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On-road measurements of nanoparticle emissions

On-Road Measurements of Spark Ignition Nanoparticle Emissions

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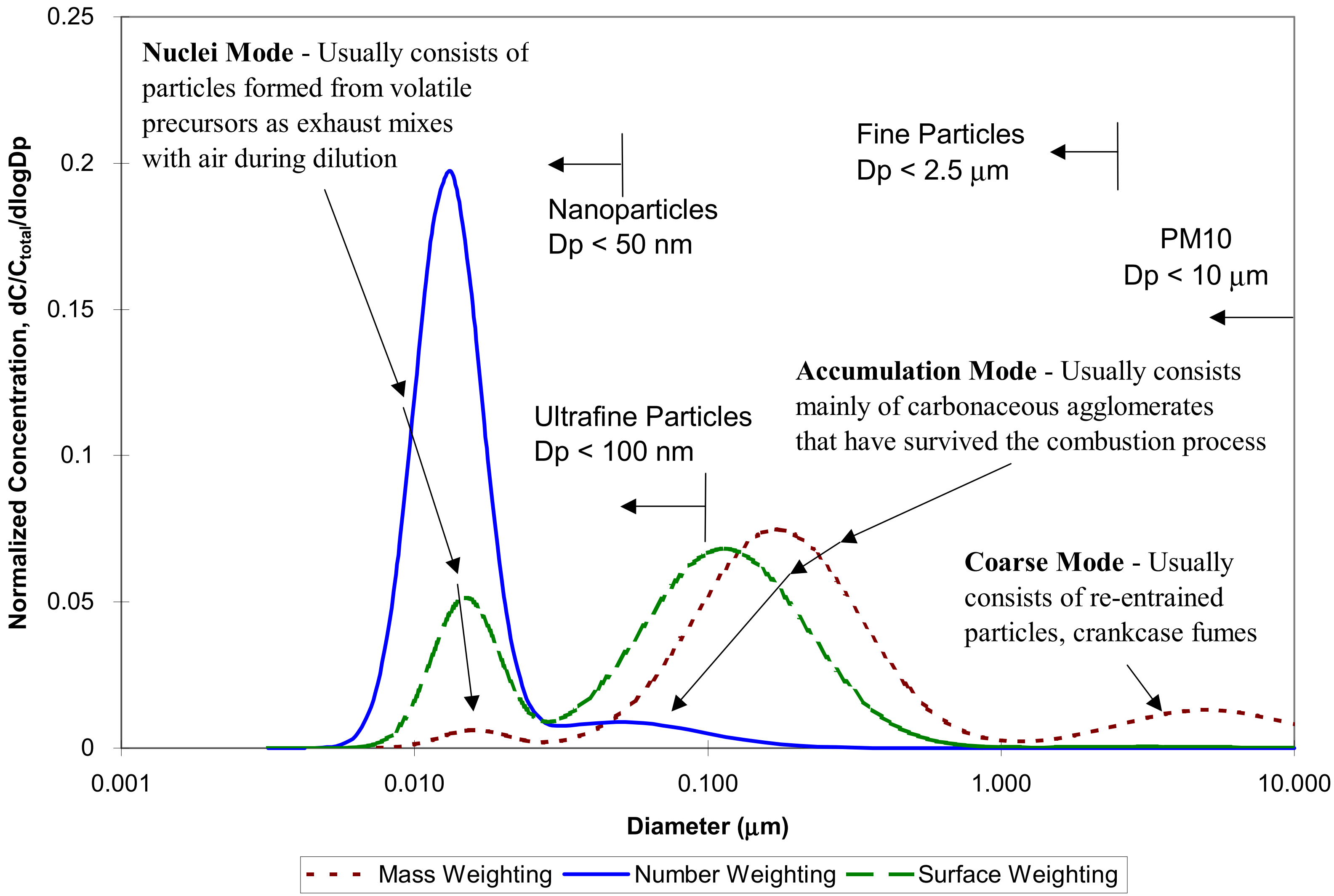
Typical Diesel Particle Size Distributions, Number, Surface Area, and Mass Weightings Are Shown

