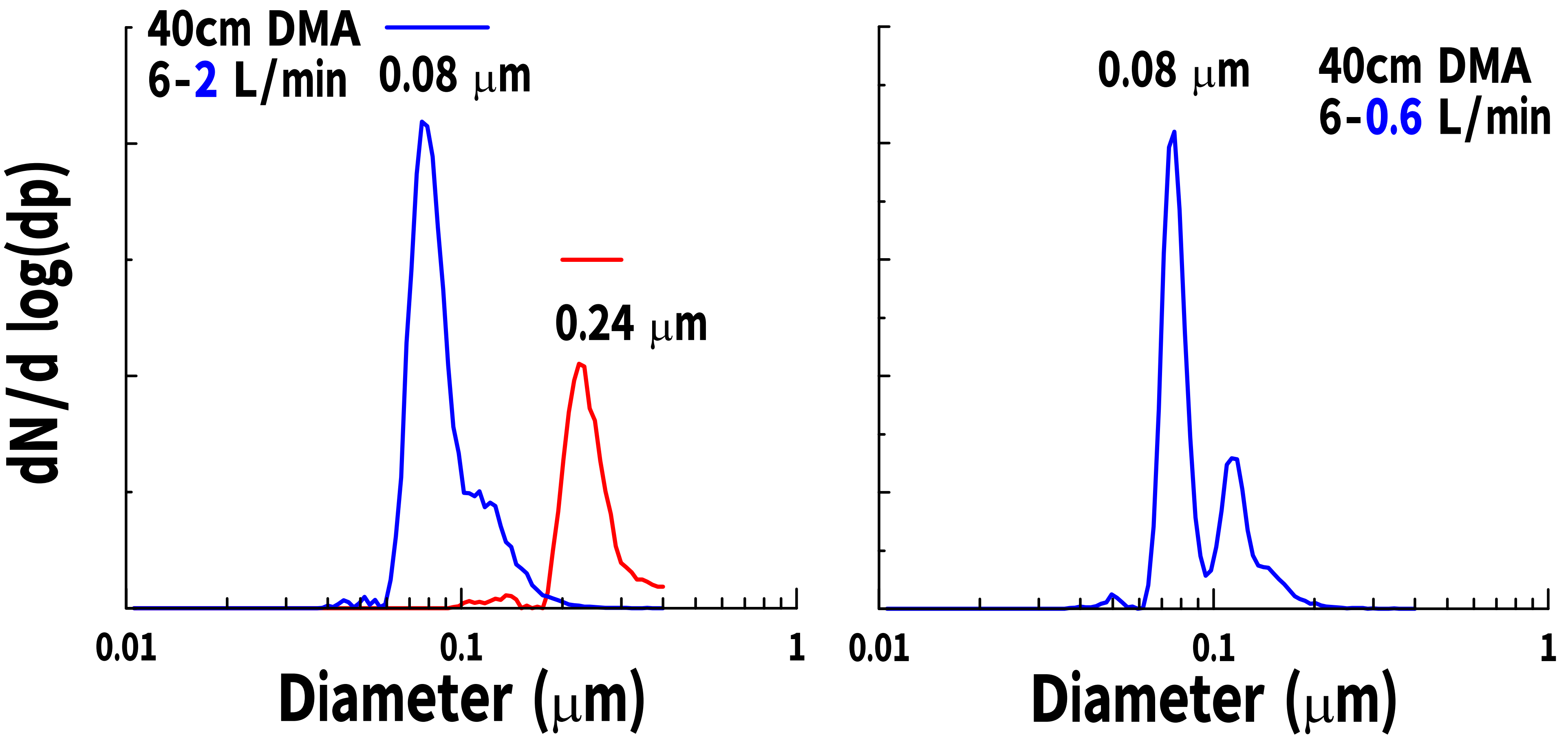
If Qa = Qs, then $\Delta Z_p = (2Qa/Qc)\, Z_{pc}$
$\Delta n_o = n_i \, (2Qa/Qc)\, Z_{pc}$ (5)

