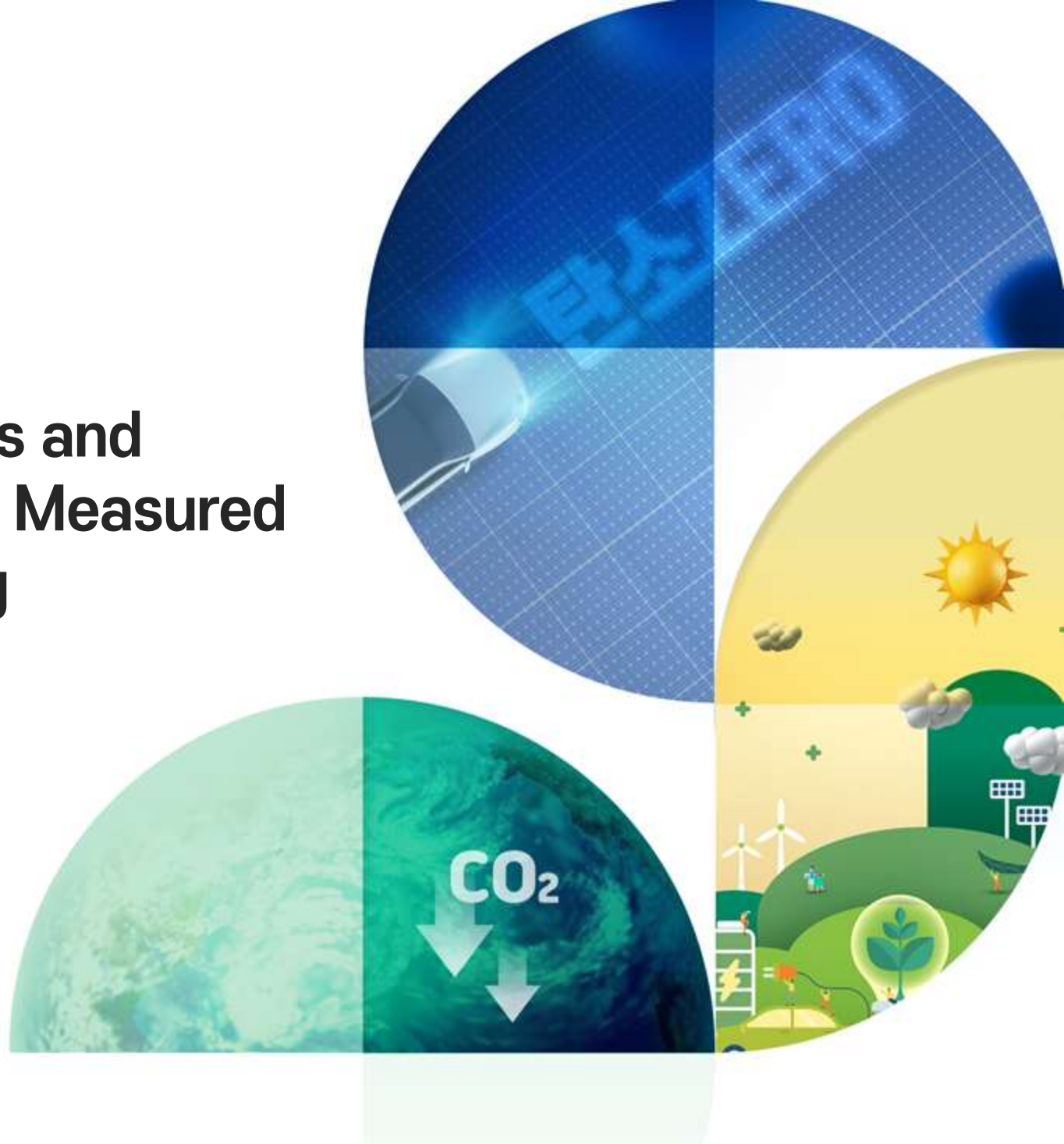


# Analysis of Particles and Gaseous Pollutants Measured in Real-road Driving

2023.11.09



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II Pretest

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IV Test Results

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# Introduction



- 1 Development of Korean VIAQ Evaluation Technology
- 2 Differences from the VIAQ-25-04 presentation

VIAQ-IWG 28th

- ▶ Analysis of Particles and gaseous pollutants measured in real road driving



# 1

# Development of Korean VIAQ Evaluation Technology

## Development of Korean VIAQ Evaluation Technology



Funding



Ministry of Land, Infrastructure and Transport



Korea Agency for Infrastructure Technology Advancement

Research Period

2023. 04. 01. ~ 2026. 12. 31. (45months)

Research Overview



Final Goal

Development of standardized VIAQ evaluation technology and the chambers for laboratory test

# 2 Differences from the VIAQ-25-04 presentation

Item	2022	2023	Difference
Substances	PM-2.5, PM-0.25 ~ PM-32, PN, 10 ~ 420 nm particles, 2.2 ~ 7 nm particles, NOx, Black Carbon (BC) CO, CO <sub>2</sub>	PM-2.5, PN, NOx	Excluded due to stability issues with nanoparticle and black carbon measurement equipment.
IN/OUT	Only Indoor air	Both indoor and outdoor air	Simultaneous measurement
Powertrains	GSL, DSL	GSL, DSL, HEV, BEV	With more diverse powertrains
Route	Urban, Urban + Highway	Urban + Highway	To compare regional differences by taking two routes (future work)
HVAC	A/C OFF (in manual mode)	A/C ON (in manual mode)	No issues of humidity or temperature



# Pretest



- 1 Measurement Setup
- 2  $PM_{2.5}(\mu g/m^3)$
- 3  $PM_{2.5}(\#/cm^3)$
- 4  $NO_x(ppb)$

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▶▶ Analysis of Particles and gaseous pollutants measured in real road driving



# 1 Measurement Setup (APM Engineering Co., Ltd)

## ● In-vehicle equipment installation

- ☑ The installation environment was installed in the same configuration as that of Seokyeong University.
- ☑ Through the program developed by the APM company, it is designed to enable real-time data storage, measurement concentration check, and concentration change at road locations.
- ☑ The vehicle was measured using only Kia Motors' Sportage (2019) type.

Equipment installation in the vehicle

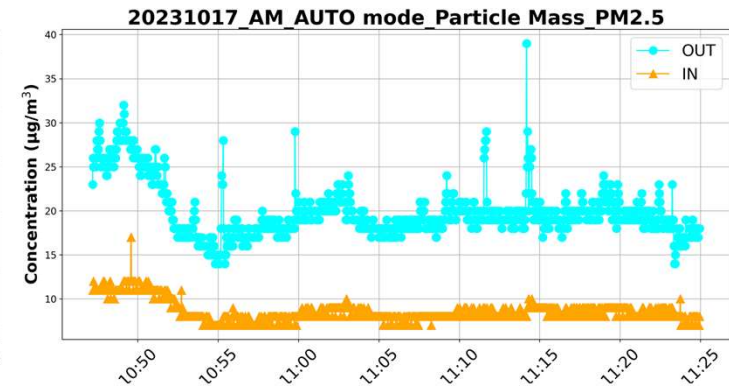
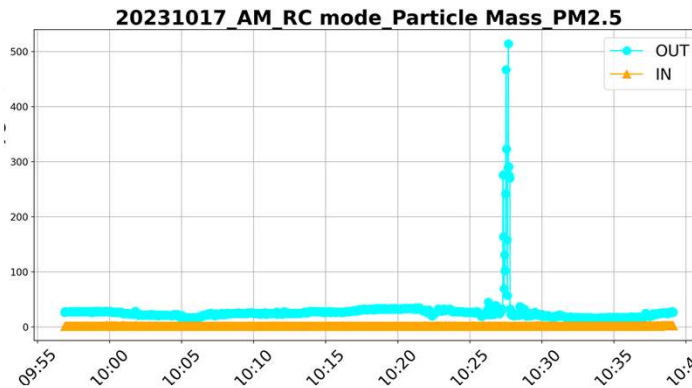
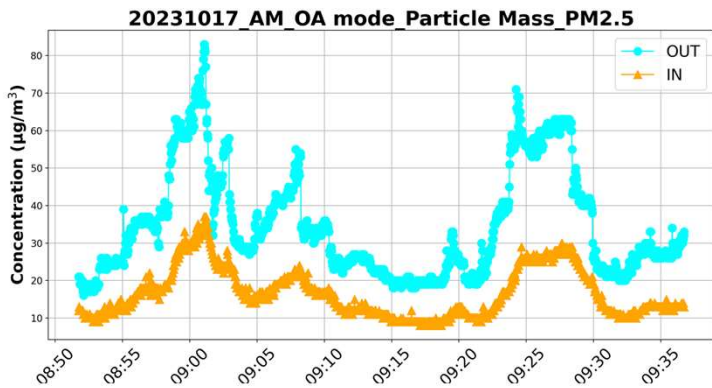
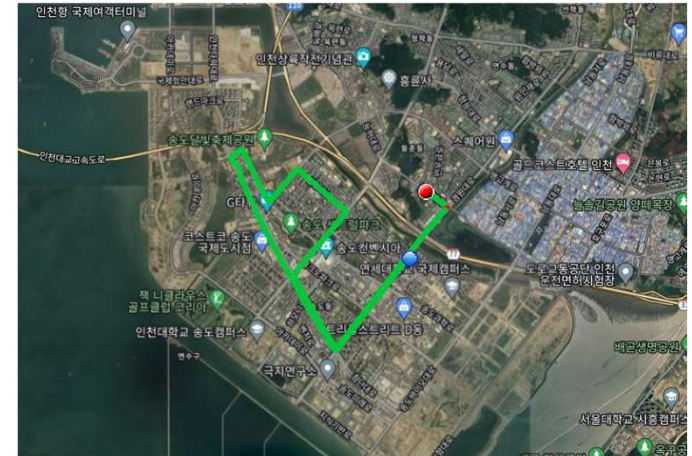
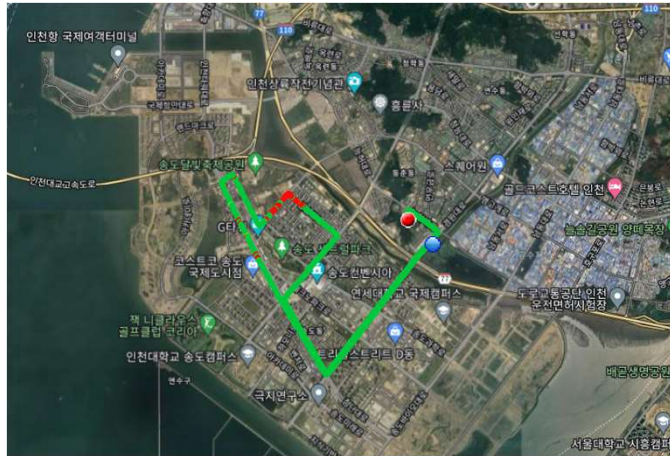


