# Soil and Road Dust Emissions - Missing Link Between Monitored and Simulated $PM_{2.5}$: Case Study of Hanoi, Vietnam

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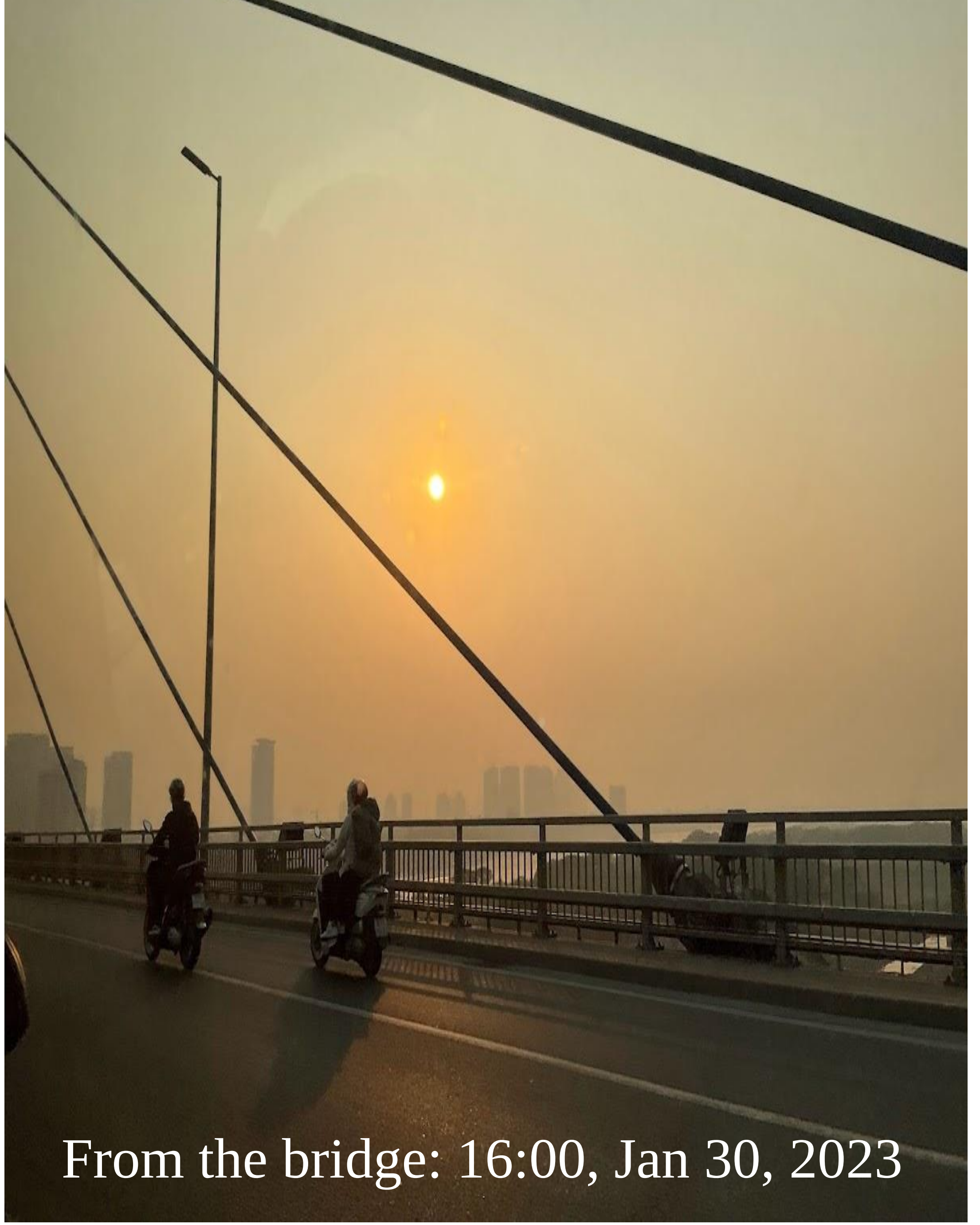
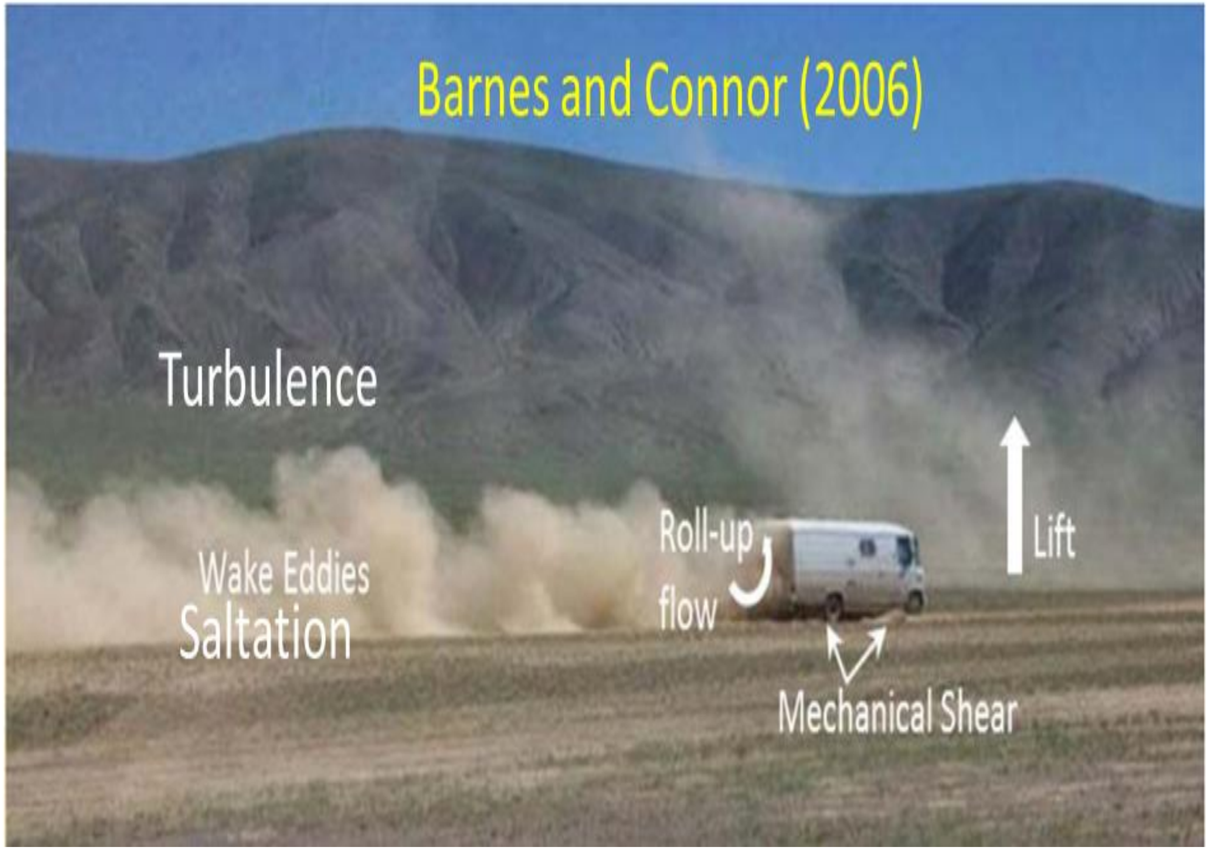