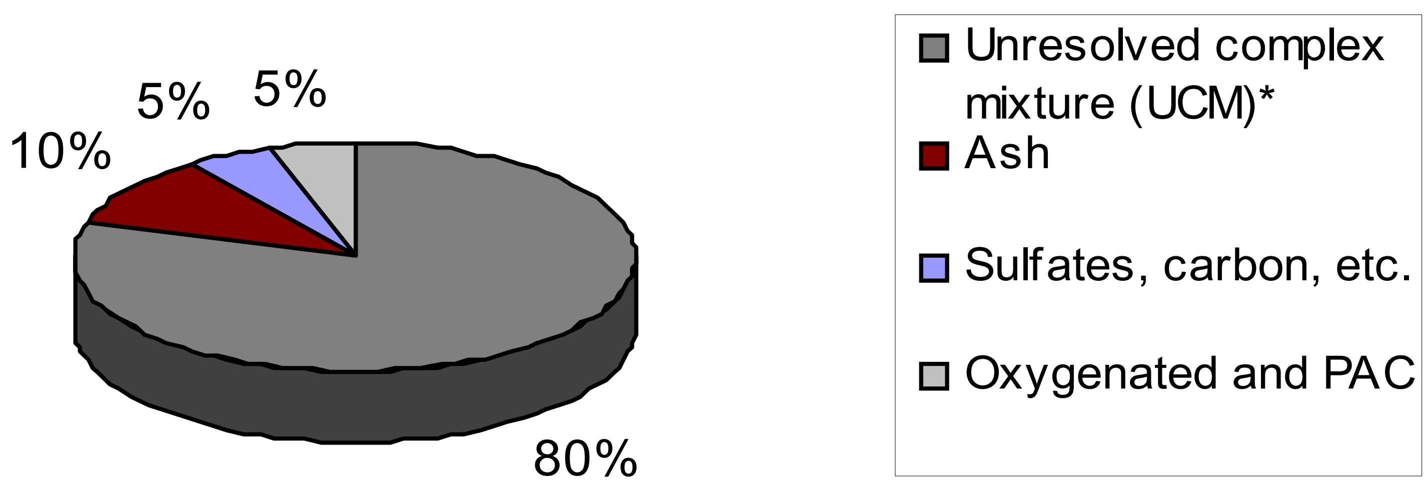


Nanoparticle Formation: Current working hypothesis - based mainly on Diesel studies

- Most of the particles are formed from volatile precursors by nucleation and growth as the exhaust dilutes and cools in the atmosphere
  - Nanoparticles are volatile and easily removed by heating
  - The formation of nanoparticles is **very, very** dependent on dilution conditions
- Heavy hydrocarbons (lube oil) and sulfuric acid are primary constituents of nanoparticles –ash may play an important role for some engines
- Low levels of soot in the exhaust compared to volatile precursors make **volatile** nanoparticle formation more likely – at least under some lab conditions

Particles from Spark Ignition Engines - Approximate Composition of Exhaust Particulate Matter

Well Maintained Port Fuel Injection Engines



*Includes branched and cyclic compounds

Based on Ricardo data

Particle Emissions from Port Fuel Injection (PFI) Spark Ignition Engines

- PFI engine exhaust particles are quite different from diesel particles
  - They usually smaller
  - They are composed primarily of volatile materials
  - Formation likely to be associated by local inhomogeneous conditions - big droplets, crevices
  - Lube oil may play an important role – especially in worn engines
    - » Volatile material
    - » Ash
- PFI emissions are strongly influenced by dilution and sampling conditions, and past history
  - They are formed from volatile precursors during dilution
  - Storage and release of precursors from exhaust system may be involved
  - Sulfuric acid-water nucleation and hydrocarbon absorption and, possibly, direct nucleation of heavy hydrocarbon derivatives

U of M Mobile Laboratory built to study formation of nanoparticles in the atmosphere for the CRC E-43 project

Principal Instruments in MEL

- SMPS to size particles in 9 to 300 nm size range
- ELPI to size particles in 30 to 2500 nm size range
- CPC to count all particles larger than 3 nm
- Diffusion Charger to measure total submicron particle surface area
- Epiphaniometer to measure total submicron particle surface area
- PAS to measure total submicron surface bound PAH equivalent
- CO_2 , CO, and NO analyzers for gas and dilution ratio determinations

