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Size Distribution and Deposition in Human Respiratory Tract: Particle Mass and Number

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TOXICITY OF ULTRAFINES

(MAUDERLY et al.)

- FINER PARTICLES PENETRATE MORE READILY INTO CELLS AND THROUGH TISSUE BARRIERS
- FINER PARTICLES HAVE GREATER SURFACE AREA PER UNIT MASS, AND A LARGE NUMBER OF TOXIC REACTIONS OCCUR AT THE SURFACE
- FINER PARTICLES DISSOLVE MORE READILY THAN LARGER PARTICLES THUS ENHANCING THE BIO-AVAILABILITY OF SOLUBILIZED COMPOUNDS
- EPIDEMIOLOGICAL STUDIES INDICATE THAT THE IMPORTANCE OF ULTRAFINES REMAINS SPECULATIVE

OBJECTIVES

- **TO DETERMINE THE REGIONAL DEPOSITION OF PARTICULATE MATTER IN HUMAN LUNGS FOR A VARIETY OF STEADY-STATE ENGINE OPERATING CONDITIONS, FUEL FORMULATIONS AND COMBINATIONS OF AFTERTREATMENT DEVICES.**

- **TO CHARACTERIZE THE SIZE DISTRIBUTION AND MASS EMISSION RATES OF PARTICULATE MATTER EMISSIONS FROM OFF-ROAD AND ON-HIGHWAY HEAVY-DUTY VEHICLES OPERATING ON CONVENTIONAL DIESEL, AND ULTRA-LOW SULFUR SYNTHETIC DIESEL FUELS.**

BACKGROUND

- **REGIONAL DEPOSITION IS DEFINED AS THE FRACTION OF PARTICLES INSPIRED WHICH IS DEPOSITED IN THE REGION OF INTEREST.**
- **MODEL FOR POLYDISPERSED AEROSOLS (0.5 nm TO 15 µm) DEVELOPED KOBRITCH, RUDOLF, AND STAHLHOFEN (1994) WAS EMPLOYED.**
- **HOWEVER, REGIONAL DEPOSITION IN HUMANS HAS SO FAR ONLY BEEN MEASURED WITH PARTICLES WITH DIAMETERS GREATER THAN 100 nm.**