The indoor/outdoor air inlet and vent line



# 2 PM<sub>2.5</sub> (µg/m<sup>3</sup>) - APM Engineering Co., Ltd

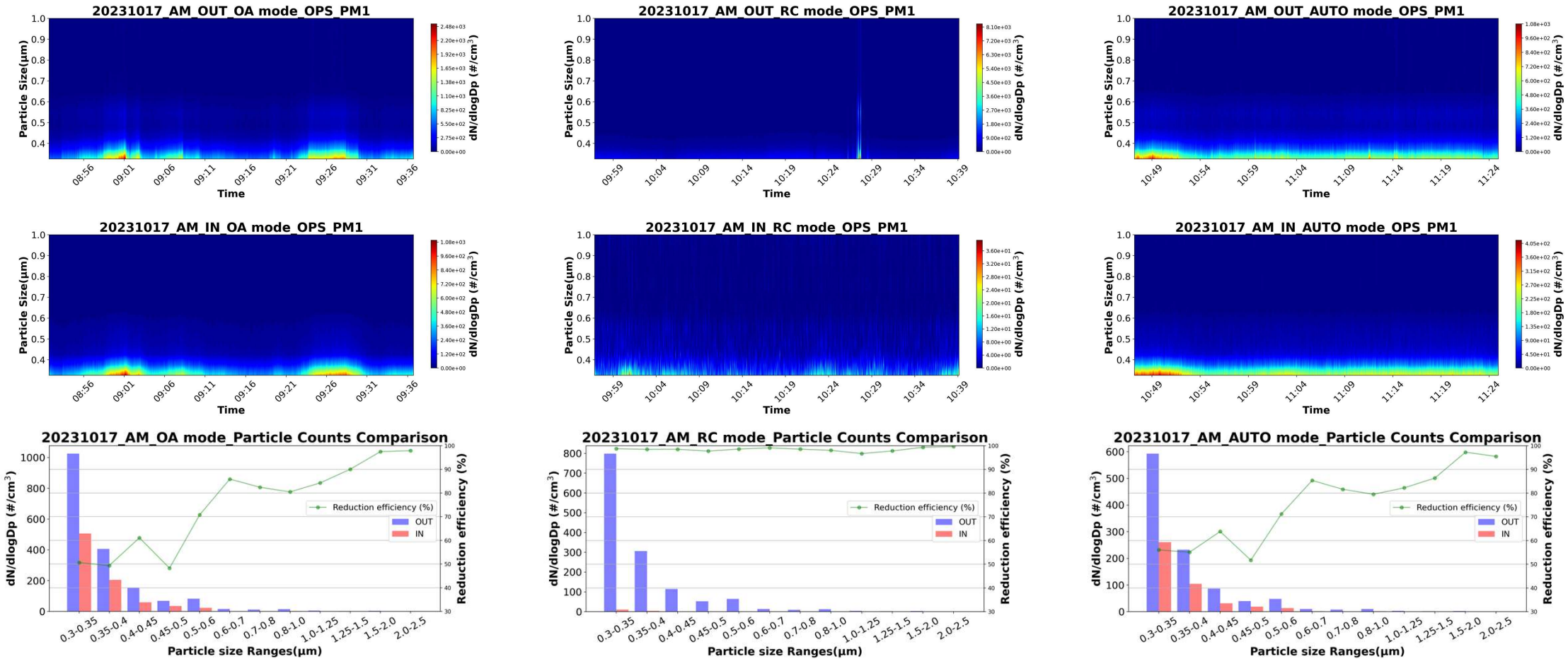
- ✓ **OA** : It was confirmed that the internal concentration also changed according to the amount of change in the external concentration when the vehicle was in the outside air conditioning mode.
- ✓ **RC** : It is determined that the internal concentration is not affected by the change in concentration outside the vehicle.
- ✓ **AUTO** : The indoor concentration is repeatedly increased or decreased according to the mode change, but it is usually in the outdoor mode, so it was confirmed that the same changes according to the amount of change in external concentration.





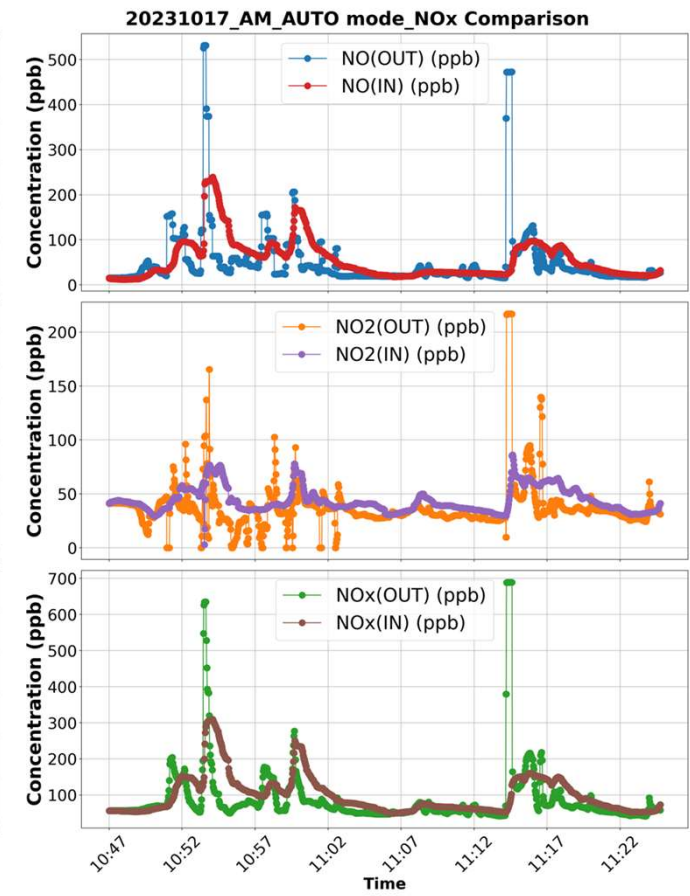
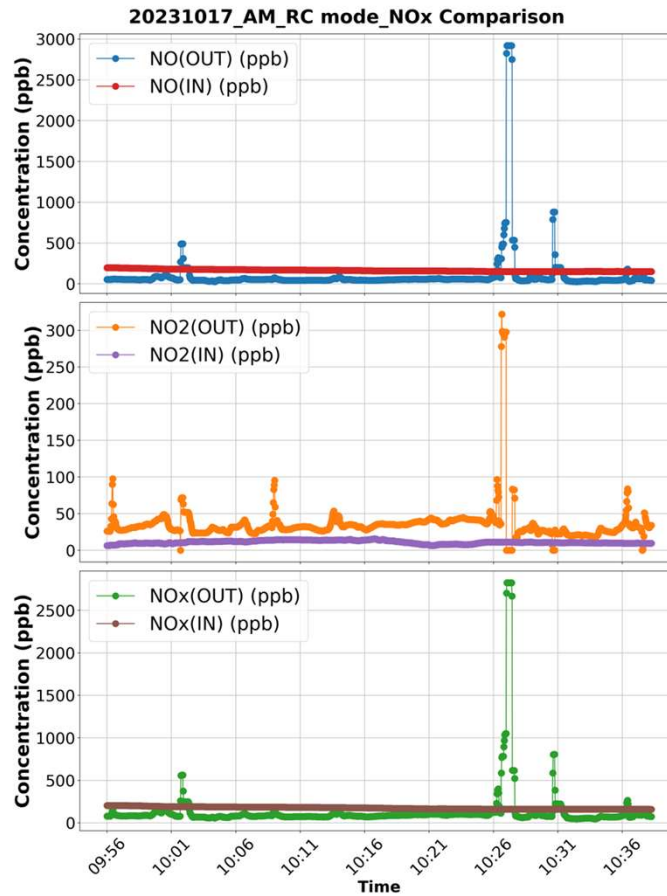
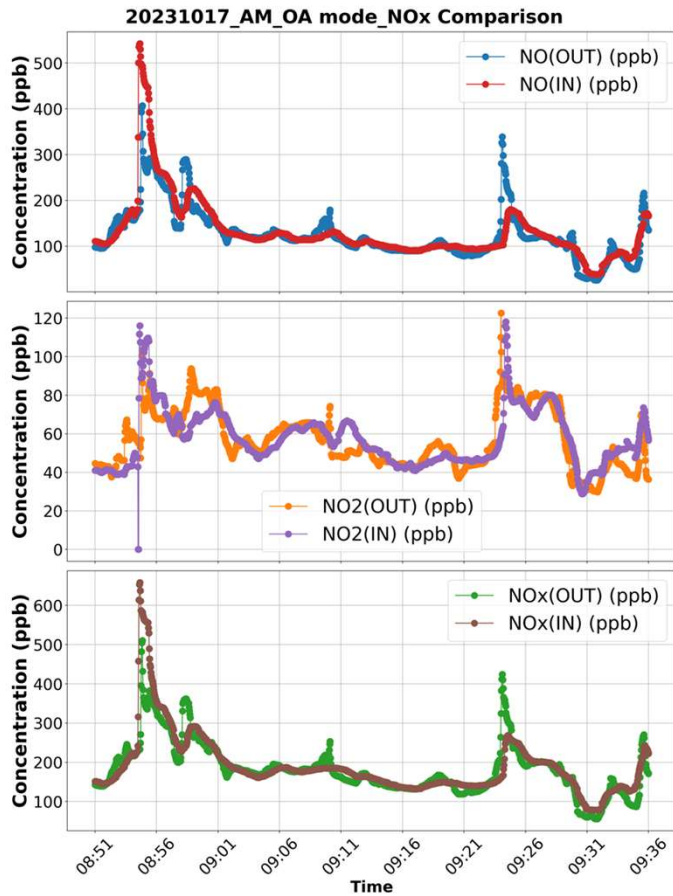
# 3 PM<sub>2.5</sub>(#/cm<sup>3</sup>) - APM Engineering Co., Ltd

☑ PN results showed the same pattern as PM. As for the concentration, the largest amount of particles was measured at 0.3–0.35 μm, and it was confirmed that the smaller the size of the particles, the greater the inflow inside.



