

DRAFT

Chemical and Bioassay Analyses of Emissions from Two CNG Buses with Oxidation Catalyst

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Summary of Previous Results

- Tested two buses:
 - 1) 2001 Cummins Westport C Gas Plus engine with OxiCat
 - 2) 2000 DDC S50 engine with and without OxiCat
- HCHO, NMHC, and CO were reduced significantly by OxiCat on CNG bus
- Some reductions in ultrafine particle number concentrations, PM, BTEX, and Butadiene
- No measurable effect on CH₄, CO₂, and NO_x
- Variability and uncertainty in some measurements were observed

Scope and Methods

- **Test vehicles and experimental approach as described previously**
- **Testing: March-June '02**
- **PAH's: filter/PUF/XAD, GC-MS**
Dept.Environment.Tox. - UCD
- **Bioassay-Mutagenicity: filter/PUF**
Dept.Environment.Tox. - UCD
- **EC/OC: quartz filter/TOR - SCAQMD**
- **Metals: Teflon filter/XRF- DRI**

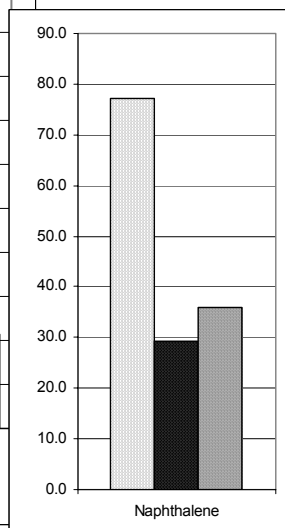
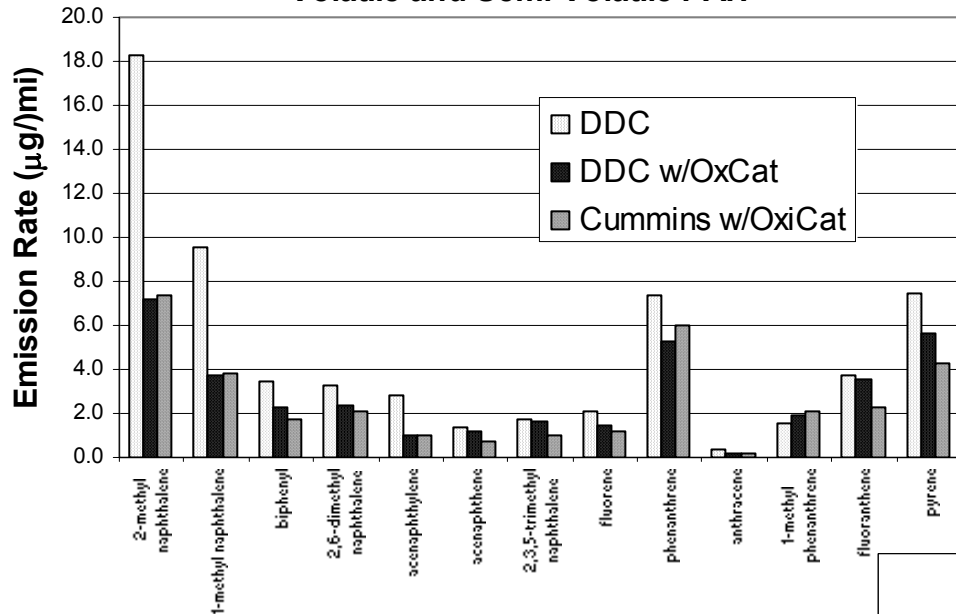