Collected particles $= Qa \, n_i \, (2Qa/Qc)\, Z_{pc}$ (6)
for unit time

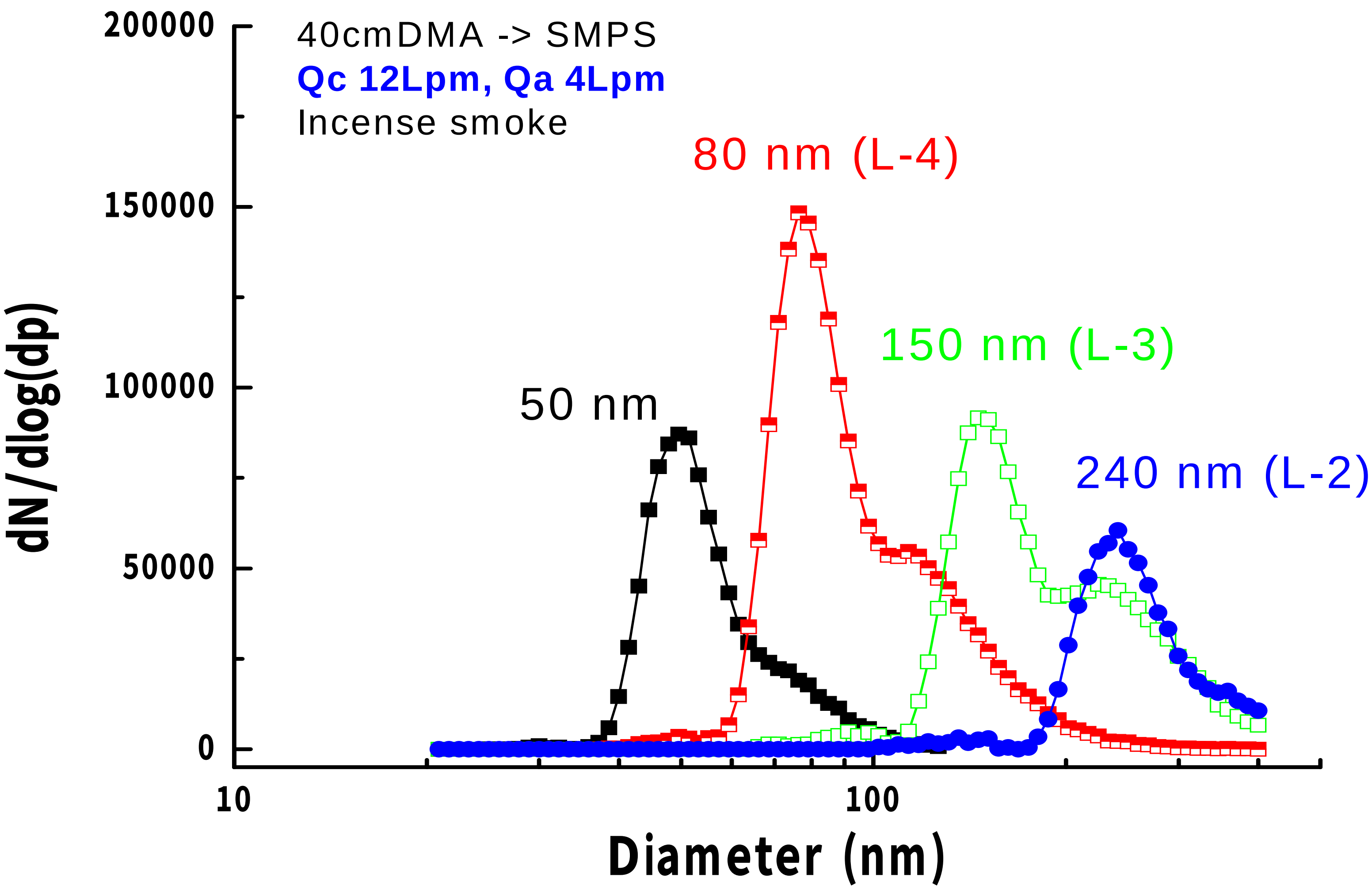
Ambient aerosol concentration at DMA outlet



Size distribution of outlet aerosol from DMA (sequentially measured by SMPS)



Size distribution of outlet aerosol from DMA (sequentially measured by SMPS)



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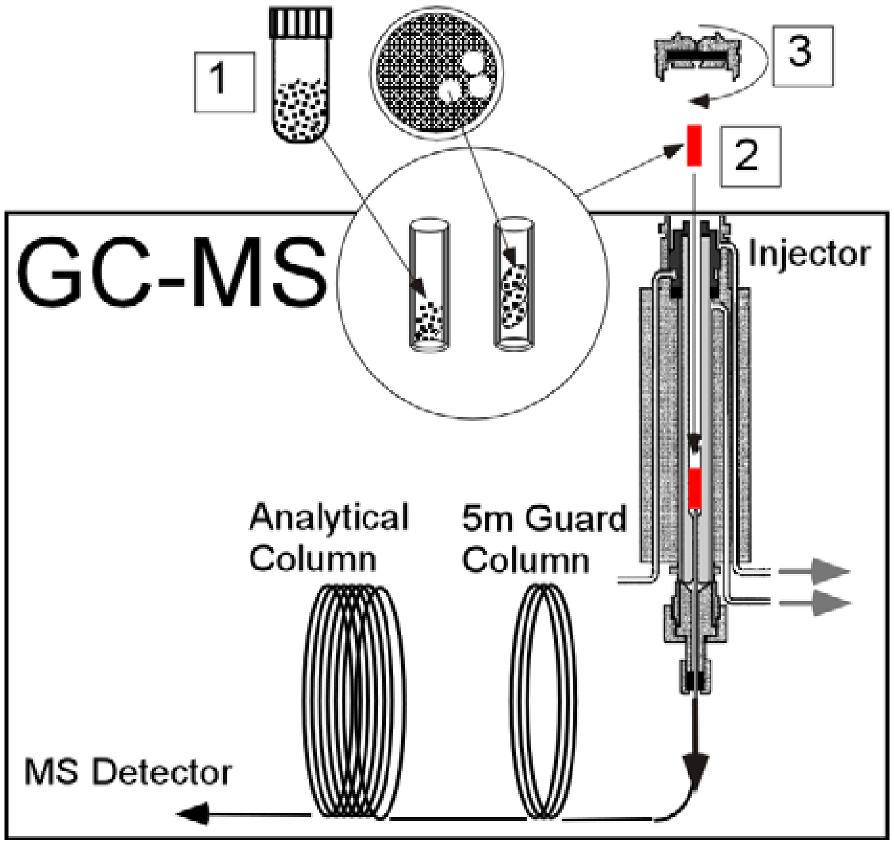
PAH analysis using direct injection GC-MS