# 4 NOx(ppb) - APM Engineering Co., Ltd

- ☑ It shows the same pattern as the concentration value of PM and PN.
- ☑ However, unlike particles, if there is a high concentration of NOx inside in OA mode and AUTO mode, the concentration decreases relatively slowly because there is no complete air circulation inside the vehicle.





# Test Setup



- 1 Test Method
- 2 Test Route
- 3 Test Vehicle
- 4 Measurement Setup

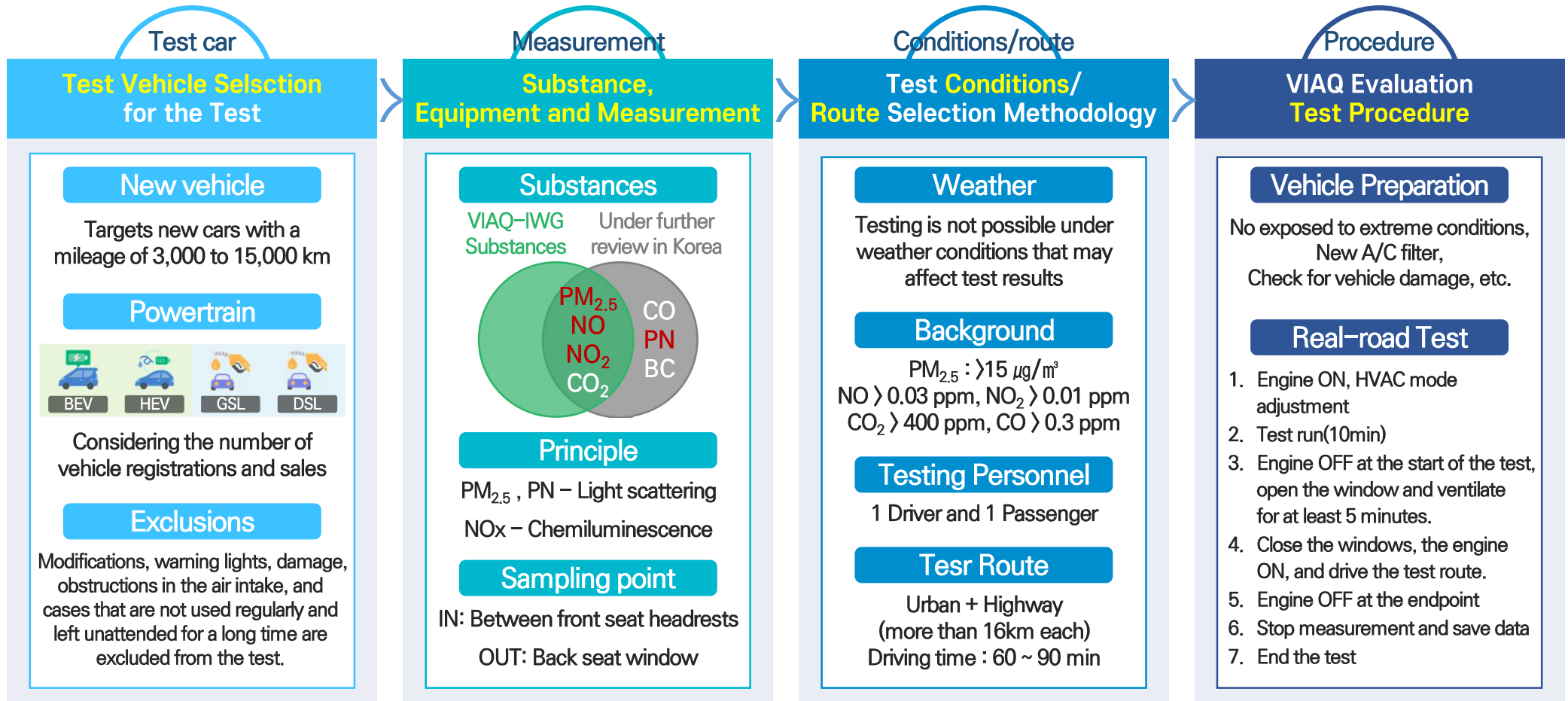
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measured in real road driving



# 1 Test Method

## Real road driving test method for the evaluation of VIAQ

✓ An evaluation concept was established by reflecting on the contents confirmed at the VIAQ-IWG 27th meeting and the actual situation of the Republic of Korea.



# 1 Test Method

## ● HVAC mode setting

- ✓ HVAC modes are divided into three types: RC, OA, Auto
- ✓ The air cleaning function is turned on in all conditions.

### RC(recirculation) mode

#### Temperature

22°C or medium

#### Fan speed

Medium or 50%



#### A/C & HVAC

A/C "ON"



### OA(outside air) mode

#### Temperature

22°C or medium

#### Fan speed

Medium or 50%



#### A/C & HVAC

A/C "ON"



### Auto mode

#### Temperature

22°C or medium

#### Auto

Medium or 50%



#### A/C & HVAC

A/C "ON" or "OFF"



# 1 Test Method

## Air conditioning setting function

- ✓ All vehicles used in the test had the ‘outside air blocking option’ in the air conditioning settings.
- ✓ The air cleaning function is turned on in all conditions.
- ✓ In OA and RC modes, ‘tunnel section’ and ‘other blocked section’ options need to be unchecked.
- ✓ In Auto mode, those functions need to be checked so that HVAC mode can be automatically changed to OA or RC while driving.



### HVAC setting

...

#### Blocking outside air

- ✓ Washer fluid interlocking
- ✓ Tunnel section
- ✓ Other blocked sections

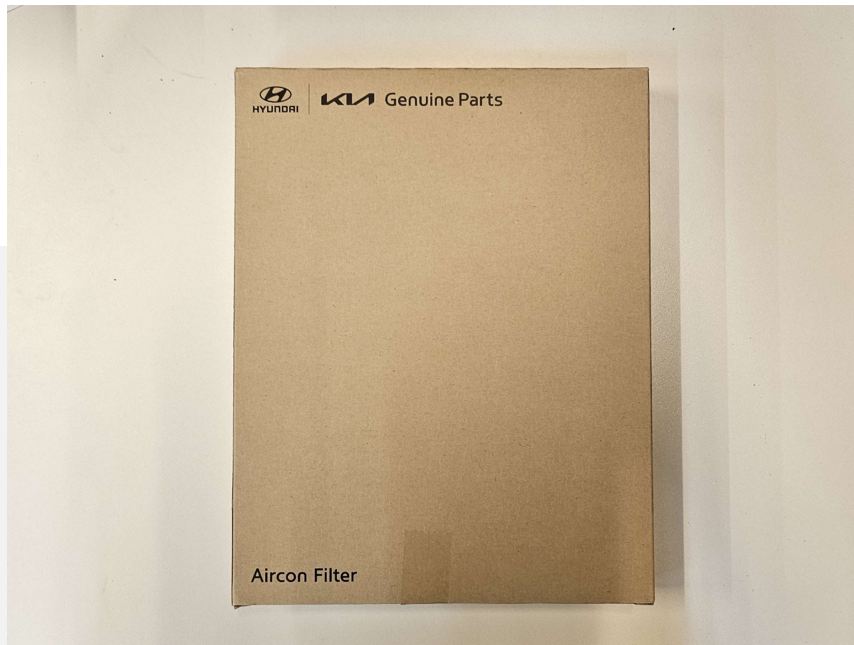
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# 1 Test Method

## ● New air conditioner filter

- ✓ A new genuine aircon filter including an activated carbon layer was used.
- ✓ The filter was replaced with a new one before testing.

Genuine filter with activated carbon layer





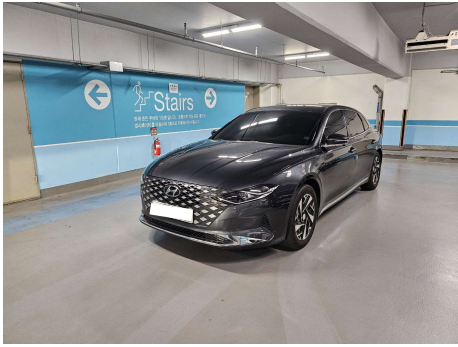
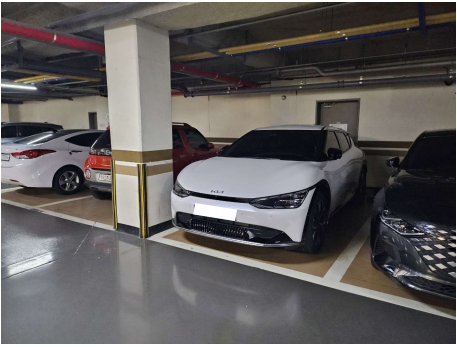




