



Updated Speciation Profiles in MOVES

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Summary

- Background on speciation in MOVES and SMOKE
 - Onroad
 - Nonroad
- Proposed changes to speciation
 - Heavy-duty 2010+
 - Large nonroad Tier 4 engines



Background

- MOVES VOC and PM must be allocated into constituent chemical species prior to air quality modeling
 - This is done through application of speciation profiles
- Prior to MOVES2014, mobile source VOC and PM were speciated outside of MOVES using the SMOKE emissions processor
 - For VOC, speciation profiles of individual chemical compounds were applied and these compounds were then grouped into chemical mechanism species with similar properties in the air quality model
 - For PM, simplifying chemical mechanisms not used in CMAQ, EPA's air quality model
 - PM species input directly into model

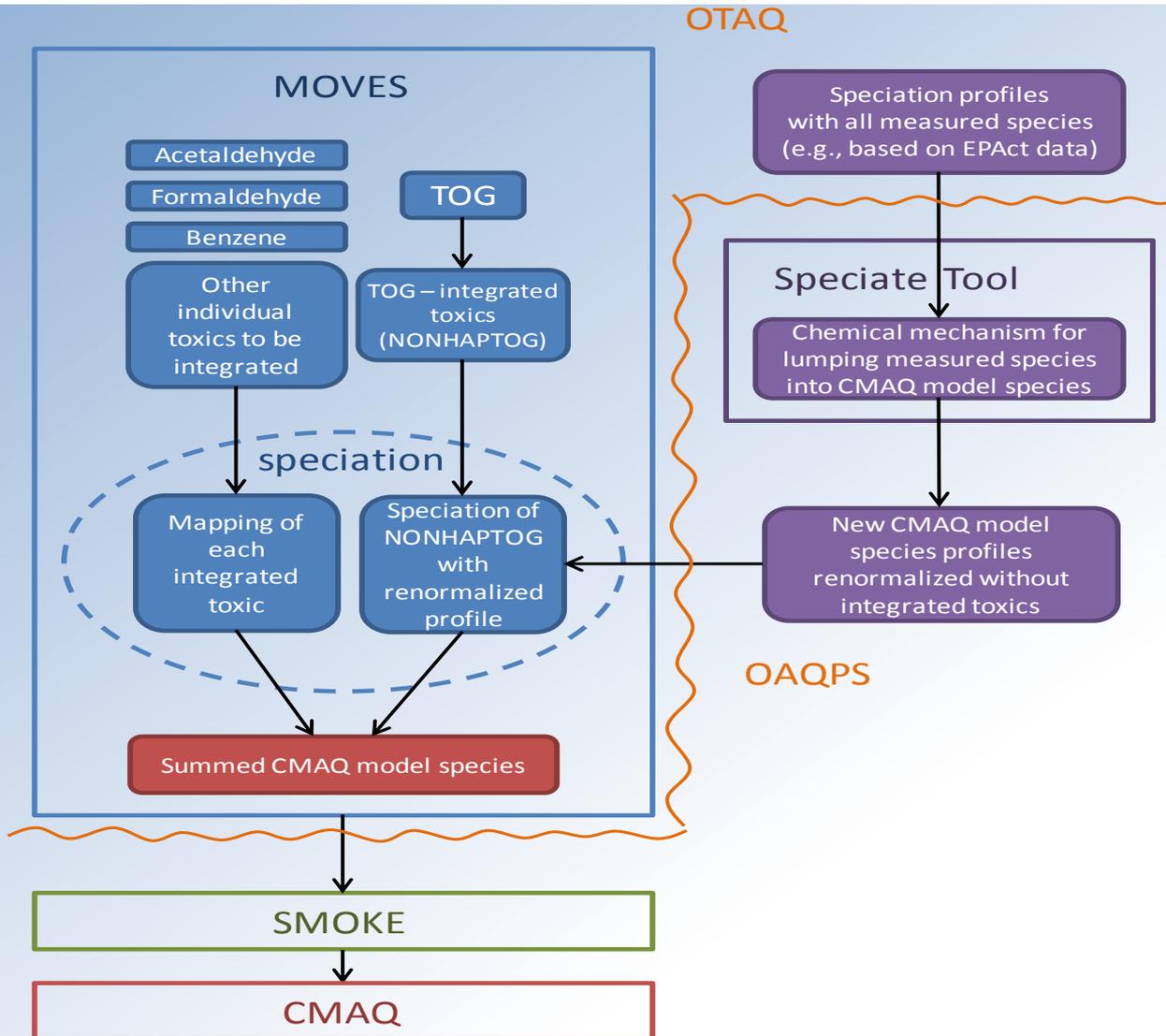


Background: Onroad Speciation

- Speciation profiles can vary by source type, emission process (exhaust, permeation, evaporative), fuel type (diesel versus gasoline), fuel blend (e.g. E0, E10), emissions control technology
 - Mix of technologies, fuel types, etc. can also vary by location
 - SMOKE dealt with all these complexities by weighting various profiles
 - Became increasingly burdensome
- MOVES2014 included VOC and PM speciation for onroad sources
 - Since MOVES estimates emissions of individual toxic compounds, these emissions must be “integrated” into the profiles



Onroad Speciation in MOVES



Background: Nonroad Speciation

- MOVES2014a updated toxic emission rates for nonroad engines based on newer data, as well as speciation profiles based on the same datasets
- Grouping individual VOC compounds into chemical mechanism species is done in SMOKE rather than MOVES
 - For nonroad, MOVES produces VOCs grouped by profile:
 - Profiles are defined by:
 - Engine Type (e.g. CI, SI 2-stroke, SI 4-stroke), Engine Tech (e.g. Tier 1), Engine Size (e.g. >75 HP), Fuel (e.g. Diesel, CNG), fuel subtype (e.g. E0, E10), emission process (e.g. exhaust, evaporative)
 - Because users can group emissions by profile, no need to weight profiles, and speciation can be easily applied in SMOKE
 - Allows application of new chemical mechanisms in SMOKE without re-running MOVES



Proposed Update to Speciation for 2010 and Later Highway Diesels

- MOVES2014a applies speciation from 2007-2009 engines to all 2007 and later engines
 - Data from HEI's Advanced Collaborative Emissions Study (ACES) Phase 1
- Emission control technology very different for engines meeting more stringent 2010 and later standards than for 2007-2009 engines
- Data from ACES Phase II recently became available
 - Speciated emissions from 2010 on-highway heavy-duty diesel engines equipped with diesel particulate filter (DPF) and selective catalytic reduction (SCR) systems
- Large effect on VOC speciation
 - e.g. formaldehyde is a much lower fraction of VOC
- We are proposing applying these data to all 2010 and later engines



Speciation for Nonroad Diesel Tier 4 Engines

- Nonroad Diesel Tier 4 engines <56 kW
 - Tier 4 NMHC emissions standards relatively unchanged from Tier 2
 - No EPA certified engines are equipped with diesel particulate filters (DPF) or selective catalytic reduction (SCR) systems
 - Considering using the same Tier 2 VOC emission profile in the next version of MOVES as used in MOVES2014
- Nonroad Diesel Tier 4 engines > 56 kW
 - Significant reduction in NMHC and NOx emissions
 - DPF penetration ~ 40%
 - SCR penetration between 90-100% (2014 EPA Certification data)
 - MOVES2014 uses the ACES Phase I onroad profile (DPF equipped heavy-duty onroad engines)
 - Considering using ACES Phase II onroad profile (DPF+SCR equipped heavy-duty onroad engine) for next version of MOVES