Phenanthrene	PHE
Anthracene	ANT
Fluoranthene	FLU
Pyrene	PYR
Benzo(a)anthracene	BaA
Chrysene	CHR
Benzo(b)fluoranthene	BbkF
Benzo(k)fluoranthene	
Benzo(e)pyrene	BeP
Benzo(a)pyrene	BaP
Indeno(1,2,3-cd)pyrene	IND
Dibenzo(a,h)anthracene	DBahA
Benzo(ghi)perylene	BghiP

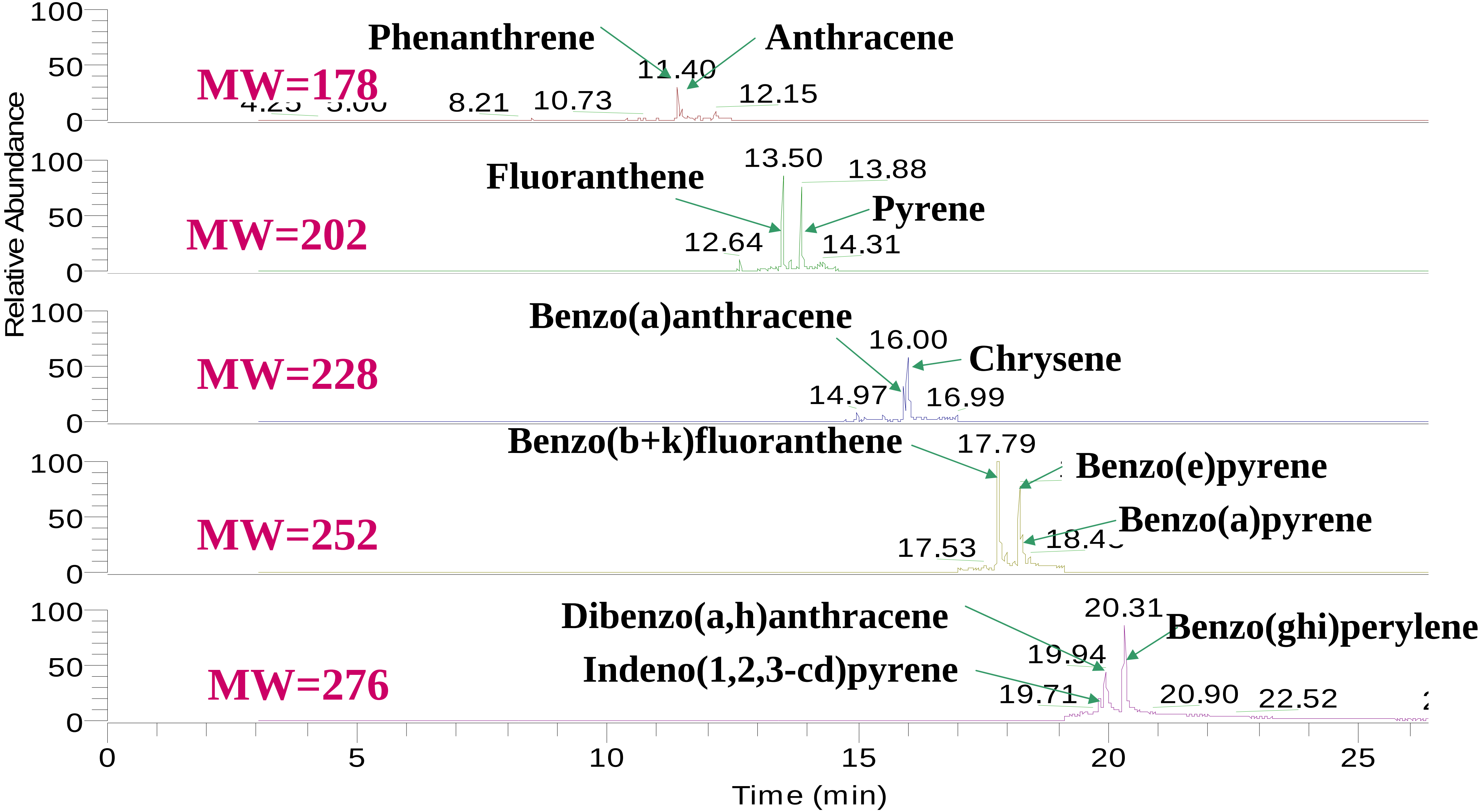
GC conditions

- Instruments: Thermoquest TraceGCQ
- Column:
  SGE HT8, 30 m x 0.25 mm i.d.,
  Film thickness: 0.25mm
- Carrier Gas : He 1mL/min