# 3 Test Vehicle

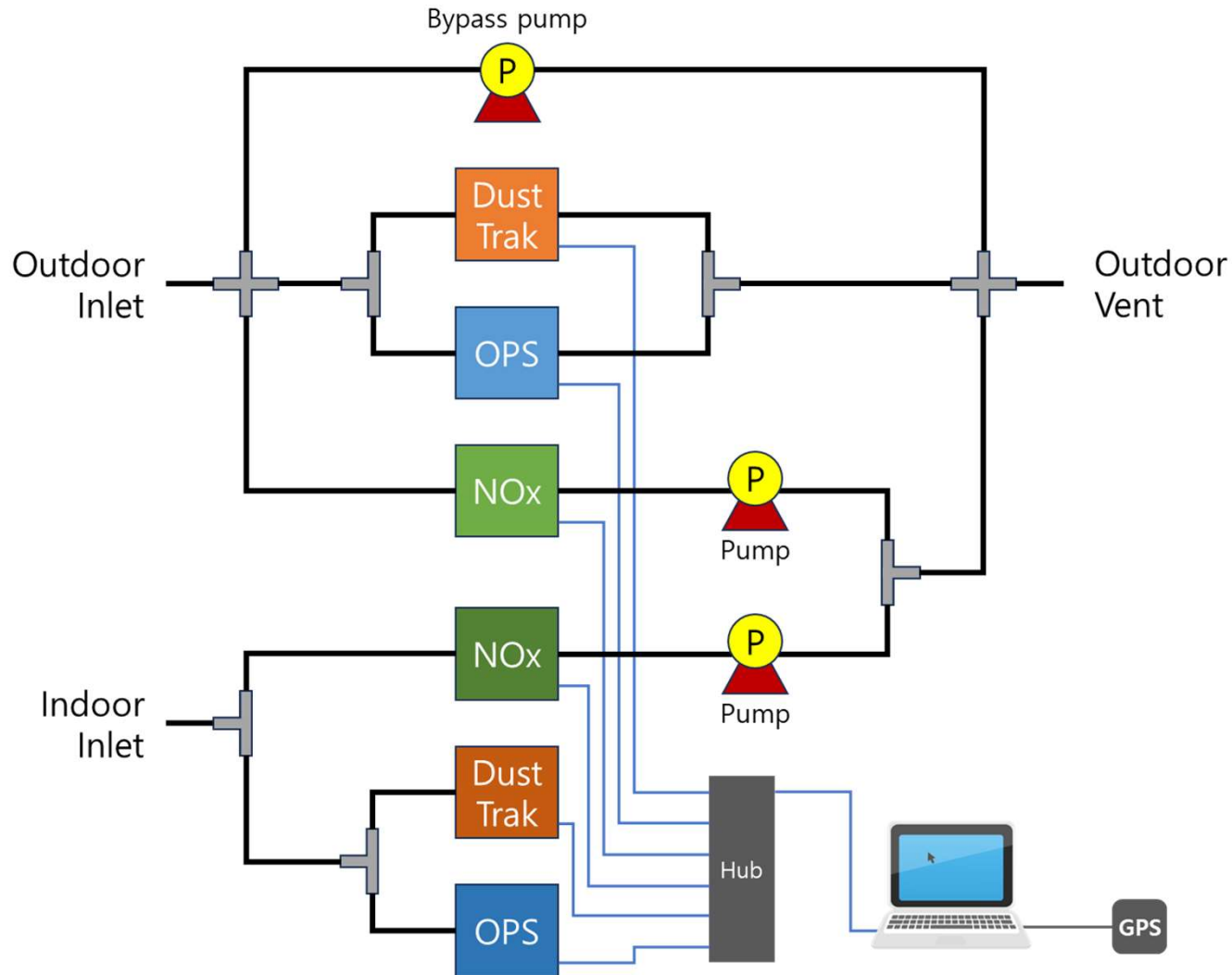
## ● Vehicle information used for the test

- ☑ Difficulties in securing new vehicles with a range of 3,000 ~ 15,000 km.
- ☑ Four types of powertrains(GSL, DSL, HEV, EV) were used for the test

Item	GSL	DSL	HEV * gasoline	EV
Vehicle				
Manufacturer	Hyundai	Hyundai	Hyundai	KIA
Type	SUV	SUV	Sedan	SUV
Model	Santafe 2.5	Santafe 2.2 AWD	Grandeur IG 2.4	EV6 2WD
Model year	2023	2021	2021	2023
Mileage (km)	12,590	69,324	48,338	29,299

# 4 Measurement Setup

## Measurement equipment layout

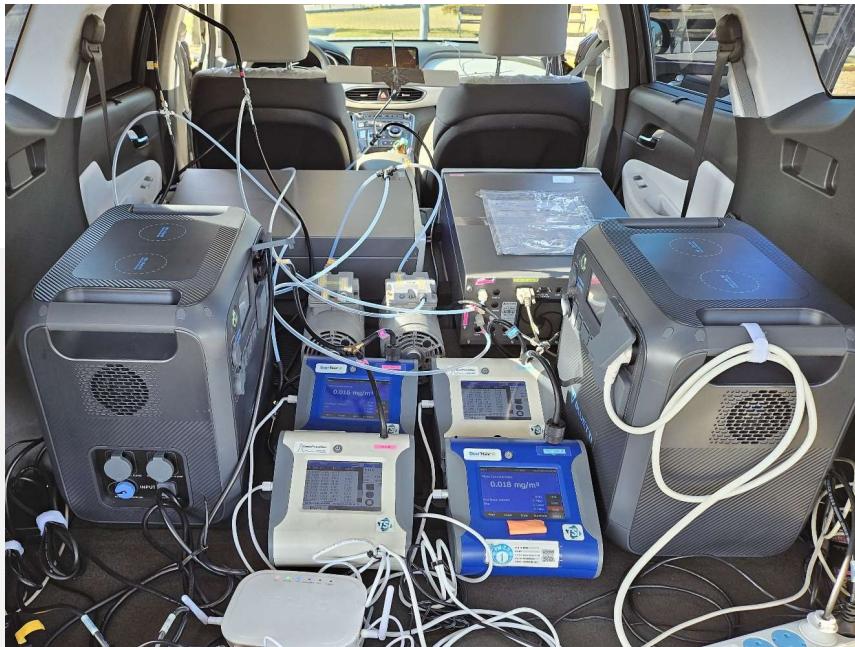


# 4 Measurement Setup

## In-vehicle equipment installation

- ✓ Two units each of equipment for simultaneous measurement of indoor and outdoor air( $PM_{2.5}$ , PN, NOx).
- ✓ Two power banks for power supply to the equipment.
- ✓ Data measured every second are merged through the program.
- ✓ The outdoor air inlet and vent line are secured through the back seat window on the driver's side.

Equipment installation in the vehicle






The outdoor air inlet and vent line



# 4 Measurement Setup

## Equipment detailed specifications

Item	TSI DUSTTRAK	TSI OPS	Serinus 40
			
Target substance	Particle	Particle size	NO, NO <sub>2</sub> , NO <sub>x</sub>
Measurement principle	90° light scattering	120° light scattering	Chemiluminescence
Range	0.001 ~ 400 mg/m <sup>3</sup>	Particle : ~ 3,000 particles/cm <sup>3</sup> Mass : 0.001 ~ 275,000 μg/m <sup>3</sup>	0 ~ 20 ppm
Flow Rate	3.0 L/min	1.0 L/min	0.6 L/min



# Test Results

- 1  $PM_{2.5}(\mu g/m^3)$
- 2  $PN(\#/cm^3)$
- 3  $NO_x(ppb)$

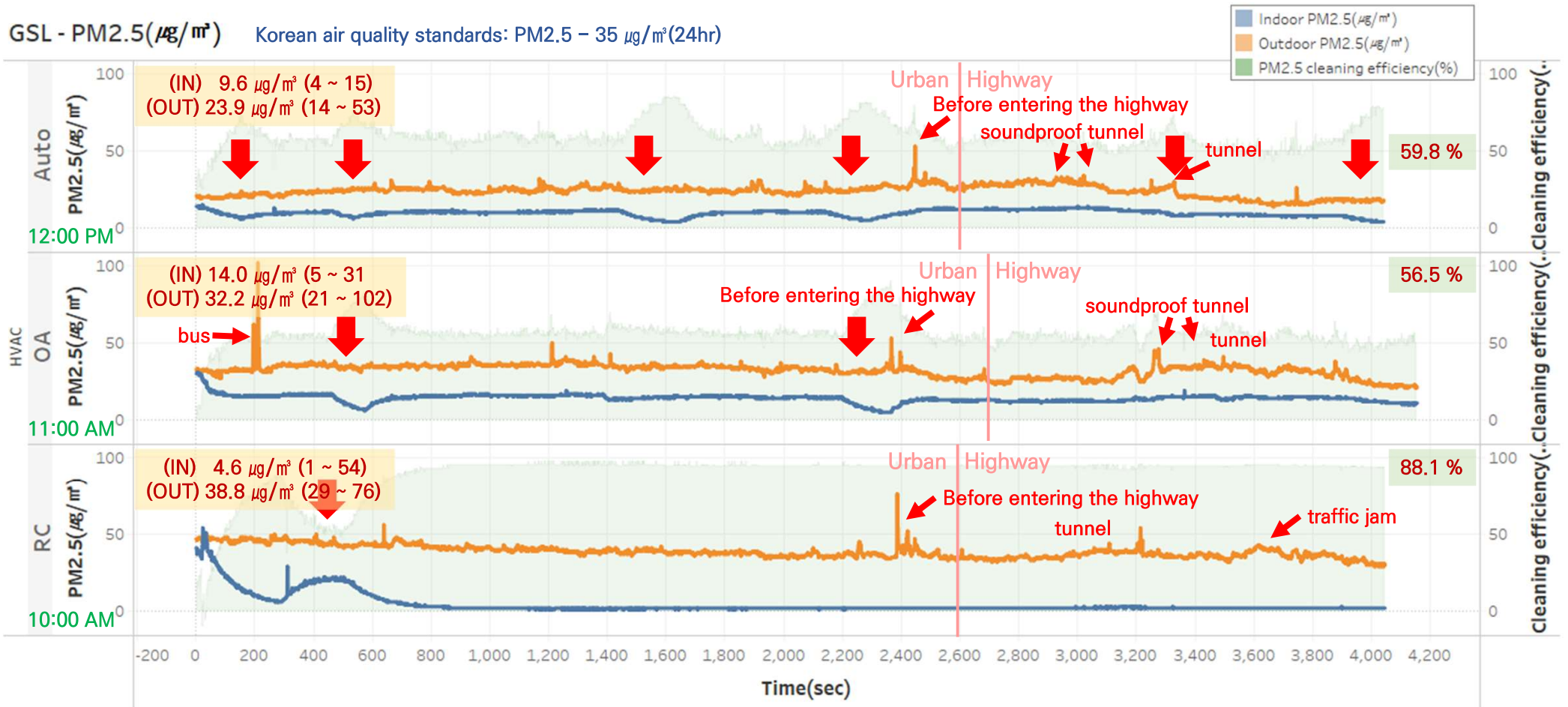
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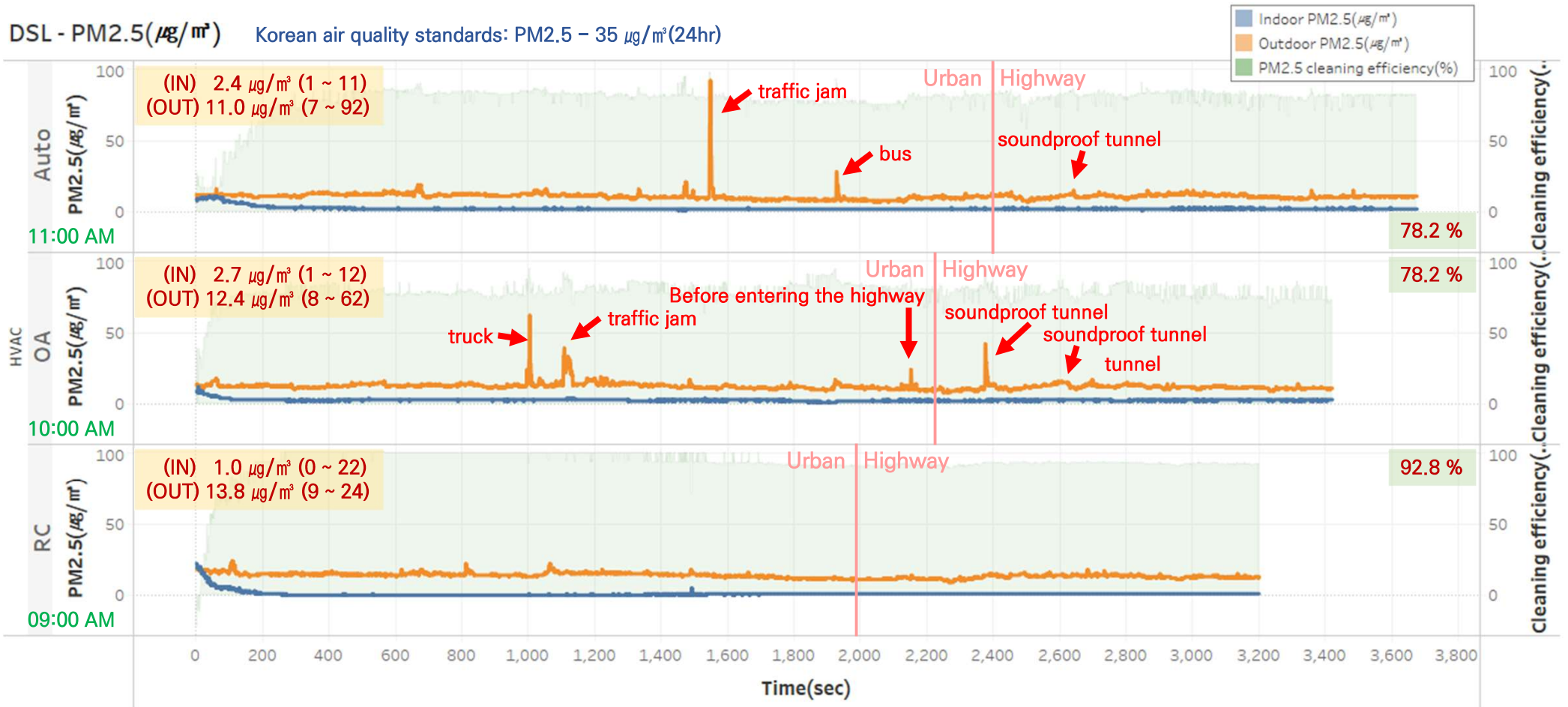
# 1 PM<sub>2.5</sub> (μg/m<sup>3</sup>) – GSL (Route A)