# Highlights

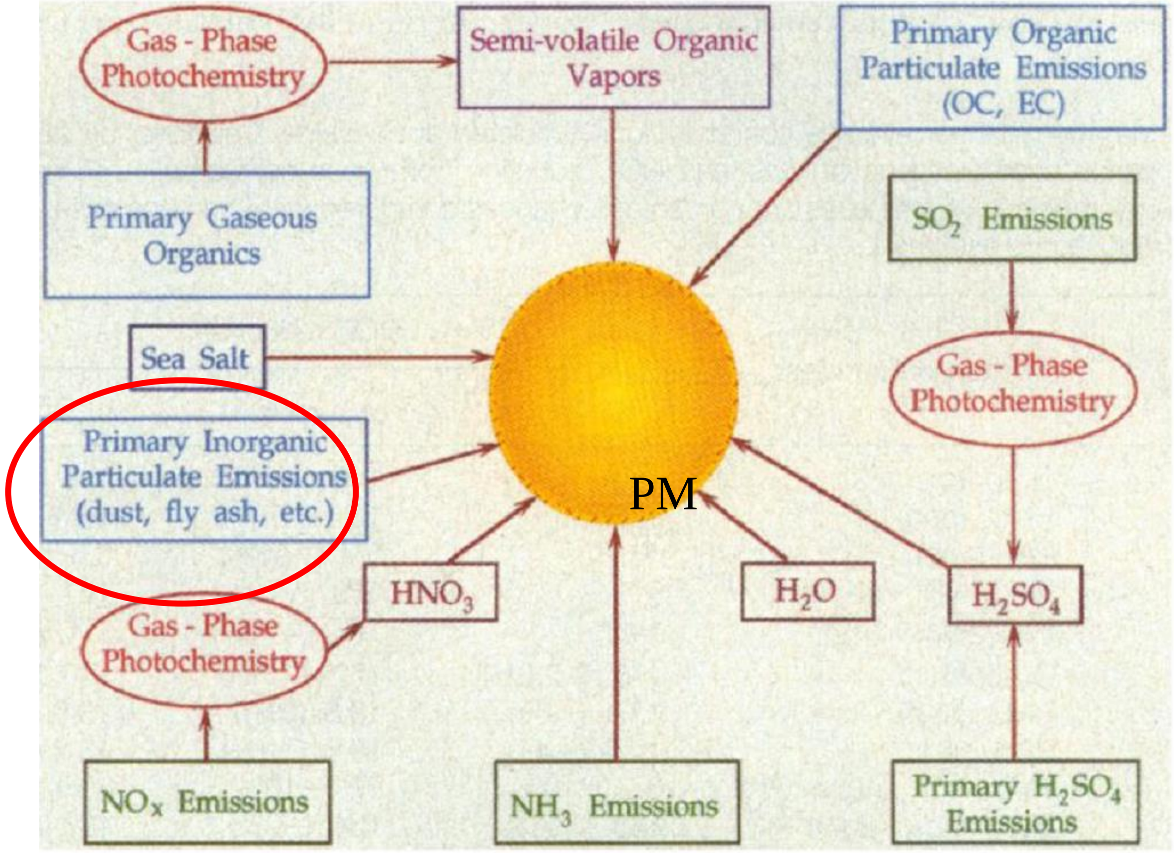
1) Fugitive soil and road dust emissions: effects, mechanisms and challenges for quantification
2) Integration of technical tools for understanding source-receptor relationship
3) Quantification of road dust emissions: results of WB project for AQM in Hanoi



# (1) Soil and road dust emissions



- Effects of atmospheric dust
  - Health: $PM_{10}$, $PM_{2.5}$ , and associated toxic materials (heavy metals, As, etc.)
  - Atmospheric visibility
  - Deposition: soil fertility and ecosystem functions: local (vegetation) and large scale (fallout to ocean and continents)
  - Climate: contribute to mineral dust/aerosol load ➔ dimming, cooling




Source: Meng et al. (1997), *Science*.

