발제문

자동차 배기가스 규제 및 도쿄 미세먼지(PM) 농도 감축

미노우라 히로아키
일본 아시아대기오염연구센터 대기연구부장

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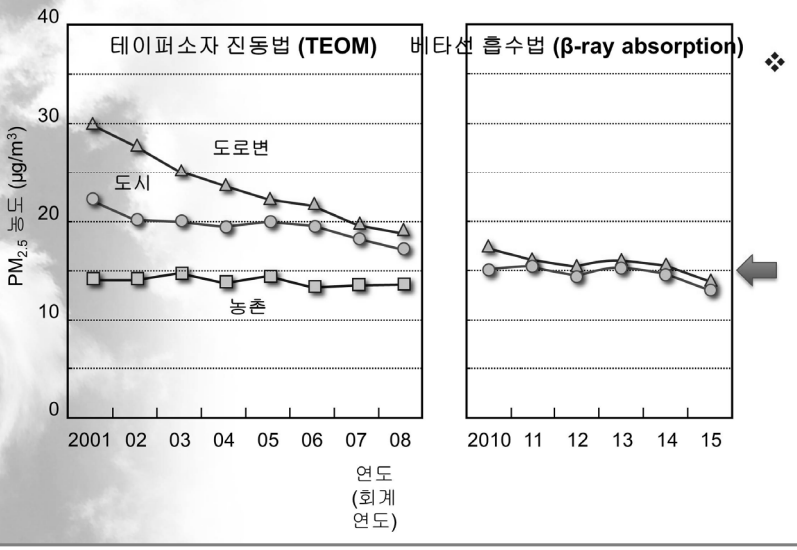
초미세먼지($PM_{2.5}$)의 연간 변화



❖ 도로변 및 도시 지역의 $PM_{2.5}$ 농도가 감소 추세를 보여 일본 기준치인 15μg/m³ 까지 감소 (연평균)

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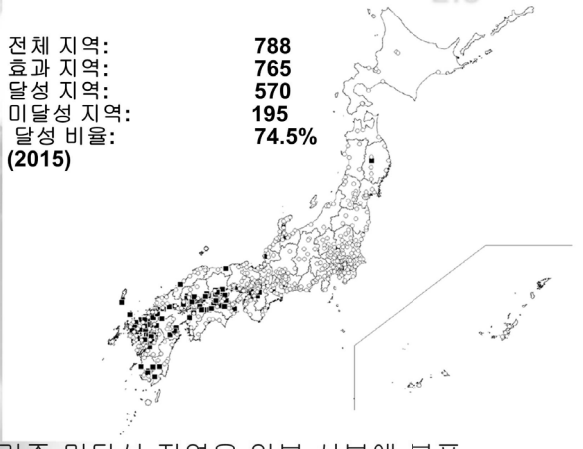
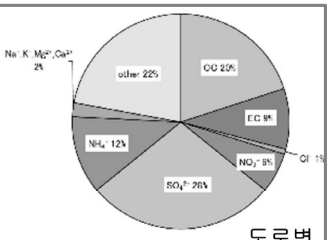
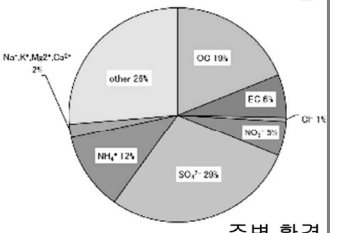
$PM_{2.5}$ 현황



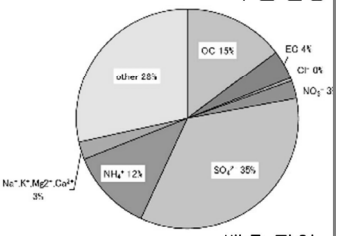
전체 지역: **788**
효과 지역: **765**
○ 달성 지역: **570**
■ 미달성 지역: **195**
달성 비율: **74.5%**
(2015)



도로변



주변 환경



배후 지역

❖ $PM_{2.5}$ 기준 미달성 지역은 일본 서부에 분포.
❖ 원소탄소(EC) 농도는 도로변에서 높고, 황산염 농도는 배후 지역에서 높음.

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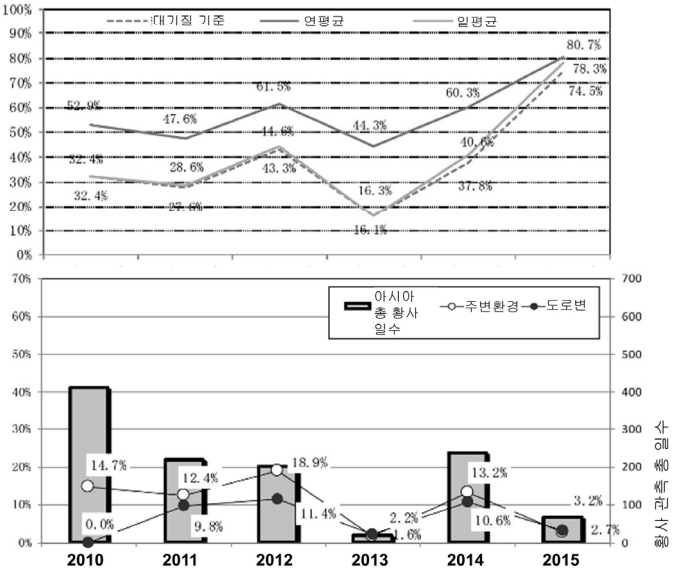
$PM_{2.5}$ 대기질 기준의 달성 비율

연평균 기준:
연평균 기준은 **15 μg/m³** 미만

일평균 기준:
98%가 **35 μg/m³** 미만

황사의 영향으로 인한
미달성 지역



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일본의 과거 대기질 문제

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일본의 과거 대기질 문제 2

	1960년대	1970년대	1980년대	1990년대	2000년대 이후
공장 및 산업 분야	흡연규제법 (1962) 대기관리법 (1968) 황사, SO_2 황산화물 총량규제 (1974) 질소산화물 배출기준 (1973) NO_x 질소산화물 총량규제 (1981)				
교통 분야	일산화탄소/탄화수소/질소산화물 배출규제 (1973) 트럭/버스 질소산화물 규제 (1977) 일본판 머스키법 (1978) NO_x 자동차 질소산화물 저감법 (1992) 미세먼지 배출 규제 (1993) PM 자동차 질소산화물/미세먼지 저감법 (2001)				