PAH Speciation for CNG Buses

CBD Results

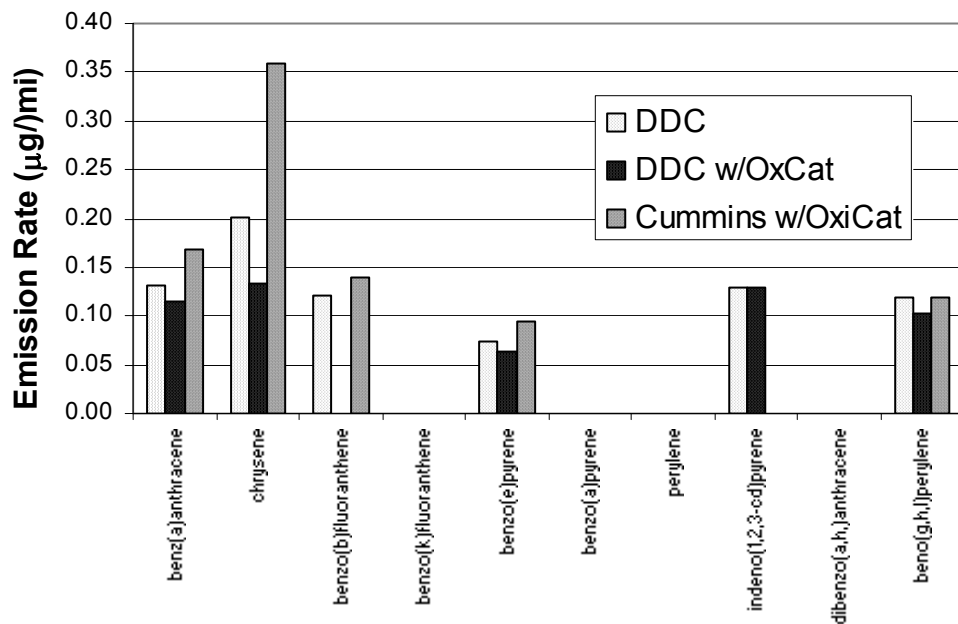
CBD-Comparision of Cummins and DDC Buses

Volatile and Semi-Volatile PAH



CBD-Comparision of Cummins and DDC Buses

PM Associated PAH

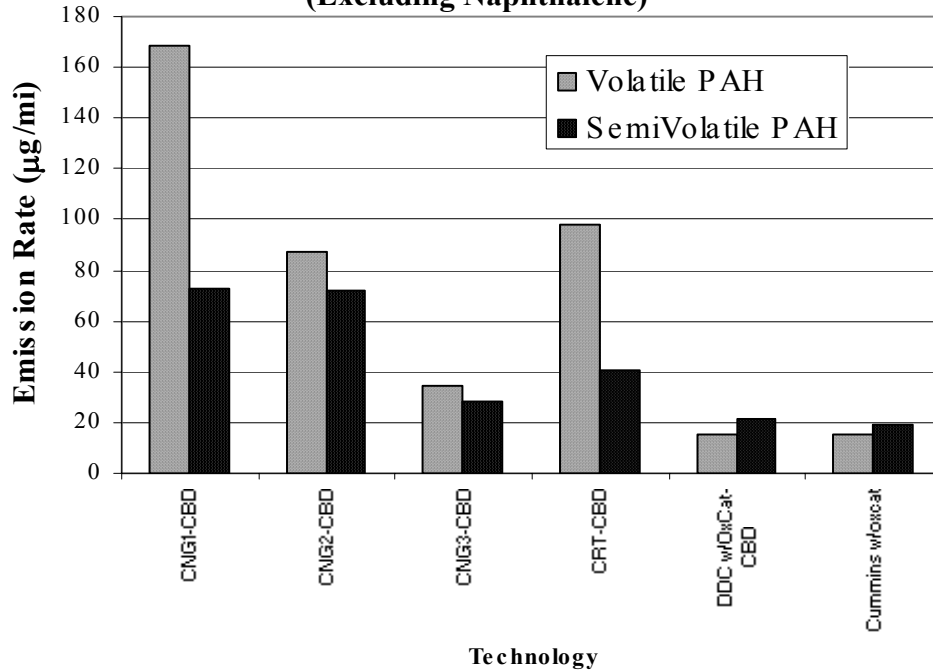


Emissions of PAH's for Cummins w/OxiCat and DDC w/OxiCat were generally comparable, except for chrysene over CBD

gram/mile emissions:
CBD > SS

Comparison of CNG and CRT/diesel (CBD)

CBD-Volatile and Semi-Volatile PAH Emission Rates (Excluding Naphthalene)



