Sensitivity of NOx Emissions for On-Road Mobile Gasoline Vehicles Estimated by MOVES2014a to Fuel Sulfur Content in Gasoline

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Abstract

Recent studies have shown that NOx emissions estimated by MOVES in NEI may be overestimated by as much as a factor of 2. As part of the effort to evaluate the NOx emissions from mobile onroad sources, the Georgia Environmental Protection Division (GA EPD) has investigated the sensitivity of NOx emissions from on-road mobile gasoline vehicles estimated by MOVES2014a to fuel sulfur content in gasoline. Sulfur has been shown to impact the efficiency of NOx control technologies on gasoline powered vehicles through interference with the catalyst, and therefore the sulfur content in gasoline can impact the NOx emissions estimated by MOVES. In MOVES2014a, default sulfur content through 2016 was assumed to be 30 ppm for gasoline, significantly higher than the 25 ppm identified in some areas with test data. However, a lot of areas have to use the default 30 ppm for sulfur content due to scarcity of data. The sulfur content for gasoline must be 10 ppm or less according to Tier 3 requirements starting in 2017 and MOVES2014a takes this into account in its default fuel blends. MOVES2014a was run with different sulfur content levels in gasoline ranging from 5 ppm to 50 ppm for Fulton county during 2014 and 2030.

Background

Recent Modeling/Satellite/Measurement studies showed large overestimations of NO_x emissions from on-road mobile sources in NEI[1,2,3,4,5,6,7]

- Such emissions in NEI estimated using MOVES for first time
- Overestimated by 30-70+%
- May mainly due to light duty gasoline vehicles
- Large impacts on modeling for ground-level ozone

MOVES overestimates NO_x emissions when higher sulfur content in gasoline is assumed.[8]

- Default sulfur content of gasoline is 30 ppm (Tier 2 gasoline[9]) for 2011 and 2014 in MOVES2014a.
- Local testing indicates a lower sulfur content (20-25 ppm), since many distributors over-complied to bank credits to get extra time for Tier 3 transition to 10 ppm.
- MOVES overestimation of higher sulfur means overestimate of NO_x emissions

Methodology

Investigate the impact of sulfur content in gasoline on NO_x emissions estimated by MOVES

- Sensitivity runs with MOVES2014a using different sulfur contents
- Modeling years: 2014 and 2030
- 13 counties in Atlanta
- Modify fuel inputs using fuel wizard in MOVES2014a. When sulfur content is changed, aromatic, E300 and T90 are also changed.
- Sulfur contents in 2014 Runs: 10, 20, 30 (MOVES default) or 50 ppm
- Sulfur contents in 2030 Runs: 5, 10 (MOVES default), 20, or 30 ppm
- Tier 2: 30 ppm
- Tier 3: 10 ppm [10]

Same inputs used in Atlanta ozone maintenance SIP

- Vehicle type and age from recently updated vehicle registration data from Polk/IHS
- VMT and speeds from Atlanta's newly developed Activity-Based Model (ABM)
- 2014 and 2030 model years for maintenance demonstration

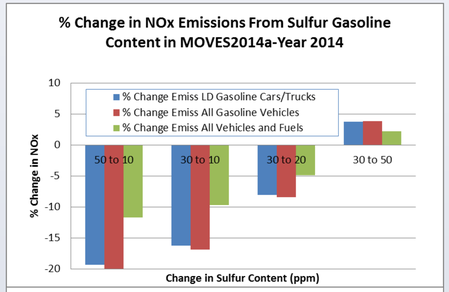
Compare NOx Emission Outputs

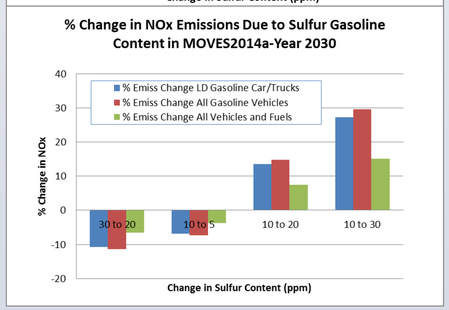
- Total emissions from light duty gasoline cars and trucks
- Total emissions from light duty, all fuel types
- Total emissions from all vehicles, all fuel types
- Total emissions, broken down by model year vehicle

