2020 National Emissions Inventory Technical Support Document: Dust – Unpaved Roads

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24.1 Sector Descriptions and Overview

The unpaved road dust sector reflects emissions of particulate matter from vehicles driving over unpaved roads. The SCCs that belong in this sector are provided in Table 24-1. Fugitive dust emissions from unpaved road traffic were estimated for PM10-PRI, PM10-FIL, PM25-PRI, and PM25-FIL. Since there are no PM-CON emissions for this category, PM10-PRI emissions are equal to PM10-FIL emissions and PM25-PRI emissions are equal to PM25-FIL emissions.

Table 24-1: SCC in the unpaved road dust sector

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2296000000	Mobile Sources	Unpaved Roads	All Unpaved Roads	Total: Fugitives

24.2 EPA-developed estimates

Uncontrolled unpaved road emissions were calculated at the county level by roadway type. This was done by multiplying the county/roadway class unpaved road vehicle miles traveled (VMT) by the appropriate unpaved road emission factor. Next, control factors were applied to the unpaved road emissions in PM_{10} nonattainment and maintenance area counties. Emissions by roadway class were then totaled to the county level and adjusted for meteorological conditions. The following provides further details on the emission factor equation, determination of unpaved road VMT, and controls.

24.2.1 Emission factors

Re-entrained road dust emissions for unpaved roads were estimated using paved road VMT and the emission factor equation from AP-42 [ref 1]:

$$E = [k \times (s/12)^{1} \times (SPD/30)^{0.5}] / (M/0.5)^{0.2} - C$$

Where k and C are empirical constants given in Table 24-2, with:

E = unpaved road dust emission factor (lb/VMT)
k = particle size multiplier (lb/VMT)
s = surface material silt content (%)
SPD = mean vehicle speed (mph)
M = surface material moisture content (%)
C = emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear (lb/VMT)

Values used for the particle size multiplier and the 1980's vehicle fleet exhaust, brake wear, and tire wear are provided in Table 24-2, and come from AP-42 defaults.

Table 24-2: Constants for unpaved roads re-entrained dust emission factor equation

Constant	PM25-PRI/PM25-FIL	PM_{10}-PRI/PM_{10}-FIL
k (lb/VMT)	0.18	1.8
C	0.00036	0.00047

Average state-level unpaved road silt content values, developed as part of the 1985 NAPAP Inventory, were obtained from the Illinois State Water Survey [ref 2]. Silt contents of over 200 unpaved roads from over 30 States were obtained. Average silt contents of unpaved roads were calculated for each sate that had three or more samples for that State. For States that did not have three or more samples, the average for all samples from all States was used as a default value. The silt content values are reported by State in Table 24-3.

Table 24-3: Surface material silt content values (%) for unpaved roads by state

States	**Surface material silt content (%)**
OR	7.2
WY	7.1
MT	6.6
MO	6.5
TX	5.6
NC	5.1
NY	4.7
OK	4.4
NM	4.3
NE, WI	4.2
AL, AR, AZ, CT, DE, DC, FL, GA, ID, KS, KY, LA, ME, MD, MA, MS, NH, NJ, ND, RI, SC, UT, VT, WA, WV	3.9
AK, HI	3.8
PA	3.3
VA	3.2
OH, SD	3.1
AZ	3.0
MN	2.7
CA, IL, IN, MI	2.6
IA	2.5
TN	2.0
NV	1.7
CO	1.5

Table 24-4 lists the speeds modeled on the unpaved roads by roadway class. These speeds were determined based on the average speeds modeled for onroad emission calculations and weighted to determine a single average speed for each of the roadway classes [ref 3]. The roadway class “Urban collector” with an average speed of 20 mph was split into two sub-categories, “Urban major collector” and “Urban minor collector”, to correspond to the roadway types found in the VMT data.

