Assessing the Anthropogenic Fugitive Dust Emission Inventory and Temporal Allocation using an Updated Speciation of Particulate Matter

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1. Introduction

Crustal materials are mainly emitted by anthropogenic and windblown fugitive dust, but also may potentially include some fly ash and industrial process emissions which are chemically similar to crustal emissions. Source apportionment studies have shown that anthropogenic fugitive dust emissions contribute on the order of 5-20% of PM2.5 (particles with an aerodynamic diameter less than 2.5 um) and 40-60% of PM10 (particles with an aerodynamic diameter less than 10 um) in urban areas that either have been or potentially may be unable to attain the National Ambient Air Quality Standards (NAAQS) for PM2.5 and/or PM10. On the other hand, air quality models suggest vastly higher contributions from current fugitive dust emission inventories, with contributions ranging from 50-80% for PM2.5 and 70-90% for PM10. These estimates are from a Desert Research Institute workshop report from May 2000 that is available from EPA's Technology Transfer Network Clearinghouse for Inventories & Emissions Factors. This paper uses an improved speciation of the particulate matter to include, in addition to the current PM species, eight trace metals as well as separate non-carbon organic matter to assess potential improvements to the emission estimates of anthropogenic fugitive dust (unpaved and paved road dust, dust from highway, commercial and residential construction and agricultural tilling).

The NARSTO 2005 assessment report stressed that emissions are at the cornerstone of air quality management decision-making. While the United States Environmental Protection Agency (EPA), Office of Air Quality Planning and Standards (OAQPS) bears the responsibility for maintaining the National Emissions Inventory (NEI) for traditional anthropogenic sources (e.g., electrical generating units and mobile sources), many nontraditional emission categories (such as fugitive dust) remain poorly characterized. Area Source Fugitive Dust Emissions are currently estimated in the National Emissions Inventory on a county-level annual basis with little information about temporal allocation. In addition, in the NEI there is no adjustment for local source removal due to small scale turbulence. Fugitive dust categories of interest include unpaved and paved road dust, dust from highway, commercial and residential construction and agricultural tilling. Of these, unpaved roads are the highest single emissions category, accounting for about one third of non-windblown fugitive dust emissions. This is followed in importance by dust from tilling, quarrying and other earthmoving. A transportable fraction as proposed by Pace (2005) is applied on a per county basis to both PM10 and PM2.5. In addition, the current temporal allocation assumes no monthly variability and no weekday/weekend variation. In essence, each day is represented identically throughout the year. This paper summarizes two phases to improve the fugitive dust emission estimates used in chemical transport modeling. The first phase involves improvements to the transportable fraction applied to the gridded emission inventory field and improvements to the temporal allocation of the fugitive dust emissions. The second phase involves a new speciation of PM2.5 from all sources that tracks eight trace metals. These trace metals are then modeled in a chemical transport model and compared with ambient measurements. These allows for better source attribution of measured trace metals to help determine emission inventory improvement at the source classification code (SCC) code level rather than at broader sector levels.

2. Spatial and Temporal Improvements to the Inventory

First, in Pace (2005), the transportable fraction is calculated on a per county basis for 3 RPOs using the BELD2 county-level land use information. The western states, (WRAP and CENRAP) are calculated using a different land use database North American Landcover Dataset 2000 (NALD 2000). In this paper, we have recalculated the transportable fraction at a 1km resolution using the newer BELD3 database for all of the CONUS. The transportable fraction is calculated for five broad land use categories (Forest, Urban, Sparsely wooded & Grass, agricultural, and barren/water). Table 1 shows the mapping of the BELD3 land use types to the five broad land use categories and the associated capture fraction. This provides a consistent method across the lower 48 states as well as a more accurate representation of the land cover. The transportable fraction represents the fraction of the emission estimate that is transported beyond the local environment from which it was generated due to the effects of land cover. Thus a dense forest would have a small fraction compared to shrubland.

Table 1: BELD3 categories, Capture Fraction Class, and Transportable Fraction

BELD3 category	Capture Fraction class	Transportable Fraction
USGS_urban	Urban	0.50
USGS_drycrop	Grass	0.75
USGS_irrcrop	Grass	0.75
USGS_cropgrass	Grass	0.75
USGS_cropwdlnd	Grass	0.75
USGS_grassland	Grass	0.75
USGS_shrubland	Water/Barren	1.00
USGS_shrubgrass	Grass	0.75
USGS_savanna	Grass	0.75
USGS_decidforest	Forest	0.05
USGS_evbrdleaf	Forest	0.05
USGS_coniferfor	Forest	0.05
USGS_mxforest	Forest	0.05
USGS_water	Water/Barren	1.00
USGS_wetwoods	Forest	0.05
USGS_sprsbarren	Water/Barren	0.00
USGS_woodtundr	Grass	0.75
USGS_mxtundra	Water/Barren	1.00
USGS_snowice	Water/Barren	1.00
All Agriculture classes	Grass	0.75
All tree classes	Forest	0.05