# Existing EI databases: poor coverage of soil/road dust

- Existing global/continental databases:
  - EDGARv6.1 for 1970-2018 (Crippa et al, 2020) explicitly covers “road transportation resuspension”
  - Others: CGRER, REASv3.2.1, ECLIPSE-GAINS-V5, CMIP6, HTAP_v2, MIX ➔ no explicit coverage of soil and road dust
- National and urban scale EI in Asia:
  - India (national, 2018): paved and unpaved road, $PM_{10}$: 4.3 Tg & $PM_{2.5}$: 0.4 Tg in 2018 (Dash et al., 2019)
  - China: urban scale, e.g., Beijing, Shanghai, Harbin, Lanzhou, etc.
  - Southeast Asia: World Bank (2021) project: Hanoi, Bac Ninh and Hung Yen of Vietnam ➔ substantial contribution to $PM_{2.5}$ load

# Soil and Road Dust Emission Process

Emissions: release components normally stay fixed in soil into air

Fugitive emissions: challenges to quantify – large uncertainties of EI

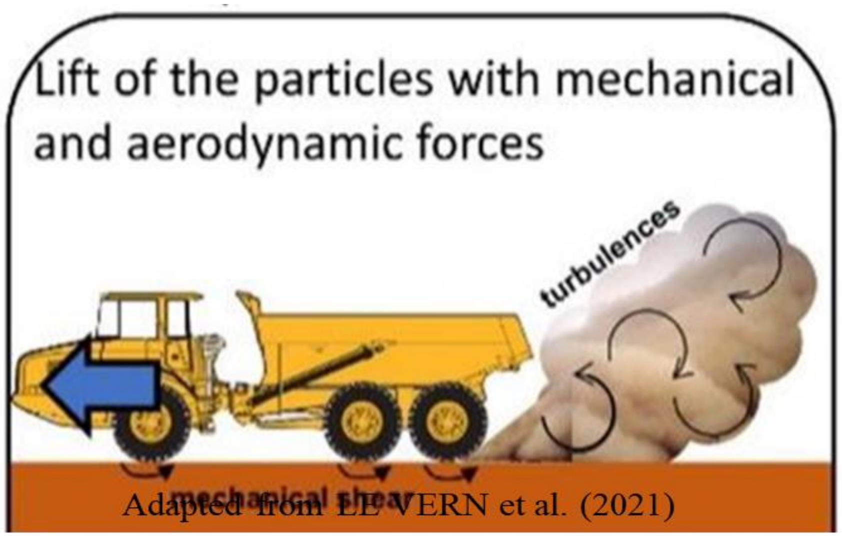
Soil dust: soil surface and meteorology (wind speed, precipitation) ➔ important in arid and semi-arid areas

Road dust: road surface (paved vs. unpaved), vehicle weight, speed, etc.

# Sources of dust on road surface

Transport emissions**: exhaust,** **tire & brake wear,** **road dust resuspension**

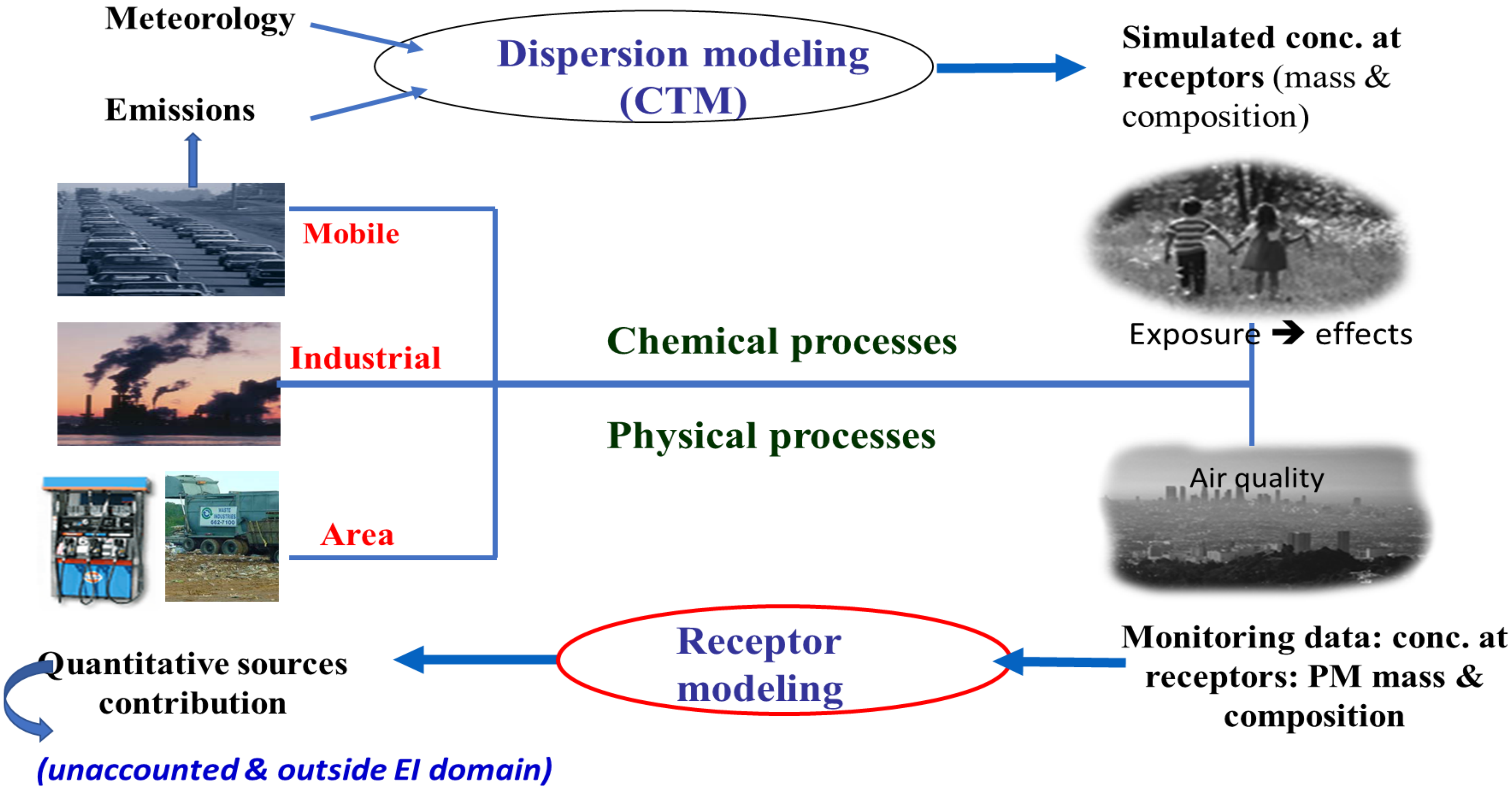
- Dust from paved road:
  - Silt material: deposition of dust from air, nearby areas, materials attached on tires, spills, road surface degradation by traffic, etc.
  - Finite reservoir of dust: with high traffic volumes the emissions rate is related to the rate of material deposition to road
- Dust from unpaved road:
  - Road/soil surface degradation by traffic: most important source of dust
  - Infinite reservoir of particles for resuspension