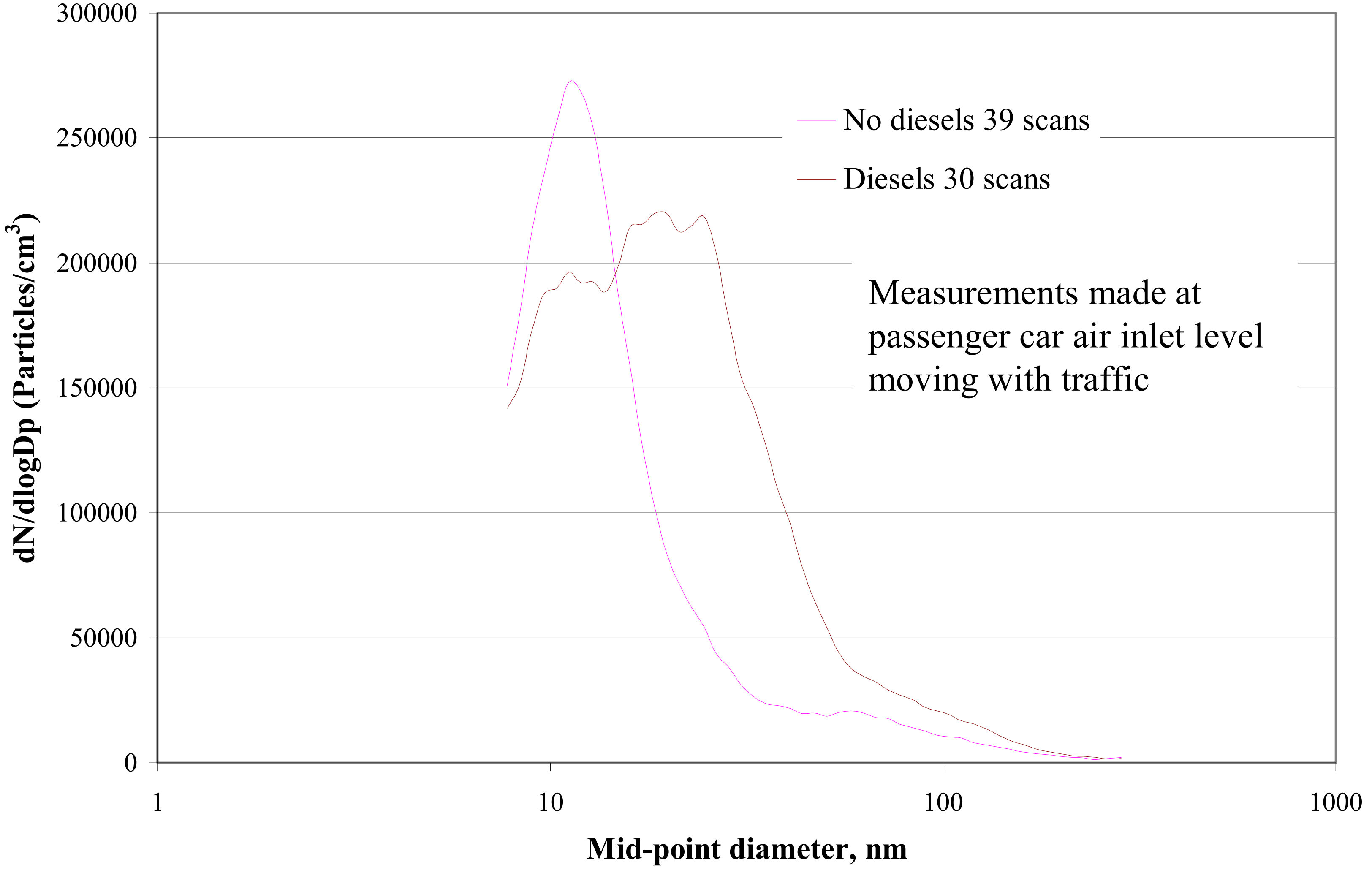
MNDOT Study
Goals and Objectives

- Determine the relationship between traffic congestion and nanoparticle concentrations over highways.