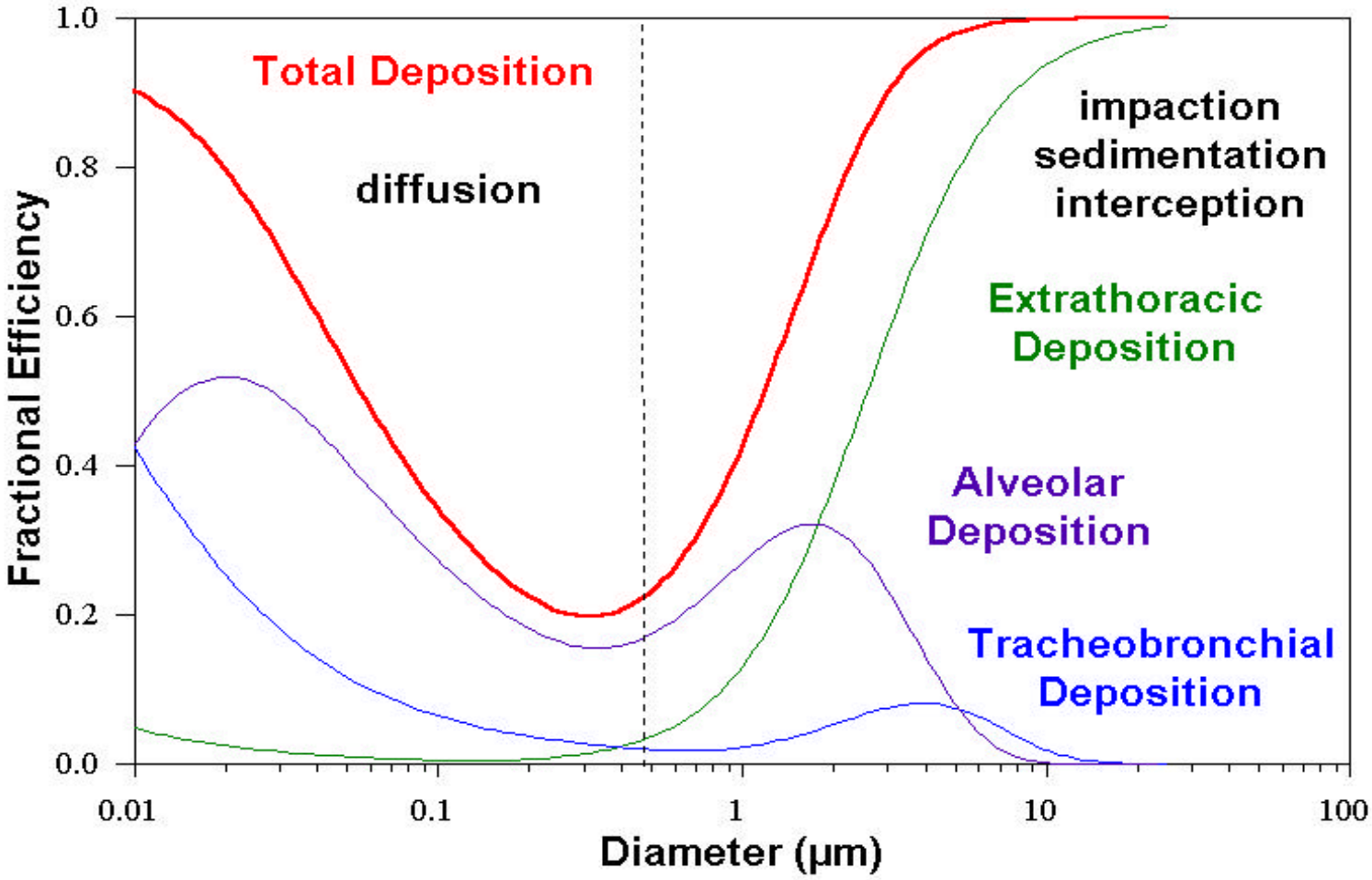
BACKGROUND

- **THE MODEL DISTINGUISHES FIVE ANATOMICAL REGIONS:**
  - **NASAL REGION**
  - **EXTRATHORACIC REGION DURING MOUTH BREATHING**
  - **TRACHEOBRONCHIAL AIRWAY**
  - **BRONCHIOLAR AIRWAY**
  - **ALVEOLAR REGION**

DEPOSITION MECHANISMS

- **NOSE, EXTRATHORACIC AND TRACHEO-BRONCHIAL REGIONS**
  - **INERTIAL IMPACTION AND BROWNIAN DIFFUSION**
- **TRACHEOBRONCHIAL AIRWAY**
  - **SEDIMENTATION AND BROWNIAN DIFFUSION**
- **ALVEOLAR REGION**
  - **GRAVITATIONAL SETTLING AND BROWNIAN DIFFUSION.**