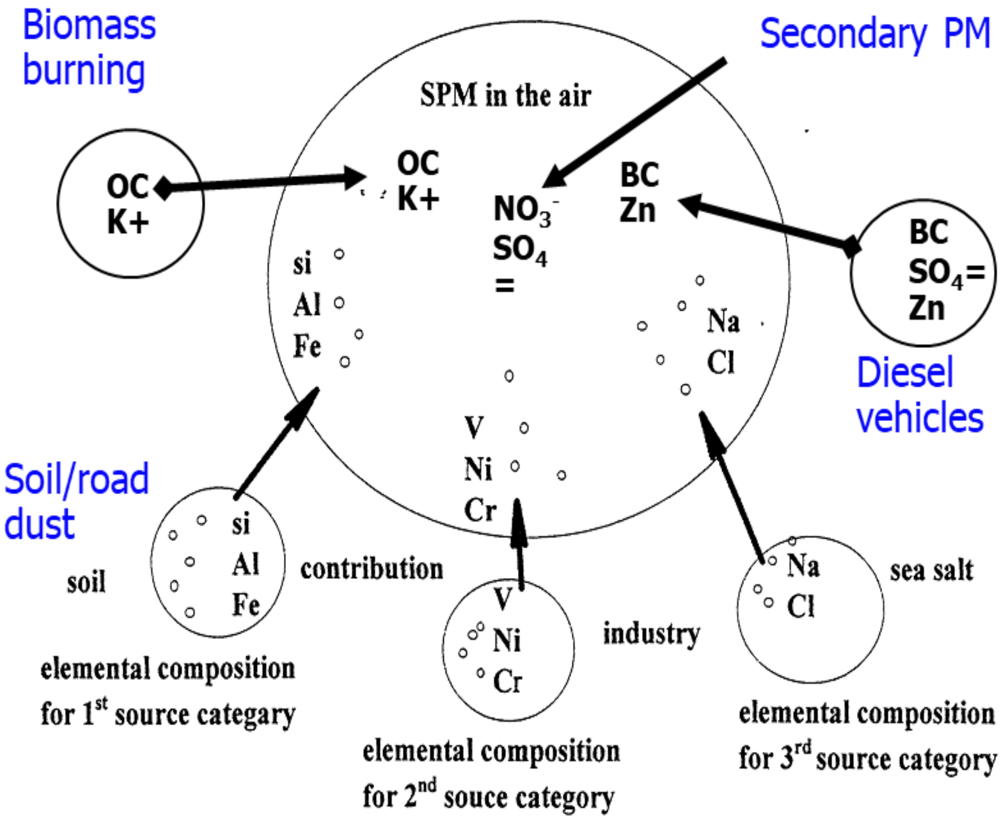

Adapted from LE VERN et al. (2021)

EF: depends on the fine particle content (silt) of road surface, moisture content, vehicle speed & weight

# (2) Technical tools for understanding source-receptor relationship in air quality management



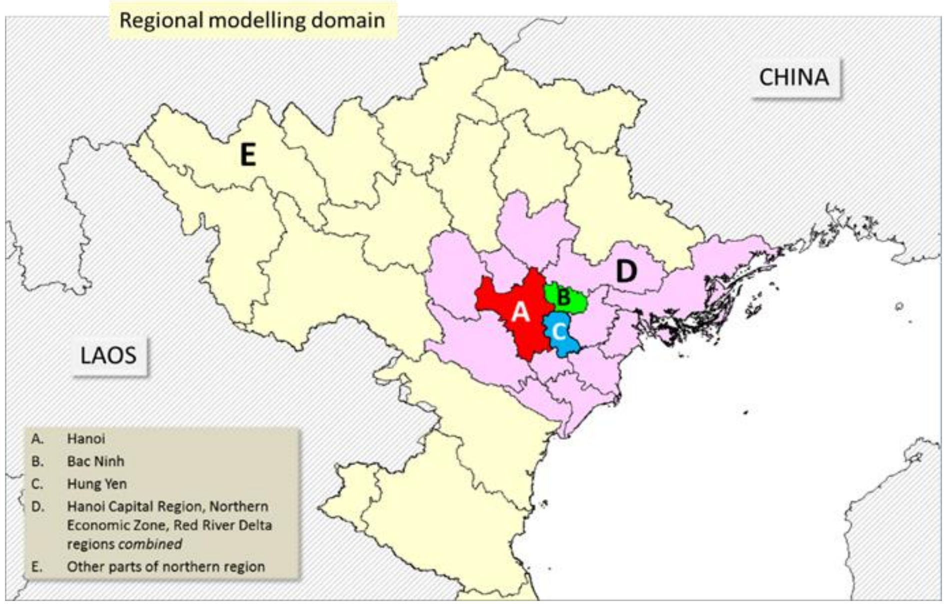
# Markers/fingerprints of emission sources in ambient PM samples