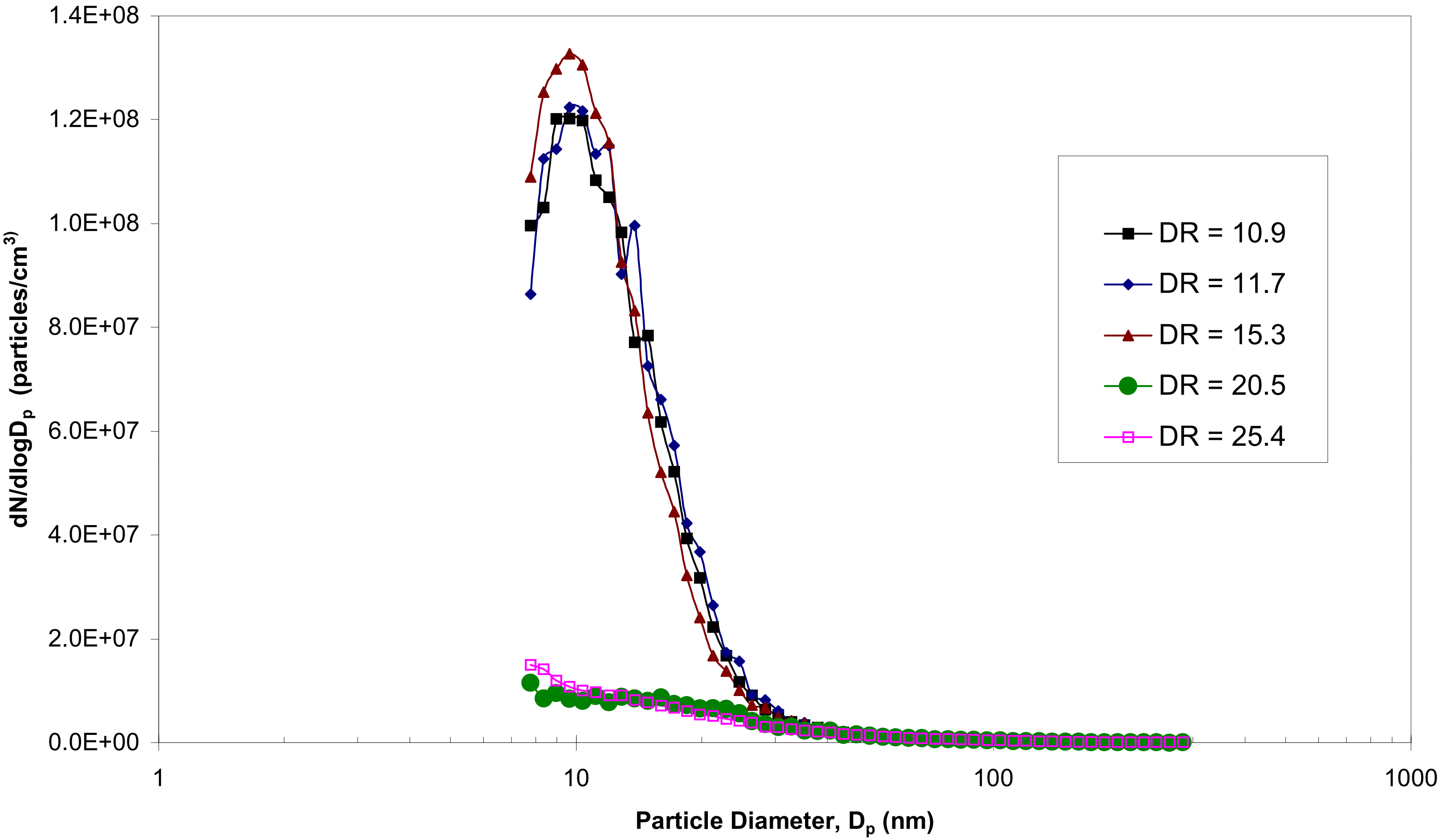
- Estimate fuel specific emissions factors for our current vehicle fleet.

- Determine the concentrations of nanoparticles in neighborhoods near major highways.