DEPOSITION IN HUMAN RESPIRATORY TRACT AS A FUNCTION PARTICLE DIAMETER

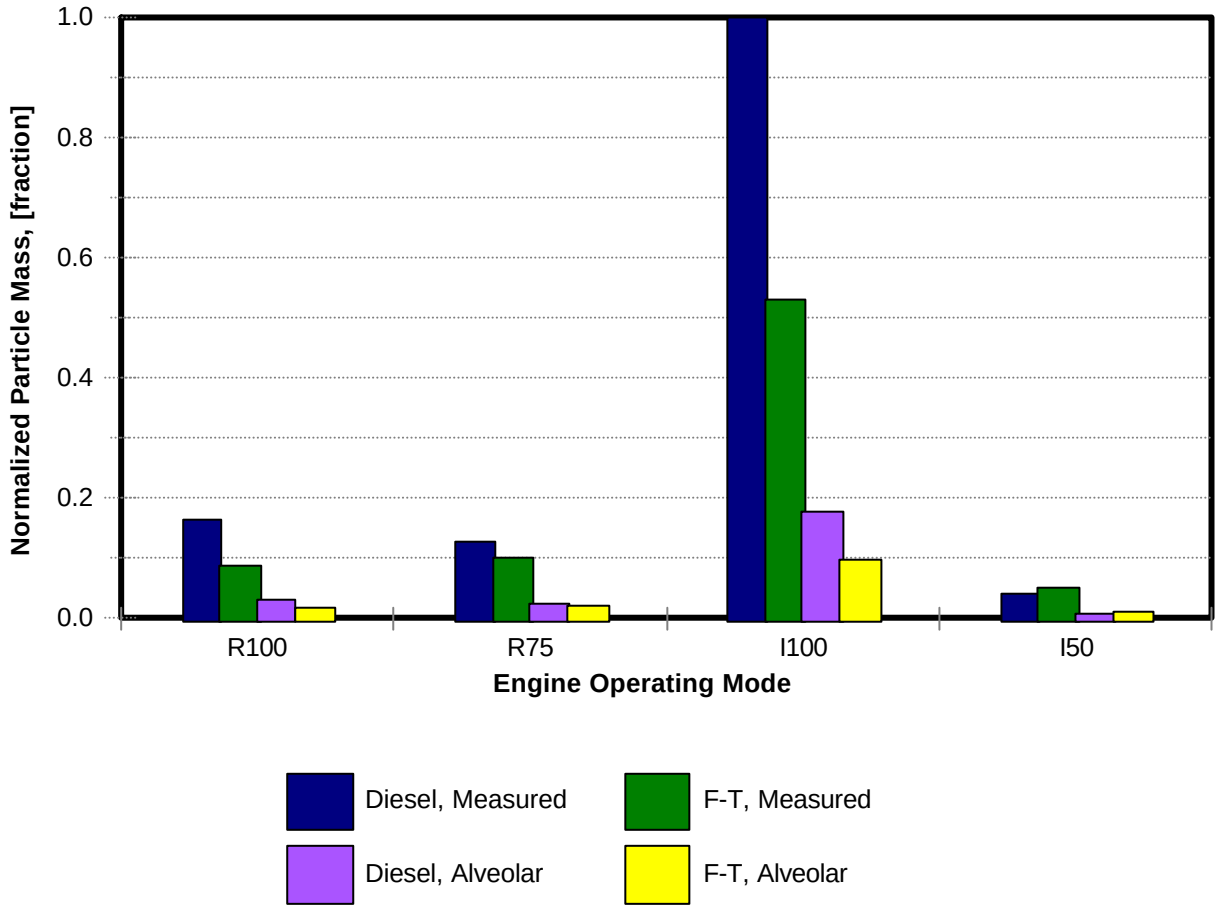


Nasal Breathing and Selected Parameters: Q = 500 cm^3s^{-1}; V = 1500 cm^3; FRC = 3300 cm^3 and f = 10

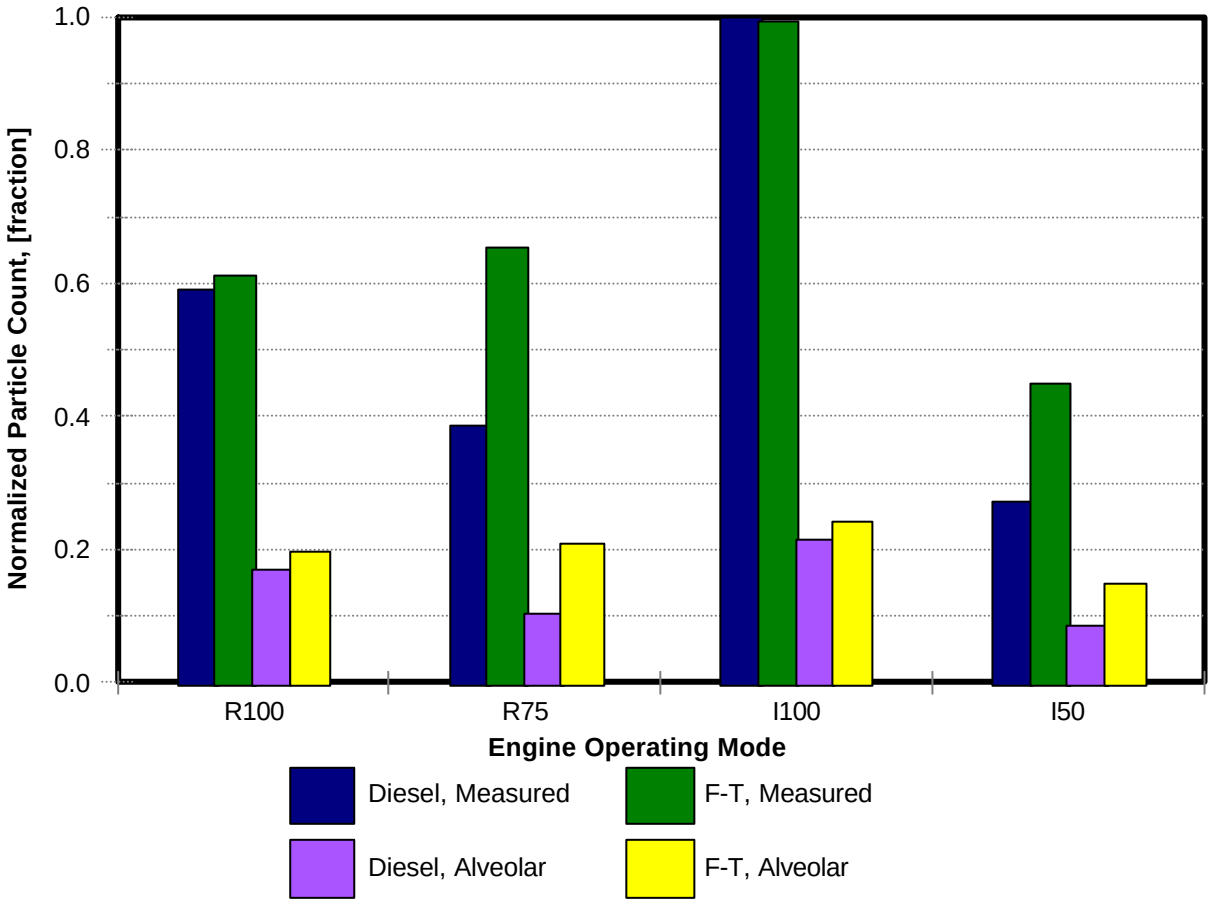
- **LOG NORMAL CURVES WERE FITTED TO NORMALIZED COUNT DISTRIBUTIONS DETECTED BY SMPS.**