| **Emission Source** | **Marker Elements** |
|---|---|
| **Soil and road dust** | **Al, Si, Sc, Ti, Fe, Sm, Ca, (Pb)** |
| Sea salt | Na, Cl, $Na^+$, $Cl^-$, Br, I, Mg, $Mg^+$ |
| Oil burning | V, Ni, Mn, Fe, Cr, As, S, $SO_4^{2-}$ |
| Coal burning | Al, Sc, Se, Co, As, Ti, Th, S |
| Iron & Steel industries | Mn, Cr, Fe, Zn, W, Rb |
| Non-Ferrous metal industries | Zn, Cu, As, Sb, Pb, Al |
| Glass industry | Sb, As, Pb |
| Cement industry | Ca |
| Refuse incineration | K, Zn, Pb, Sb |
| Biomass/Straw burning | K, $C_{ele}$, $C_{org}$, Br |
| Automobile gasoline | $C_{ele}$, Br, Ce, La, Pt, $SO_4^{2-}$, $NO_3^-$ |
| Automobile diesel | $C_{org}$, $C_{ele}$, S, $SO_4^-$, $NO_3^-$ |
| Secondary aerosols | $SO_4^{2-}$, $NO_3^-$, $NH_4^+$ |

# (3) Quantification of road dust emissions: results of WB project for AQM in Hanoi

- Project "Air quality management in Hanoi - Situation of Emission Sources & Solutions" (2019-2021)
- Activity data collection for EI compilation: NIRAS
- Emission inventory for $PM_{2.5}$ in 3 provinces and AERMOD modelling: CEMM - AIT
- GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model: IIASA
- Monitoring ambient $PM_{2.5}$ at 2 sites in Hanoi and receptor modeling (PMF) for 1 year: FMI

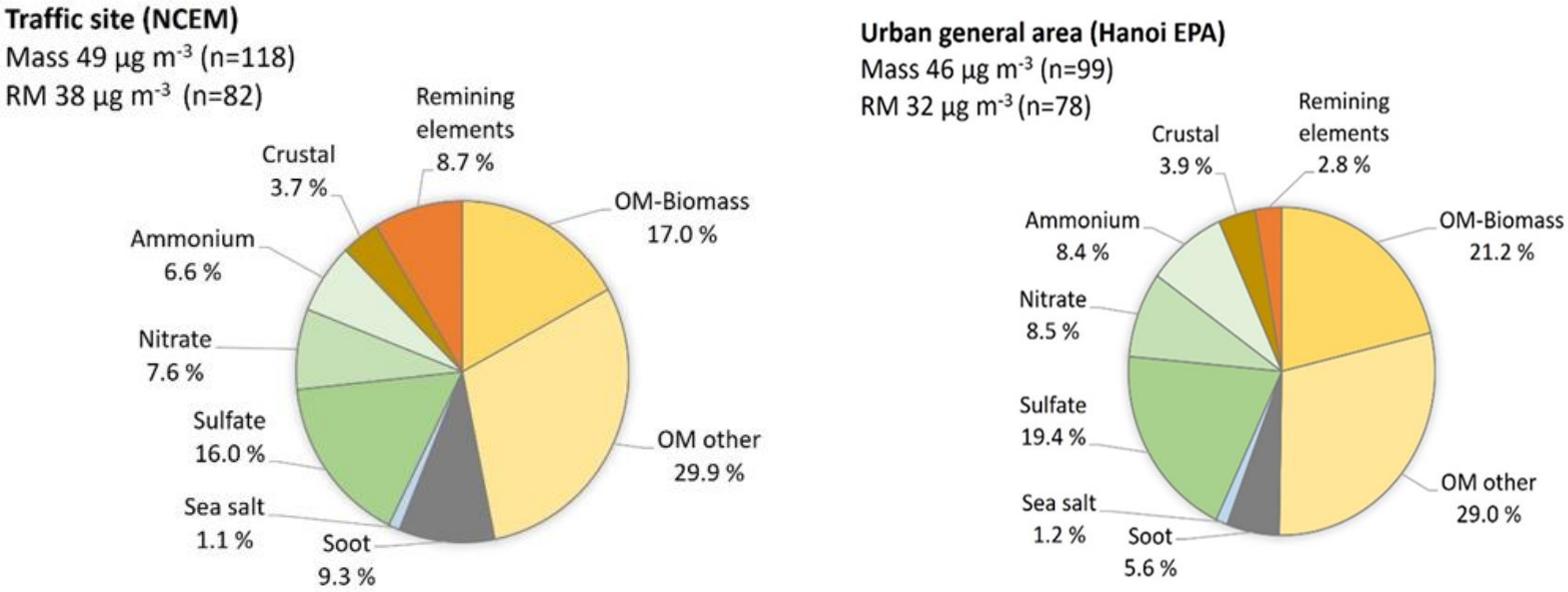



Model (GAINS) to assess impact of current and future emissions scenarios ➔ AQ plan ➔ policy recommendations