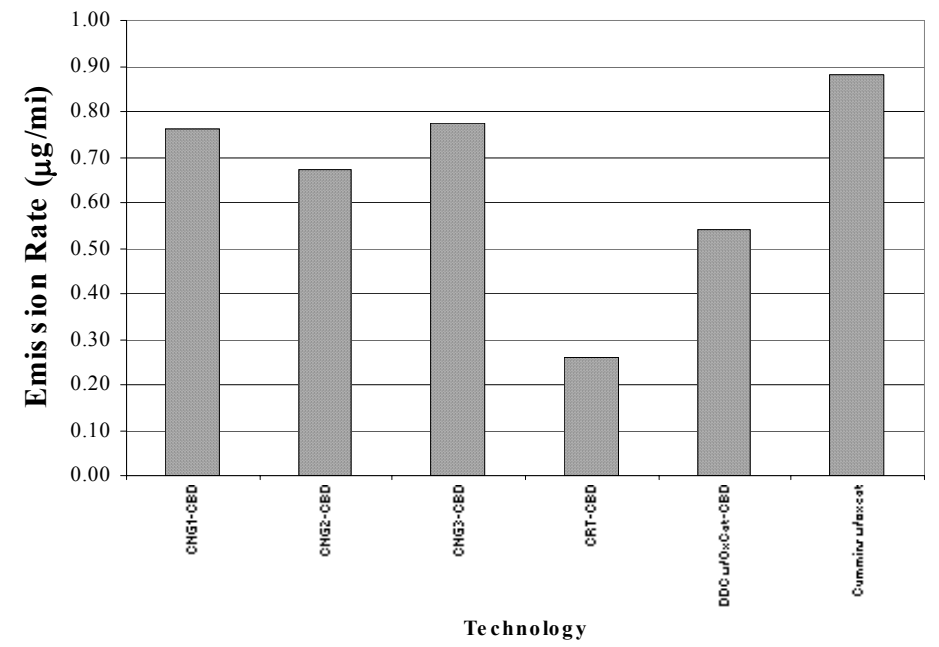
DDC CNG bus tested last year had higher emissions of volatile and semi-volatile PAH's than this year

CRT-equipped diesel bus emits less heavy-PAH's than CNG-fueled bus with or without OxiCat

CNG OxiCat better for reduction of volatile PAH's than catalyst in CRT filter

Heavy PAH emissions are similar for CNG bus with or without OxiCat

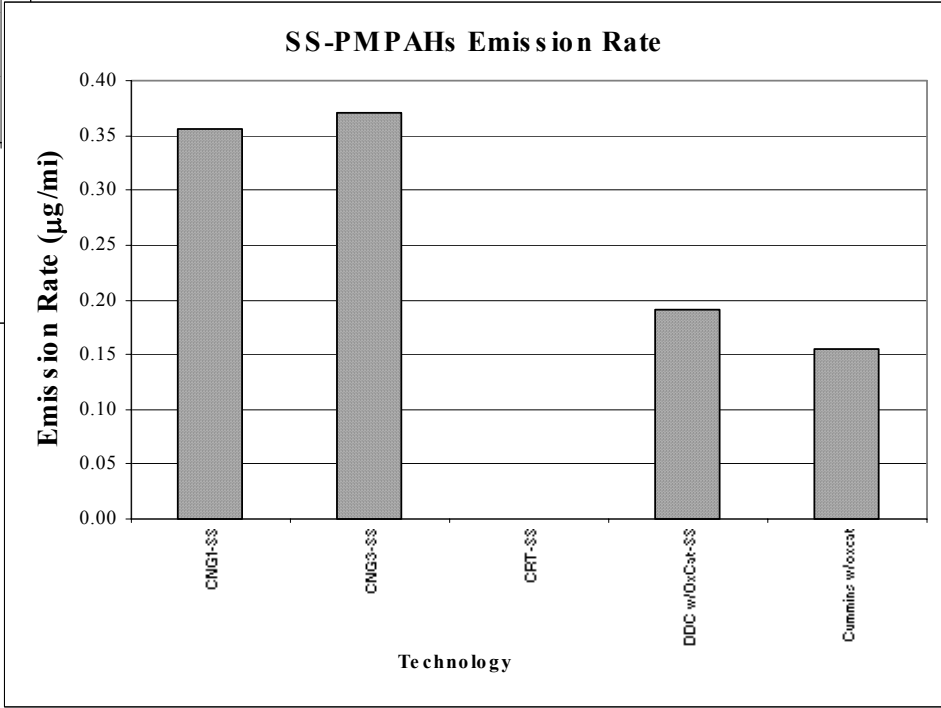
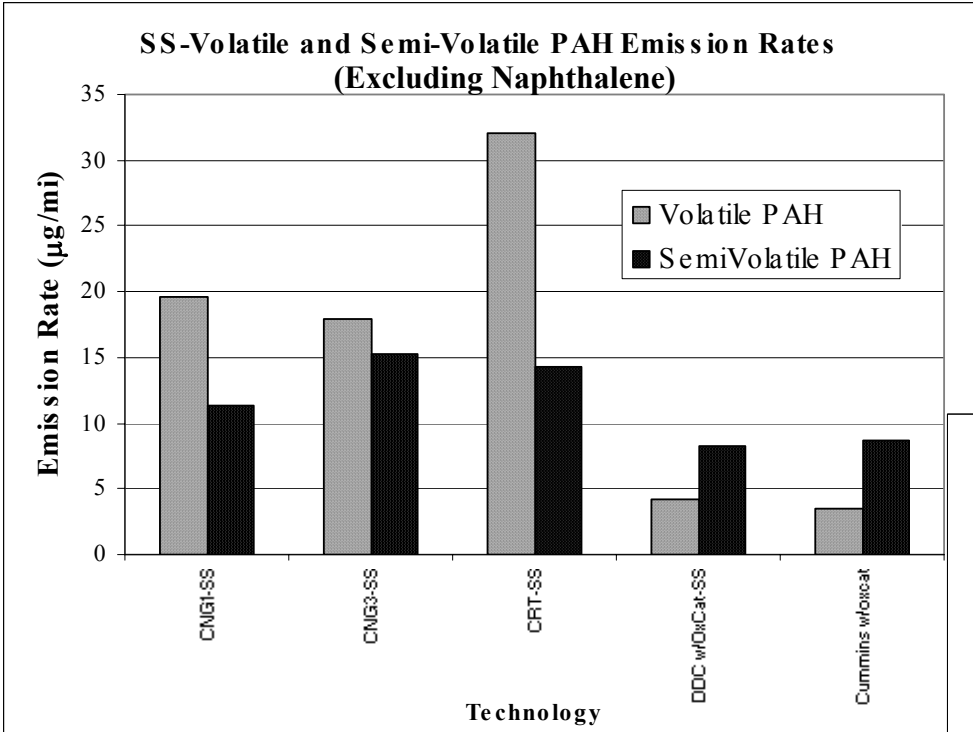
CBD-PMPAHs Emission Rate