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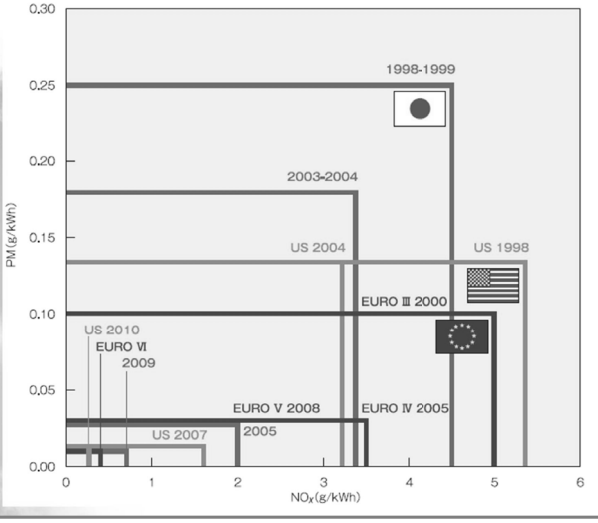
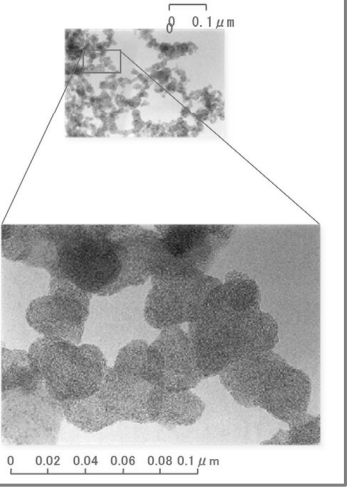
자동차 배기가스 규제로 인한 원소탄소(EC) 농도 감소





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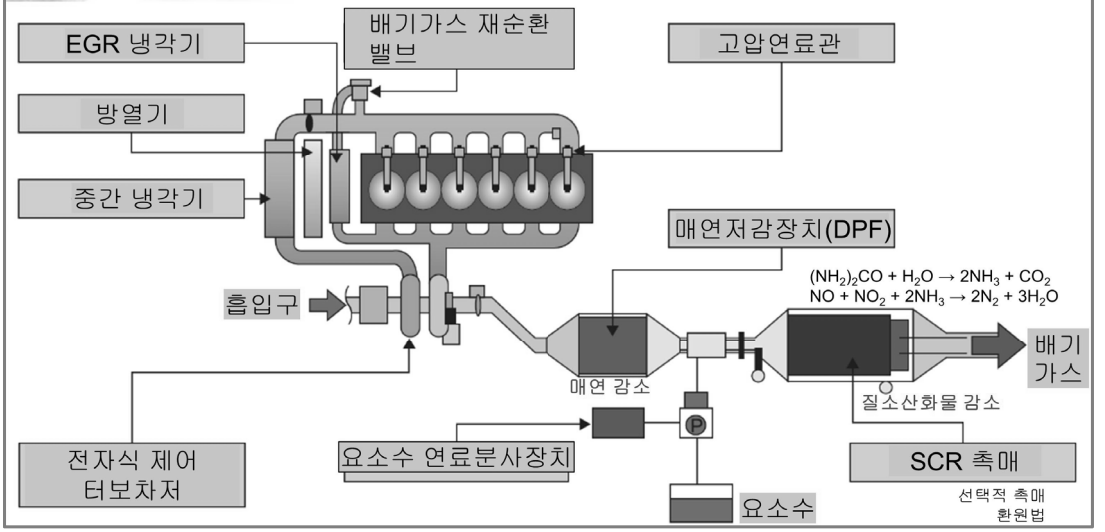
후처리 기술에 의한 매연(soot) 및 질소산화물(NOx) 환원



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도쿄 시내 미세먼지 관측

❖ 1994년부터 도시 배후 지역에서 앤더슨 샘플러 사용 및 화학분석을 통해 미세먼지를 측정.

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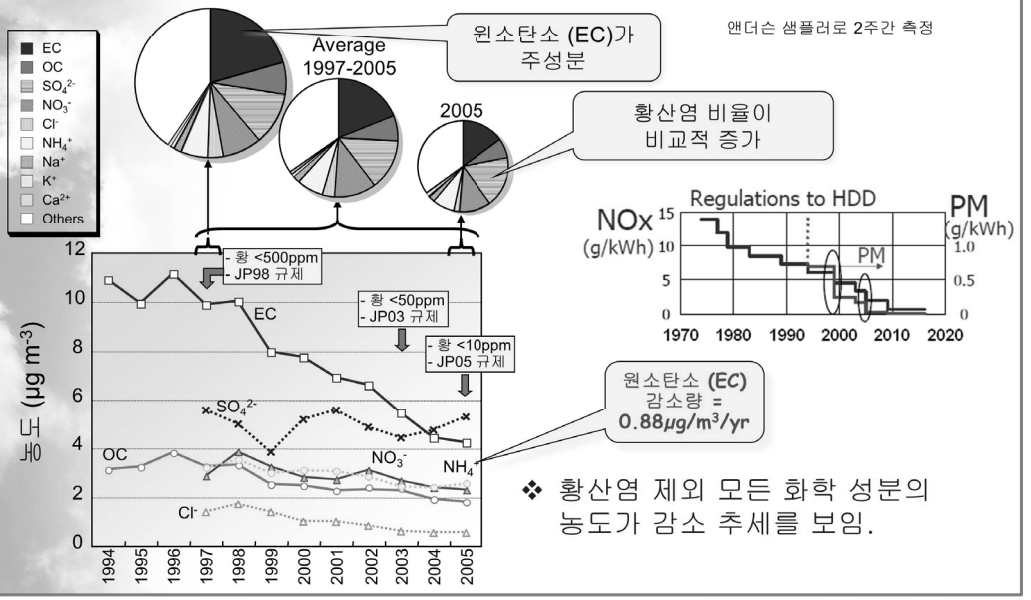
$PM_{2.1}$ 화학성분의 연간 변화



❖ 황산염 제외 모든 화학 성분의 농도가 감소 추세를 보임.