- ✓ **Auto** : Indoor concentration repeatedly increases and decreases depending on HVAC mode changes.
- ✓ **OA** : Highest average concentration. The decrease in some sections is due to checking the blocking function.
- ✓ **RC** : Lowest average concentration. Concentration temporarily increases at the beginning → due to the defogging function



# 1 PM<sub>2.5</sub> (μg/m<sup>3</sup>) - DSL (Route A)

- ✓ The outdoor air concentration was low compared to other tests.
- ✓ As in the GSL test, the average indoor concentration was highest in OA and lowest in RC.
- ✓ Due to the low outdoor air concentration, the HVAC mode in Auto did not change frequently.



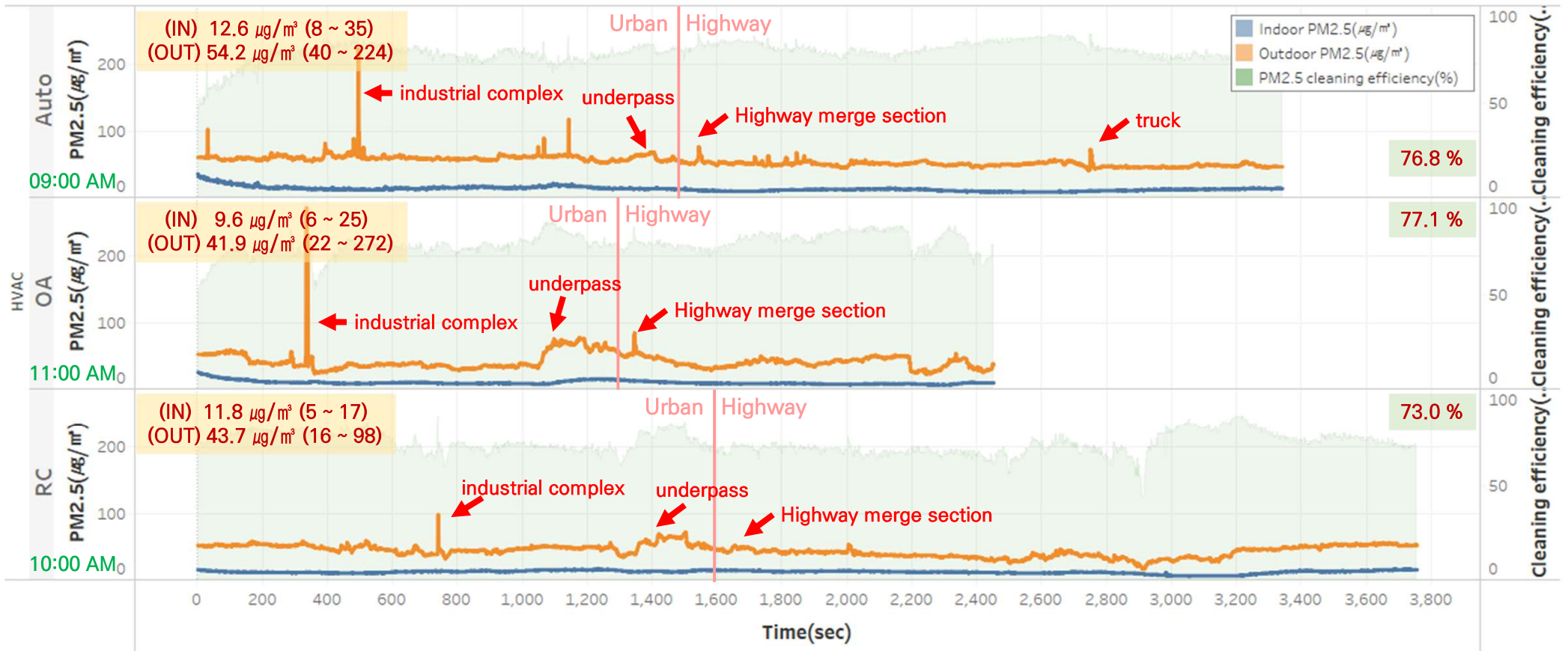




# 1 PM<sub>2.5</sub> (μg/m<sup>3</sup>) - BEV (Route B)

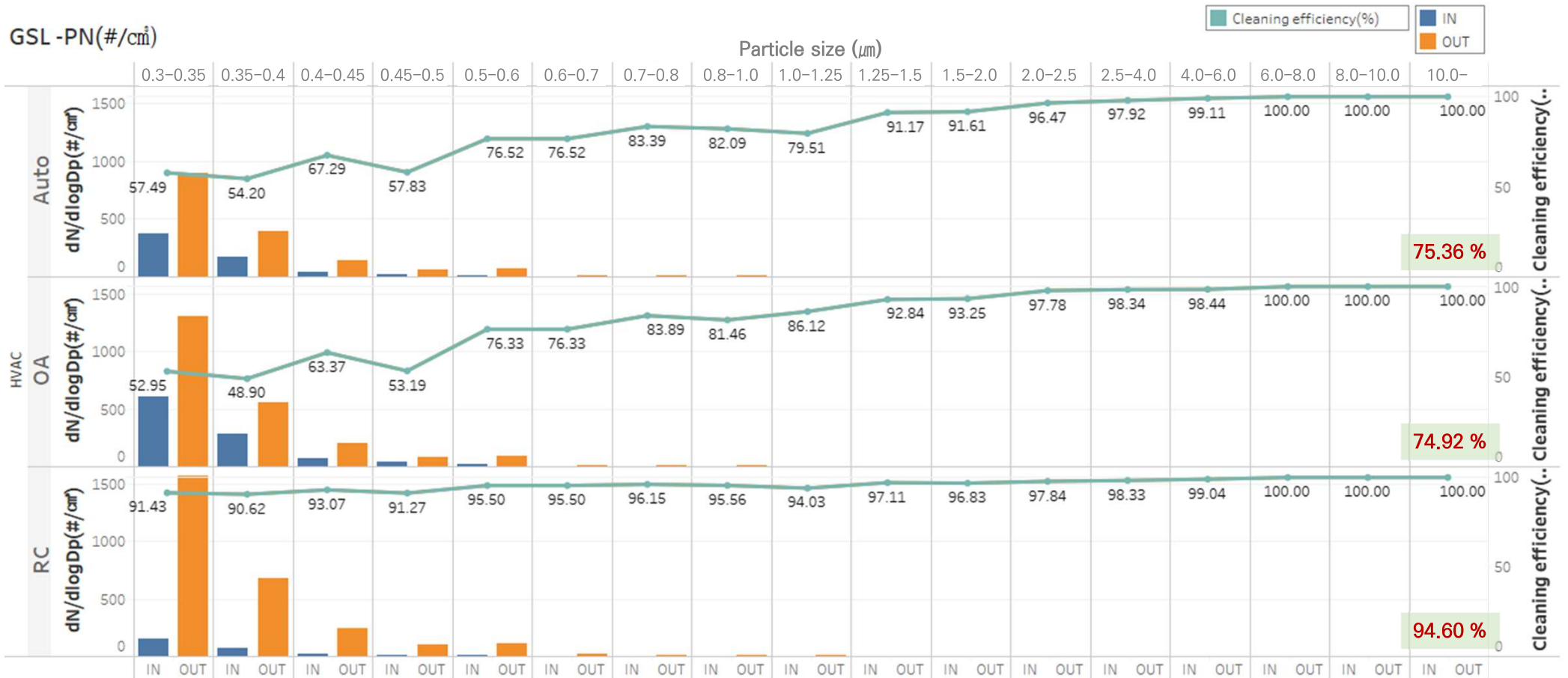
- ✓ The lowest concentration was observed in OA mode.
- ✓ Additional testing and analysis are needed to determine whether the result is due to HVAC is an testing error, a regional effect, or because it is an electric vehicle.