*Source: WB (2021)*

# Monitoring results: $PM_{2.5}$ levels and compositions (RM)

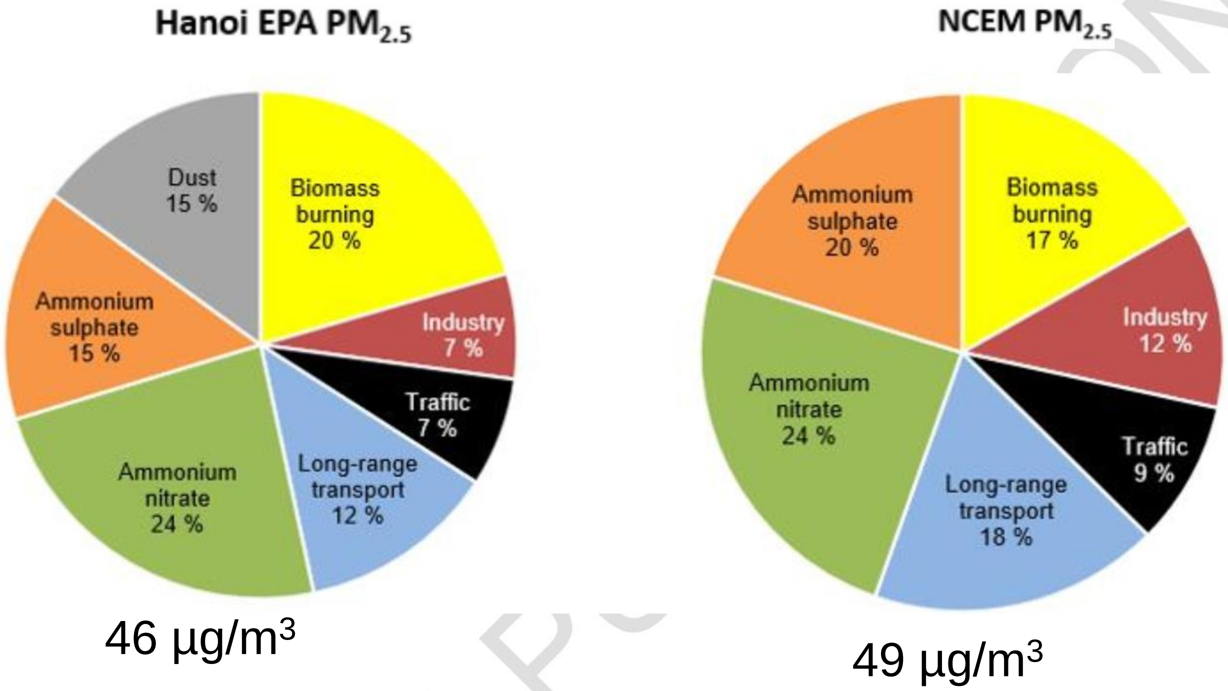
## Reconstructed mass of measured $PM_{2.5}$




Average composition of the $PM_{2.5}$ measured at 2 sites in Hanoi; OM = biomass (1.9 OC) + other (1.4 OC). Source: WB, FMI (2021) and (Makkonen et al. 2023)

# Receptor model results: source factors for $PM_{2.5}$ (2019-2020)

Figure 6. Results of source apportionment model based on the measurements of PM2.5 at Hanoi EPA and NCEM stations 2019-2020.

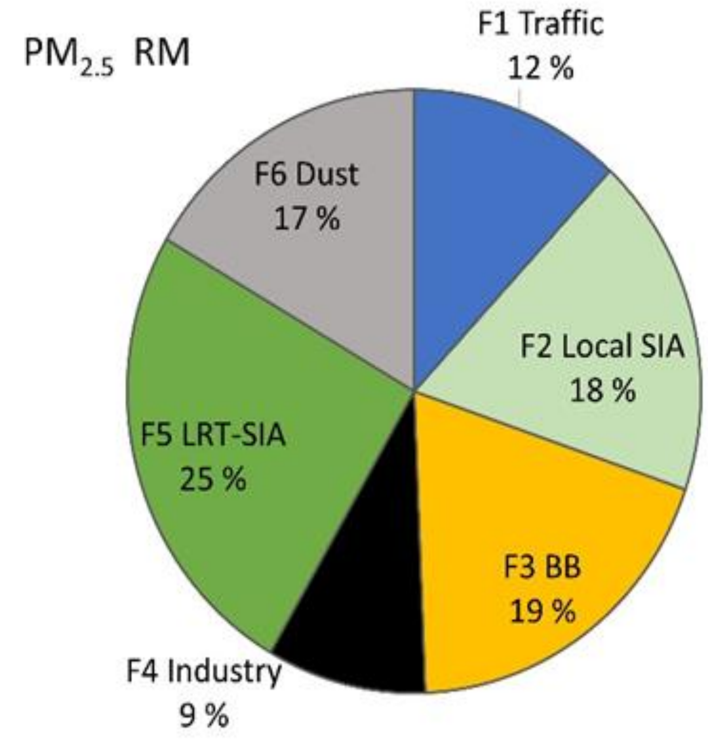



**In the source apportionment analysis of $PM_{2.5}$, six major sources were found for the NCEM data and seven major sources for Hanoi EPA station.**