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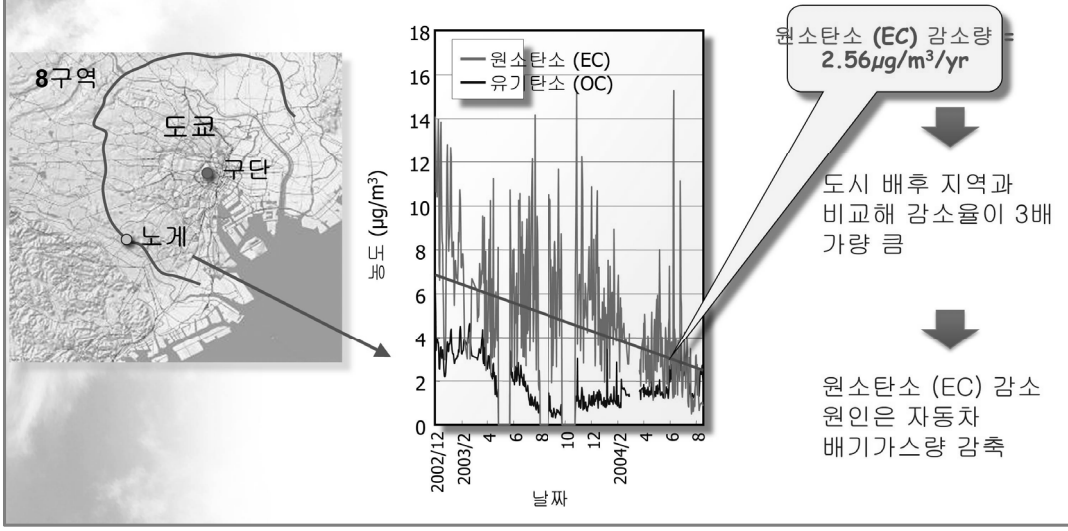
도쿄 번화가 도로변의 탄소계 $PM_{2.5}$ 농도 추이



도시 배후 지역과 비교해 감소율이 3배 가량 큼

원소탄소 (EC) 감소 원인은 자동차 배기가스량 감축

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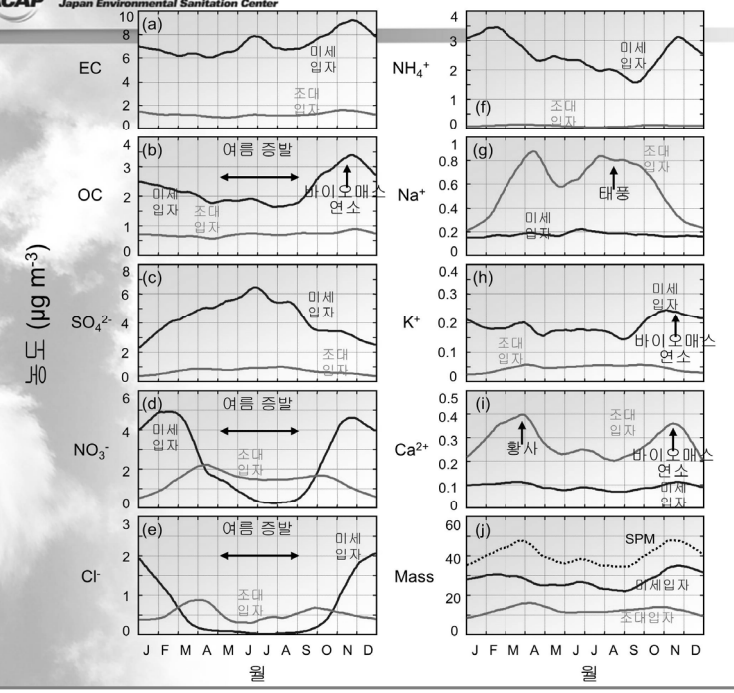

화학성분의 계절별 변화

❖ 도쿄 시내에서 확인 가능한 바이오매스 연소의 영향.

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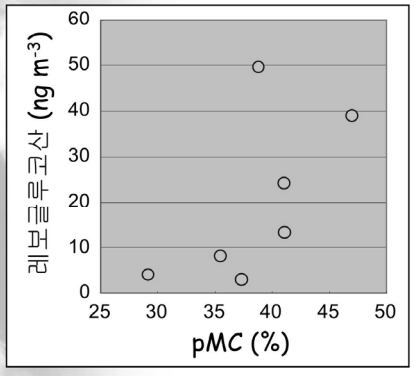
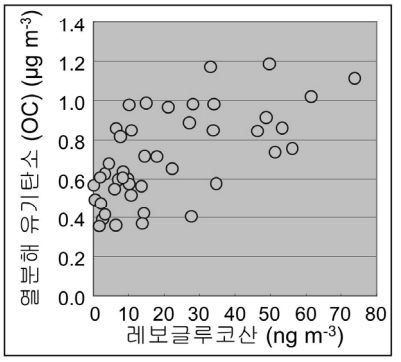
바이오매스원 지표





pMC (percent modern carbon)의 정의
pMC는 방사성 동위원소 탄소 (^{14}C)의 함유량을 이용해 계산.

{pMC = 0 (%) : 화석연료원
pMC = 100 (%) : 바이오매스원

❖ pMC 와 레보글루코산은 바이오매스원을 보여주는 지표이며, 열분해 유기탄소 (OC)와 관련이 있음.

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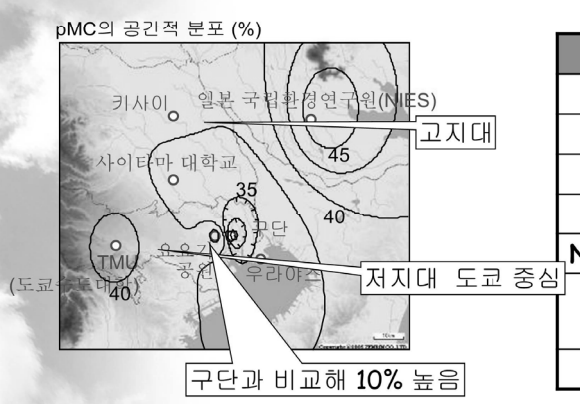
방사성탄소 분석과 pMC 분포



관측 장소	pMC (%)
우라야스	37.3
구단	29.1
사이타마 대학교	35.5
키사이	38.8
NIES (쓰쿠바 시)	47.0
TMU (하치오지 시)	41.0
요요기 공원	41.1

- ❖ pMC의 공간적 분포를 통해 농촌 지역에 비해 도쿄 중심가 (시내)에서 바이오매스 기여도가 낮음을 확인 가능.
- ❖ 그러나, pMC를 통해 도쿄 중심가에서도 탄소의 29%가 바이오매스에서 나온다는 것 또한 확인 가능.