NOTE: CNG1, CNG2 and CRT results from '01 testing

Comparison of CNG and CRT/diesel (SS)

For SS, trends are similar as those observed for CBD, except for PM-associated PAH

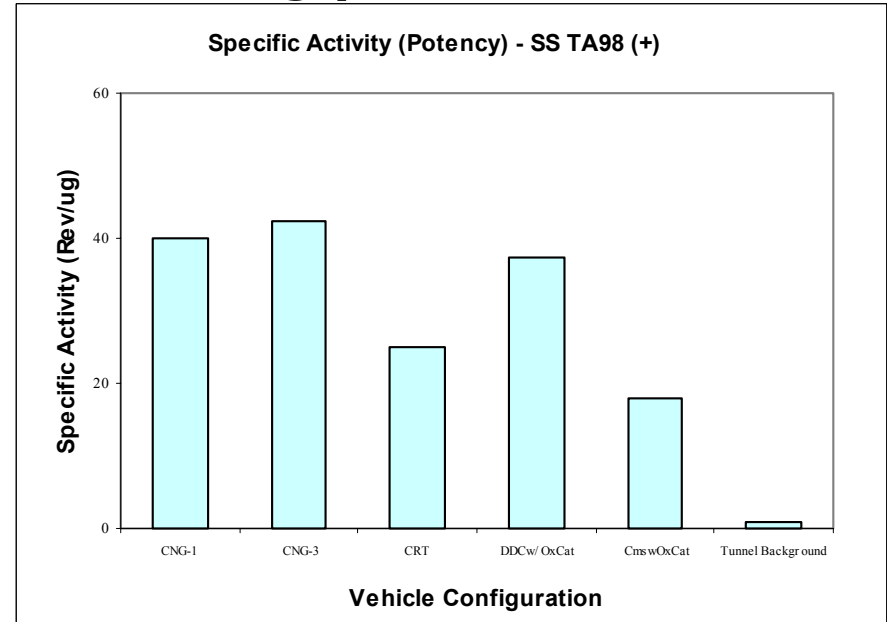
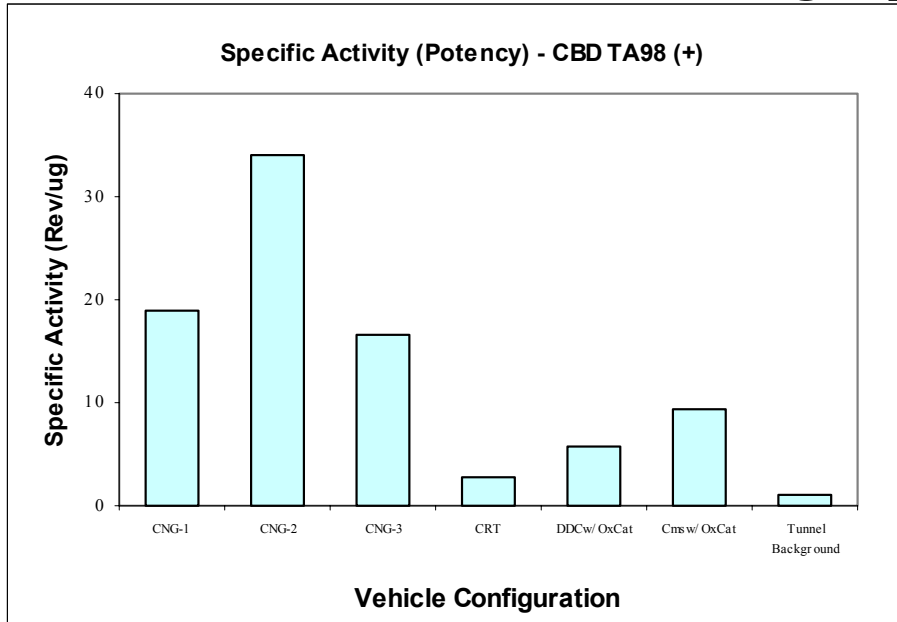