- **MASS MEDIAN DIAMETERS (MMD) OF MASS DISTRIBUTIONS WERE CALCULATED FROM COUNT MEDIAN DIAMTERS AND GEOMETRIC STANDARD DEVIATIONS OF CORRESPONDING NUMBER DISTRIBUTIONS USING HATCH-CHOATE EQUATION.**

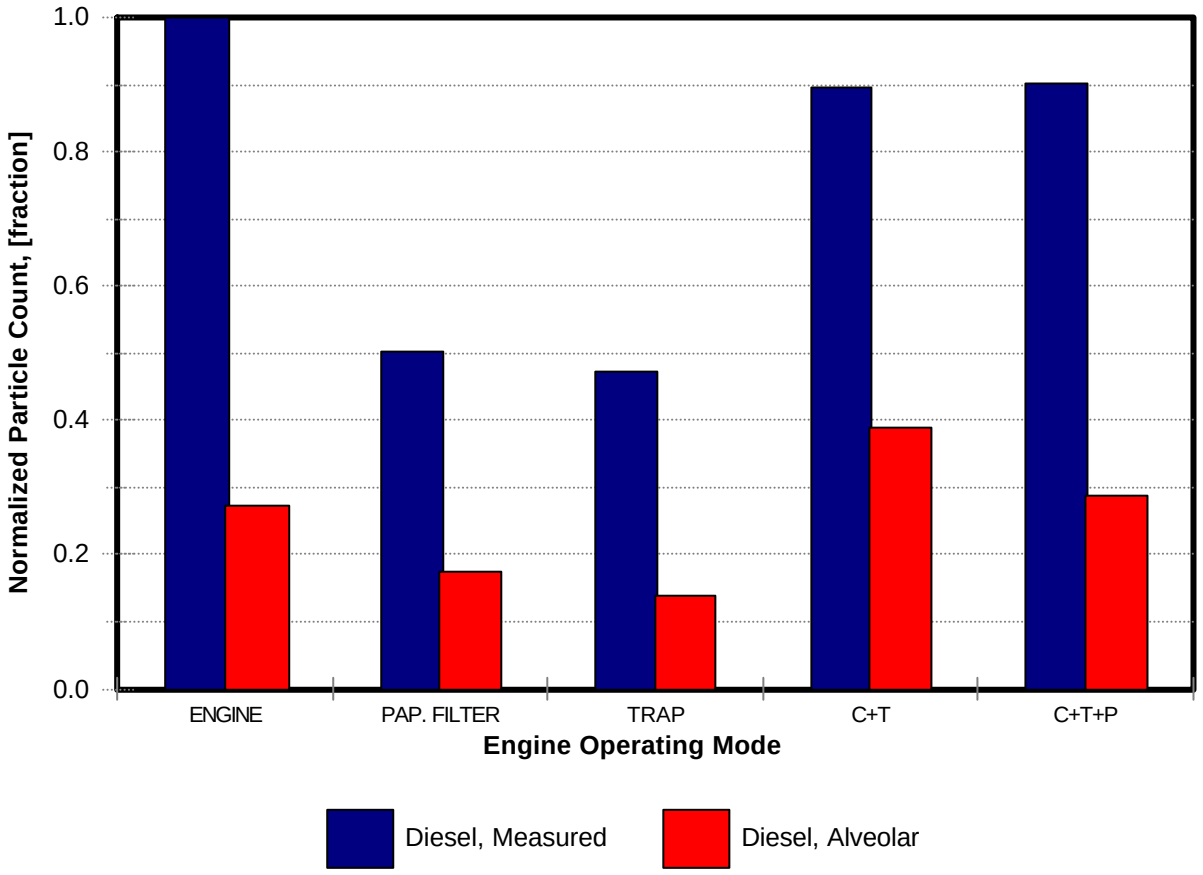
- **PARTICLE MASS WAS ESTIMATED ON THE BASIS OF AN ASSUMED PARTICLE DENSITY OF 1 g/cm^{3}.**



