Assessment of Possible Worst-Case NO_2 Exposure Scenarios Related to Catalyst-Based Diesel Particle Traps

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Outline

- Overview of problem
- NO_2 and PM health effects

  Evaluating this trade-off will be important
- Exposure scenarios evaluated
  - Assumptions
  - Conditions
  - Calculations of NO_2 and DPM concentrations
- Conclusions

Acknowledgements

- Bart Croes, Paul Henderick, ARB
- Supporting studies:
  - UCLA/UCR-CECERT School Bus Study; Behrentz et al., 2004; Fitz et al., 2003
  - ARB Mobile Platform Study, Westerdahl et al., 2004
  - Johnson Matthey idling study, Allansson et al., 1999
  - Kittelson et al., 1988; high-speed following
  - Chan et al., 2001; idling and modeling study
  - ARB CNG and Diesel Bus Study, Ayala et al.

Overview of Problem

- **To create lower ignition temperatures to burn off soot, some traps convert NO to NO_2. Excess is emitted.**

  If NO_2/NOx fraction increases for diesel fleet due to trap retrofit:

  - **Regional NO_2, ozone, nitric acid, and ammonium nitrate PM can increase if NO_2/NOx fraction > 20%**

    (At fractions < 20%, VOC reductions offset the increases; assumes engine-out NO_2 fraction is 5%)

  - **Some microenvironments may exceed NO_2 standards (CA 1-hour 250 ppb)**

Our Questions

- **Where might higher NO_2 emissions be a problem?**
- **Does the problem go away with a 20% limit?**
- **Is our information adequate to answer these questions?**

  If no, what information is necessary?

Health Effects of NO_2 and PM

- **NO_2:**
  - **Epi: hospital admissions, reduced lung function, mortality. (This may be a co-pollutant effect.)**
  - **Human exposure studies: these effects generally not found at levels of stds, may have a threshold; asthma effects may be important**
- **PM:**
  - **Epi: hospital admissions, respiratory infections, mortality. (Higher dose response)**
  - **Human studies: better agreement**

Additional Key Question

- **How can we compare the trade-off between increased NO_2 and decreased DPM exposures?**

Assumptions

- Occupational exposures not considered
- Property-line concentrations are lower due to more dilution than some roadway conditions
- “High” scenarios can happen simultaneously, allowing superposition of effects, but “extreme” conditions can only happen individually

High Exposure Scenarios

1. Freeways with high truck traffic, high CB-DPF penetration (710) (background NO_2 taken into account)

2. School buses with CB-DPF and self-pollution rates as measured in School Bus Study (background not taken into account)

3. Closely-followed, low-exhaust pipe, diesel vehicle with CB-DPF at slow speeds, wind <0.1 m/s

Scenario Conditions

- "Extreme"
  - highest of 4 days 710 freeway NOx, 670 ppb
  - 90% trap penetration
  - 70%NO_2/NOx fraction (peak NO_2 conditions)
  - 50 g/mi NOx (NYBC Cycle)
  - 0.1% self-pollution rate (typical older bus, closed windows)
  - dilution of 6 (2 m, no speed, no wind, centerline)
- "High"
  - average 710 freeway NOx, 470 ppb
  - 50% trap penetration
  - 50% NO_2/NOx fraction
  - 30 g/mi NOx (UDDS Cycle)
  - 0.04% self-pollution (typical newer bus)
  - dilution of 1000 (30 m, 55 mph). Not really "high"
- Current 20% limit
  - "high" conditions with 20% NO_2/NOx fraction