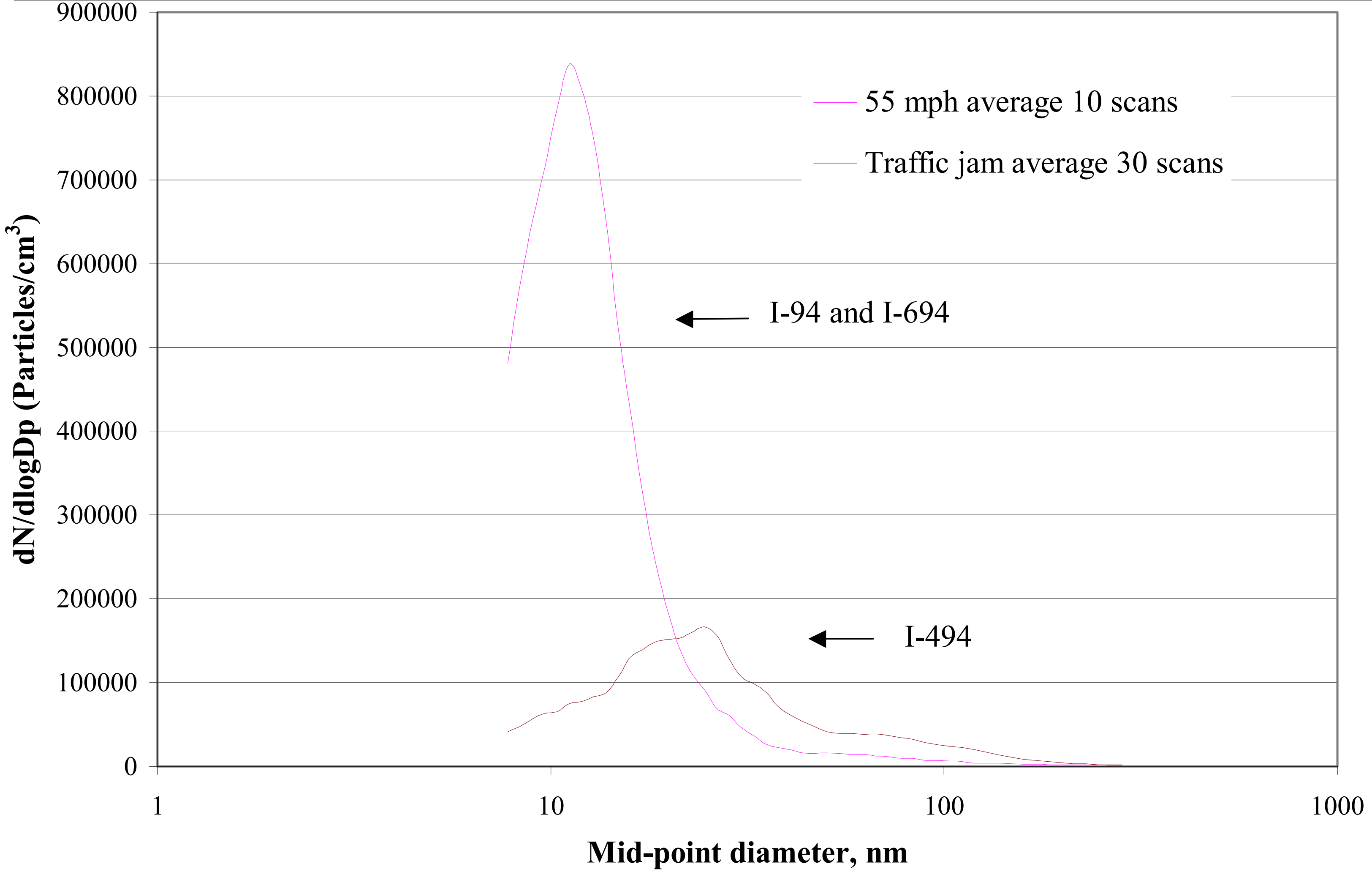
Nanoparticles exist over Minnesota highways – both with and without significant Diesel traffic