- Temp Condition: 80^{o}C (1 min, hold)
  15^{o}C/min to 350^{o}C (9 min)
- Inj. Temp: 300^{o}C, Splitless Injection

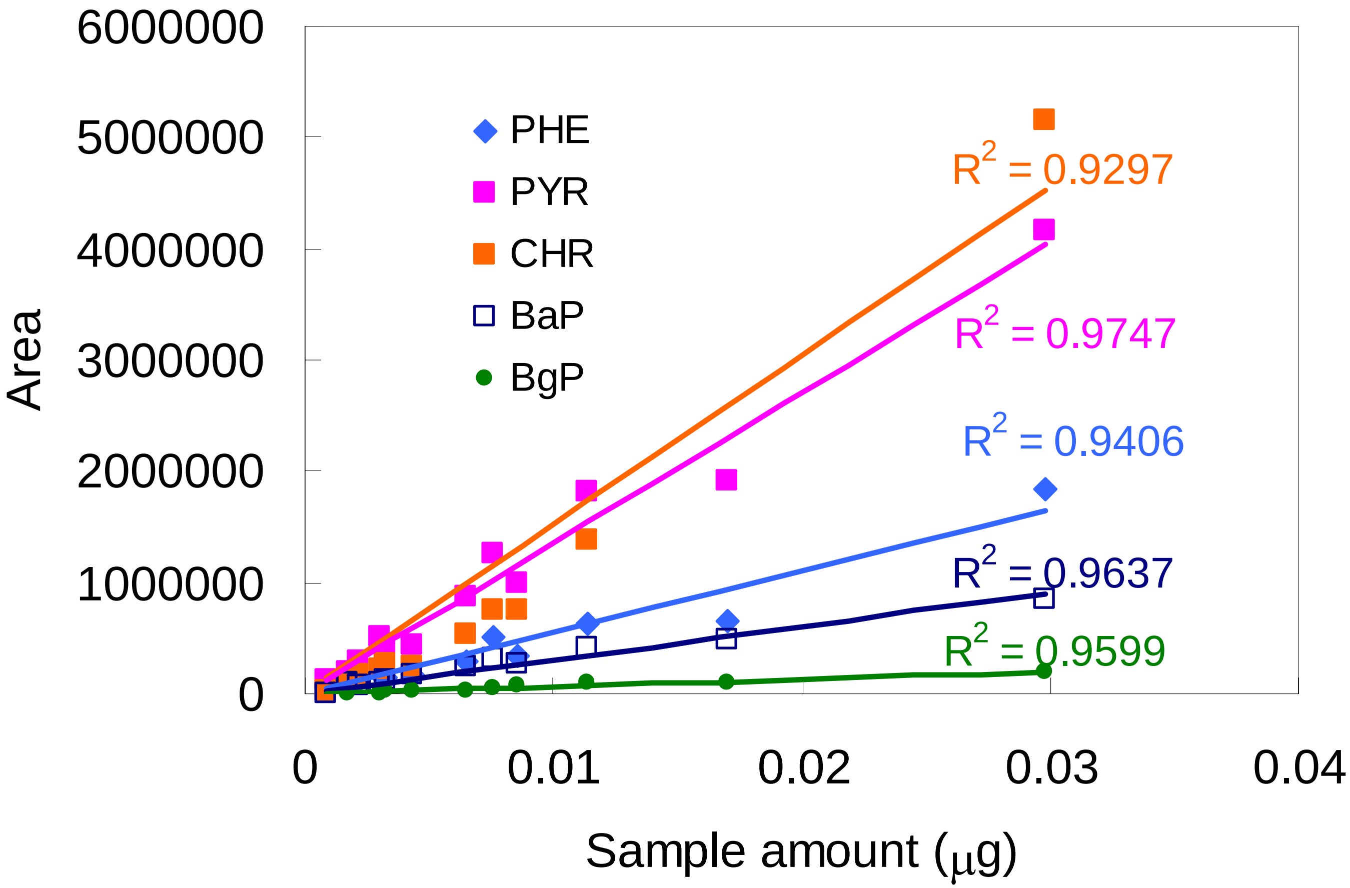
MS conditions

- Ion Source Temp: 225ºC
- Transfer Line Temp: 300ºC
- MS Mode: Selected Ion Monitoring (SIM Mode)
- Standard Sample:
  NIST Standard Reference Material 1649
  (Ambient Particulate Matter)
- PAH concentration was determined by comparison of peak area of the standard sample and collected sample.