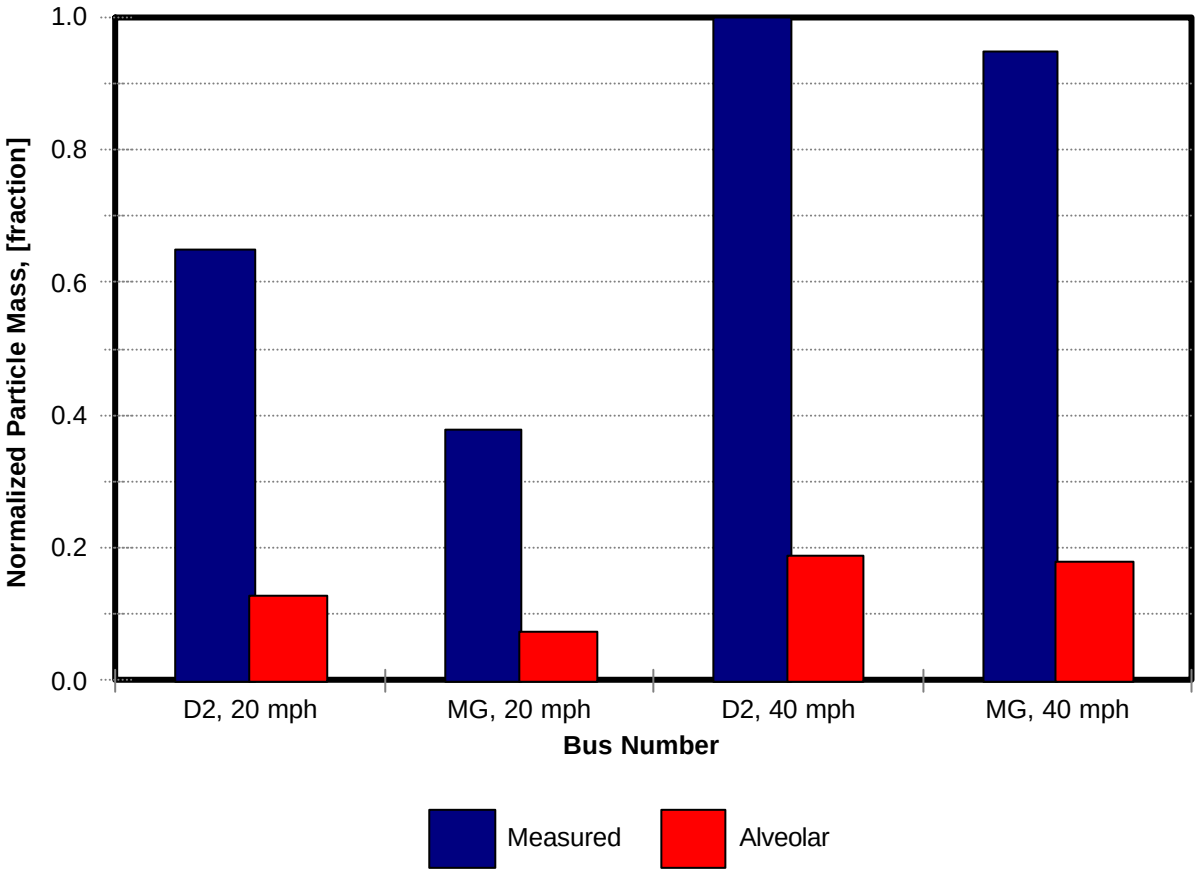
Isuzu C-240, Steady-State, Diesel No. 2 and F-T Synthetic Diesel, Untreated Exhaust, Normalized Particle Mass Concentrations, Regional Deposition of DPM, Effects of Fuel Formulation