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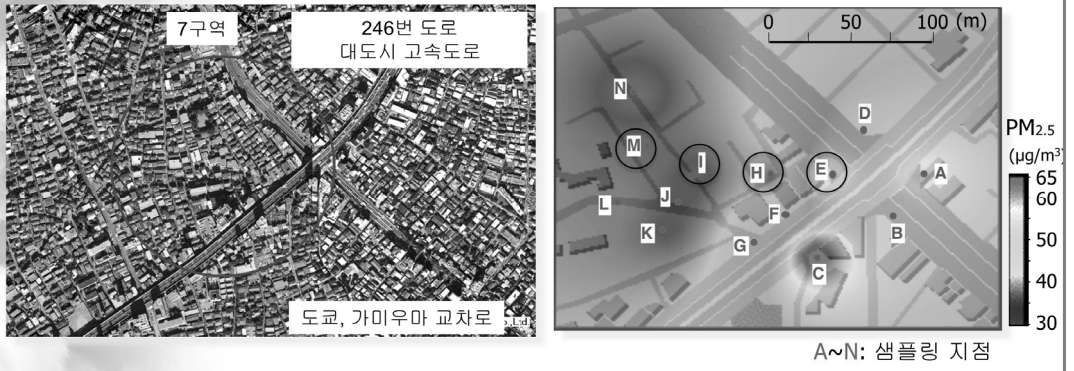
$PM_{2.5}$ 의 공간적 분포



A~N: 샘플링 지점

- ❖ 혼잡한 간선도로를 마주한 장소는 높은 $PM_{2.5}$ 농도를 보이나, 좁은 도로에 들어서면 모든 도로에서 $PM_{2.5}$ 농도가 감소.

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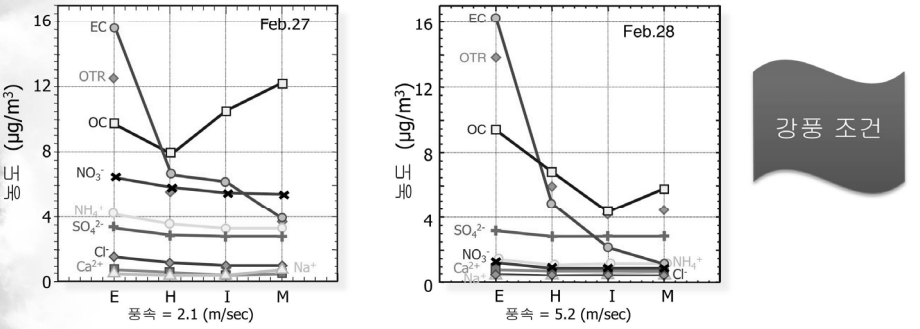
원소탄소 (EC), 유기탄소 (OC) 및 이온의 공간 감쇠



- 도로변 (E)에서 내부 지역 (M)으로 갈수록 원소탄소 (EC)의 공간 감쇠가 두드러짐.
- 지점 E에서 EC, OC 및 황산염의 농도가 풍속에 대해 일정하게 유지됨.
- 차량을 제외한 다른 근원의 영향이 있음을 내부지역의 OC를 통해 알 수 있음.

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요약

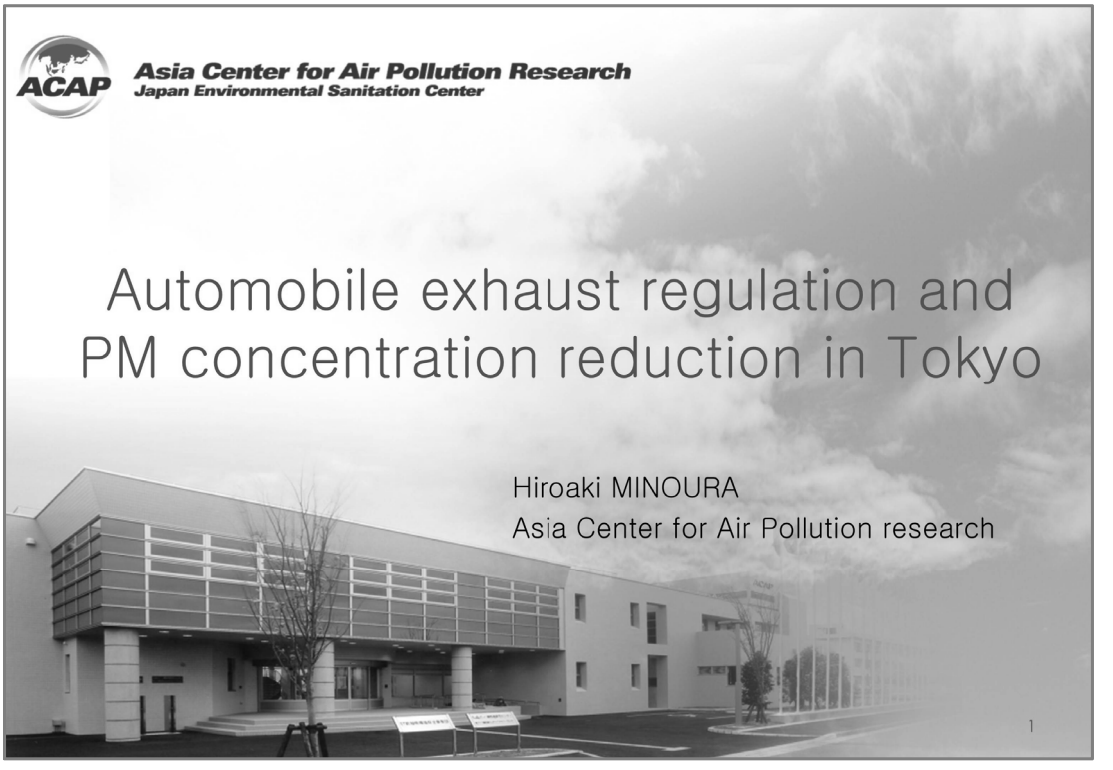
- 도로변 및 도시 지역의 $PM_{2.5}$ 농도가 감소 추세를 보였으나, 서부에 위치한 지역의 3/4 에서 일본 기준치인 15μg/m³ 를 초과.
- $PM_{2.5}$ 의 원소탄소(EC) 농도가 자동차 배기가스 규제로 인해 급격하게 감소했으며, 새로운 감축 목표는 황산염을 대상으로 함.
- 자동차는 여전히 $PM_{2.5}$ 발생의 주요 원인.
- 바이오매스 연소의 유기탄소(OC) 기여는 도쿄 중심가에서 확인됨.