A second improvement to the methodology is to modify the temporal activity factors used in the emissions processing. The source categories of emissions from fugitive dust include unpaved road dust, paved road dust, commercial construction, residential construction, road construction, agricultural tilling, livestock operations, and mining and quarrying. For each of these categories, revisions are made to the monthly, weekly, and daily temporal profiles. The rationale for these temporal allocation changes is that we have activity factors for associated sectors that differ from the activity factors that have been assumed for the fugitive dust emissions. An example of this is agricultural tilling. We have a temporal profile for the combustion emissions of agricultural equipment in the non-road mobile source sector that is different than the fugitive dust emissions from agricultural tilling. We harmonized the temporal factors for each the fugitive dust sectors with other components of the emission inventory and processing platform where appropriate and summarize our proposed changes.

3. Speciation Improvements to the Inventory

In the second phase, we updated the speciation of PM2.5 from all sources including the dust sources. These updates to the speciation of PM2.5 were made possible as a result of the work of Reff et al (2009). In this paper, an inventory for trace metals from PM2.5 was derived using EPA's SPEICATE database and ground-based measurements in the CONUS. Composite PM2.5 profiles containing the trace metals were then mapped to all available source classification codes. The miscellaneous component of PM2.5 (aka PMFINE) was broken down into 14 components. These 14 components are show in Table 3.

Table 3: The Revised Speciation of PMFINE and the reasons for making them explicit.

New Species	Reason
PH20 (Water)	Already explicit in CMAQ
PCL (Chloride)	Already explicit in CMAQ
PNA (Sodium)	Already explicit in CMAQ
PNH4 (Ammonium)	Already explicit in CMAQ
PNCOM (non-Carbon Organic Matter)	to accurately model total organic mass
PCA (Calcium)	For ISORROPIA v2.0, and for crustal matter
PSI (Silicon)	To represent crustal matter
PMG	For ISORROPIA v2.0
PMN	For AQCHEM
PAL (Aluminum)	To represent crustal matter
PFE (Iron)	To represent crustal matter & for AQCHEM
PTI (Titanium)	To represent crustal matter
PK (Potassium)	For ISORROPIA v2.0
PMOTHR	Remaining part of PMFINE (renamed)

With this new speciation, we are now able to view the emission inventory in much more detail. We can see which Source Classification Codes are associated with particular trace metals. For example, 89% of Silicon inventory in the unadjusted 2002 National Emissions Inventory is dominated by six sources: agricultural tilling, unpaved road dust, External Combustion Boilers, Paved Road Dust, construction, and mining and quarrying. Of these six sources, five of them are in the area source fugitive dust inventory.

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4. Preliminary Results

CMAQv4.7.1 (Byun and Schere, 2006) was used to study the impact of the changes to the emissions processing on the model results. We ran three versions of the chemical transport model: (1) without any area source fugitive dust sources but included the revised speciation (2) with area source fugitive dust sources and the revised speciation but no temporal or spatial updates from phase 1 (3) with all the changes in phase 1 and phase 2. We then compared the trace metals to the observed metals at IMPROVE and CSN monitoring sites for January and July 2002.

5. Discussion

By revising the speciation profiles from PM2.5 to include trace metals that are readily measured at monitoring locations, we are able to study the impact of changes to the emission inventory processing (temporal and spatial allocation), and begin to make improvements to our emission inventory. Using

Silicon as an example, we see that the model has a high bias for Silicon in the winter by a significant factor. We can then go to our inventory by SCC code and trace metals to see that the high bias in the winter is due to at least 2 causes: overestimates of Silicon from the Electric Utility sector and from fugitive dust. We can then look for improvements to specific sectors by reviewing the methods and assumptions associated with a particular SCC. For Silicon, we see that Agricultural Tilling is overestimated in the winter probably because the inventory estimate does not account for or poorly accounts for the meteorological effects of snow and rainfall on agriculture tilling. We plan to modify the emission estimates for this sector significantly by accounting for meteorological effects in the emission processing.

6. Summary

This paper summarizes initial work to improve the speciation of the particulate matter in order to assess potential improvements to the emission estimates of anthropogenic fugitive dust (unpaved and paved road dust, dust from highway, commercial and residential construction and agricultural tilling). We included proposed changes to the fugitive dust emission processing as well as how we plan to ascertain which components of the emission inventory can be improved using a detailed speciation of PM2.5 in a chemical transport model. Updates to CMAQ to incorporate these changes will be included in the next release of CMAQ.

References

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