EV - PM<sub>2.5</sub> (μg/m<sup>3</sup>) Korean air quality standards: PM<sub>2.5</sub> - 35 μg/m<sup>3</sup> (24hr)



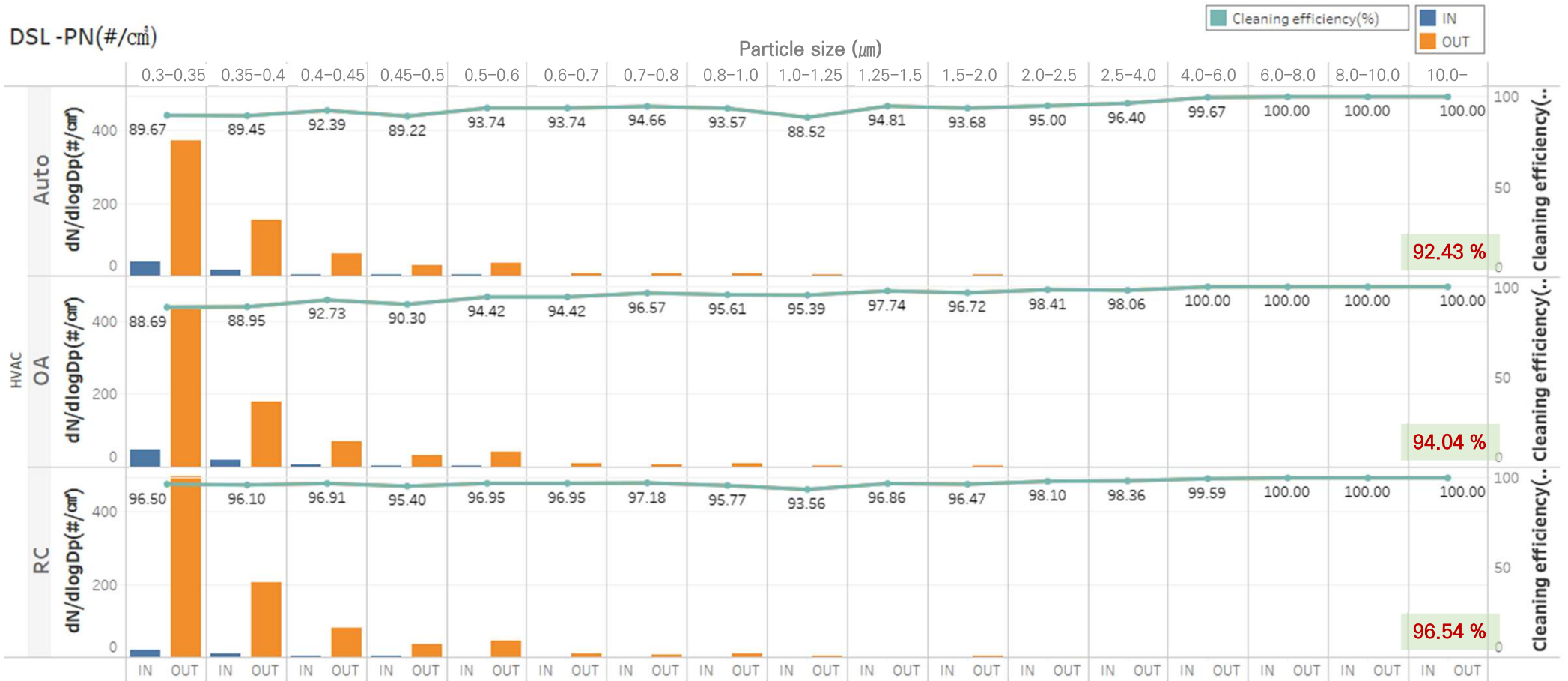
# 2 PN(#/cm<sup>3</sup>) - GSL (Route A)

- ☑ Shows similar changes to PM<sub>2.5</sub> concentration changes due to HVAC. Particles > 1.0 μm most have been removed.
- ☑ RC : The average cleaning efficiency is 94.60%
- ☑ OA & Auto : The average cleaning efficiency in Auto and OA is similar.



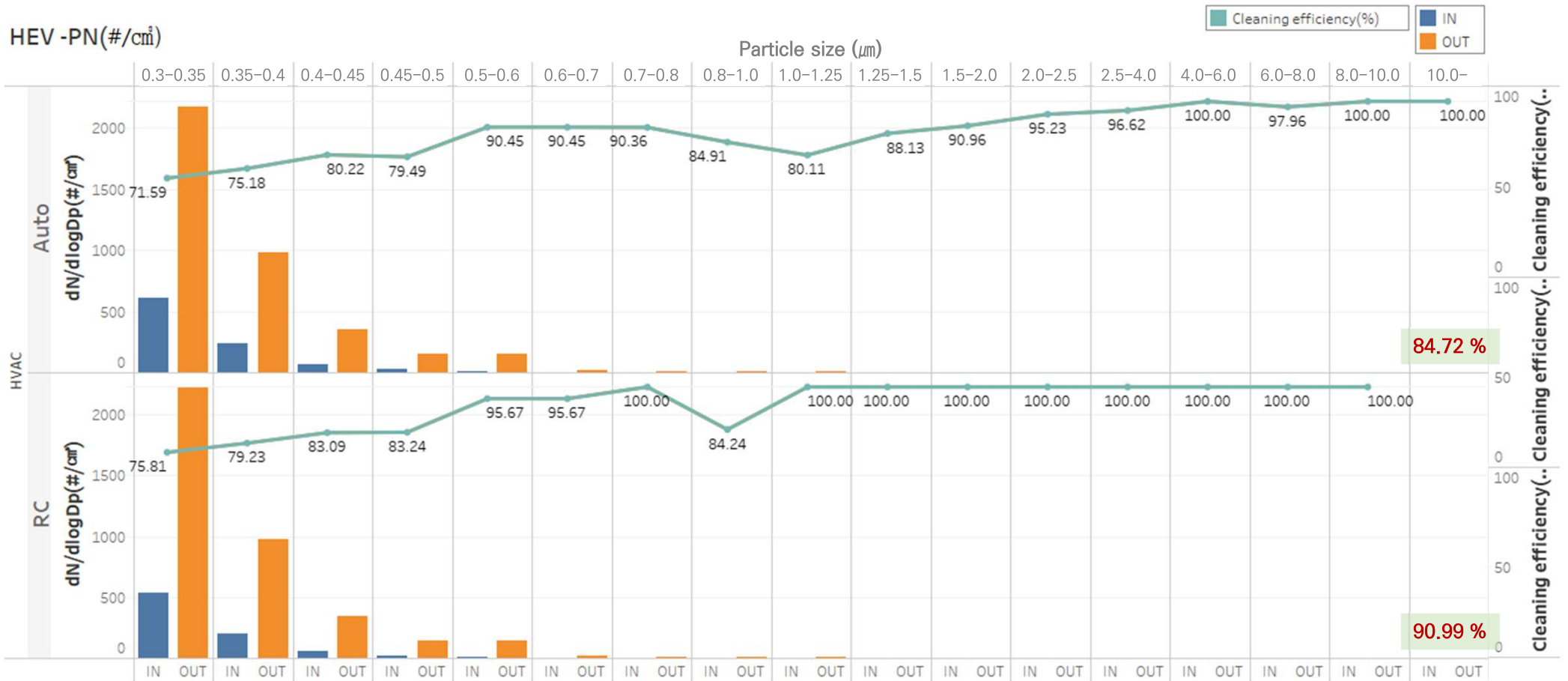
# 2 PN(#/cm<sup>3</sup>) - DSL (Route A)

- ✓ The cleaning efficiency of over 90% was observed under all conditions.
- ✓ The high removal efficiency could be attributed to the low outdoor air concentration level.
- ✓ While the PM<sub>2.5</sub>(μg/m<sup>3</sup>) cleaning efficiency differed depending via HVAC, the PN cleaning efficiency was similar in each condition.



# 2 PN(#/cm<sup>3</sup>) - HEV (Route A)

- ✓ The cleaning efficiency is **higher in RC than in Auto.**
- ✓ As with the PM<sub>2.5</sub> results, additional tests and analysis are needed due to the lack of test data.