Results

Sulfur Content in Gasoline Does Not Account for Large Discrepancy Reported

Results Measured and Graphed as % Change in NO_x Emissions With Modification of Sulfur Content for Years 2014 and 2030

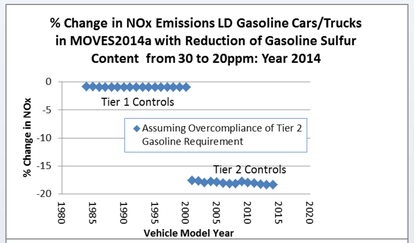


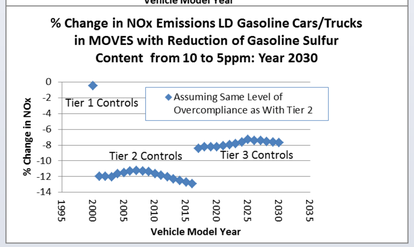


Going from 30 to 20ppm, the minimum likely observed sulfur content in 2011 or 2014 gasoline, results in:

- Emission decrease in 2014 of less than 10%
- Emission decrease still only around 10% when only looking at gasoline powered vehicles with 2030 emissions when Tier 3 would be in effect (including whole vehicle population, well below 10%)
- Only slightly higher maximum difference with 2030 than 2014 (10% vs. 8%)
- The % discrepancy in NO_x emissions claimed in other recent studies much higher, from 30% to over 70% overestimation
- This % change in studies still substantially greater than extreme case of going from 50ppm to 10ppm for 2014 which is 20% or less

Emissions Impact of Over-complying Tier 2 and 3 Gasoline Standards[9,10] by Model Year of Vehicle:





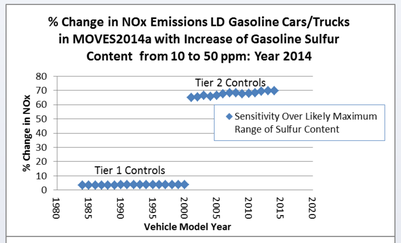
Over-complying Tier 2 Gasoline Standard (30ppm) with 20ppm Gasoline in 2014 By Model Year:

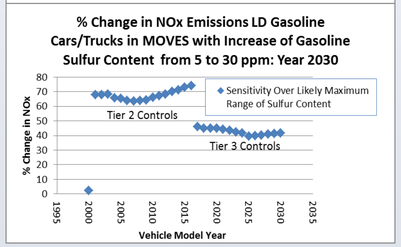
- Impacts Tier 2 controlled light duty gasoline cars/trucks only
- Even if looking at just Tier 2 vehicles, the % change is still well below the low range of the overestimation by recent studies (18% vs. 30%)
- Tier 2 is being replaced with Tier 3 vehicles and gasoline with 10ppm sulfur content starting this year
- Issue of over-compliance regarding 30ppm will not be issue with future NEIs beyond 2017
- Now look to future, choosing maintenance plan 2030 year.

Over-complying Tier 3 Gasoline Standard (10ppm) with 5ppm Gasoline in 2030 to Compare Future Effects:

- Impacts Tier 2&3 controlled light duty gasoline cars/trucks only
- Tier 1 only 2000 model year or earlier, insignificant impact
- Impacts Tier 2 controlled vehicles the most (Tier 3 may include controls beyond catalysts poisoned by sulfur), but still maximum impact only 13% or less.
- Tier 3 vehicles will dominate by 2030 and are impacted less than 10% even in worst model year case
- Banking for 10 ppm standard probably long gone by 2030 and no indication of a future stricter standard, over-compliance less likely, thus 5ppm a very conservatively high estimate

Sensitivity of MOVES2014a to Full Range of Possible Sulfur Content By Model Year of Vehicle





Sensitivity for Year 2014 Going from 10 to 50ppm:

- Significant for Tier 2 controlled light duty gasoline cars/trucks only (Tier 1 impacts <4%)
- LD gasoline vehicle sulfur content needs to be 5 times the requirement before imitating the range of overestimation of recent modeling/satellite/measurement studies
- Extremely unlikely sulfur content would accidentally be that high
- MOVES2014 model identifies highest impact of sulfur on catalyst in the case of Tier 2 vehicles: Tier 2 sensitivity matching recent laboratory and emission control studies cited in EPA's fuel effects report as of MOVES2014's [11]