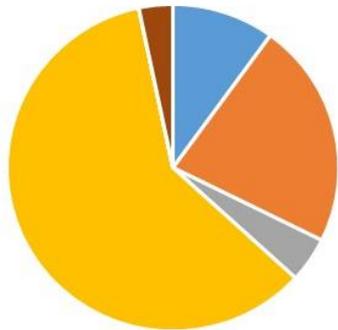
VOC profiles for Nonroad emissions

- The following profiles are used in SMOKE to speciate VOC emissions from MOVES
- All of these profiles are found in SPECIATE database
 - <https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40>
 - 95327 – Spark ignition exhaust; 2-stroke off-road engines; Non-oxygenated gasoline
 - 95328 -- Spark ignition exhaust; 2-stroke off-road engines; E10 ethanol gasoline
 - 95329 -- Spark-Ignition Exhaust; 4-stroke off-road engines; Non-oxygenated gasoline
 - 95330 -- Spark-Ignition Exhaust; 4-stroke off-road engines; E10 ethanol gasoline
 - 95331 -- Diesel Exhaust Emissions; Pre-Tier 1 Off-road Engines
 - 95332 -- Diesel Exhaust Emissions; Tier 1 Off-road Engines
 - 95333 -- Diesel Exhaust Emissions; Tier 2 Off-road Engines
 - 95335 -- Diesel Exhaust; Onroad Heavy-heavy duty truck; 2011 model year
 - Proposed for Nonroad Tier 4 Diesel >56 kW



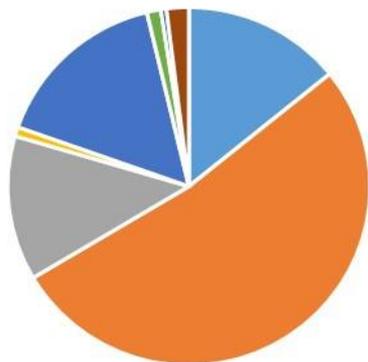
Proposed Update to PM Speciation

ACES Phase I (2007 HD Diesel) PM Speciation



■ EC ■ OC ■ NCOM ■ SO4= ■ NO3 ■ NH4+ ■ PH2O ■ Other

ACES Phase II (2010 HD Diesel)



- ACES Phase I PM profile (2007 HD technology)
 - Large contribution of SO₄ emissions, from regeneration events—where the accumulated particulates, including sulfur, are removed from the diesel particulate filter
- ACES Phase II PM profile (2010 HD technology)
 - Large reduction in PM_{2.5} emissions from the ACES Phase I profile¹,
 - Phase II data does not include DPF regeneration events, and minimal SO₄ measured in Phase II
- Considering using of the ACES Phase I PM_{2.5} profile for all 2007+ trucks and Tier 4 >56 kW engines
 - California Air Resources Board testing^{2,3} has shown regeneration events occur on 2010+ technology on-highway trucks, but at a lower frequency
 - Not reflected in the ACES Phase II PM profile

¹ Khalek, I. A., et al. (2015). "Regulated and unregulated emissions from modern 2010 emissions-compliant heavy-duty on-highway diesel engines." Journal of the Air & Waste Management Association 65(8): 987-1001.

² Chris Ruehl, Jeremy Smith, John Collins, Donald Chernich, Harold Dwyer. Mass Balance and Emissions from both active and passive regenerations of heavy duty diesel particulate filters.

³ 26th CRC Real World Emissions Workshop. March 13-16, 2016.

³ Jeremy Smith et al. Characterization of chemical composition of particulate matter from modern heavy-duty vehicles under real-world driving conditions. 26th CRC Real World Emissions Workshop. March 13-16, 2016.



Summary

- Proposing to replace highway diesel VOC speciation for 2010 and later engines with recent data on those technology engines from ACES Phase II
- Considering using ACES Phase II onroad profile (DPF+SCR equipped heavy-duty onroad engine) for nonroad Tier 4 VOC emissions in the next version of MOVES
- Considering maintaining the use of the ACES Phase I PM_{2.5} profile for all 2007+ trucks and nonroad Tier 4 >56 kW engines