ACAP
경청해주셔서
감사합니다.

발제문

Automobile exhaust regulation and PM concentration reduction in Tokyo

Hiroaki MINOURA
Asia Center for Air Pollution research



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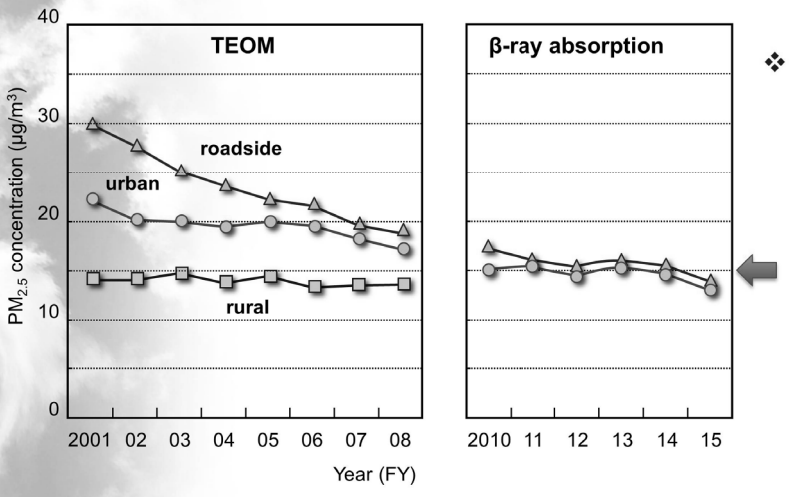
Annual change in $PM_{2.5}$



❖ $PM_{2.5}$ concentration at roadside and urban area showed decrease trend and finally meet Japanese standard of 15μg/m³ (annual mean)

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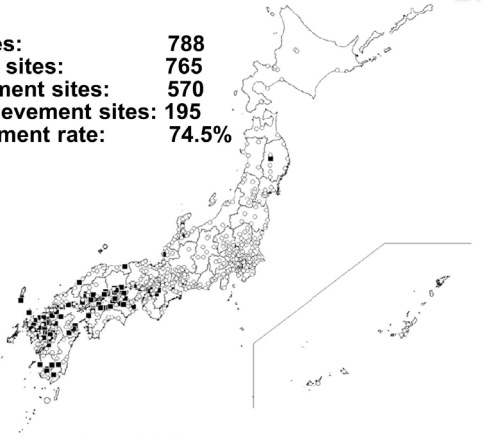
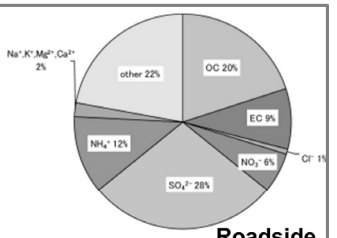
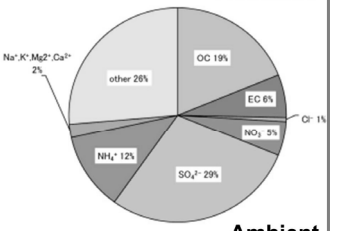
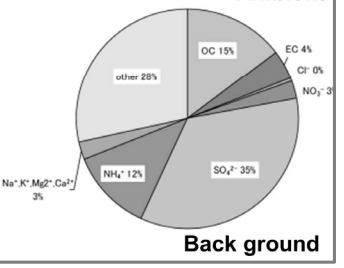
Current situation of $PM_{2.5}$

Total sites: 788
Effective sites: 765
○ Achievement sites: 570
■ Non-achievement sites: 195
Achievement rate: 74.5%
(2015)









❖ Non-achievement site of $PM_{2.5}$ standard distributed in the western part of Japan.
❖ EC concentration is remarkable at roadside, sulfate is dominant at back ground.

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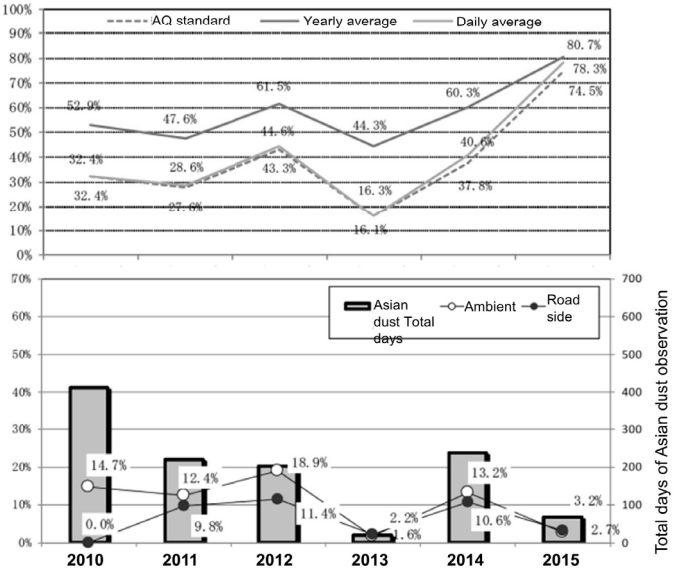
Achievement ratios of $PM_{2.5}$ AQ standard

Yearly average standard:
Yearly average value is less than 15 μg/m³

Daily average standard:
98th percentile value is less than 35 μg/m³

Non-achievement sites due to influence of Asian dust



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Japanese AQ issues in the past

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Japanese AQ issues in the past 2

	1960s	1970s	1980s	1990s	After 2000
Factory and Industrial sector	Smoke regulation law (1962)	Clean Air Act (1968)	SOx total amount regulation (1974)	NOx emission standard (1973)	NOx total amount regulation (1981)
Traffic sector		CO/HC/NOx emission regulation (1973)	Truck / bus NOx regulation (1977)	Japanese version Muskie regulation (1978)	Automobile NOx Reduction Law (1992)
				PM emission regulation (1993)	Automobile NOx / PM Reduction Law (2001)