Chromatograms (NIST SRM1649)



Calibration curves (NIST SRM1649)



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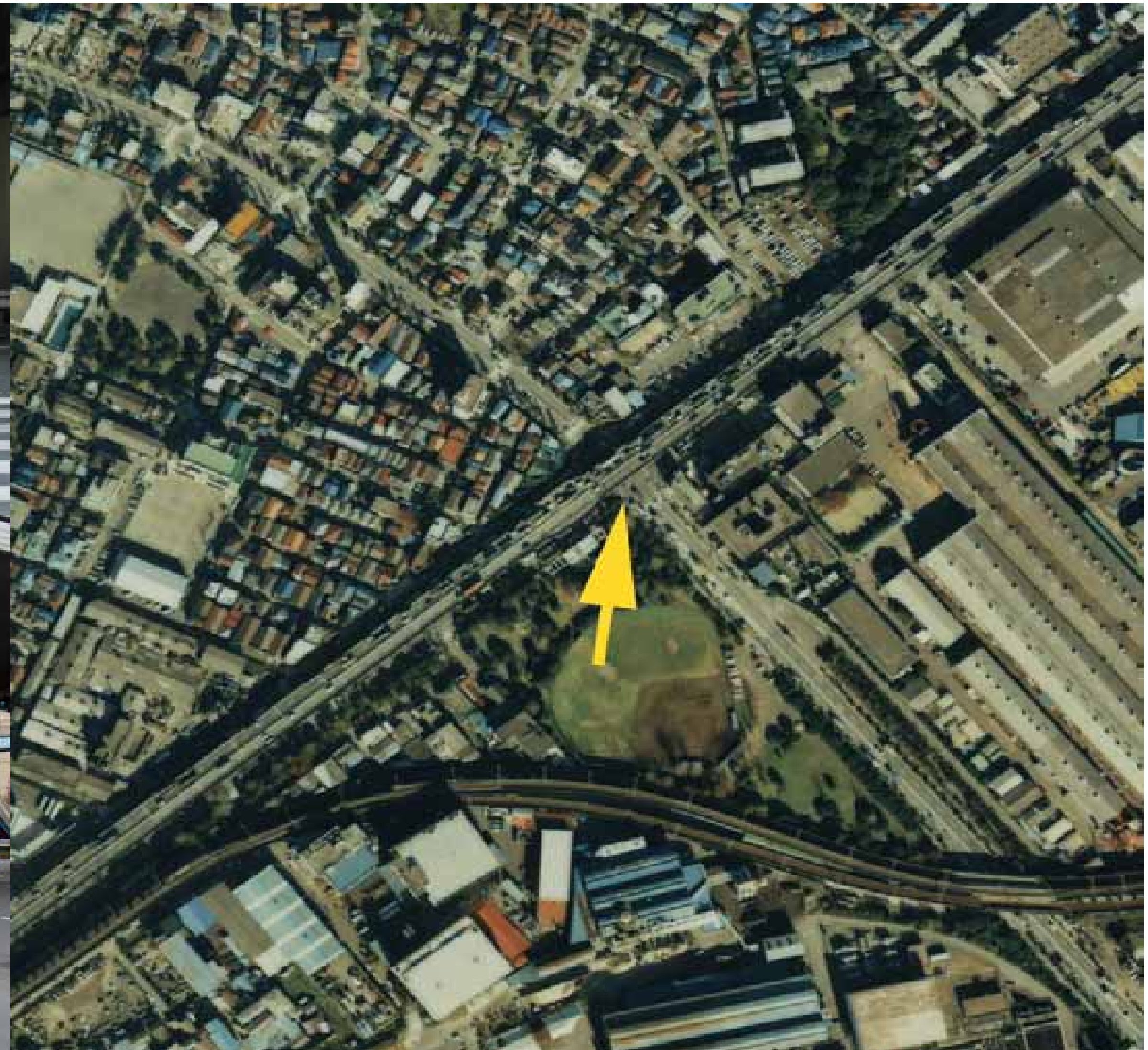
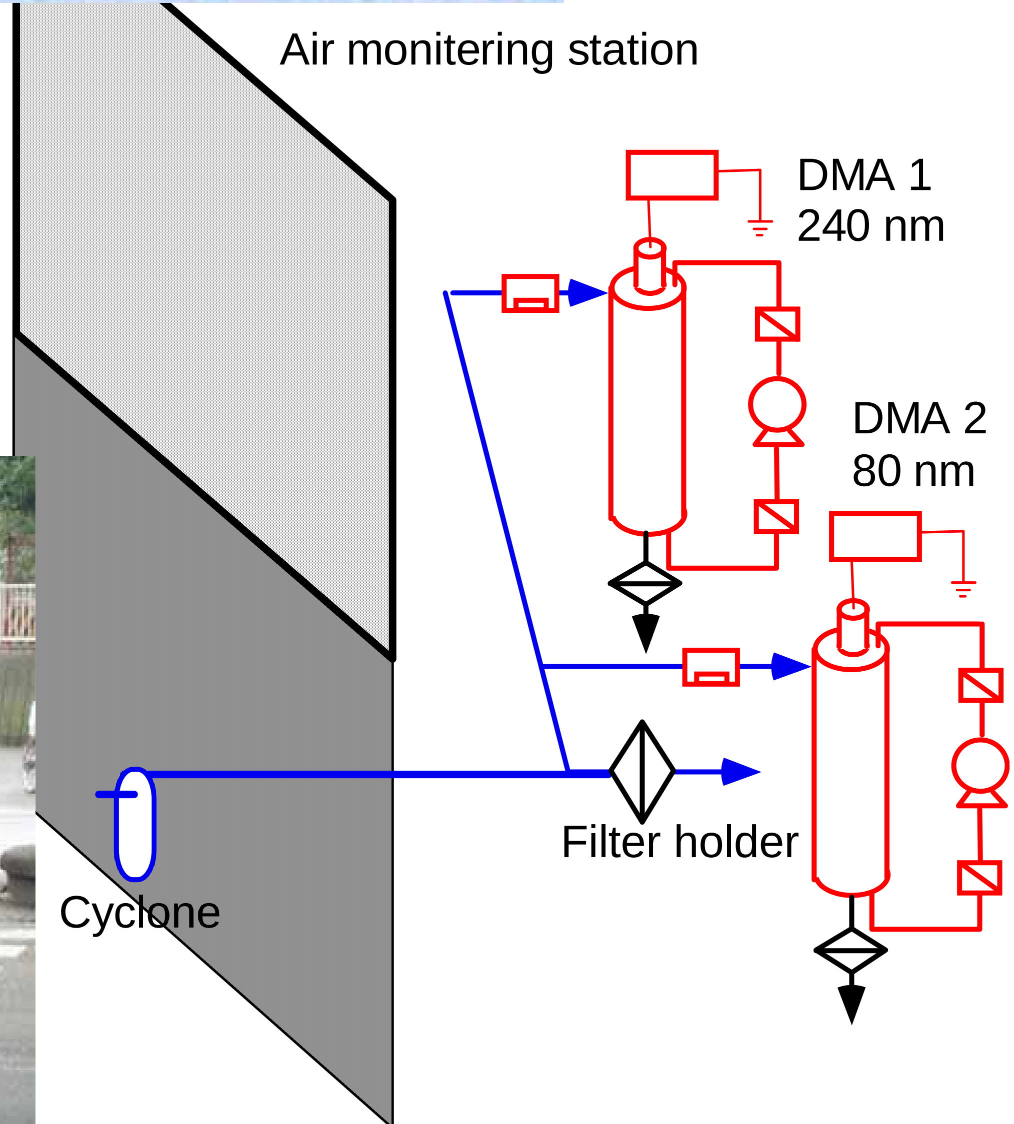
Ikegami-shincho, Kawasaki, Japan