Sensitivity for Year 2030 Going from 5 to 30ppm:

- Significant for Tier 2 controlled light duty gasoline cars/trucks only (Tier 1 impacts <4%)
- Tier 3 controlled vehicles not as sensitive; perhaps catalyst interfered less by sulfur in gasoline according to MOVES2014: Mimics sulfur content impacts seen with recent laboratory and emission control studies cited in EPA's recent fuel effects report[11]
- Further study on lesser Tier 3 sensitivity being considered
- LD gasoline vehicle emissions for 2030 mimics overestimation claimed by recent studies (30-70%+) only when comparing sulfur levels 3 times requirement versus 50% overcompliance
- Chance of such occurrence nil
- Likely not be overestimation due to over-compliance with Tier 3 gasoline rule by 2030
- MOVES2014a might slightly underestimate sulfur content first few years Tier 3 gasoline implementation (e.g., 2017-2020): Some suppliers under-complying using banked credits for Tier 2 to Tier 3 transition
- MOVES2014a fuel defaults would then theoretically underestimate NOx emissions slightly (<10%) for these years (2017-2020)

Conclusion

- MOVES2014a sensitivity of NOx emissions to sulfur content such as use of 30ppm defaults instead of 20ppm (the biggest likely error versus local fuel data), does not account for the large overestimation of NO_x identified in recent modeling/satellite/measurement studies for 2011 and 2014
- MOVES2014a sensitivity of NO_x emissions to sulfur content in line with laboratory and emission control studies cited in recent EPA's fuel effects report[11]
  - Sensitivity by vehicle model year mimicking tier levels
- MOVES2014a sensitivity of NO_x emissions to gasoline sulfur content in future years (e.g., budget year 2030) is similar to year 2014, even at lower sulfur levels.
- Over-compliance with Tier 3, 10ppm requirement. involves much smaller S variation (5 to 10ppm for Tier 3 vs. 20 to 30ppm for Tier 2 requirement as worst cases) so less impact. Under-compliance with banking credits likely to fade away in the near future. Therefore 10ppm MOVES2014a default after 2016 may be fine.
- Sulfur issue could be contributor to overestimation for 2011 and 2014 seen in studies, but not major one and decreases after banking period impacts fade
- Local blend data still better than default blends, with impacts significant, just not 30% or more.
- EPA planning to replace 30ppm S with more realistic 24ppm S in NEI2014 and future MOVES versions for default Tier 2 gasoline

References/Footnotes ("Recent Studies" Refer to Studies Since 2014)

[1]Anderson D.C. et al. (2014) Measured and modeled CO and NOy in DISCOVER-AQ: an evaluation of emissions and chemistry over the eastern U.S. Atmos. Environ., 96, 78-87.

[2]Canty T.P. et al. (2015) Ozone and NOx chemistry in the eastern US: evaluation of CMAQ/CB05 with satellite (OMI) data. Atmospheric Chemistry & Physics, 15, 4427-4461.

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[4]Kota S.H. et al. (2014) Evaluation of on-road vehicle CO and NOx national emission inventories using an urban-scale source-oriented air quality model. Atmos. Environ., 85, 99-108.

[5]Liu B. and Frey H.C. (2015) Variability in light-duty gasoline vehicle emission factors from trip-based real-world measurements. Environ. Sci. Technol., 49(20), 12525-12534, September 24.

[6]May A.A. et al. (2014) Gas- and particle-phase primary emissions from in-use, on-road gasoline and diesel vehicles. Atmos. Enviorn., 88, 247-260, January 28.

[7]McDonald B. et al. (2015) Modeling ozone in the eastern United States using a fuel-based mobile source emissions inventory. AGU Fall Meeting, San Francisco, CA, December 14.

[8]Sowards, G. (2016) Improved Air Quality Through the Use of Tier 3 Fuels in Utah. Presentation to the Utah House of Representatives National Resources, Agriculture, and Environment Interim Committee, Salt Lake City, Utah. September 20.

[9]70 FR 70498

[10]81 FR 23641

[11] USEPA Office of Transportation and Air Quality. *Fuel Effects on Exhaust Emissions from On-Road Vehicles in MOVES2014, Final Report*. EPA-420-R-16-001. Assessment and Standards Division. Ann Arbor, MI. February 2016.