Dust, SO_2 → NO_x → PM

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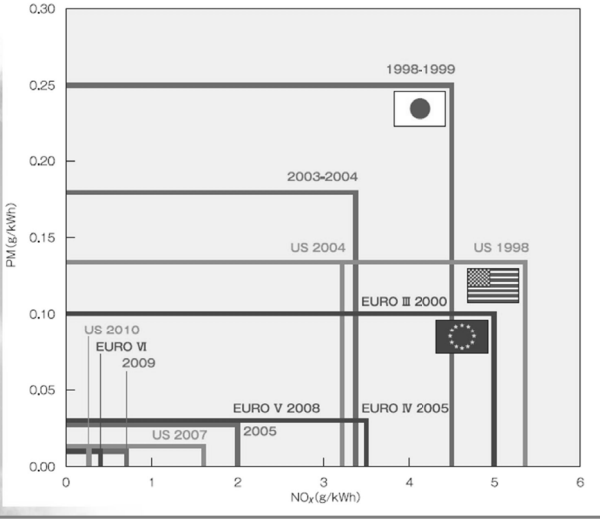
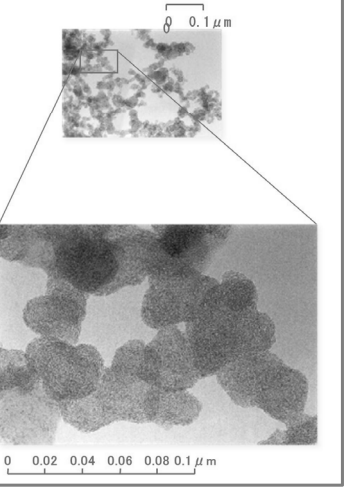
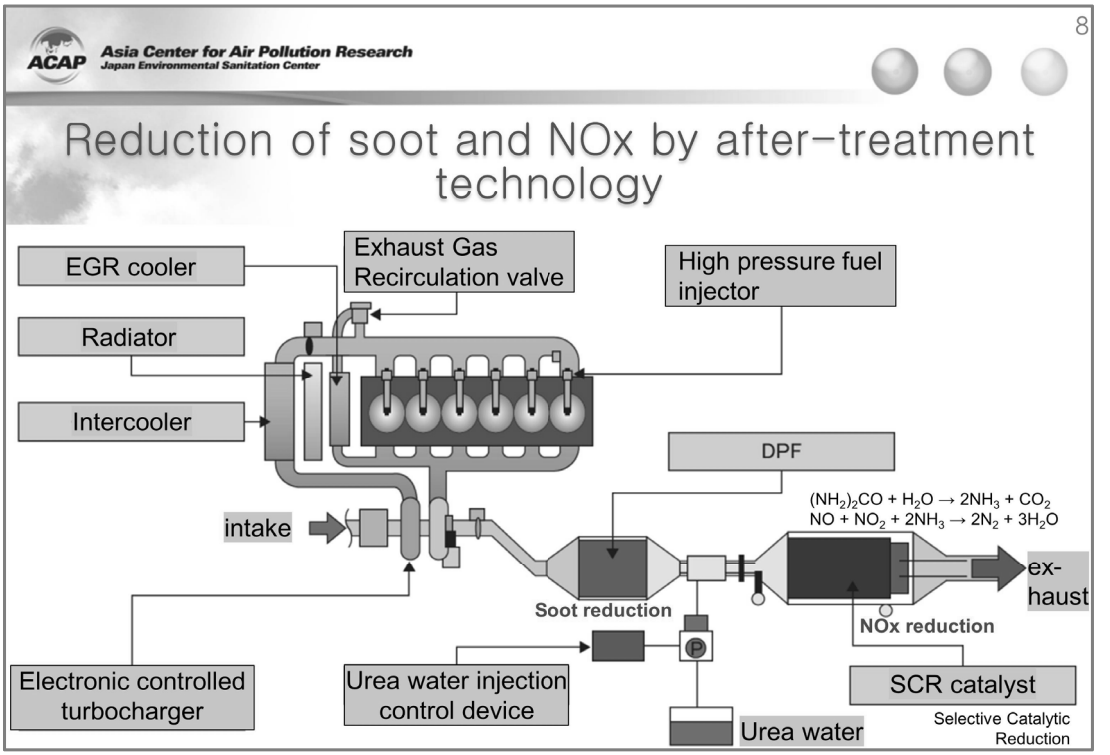
Reduction of EC concentration due to vehicle exhaust regulation






8
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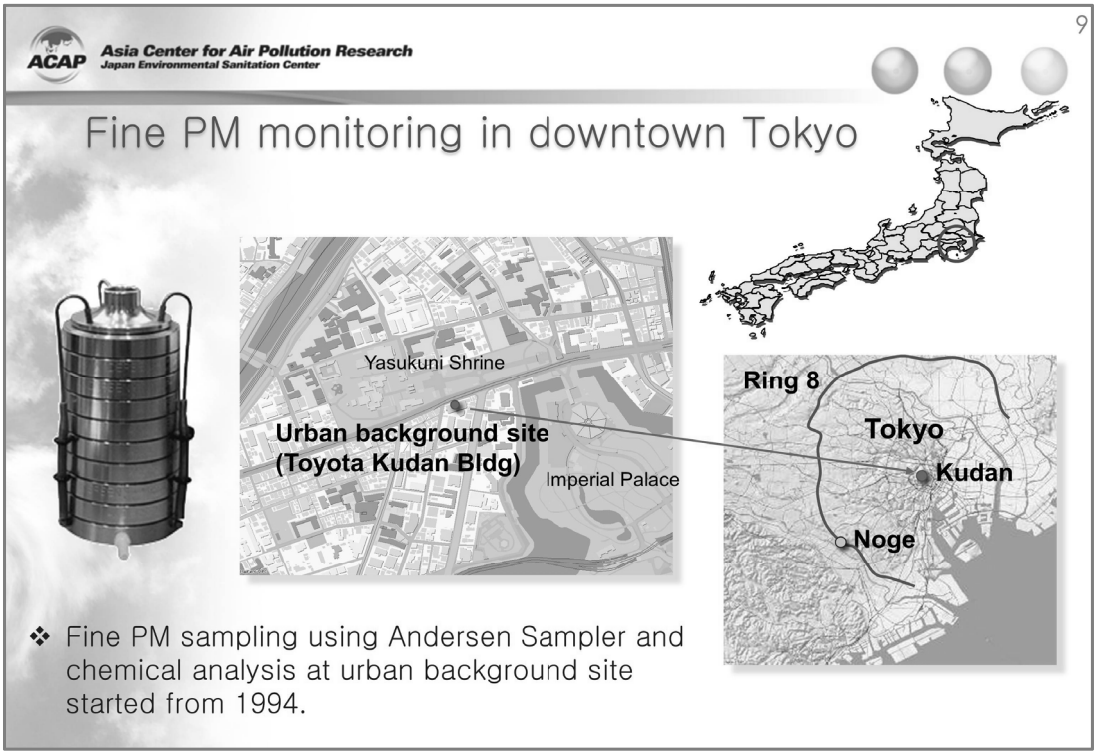
Reduction of soot and NOx by after-treatment technology
EGR cooler
Exhaust Gas Recirculation valve
High pressure fuel injector
Radiator
Intercooler
DPF
intake
$(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2$
$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$
ex-haust
Soot reduction
NOx reduction
Electronic controlled turbocharger
Urea water injection control device
SCR catalyst
Selective Catalytic Reduction
Urea water