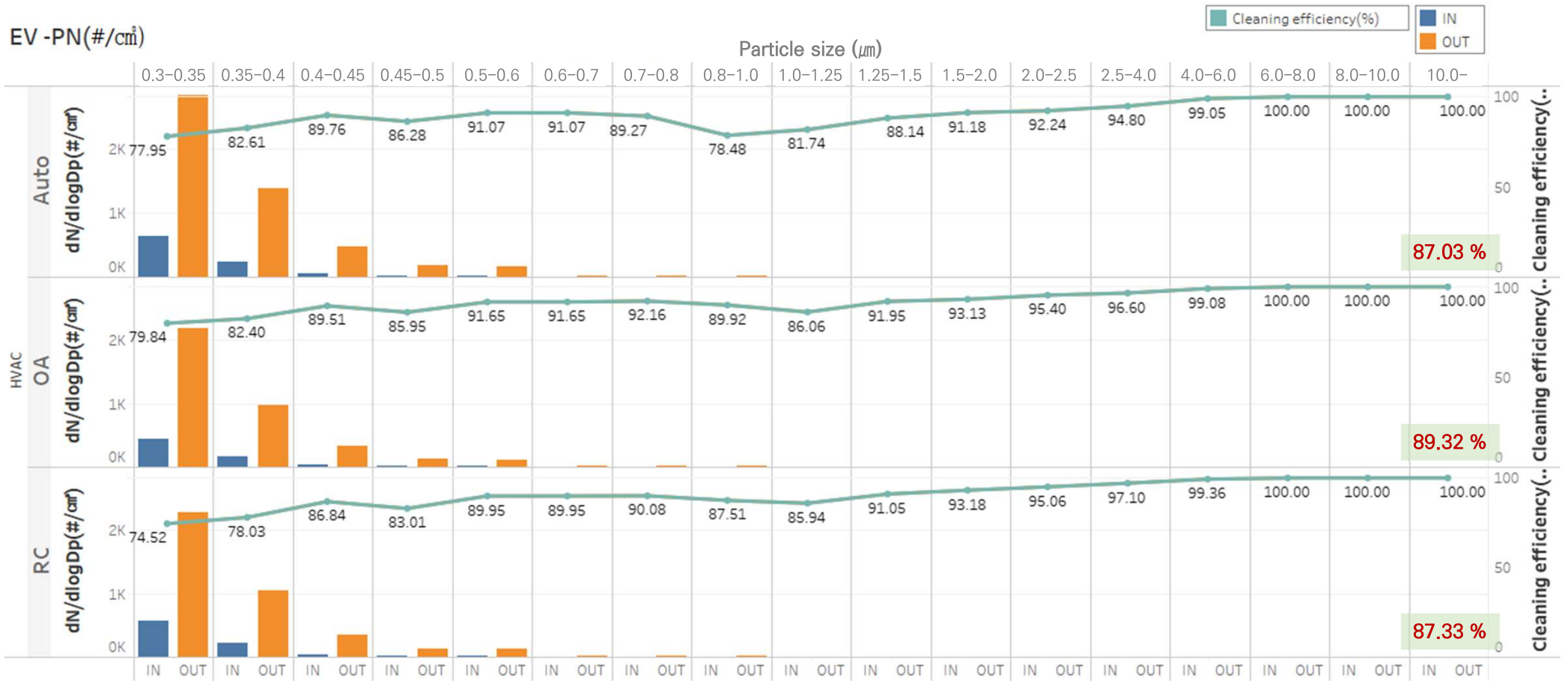


84.72 %

90.99 %

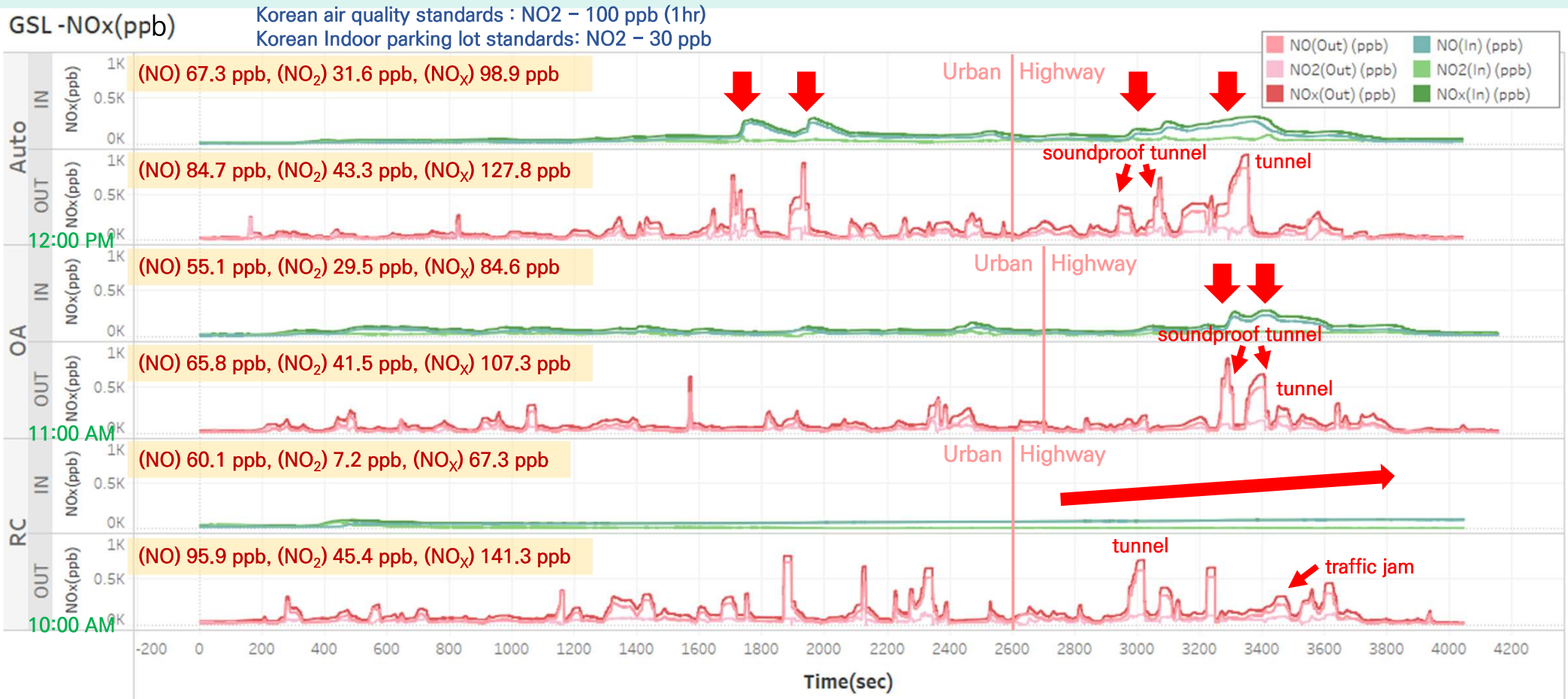
# 2 PN(#/cm<sup>3</sup>) - BEV (Route B)

- ☑ The average cleaning efficiency is over 80% in all conditions.
- ☑ As with the PM<sub>2.5</sub> results, additional tests and analysis are needed.



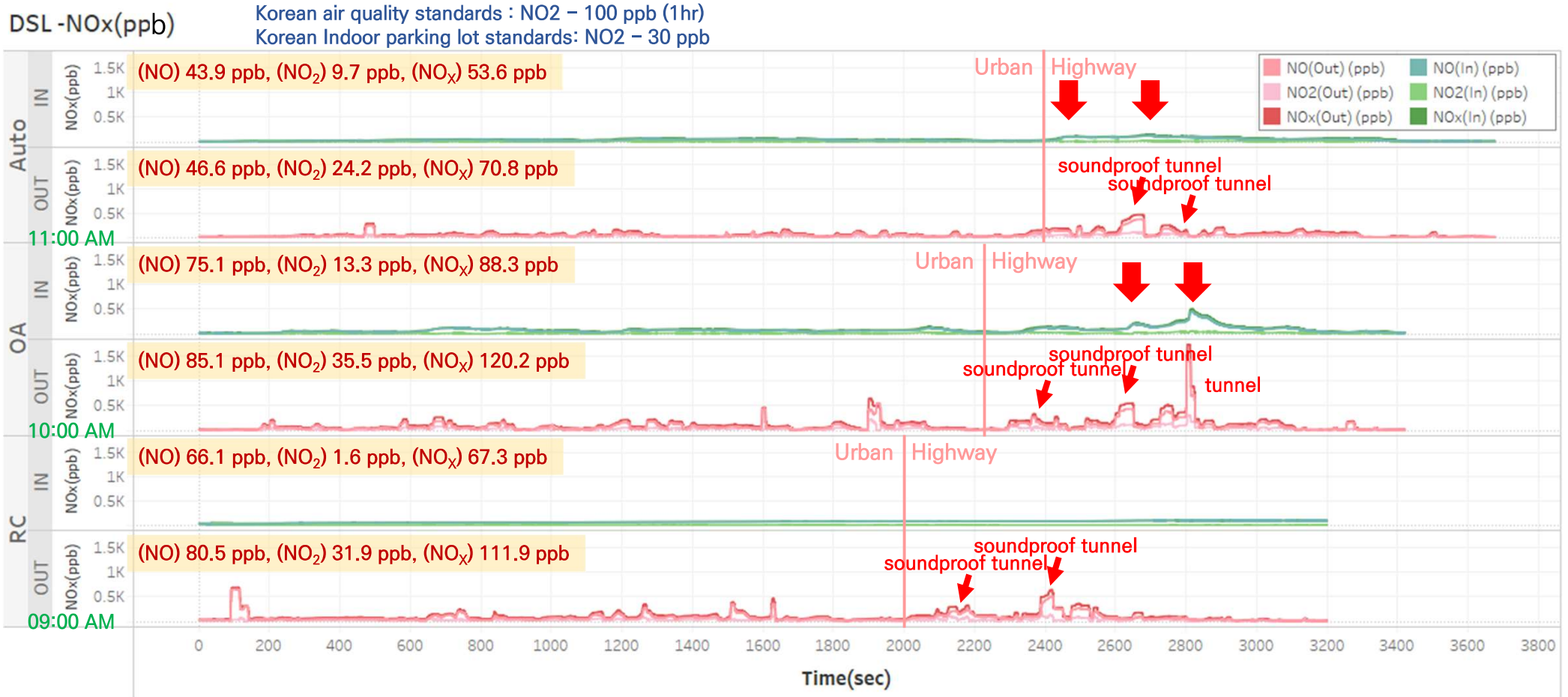
# 3 NOx(ppb) - GSL (Route A)

- ☑ Regardless of whether indoor or outdoor, NO concentration was higher than NO<sub>2</sub> concentration.
- ☑ Indoor NO concentration is lowest in OA and Indoor NO<sub>2</sub> was lowest in RC.
- ☑ OA & Auto : The concentration repeatedly increases and decreases.
- ☑ RC : The concentration of NO steadily increased.