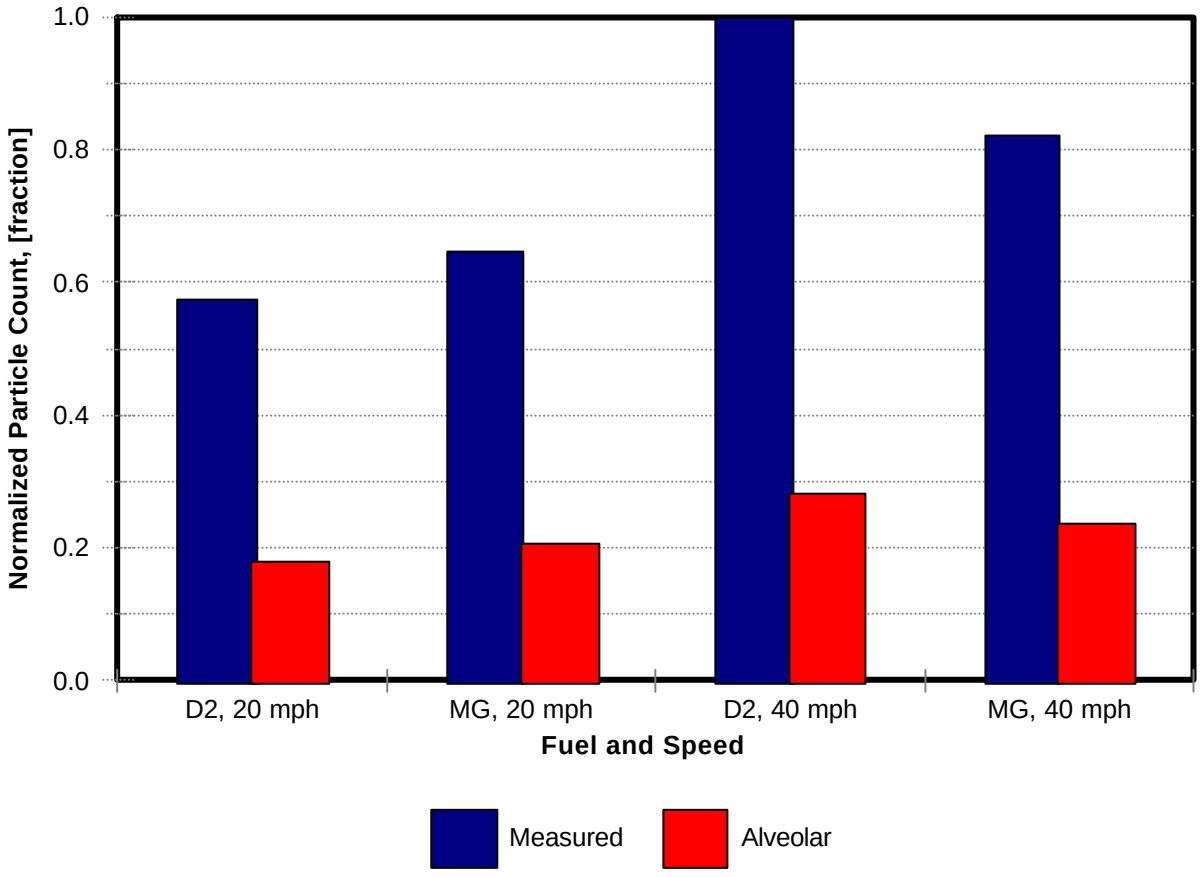
Isuzu C-240, Steady-State, Diesel No. 2 and F-T Synthetic Diesel, Untreated Exhaust, Normalized Particle Number Concentrations, Regional Deposition of DPM, Effects of Fuel Formulation