*Source: WB (2021)*

## Updated PMF results

*(Makkonen et al. 2023)*



# EI component of WB project for road dust $PM_{2.5}$



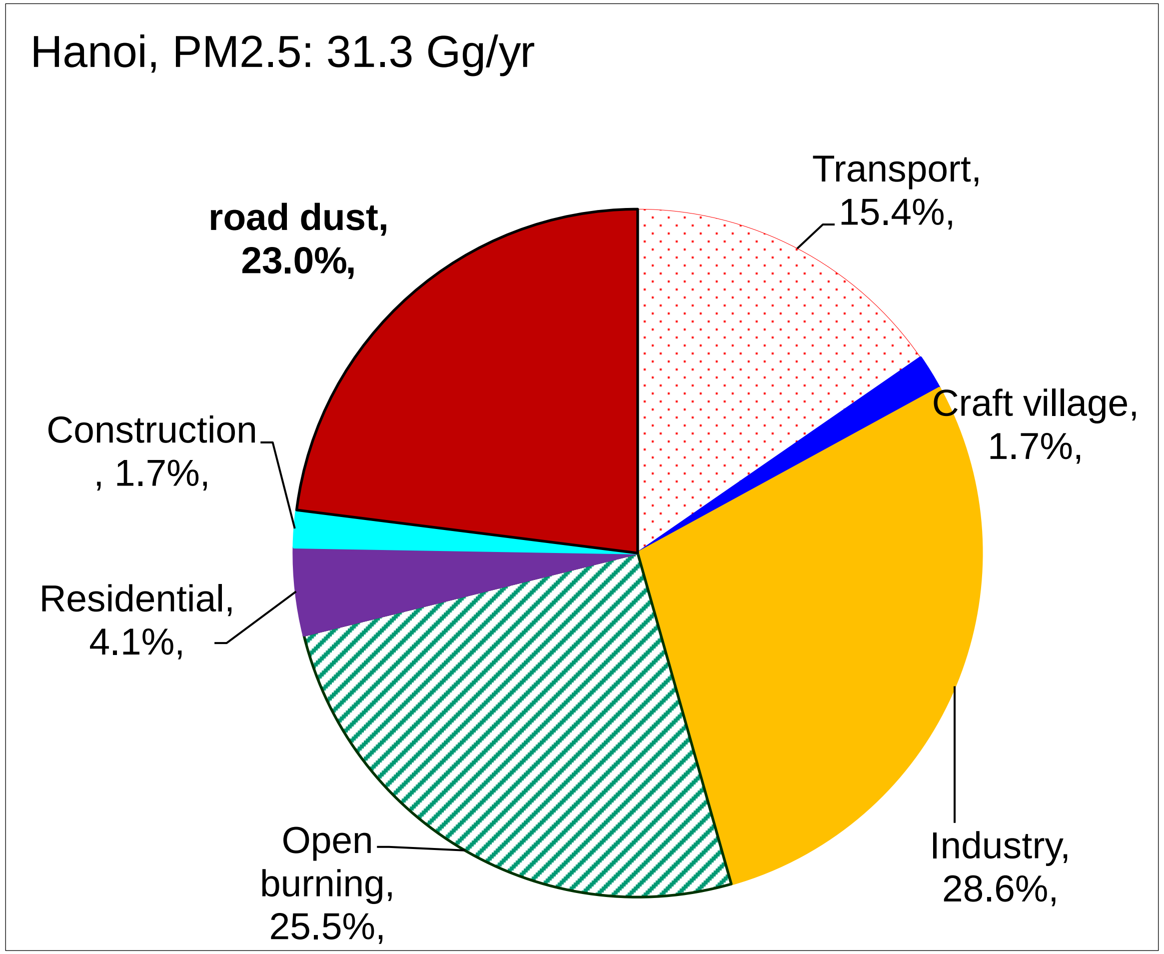
- Paved road: 2015 (6,580 t) and 2019 (10,000 t)
  – Calculation method: AP-42, USEPA (updated 2011)
  – VKT from on-road transport sector: 95% MC and 100% of other traffic fleets
  – Silt loading: taken from Phi et al. (2018)
  – Assumed controlled 30% (if 2 times water spray/day = 60% controlled)

Unpaved roads: 2015 (691 t) and 2019 (830 t)
  – Calculation method: AP-42, USEPA (2009)
  – Assume only 5% of MC running on unpaved roads
  – Use the ratio of EF for MC to PC for paved road ~ 1/15 (0.065)