Drive cycle dependence observed in gram/mile emission of PAH's

NOTE: CNG1, CNG2 and CRT results from '01 testing



Comparison of Specific Mutagenic Activity (Potency)

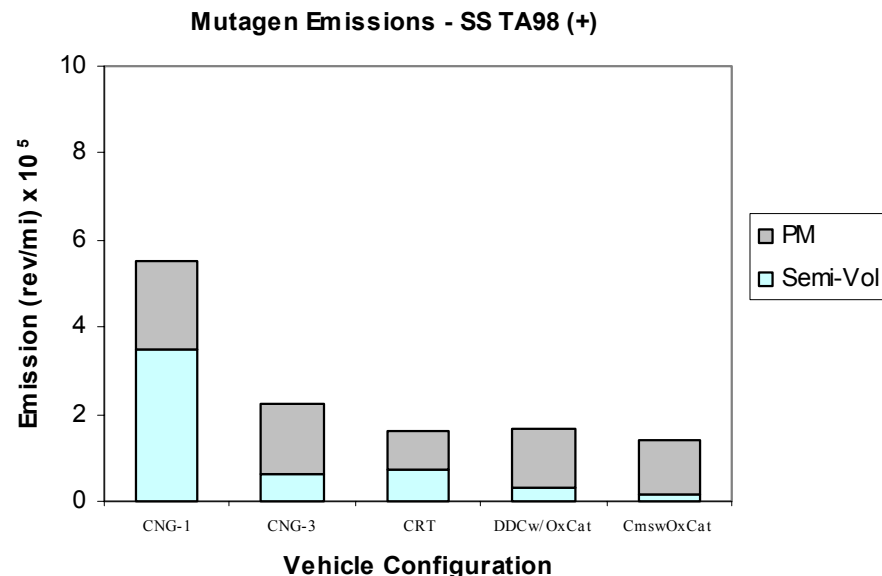
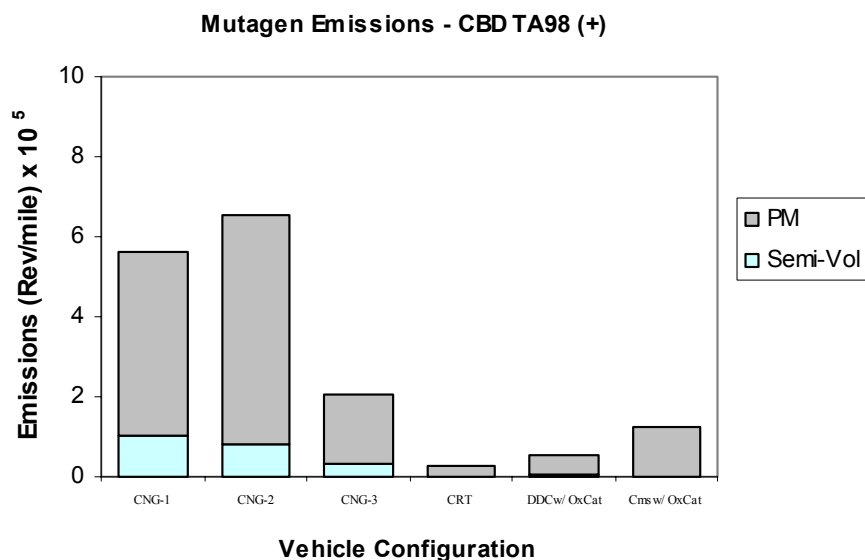