Scenario Time and Conversion of Standard

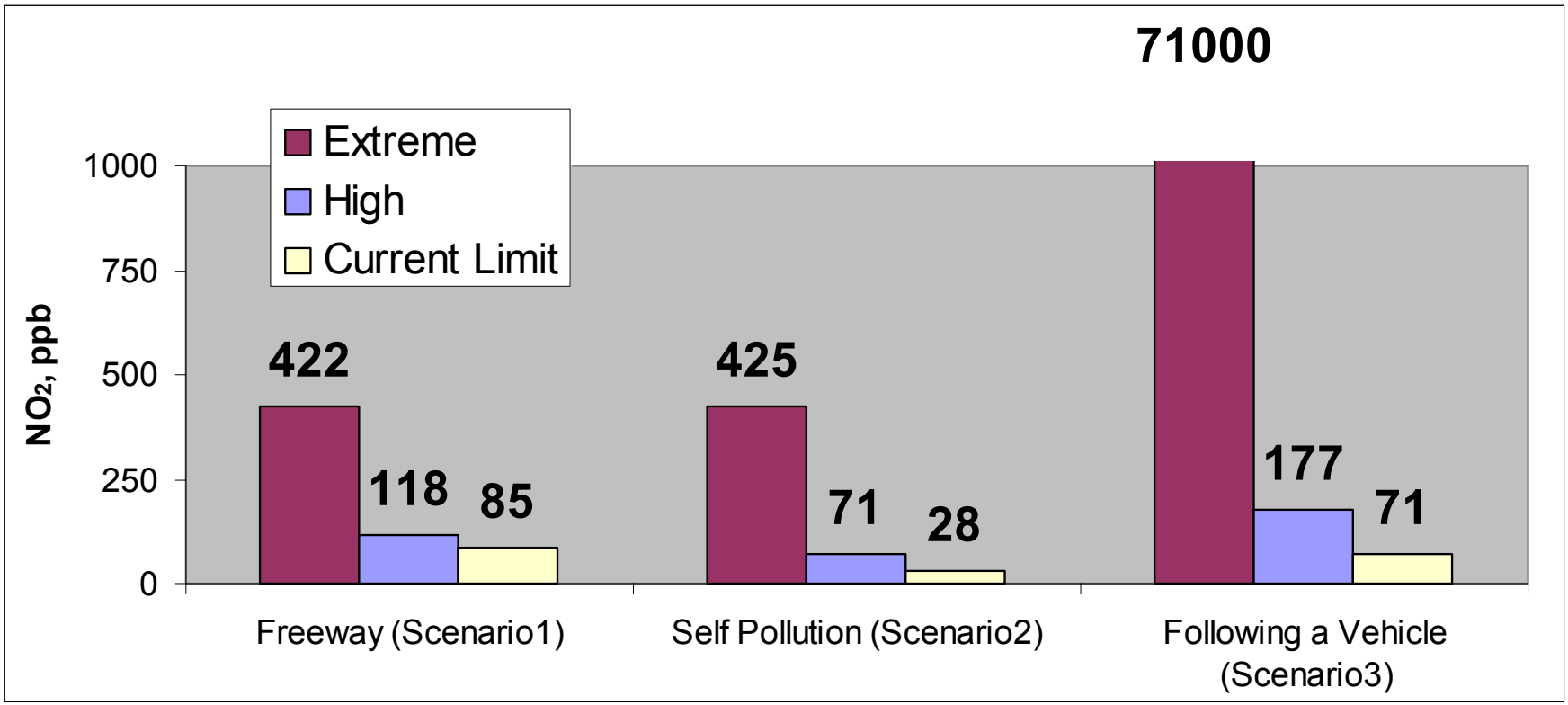
- **Scenarios considered to last 15 minutes at a time**