9
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Fine PM monitoring in downtown Tokyo
Yasukuni Shrine
Urban background site
(Toyota Kudan Bldg)
Imperial Palace
Ring 8
Tokyo
Kudan
Noge
❖ Fine PM sampling using Andersen Sampler and chemical analysis at urban background site started from 1994.

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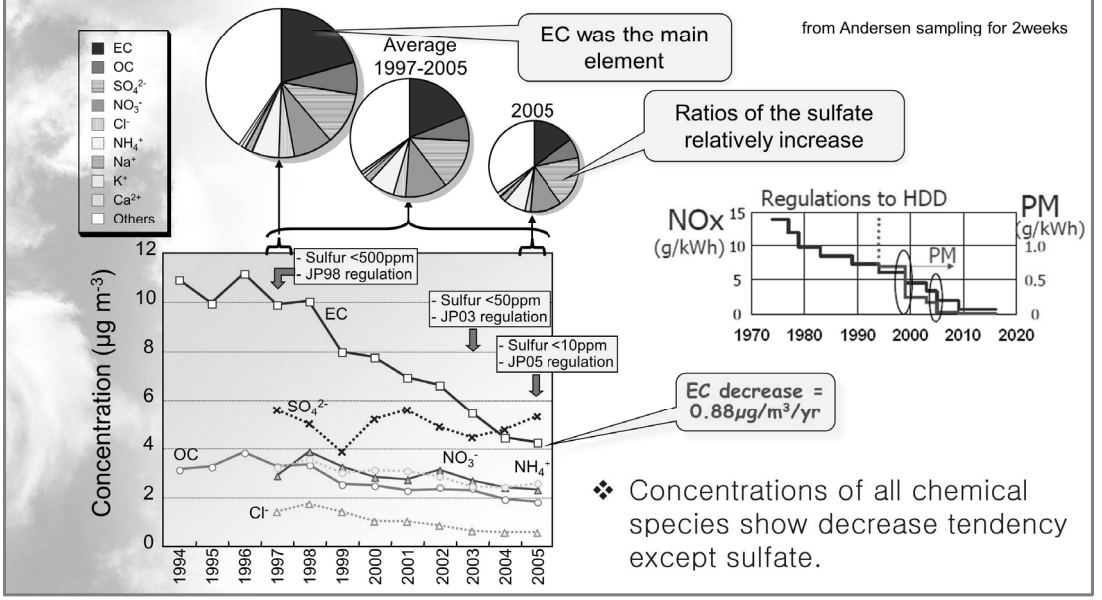
Yearly variations of chemical components in $PM_{2.1}$



❖ Concentrations of all chemical species show decrease tendency except sulfate.

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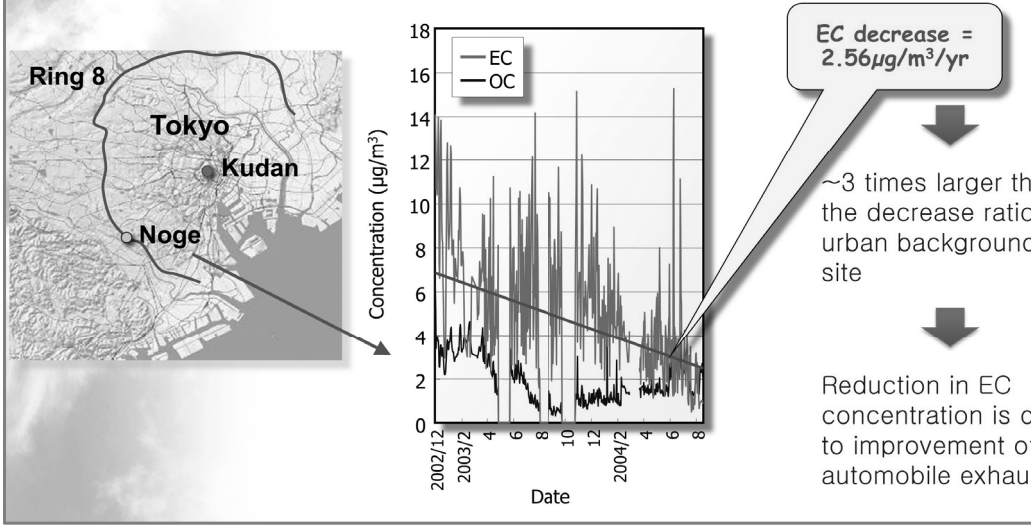
Carbonaceous $PM_{2.5}$ concentration trend at busy roadside in Tokyo



~3 times larger than the decrease ratio of urban background site

Reduction in EC concentration is due to improvement of automobile exhaust

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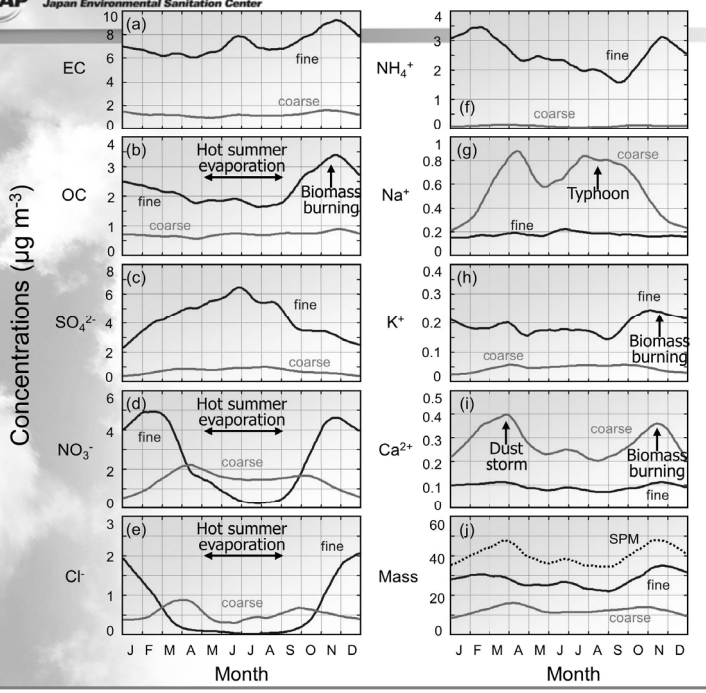

Seasonal variations in chemical compositions

❖ Influence of biomass burning can be seen in downtown Tokyo.