DDC CNG tested this year had similar potency to same bus tested last year

CNG OxiCat and CRT vehicles generally seemed to have reduction in potency, but appeared to be drive cycle dependent



Comparison of Total Mutagen Emissions



CNG bus tested last year had higher mutagen emissions than same vehicle tested recently

Over CBD, PM and semi-volatile mutagen emissions were highest for CNG bus without OxiCat

Over the CBD, OxiCat and CRT appear to decrease mutagen emissions

CRT mutagen emissions appear to be lower than the Cummins OxyCat

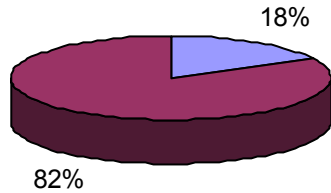
Over the SS, the CNG OxiCat and CRT appears to have similar or slightly decreased emissions compared to CNG without OxyCat

PM Composition

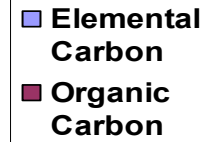
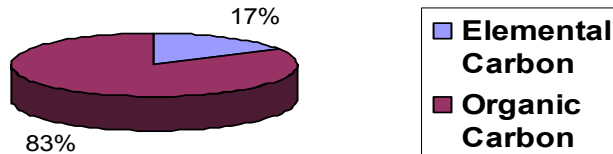
SS Results

CBD Results

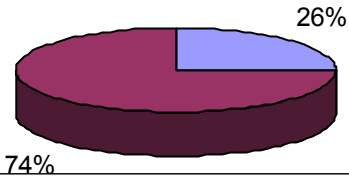
CumminsWestport w/OxiCat - SS



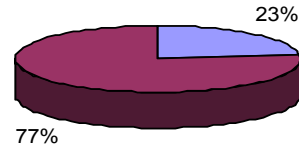
CumminsWestport w/OxiCat - CBD



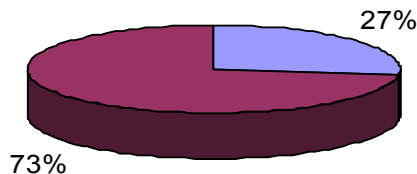
DDC CNG-3 w/OxiCat - SS



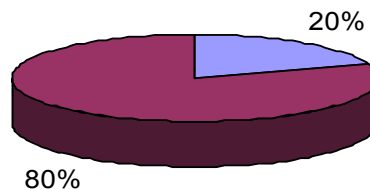
DDC CNG-3 w/OxiCat-CBD



DDC CNG-3-SS



DDC CNG-3-CBD



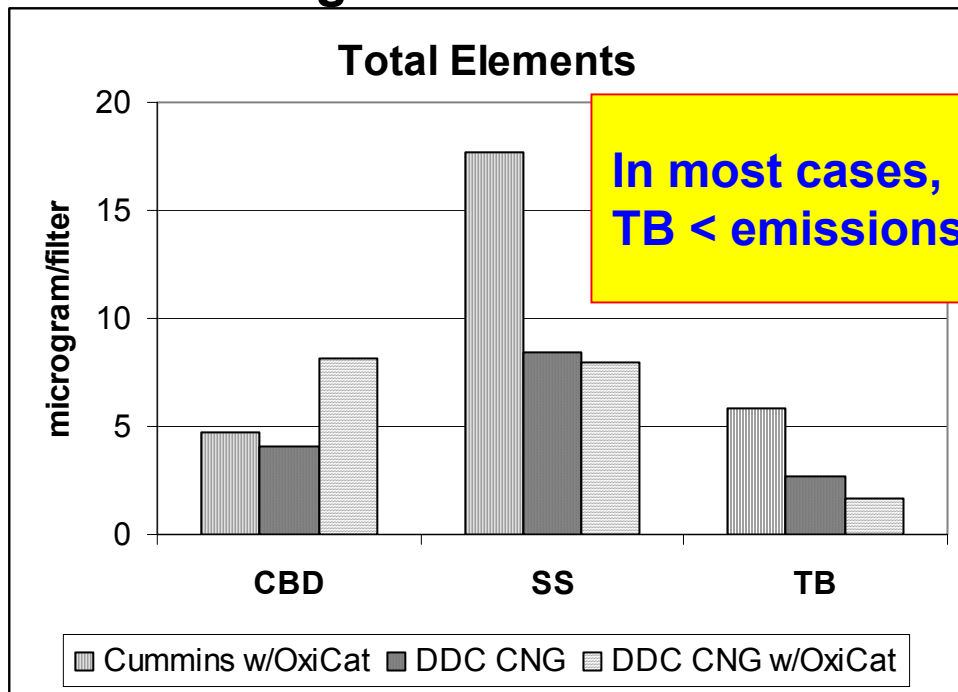
CNG PM (with or without OxiCat) is primarily OC