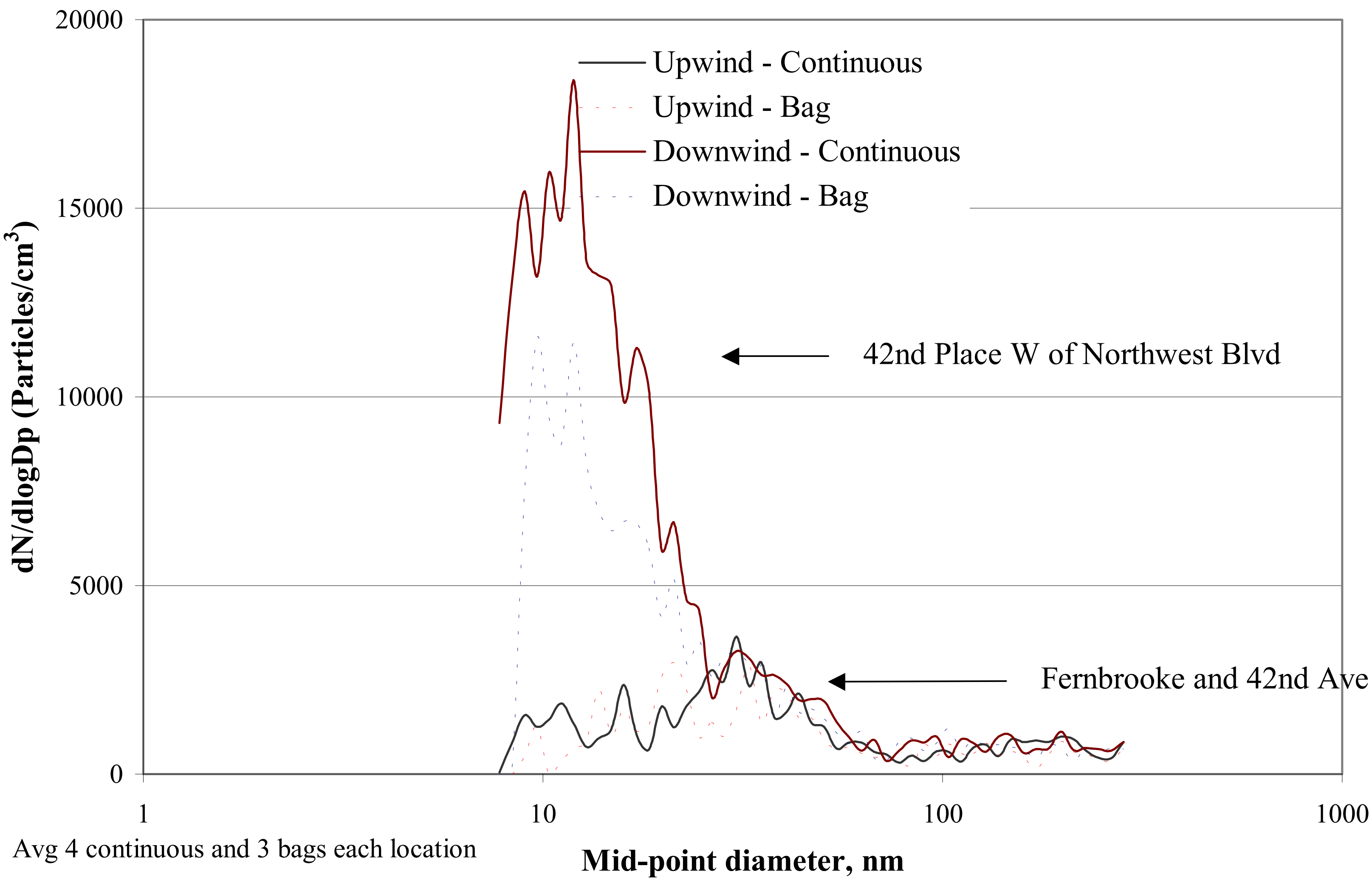
Size Distributions, 1993 GM 2.3L Quad-4, 3500 RPM, 100 kPa MAP, Single Stage Ejector Diluter



More nanoparticles are present in fast moving traffic than in traffic jams



Measurements upwind and downwind of Interstate 494 – particles persist downwind



Avg 4 continuous and 3 bags each location

Fuel specific emissions may be calculated by comparing on-road and background – these measurements made at low ambient temperature, ~ 5 C

- We determine fuel specific number and mass emissions, EI_N (particles/kg_{fuel}) and EI_m (mass/kg_{fuel}) from:

$$EI_N = \frac{N}{(x_{CO} + x_{CO_2})(M_C / M_{air}) y_{C_{fuel}} \rho_{air}}$$

$$EI_m = \frac{m}{(x_{CO} + x_{CO_2})(M_C / M_{air}) y_{C_{fuel}} \rho_{air}}$$

(all values corrected for background)

- These values mass be converted to particles/mile or mass/mile if fuel consumption is known (assume 20 MPG) using:

$$particles / mile = EI_N / (\rho_{fuel} MPG)$$

On road number and mass emission factors	
EI_N CPC (particles/g_{fuel})	2 – 11 x 10^{12}
EI_N SMPS (particles/g_{fuel})	1 – 3 x 10^{12}
EI_m SMPS (μg/g_{fuel})	70 – 330
Particles/mile CPC	3 – 14 x 10^{14}
Particles/mile SMPS	1 – 4 x 10^{14}
mg/mile SMPS	10 -19

Recent European measurements show gasoline off cycle, gasoline direct injection and Diesel in same number emission range (Färnlund et al., 2001)