- **One-hour 250 ppb standard converted to 15-minute standard of 370 ppb via:**

$$(\text{Conc})^{3.5} \times \text{averaging time} = \text{constant}$$

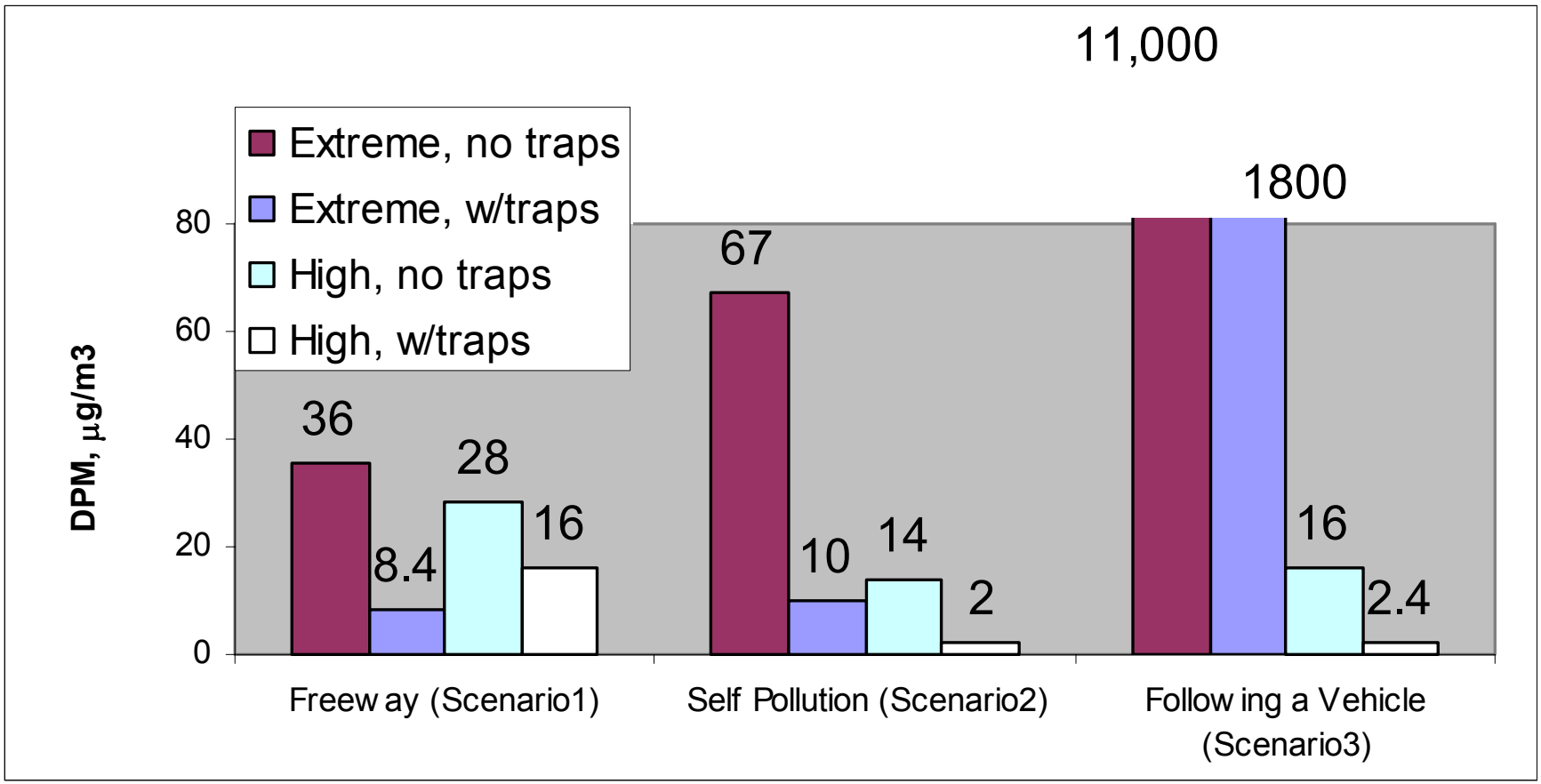
(OEHHA, 1999; ten Berg at al., 1986)

NO_2 Results



Background included **---Background not considered---**

DPM Results


11,000
Extreme, no traps
Extreme, w/traps
High, no traps
High, w/traps
1800
80
67
60
DPM, µg/m3
40
36
28
20
16
8.4
10
14
2
16
2.4
0
Freeway (Scenario1)
Self Pollution (Scenario2)
Following a Vehicle (Scenario3)

Conclusions

- "Extreme" scenarios appear to violate 15-minute 370 ppb standard individually (NO_2/NOx fraction 70%)
- "High" exposure scenarios do not appear to violate 370 ppb, but can come close if scenarios occur simultaneously
- NO_2/NOx fraction of 20% appears to prevent exceedences of 370 ppb, with the following caveat...

Caveat

- **Insufficient information for Followed-Vehicle Scenario 3 led to:**
  - **Concentrations and dilution rates ranging over several orders of magnitude**
    - **Followed-vehicle "extreme" too high to be realistic**
    - **"High" was too low to be conservative**
    - **Actual worst case and typical, low-dilution conditions probably in-between**
- **Actual measurements are probably necessary to ensure a given CB-PDF NO_2/NOx fraction does not exceed a given NO_2 concentration**

DPM Reductions

- **DPM reduction benefits very significant:**
  - **As exposure scenarios worsen and NO_2 concentrations increase, traps become increasingly valuable to reduce DPM**
  - **Across <u>all</u> scenarios, each 100 ppb NO_2 increase from CB-DPFs appears to also involve a 7 to 17 µg/m³ decrease in DPM**

The End

- Questions?