# EI for Hanoi for 2015 (WB, 2021)

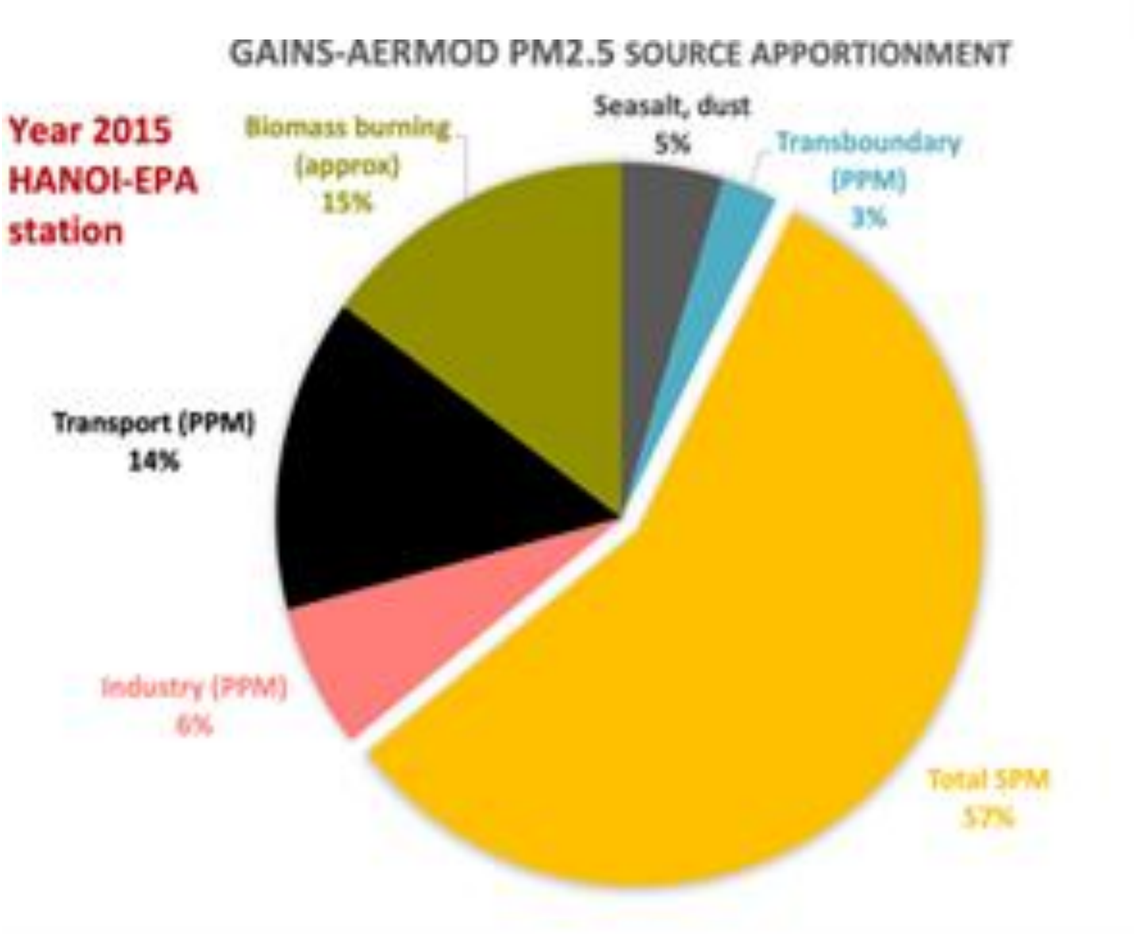


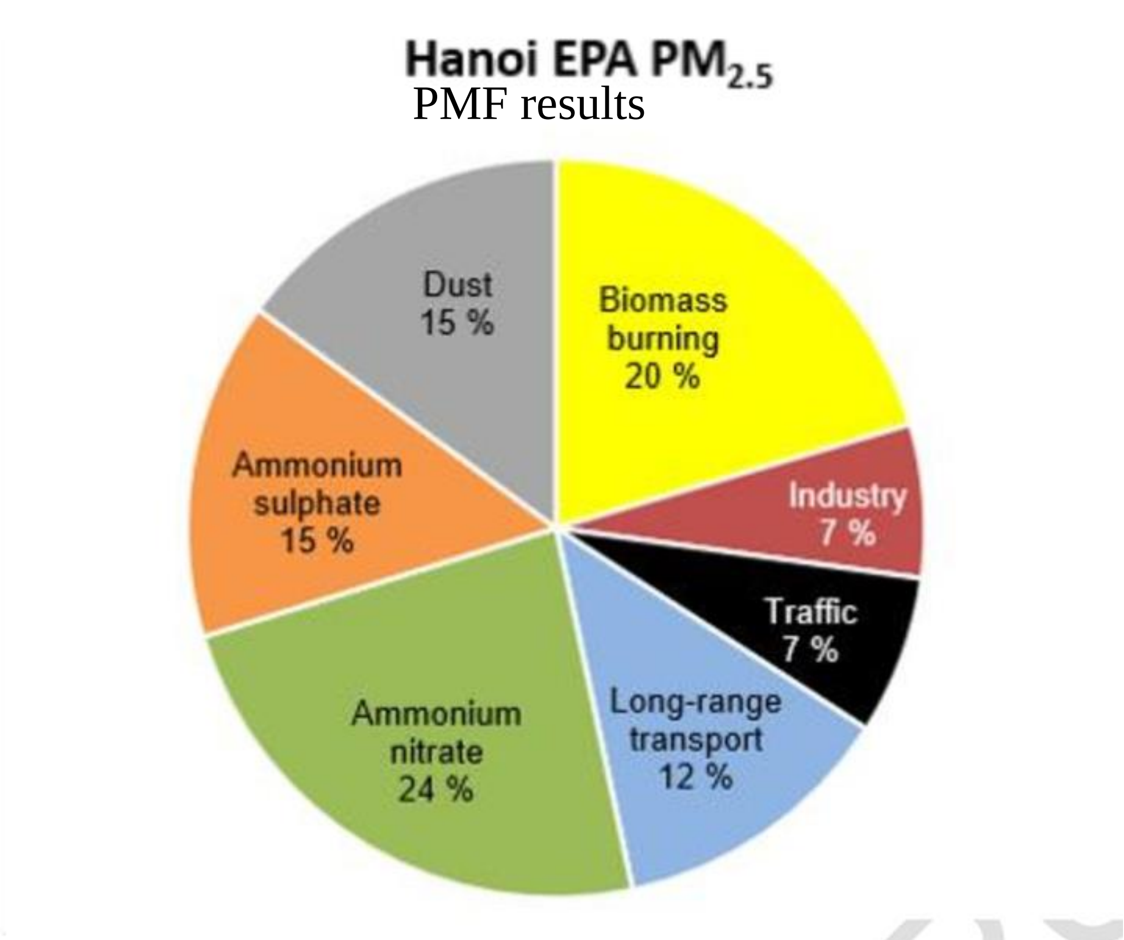
**Ha Noi, 2015: 31.3 Gg/year**




EI of 2015: ABC-EIM and GAINS produce similar results ➔ used for GAINS dispersion modeling

# GAINS results with the emission input based on EI for Hanoi




Improve agreement between GAINS outputs with PMF for 2 sites (WB, 2021): total $PM_{2.5}$ mass by GAINS-AEROMOD (44-48 µg/m$^3$), consistent key source factors found by both approaches

# Summary

- Road dust resuspension is important PM source ($PM_{2.5}$, $PM_{10}$, TSP) but is currently poorly covered by existing emissions inventories;
- Hanoi: road dust shows significant contribution to $PM_{2.5}$ based on monitoring, receptor modeling and dispersion modeling:
  - Improving EI of road dust helps to increase agreement between monitored and simulated $PM_{2.5}$ levels and composition
  - Emission control for road dust helps to improve $PM_{2.5}$ air quality
- Challenges to improve accuracy soil/road dust EI: need monitoring data to quantify activity data and EF on various types of road ➔ improve the formula for EI for the local conditions

# THANK YOU FOR YOUR ATTENTION !

Acknowledgment:

- WB project: providing funding support for a comprehensive assessment of air quality in Hanoi and surrounding provinces
- Colleagues from the NIRAS team for data collection, AIT-CEMM for EI development, FMI-CEM for monitoring and IIAS for GAINS results
- Organizers of the conference