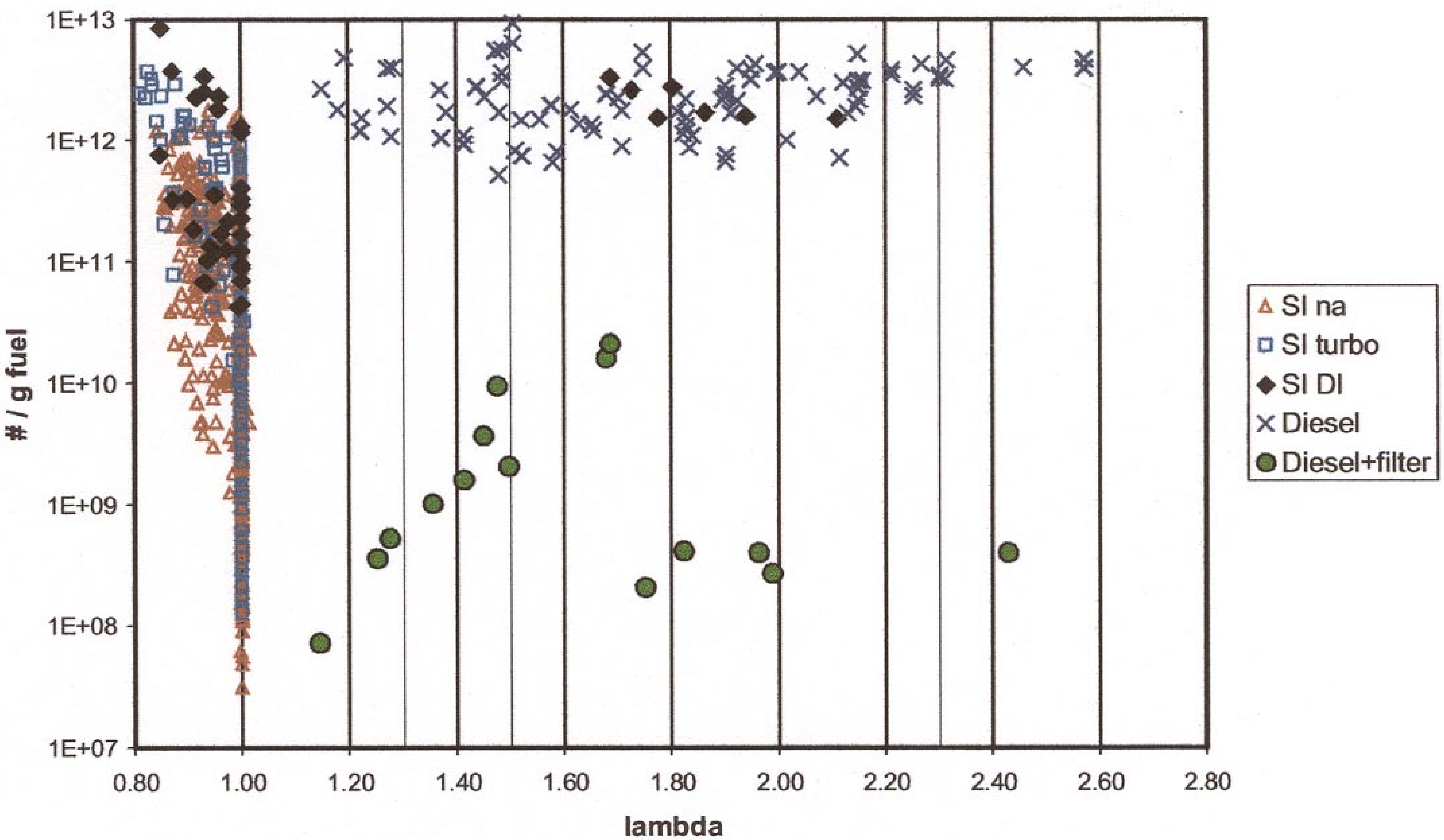


Figure 3 - Total particle number per fuel mass related to lambda

Conclusions – spark ignition engine nanoparticles

- Both Diesel and spark ignition engines have significant on-road nanoparticle emissions
- The size distributions for spark ignition engines exhibit relatively large nuclei modes and small accumulation modes (low mass emissions) compared to Diesel engines
- Similar size distributions have been observed in the laboratory and on-road
- More spark ignition particles are present in faster moving traffic and as fleet accelerates – storage and release effect
- On-road fuel specific number emissions at high end of lab measurements reported in the literature. These measurements were made at low ambient temperatures (~ 5 C) likely to increase nanoparticle formation – more work must be done.