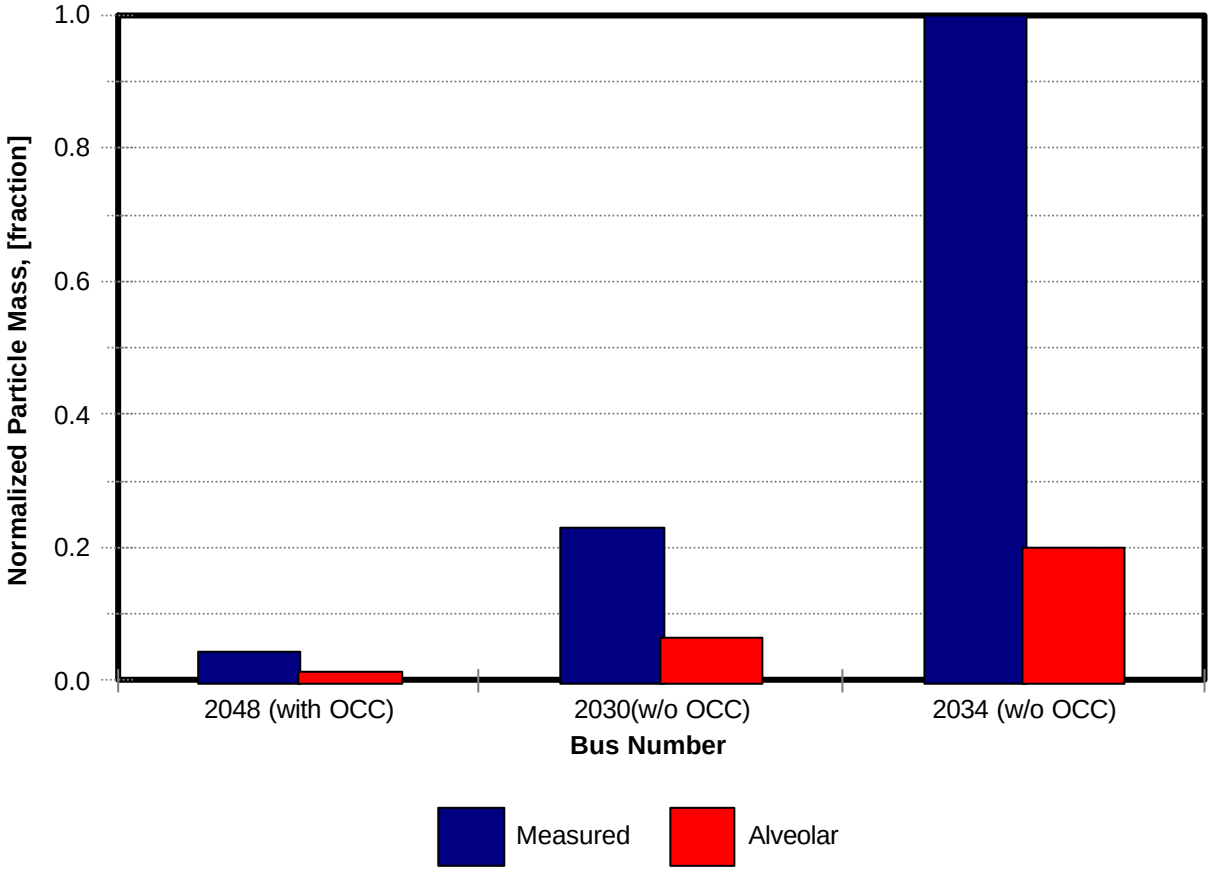
Isuzu C-240, Steady-State, R-75, Diesel No. 2, Normalized Particle Number Concentrations, Regional Deposition of DPM, Deposition in Alveolar Region, Effects of After-treatment Process