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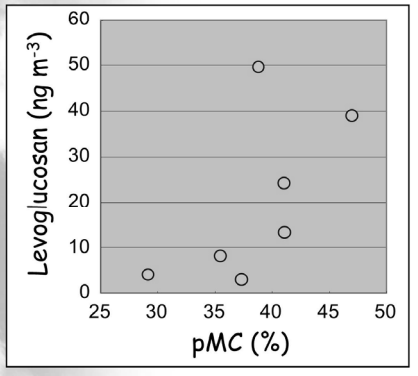
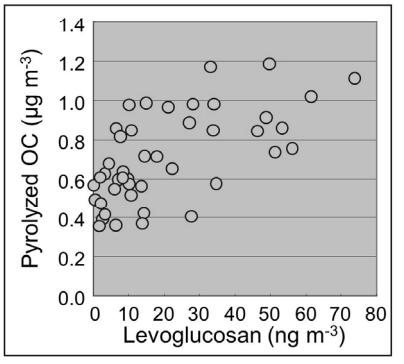
Indicators of Biomass source





Definition of pMC
(percent modern carbon)
pMC is calculated from the content of ^{14}C.

{ pMC = 0 (%) : fossil fuel source
pMC = 100 (%) : biomass source

❖ pMC and levoglucosan are indicators showing biomass origin, and they correlate with Pyrolyzed OC.

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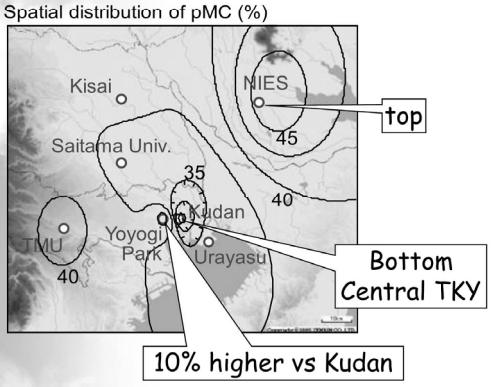
Radio carbon analysis and distribution of pMC



Obs. site	pMC (%)
Urayasu	37.3
Kudan	29.1
Saitama Univ.	35.5
Kisai	38.8
NIES (Tsukuba)	47.0
TMU (Hachioji)	41.0
Yoyogi Park	41.1

- The spatial distribution of pMC showed that biomass contribution is lower in central (downtown) Tokyo comparing with rural area.
- However, pMC showed that 29% of carbon comes from biomass even in central Tokyo.

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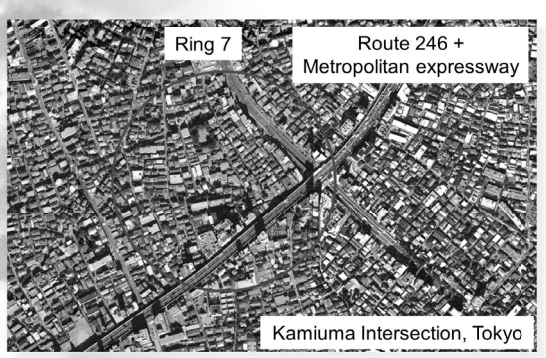
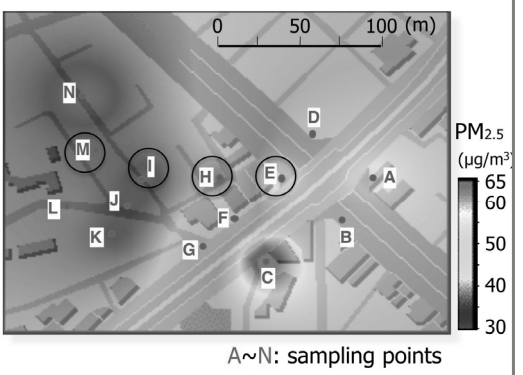
Spatial distribution of $PM_{2.5}$





A~N: sampling points

- The place facing the busy trunk road shows high $PM_{2.5}$ concentration, but when entering a narrow street the concentration decreases uniformly.

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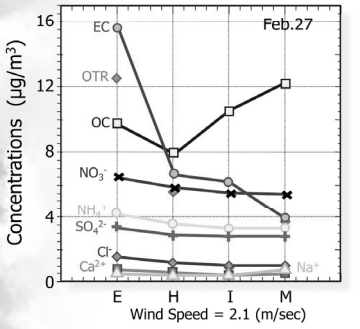
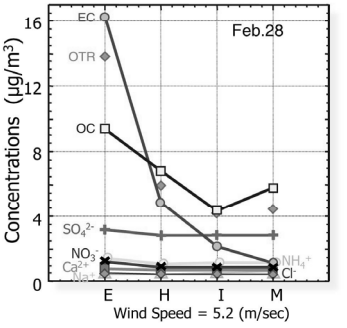
Space attenuation of EC, OC, and ions





High wind condition

- Space attenuation of EC concentration from the roadside (E) to inside area (M) was remarkable.
- The concentrations of EC, OC, and sulfate at E point were constant for the wind speed.
- Influence of the other source except for vehicle was suggested on OC at inside area.

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summary

- $PM_{2.5}$ concentration at roadside and urban area showed decrease trend, but 3/4 sites located mostly in western area exceed Japanese standard of 15μg/m^3.
- EC concentration in $PM_{2.5}$ decreased remarkably due to vehicle emission control, and new target becomes sulfate.
- Automobile still is a major source of $PM_{2.5}$
- Contribution to OC of biomass burning exist in central Tokyo.


ACAP
Thank you for
your attention