Road side at Ikegami-shincho, Kawasaki, Japan



Sampling conditions

- Date: 2005, Jan. 24 – Jan. 28
- Sampling flow rate;

  Whole: 2 L/min

  DMA 1 and 2: 4 L/min
- DMA sheath flow rate: 12L/min
- DMA 1: 1025 V, DMA 2: 6090 V
- Filter: Whatman QM-A micro quartz fibre filter

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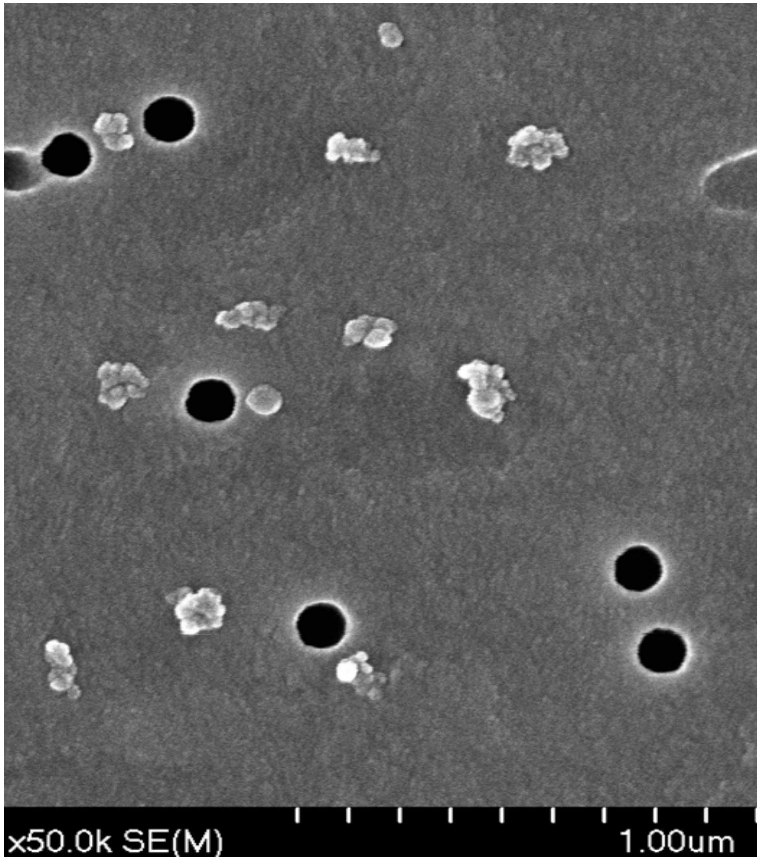
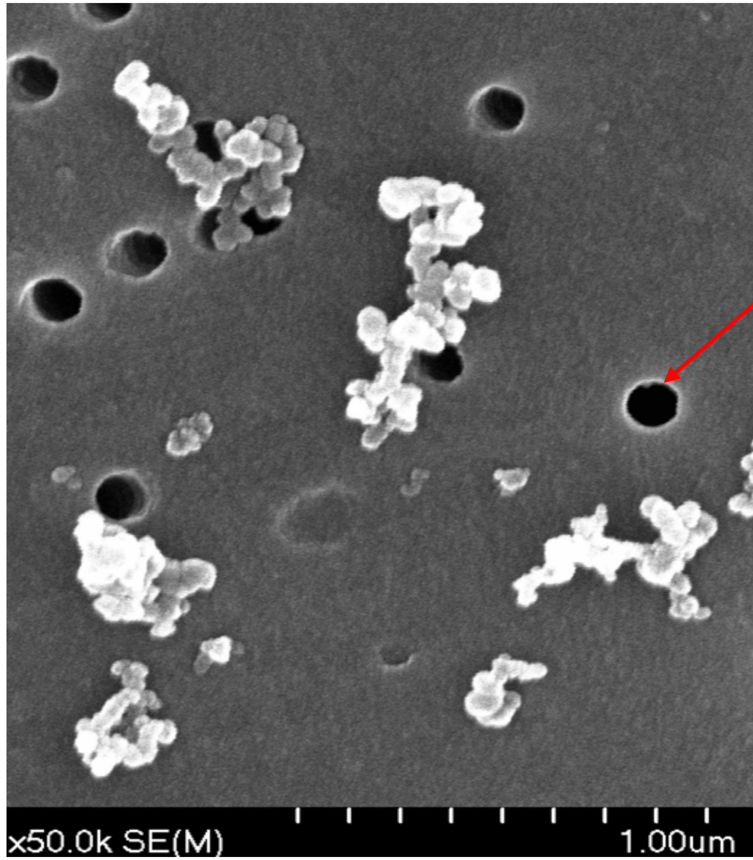
Particles deposited on DMA electrodes