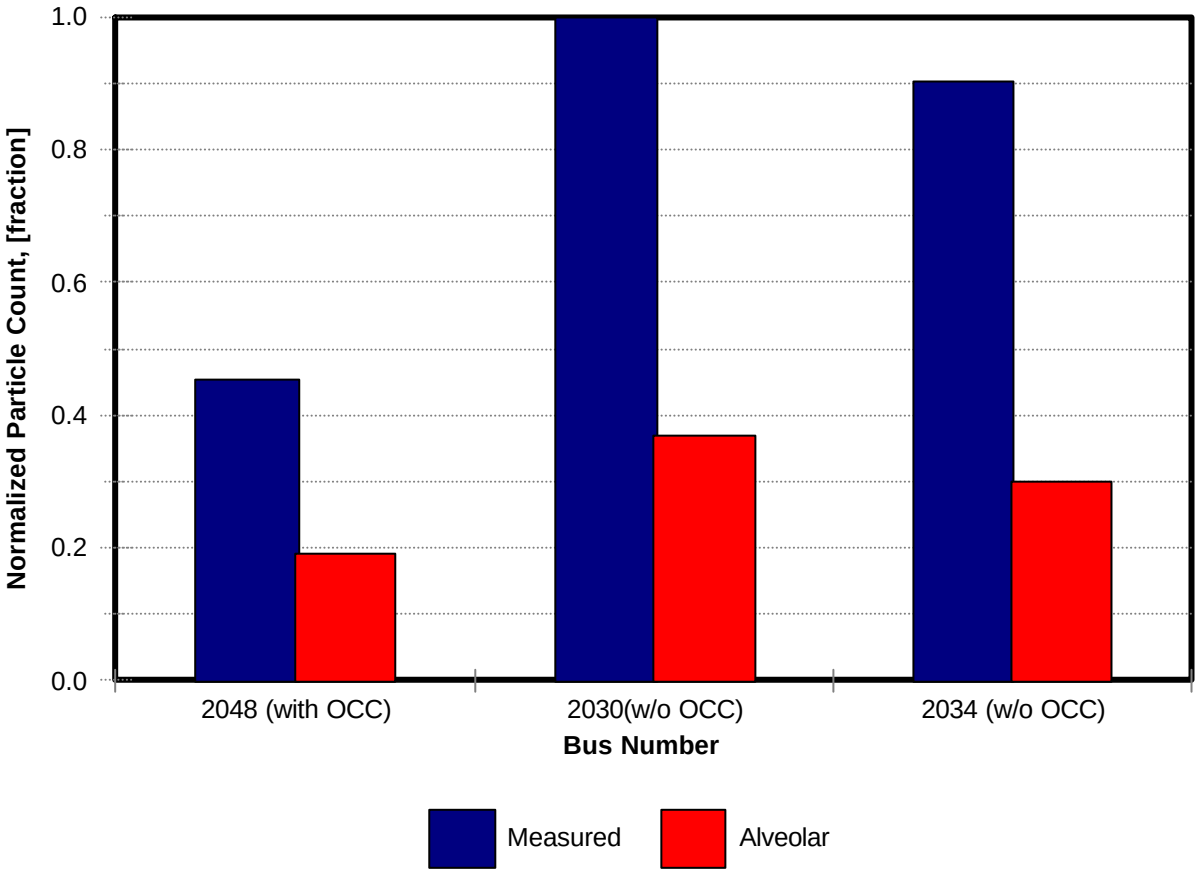
Orion/DDC 6V92 TA, Bus 2034 without OCC, Steady-State, Diesel No. 2 (D2) and Mossgas (MG), Normalized Particle Mass Concentrations, Regional Deposition of DPM, Deposition in Alveolar Region, Effects of Fuel Formulation



Orion/DDC 6V92 TA, Bus 2034 without OCC, Steady-State, Diesel No. 2 (D2) and Mossgas (MG), Normalized Particle Number Concentrations, Regional Deposition of DPM, Deposition in Alveolar Region, Effects of Fuel Formulation



Orion/DDC 6V92 TA, Steady-State, 30 mph, Mossgas Synthetic Diesel, Normalized Particle Mass Concentrations, Regional Deposition of DPM, Deposition in Alveolar Region, Vehicle-to-Vehicle Variation



Orion/DDC 6V92 TA, Steady-State, 30 mph, Mossgas Synthetic Diesel, Normalized Particle Number Concentrations, Regional Deposition of DPM, Deposition in Alveolar Region, Vehicle-to-Vehicle Variation

CONCLUSIONS

- **USE OF SYNTHETIC DIESEL (F-T DIESEL) SHOWED A REDUCTION IN PM MASS EMISSION RATES BUT AND INCREASE IN THE NUMBER OF PARTICLES DEPOSITED IN THE ALVEOLAR REGION.**

- **THE USE OF AN OCC AND CATALYZED TRAP RESULTED IN REDUCTIONS IN THE PARTICLE MASS EMISSIONS AND LOWERED MASS DEPOSITION IN THE ALVEOLAR REGION. HOWEVER, THERE WAS AN INCREASE IN THE NUMBER OF PARTICLES DEPOSITED IN THE ALVEOLAR REGION.**

CONCLUSIONS

- **HENCE, IT IS IMPORTANT THAT COUNT BASED ANALYSIS OF PM EMISSIONS BE CONDUCTED IN ADDITION TO MASS BASED EMISSIONS.**
- **EXHAUST AFTERTREATMENT DEVICES SHOULD BE OPTIMIZED FOR REDUCTIONS IN MASS AND NUMBER OF PM EMISSIONS**