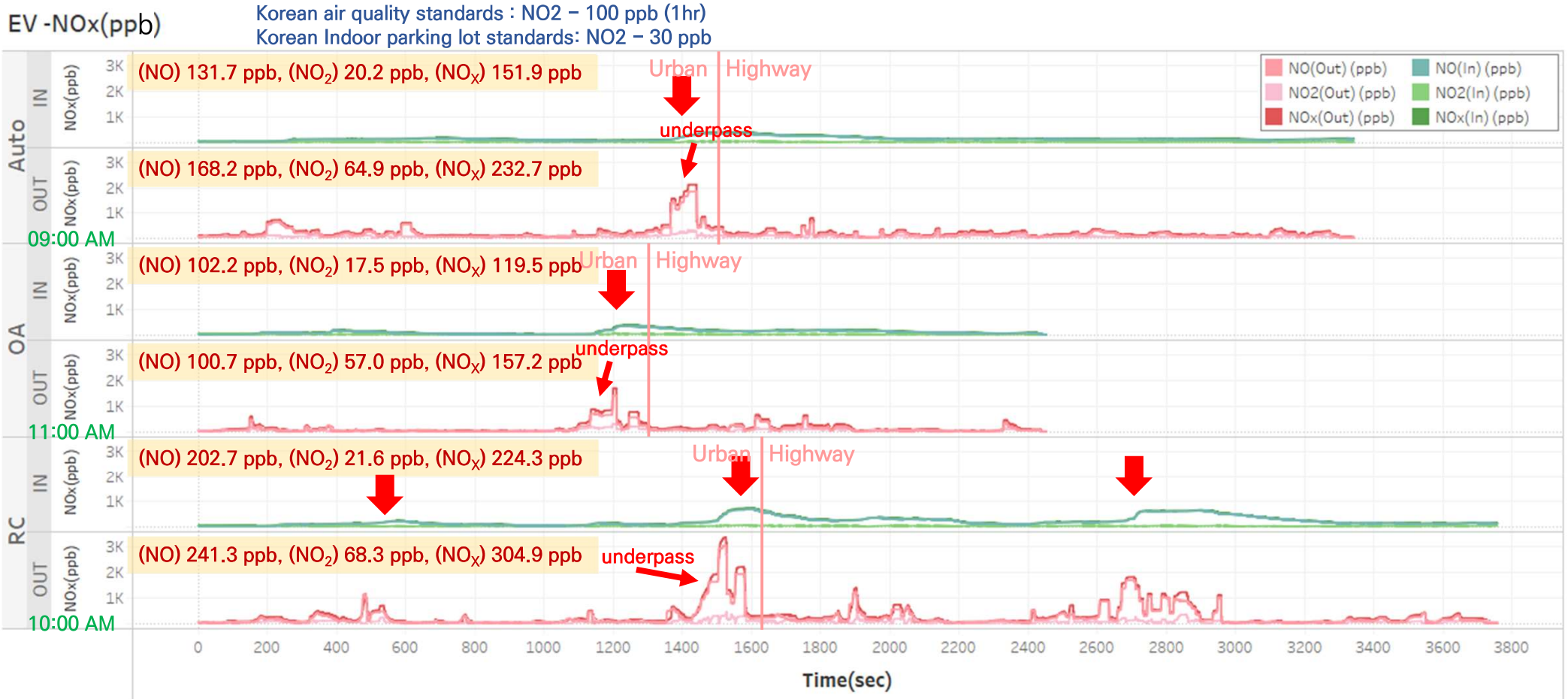
# 3 NO<sub>x</sub>(ppb) - DSL (Route A)

- ✓ NO<sub>2</sub> concentration is lower than in GSL vehicle test. Indoor NO concentration is lowest in Auto and Indoor NO<sub>2</sub> was lowest in RC.
- ✓ OA & Auto : The concentration repeatedly increases and decreases.
- ✓ RC : The concentration of NO steadily increased.(The increasing slope is less than that of GSL vehicles in RC.)



# 3 NOx(ppb) - BEV (Route B)

- ✓ RC : Unlike GSL and DSL results, indoor NOx concentration increases or decreases according to changes in outdoor.
- ✓ The increase in indoor NOx concentration due to the increase in outdoor NOx concentration is **not immediate**.
- ✓ It is difficult to measure real-time removal efficiency.







# Next Steps

- 1 Conclusion
- 2 Future plans

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▶▶ Analysis of Particles and gaseous pollutants  
measured in real road driving



## 1

## Conclusion

PM<sub>2.5</sub>

- ✓ Indoor concentration repeatedly increases and decreases depending on HVAC changes in 'Auto' mode.
- ✓ Generally showing low average concentrations in RC.
- ✓ Conversely, in EV vehicles, OA mode showed the lowest average concentration, so additional tests and analysis are needed.

## Particle Numbers

- ✓ Small size particles less than  $> 1.0 \mu\text{m}$  were mainly observed rather than large size particles.
- ✓ Particles  $> 1.0 \mu\text{m}$  most have been removed.
- ✓ In the DSL test, in which the outdoor PM<sub>2.5</sub> Conc. was low, the PN cleaning efficiency was high. So, the outdoor PM<sub>2.5</sub> Conc. on the test day may affect to results.

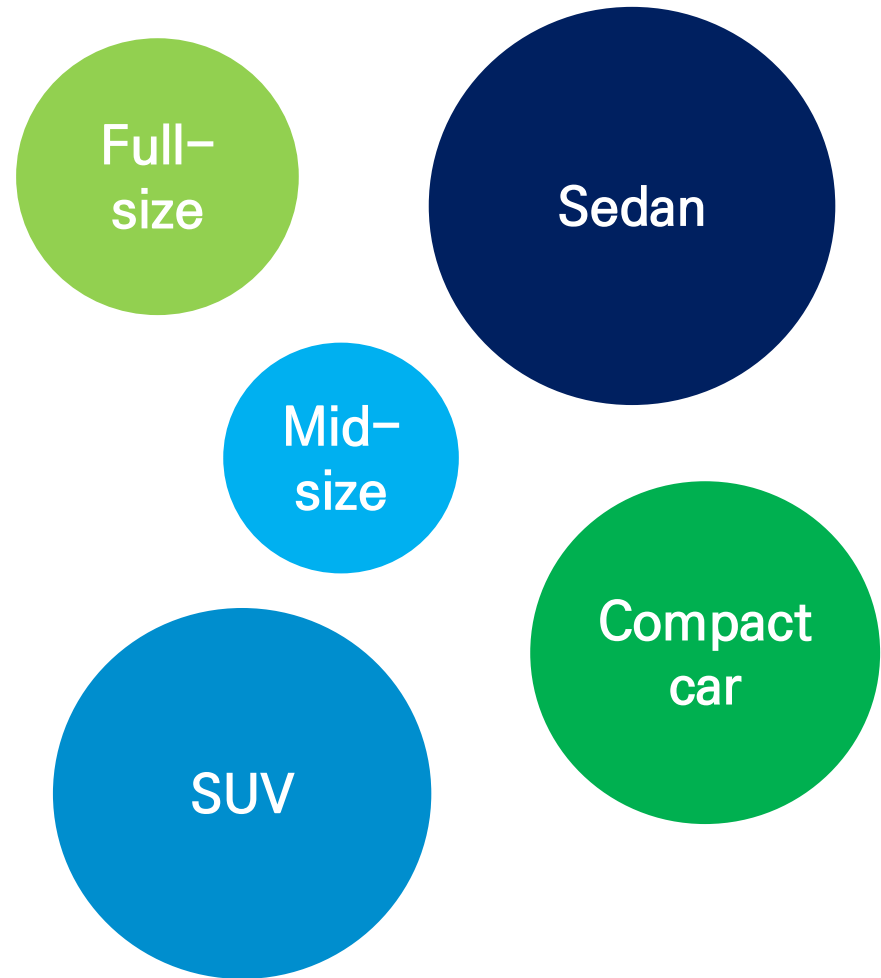
NO, NO<sub>2</sub>, NO<sub>x</sub>

- ✓ Regardless of whether indoor or outdoor, NO concentration was higher than NO<sub>2</sub> concentration.
- ✓ In DSL and GSL test, NO concentration continued to increase slightly in RC mode.
- ✓ The increase in indoor NO<sub>x</sub> concentration due to the increase in outdoor NO<sub>x</sub> concentration is not immediate.

Additional tests in various conditions(vehicle models, powertrains, background concentrations, city, etc.) are needed.

# 2 Future plans

## Expansion of target powertrains and vehicle models for the test



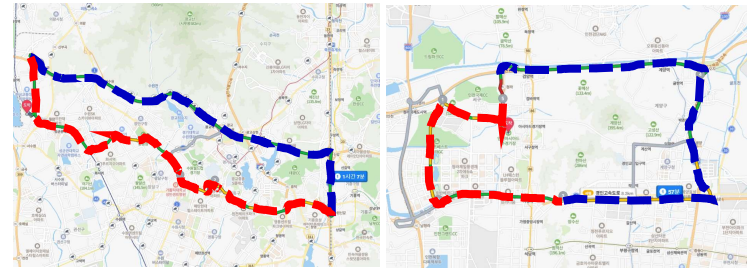
# 2 Future plans

## ● Identify VIAQ influencing factors

Whether indoor air quality is affected by wind direction.



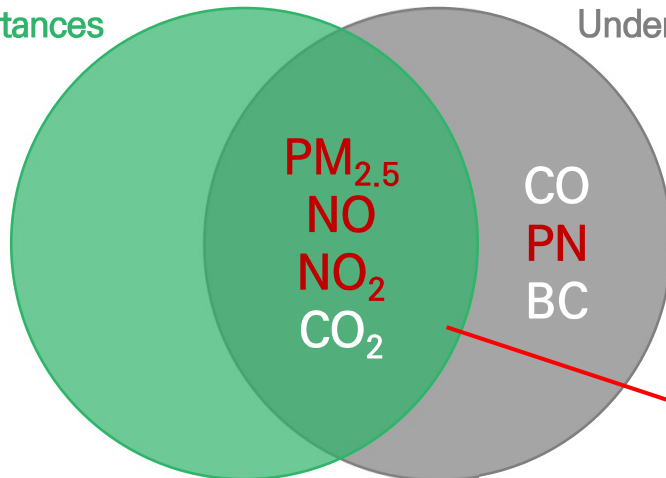
Effects due to route, region, season, etc.



## ● Substance under review

VIAQ-IWG Substances

Under review in Korea



In Korea, CO, PN, BC, etc. are being reviewed as additional substances.

The proposed substance will be confirmed through future test.

Although CO<sub>2</sub> was also measured in this test, we plan to supplement the measurement method and analyze the results with other substances through additional tests.

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- Analysis of Particles and gaseous pollutants measured in real road driving -

# Thank you

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## 질의 응답