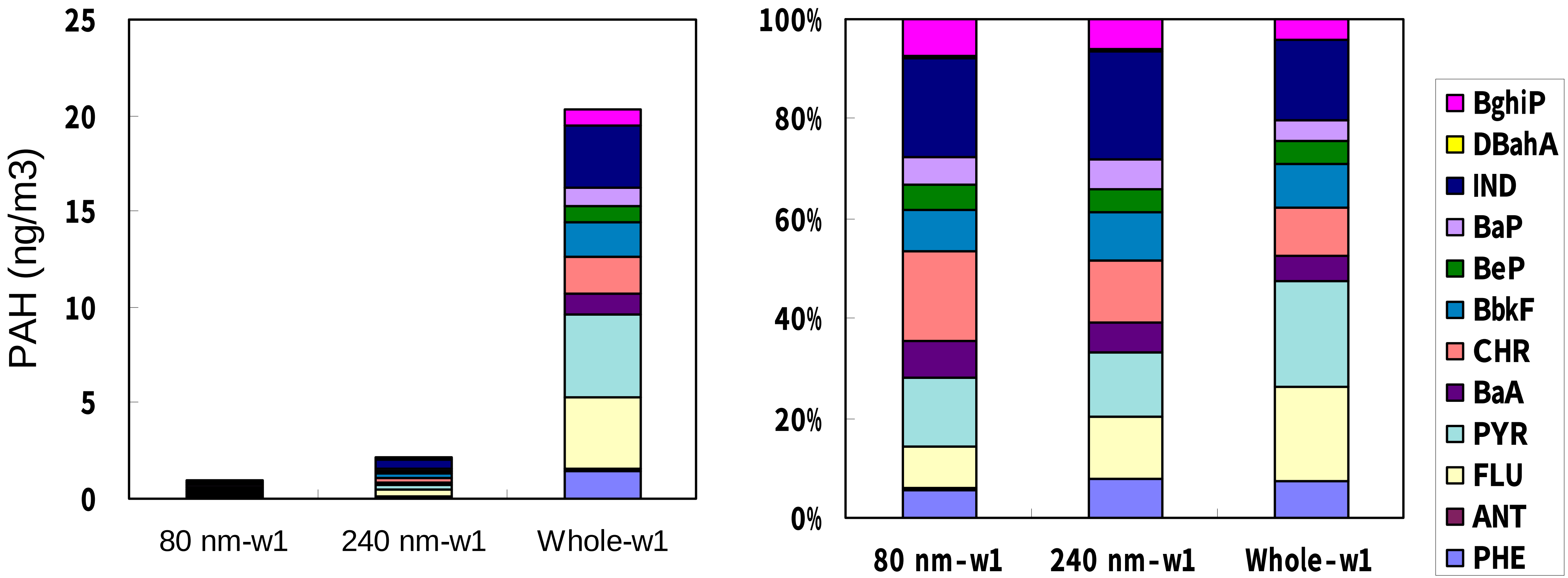
80 nm



100 nm pore

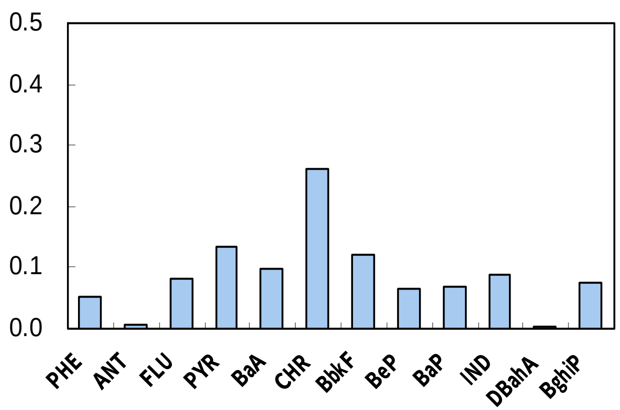
240 nm

PAHs concentration and their ratio

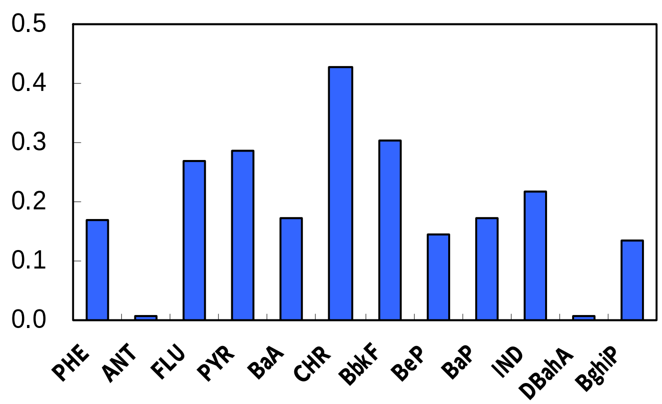


PAHs concentration and their ratio

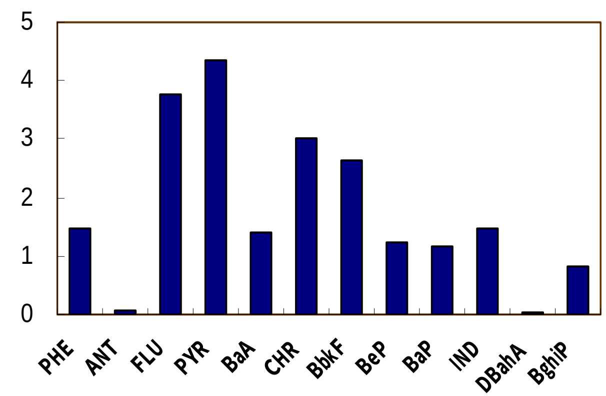
ng/m³



80 nm



240 nm



whole

Sampled ambient particles on each filter at Ikegami-shincho

Date	Whole	DMA 240 nm	DMA 80 nm
2005/Jan/24 / 2005/Jan/28	Collected particle mass* (μg)		
	600	50	30
	Whole PAH **(ng)		
	239	51.8	22.9
	BaP (ng)		
	12.9	3.8	1.5
	Sampling volume (m^3)		
	11.2	21.8	22.4

*: Sensitivity of balance =10 μg

**: Sensitivity of PAH analysis = 0.1 ng

Summary

- DMA can be used as a nanoparticle sampler.
- To increase flow ratio of aerosol flow and sheath flow of DMA means to increase particle amount through DMA slit.
- Four days sampling by this sampler at road side collected enough amount of nanoparticles for chemical analysis of PAHs.
- If we can increase DMA sheath flow-rate, we can increase sampling flow rate more than 4 l/min.

Acknowledgements

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Thank you for your attention !