EC and OC gram/mile emissions are cycle dependent

Based on gram/mile emissions OxiCat affects OC fraction



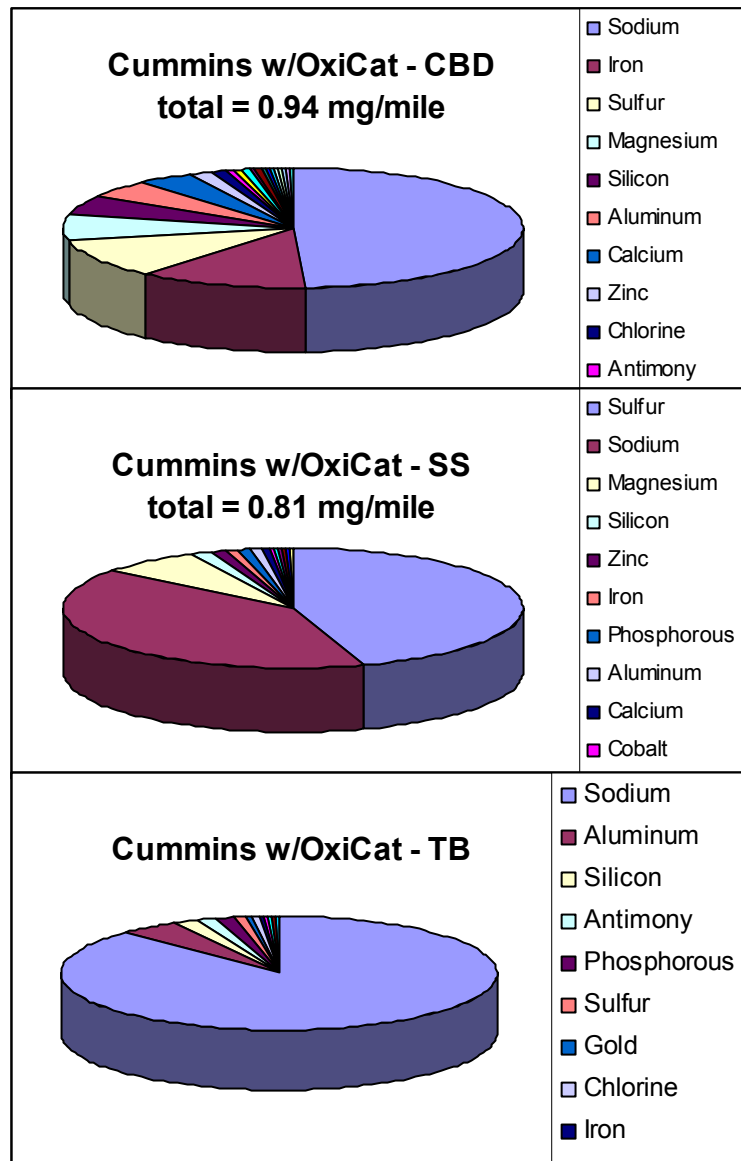
Comparison of emissions versus tunnel background



OxiCat has no effect on emissions of metals and elements

Total element emission factors similar to those obtained last year

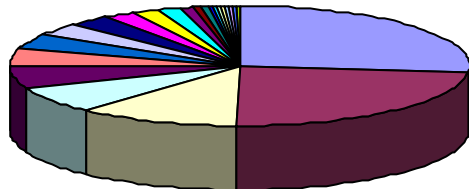
Elements



Oil additives, wear metals, and others show up in emission profile

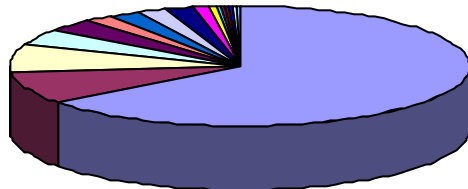
Most abundant oil components are not most abundant species in emissions

**DDC CNG - CBD
total = 0.8 mg/mile**



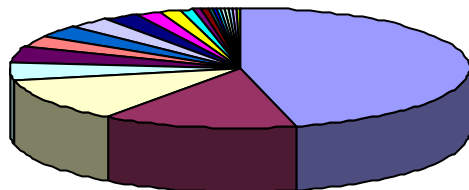
- Sodium
- Magnesium
- Aluminum
- Silicon
- Calcium
- Cobalt
- Sulfur
- Chromium
- Iron
- Zinc

**DDC CNG w/OxiCat - CBD
total = 1.6 mg/mile**



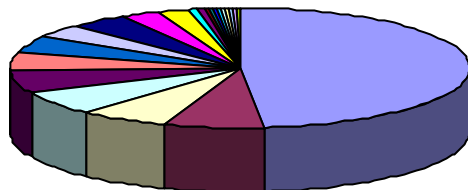
- Sodium
- Magnesium
- Aluminum
- Silicon
- Cobalt
- Iron
- Chromium
- Calcium
- Sulfur
- Zinc

**DDC CNG - SS
total = 0.38 mg/mile**



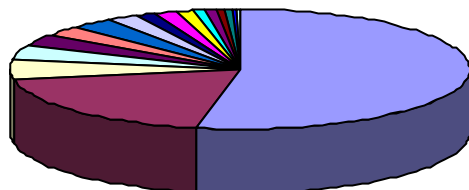
- Sodium
- Magnesium
- Sulfur
- Cobalt
- Calcium
- Aluminum
- Chromium
- Barium
- Silicon
- Zinc

**DDC CNG w/OxiCat - SS
total = 0.36 mg/mile**



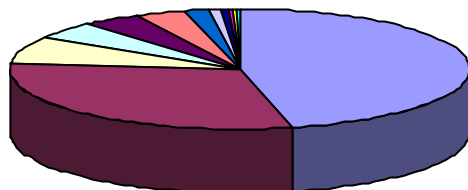
- Sodium
- Magnesium
- Calcium
- Silicon
- Sulfur
- Cobalt
- Zinc
- Iron
- Chromium
- Lanthanum

DDC CNG - TB



- Silicon
- Magnesium
- Iron
- Aluminum
- Tin
- Antimony
- Chlorine
- Calcium
- Zinc
- Lanthanum

DDC CNG w/OxiCat - TB



- Silicon
- Magnesium
- Aluminum
- Phosphorous
- Chlorine
- Sulfur
- Calcium
- Potassium
- Zinc
- Yttrium



FINAL REMARKS

- Results provide snapshot of emissions for three buses only.
- Low emissions, sampling variability, and analytical identification and quantification continue to present significant challenges for vehicle testing.
- In general, oxidation catalyst for CNG bus offers reduction of emissions for many of components measured.
- Speciated emission profiles suggest CNG catalyst offers effective control of volatile fraction.
- Catalyzed diesel trap offers effective control of PM and some PM-associated emissions.
- Depending on cycle, CNG OxyCat and CRT appear to decrease or result in similar mutagen emissions to that of CNG (without OxyCat).
 - For CBD, CRT appears to have lower mutagen emissions than CNG Cummins with OxyCat.
 - For SS, CRT appears to have higher semi-volatile mutagen emissions than the CNG Cummins with OxyCat.



What is Next?

- Continue dissemination of information:
 - <http://www.arb.ca.gov/research/cng-diesel/cng-diesel.htm>
 - conferences and peer-reviewed papers.
- What role other factors play in emissions: lube oil, fuel, sampling, etc. ?
- As vehicle control technologies change, so will emission profiles.
- Introduction of EGR, SCR, NO_x and PM aftertreatment, etc. will likely impact *un-regulated* tailpipe emissions.
- Is emissions database sufficiently populated now to develop fuel-neutral methodology to establish toxicity equivalency between vehicle technologies?