Table 24-4: Speeds modeled by roadway type on unpaved roads

Unpaved Roadway Type	Speed (mph)
Rural Minor Arterial	39
Rural Major Collector	34
Rural Minor Collector	30
Rural Local	30
Urban Other Principal Arterial	20
Urban Minor Arterial	20
Urban Major Collector	20
Urban Minor Collector	20
Urban Local	20

A report by Cowherd et al. [ref 4] estimates a range of 0.3% to 1.1% for surface material moisture content (M) from different road samples across regions of the country. EPA used expert judgment to assign surface material moisture content values from this range to counties based on regional patterns of soil moisture and precipitation [ref 4].

24.2.2 Activity data

Generally, VMT on US roads can be obtained from the Federal Highway Administration (FHWA). FHWA categorizes roads into 14 different types based on road function and access; these road types can be found in Table 24-5.

Table 24-5: FHWA road types

FHWA Road Type
Rural Interstate
Rural Other Freeways and Expressways
Rural Other Principal Arterial
Rural Minor Arterial
Rural Major Collector
Rural Minor Collector
Rural Local
Urban Interstate
Urban Other Freeways and Expressways
Urban Other Principal Arterial
Urban Major Collector
Urban Minor Collector
Urban Local
Urban Minor Arterial

Total VMT in each county is provided by FHWA to EPA for use in EPA's MOtor Vehicle Emission Simulator (MOVES) model to calculate emissions for the mobile sector. The road dust methodology uses these county-level VMT data from FHWA.

The county-level VMT from FHWA includes total VMT, but it does not provide data on how much of that VMT is on paved or unpaved roads. FHWA provided state-level data on the amount of VMT on paved and unpaved roads for most road types, except for three: Rural Local, Urban Local, and Rural Minor Collector [ref 5]. To determine how much of the total VMT is on paved or unpaved roads, the total VMT

in each county is multiplied by the ratio of state-level VMT on paved or unpaved roads to total state-level VMT on each road type.

$$VMT_{p/u,c,r} = VMT_{t,c,r} \times \frac{VMT_{p/u,s,r}}{VMT_{t,s,r}} \quad (1)$$

Where:

$VMT_{p/u,c,r}$ = Paved or unpaved vehicle miles traveled in county *c* on FHWA road type *r*
$VMT_{t,c,r}$ = Total vehicle miles traveled in county *c* on FHWA road type *r*, from equation 1
$VMT_{p/u,s,r}$ = Paved or unpaved vehicle miles traveled in state *s* on FHWA road type *r*

Because paved and unpaved VMT data were unavailable from FHWA for the Rural Local, Urban Local, and Rural Minor Collector road types, ratios for those road types were developed using state-level results from a 2008 model run from the National Mobile Inventory Model (NMIM), a precursor to MOVES. To account for the fact that some states have paved many of their unpaved roads since 2008, an adjustment factor was developed based on the change in unpaved road length. While FHWA does not provide data on paved or unpaved VMT for those three road types, it does provide data on paved and unpaved road *length* for these road types [ref 6]. The adjustment factor is based on the change in the ratio of paved or unpaved road *length* in the current inventory year to the ratio in 2008.

$$AF_{p/u,r,s} = \frac{\frac{Length_{p/u,s,r,y}}{Length_{t,s,r,y}}}{\frac{Length_{p/u,s,r,2008}}{Length_{t,s,r,2008}}} \quad (1a)$$

Where:

$AF_{p/u,s,r}$ = Adjustment factor for paved or unpaved vehicle miles traveled in state *s* on FHWA road type *r*
$Length_{p/u,s,r,2016}$ = Paved or unpaved road length in state *s* for FHWA road type *r* in year *y*
$Length_{t,s,r,2016}$ = Total road length in state *s* for FHWA road type *r* in year *y*
$Length_{p/u,s,r,2008}$ = Paved or unpaved road length in state *s* for FHWA road type *r* in 2008
$Length_{p/u,s,r,2008}$ = Total road length in state *s* for FHWA road type *r* in 2008

This adjustment factor is multiplied by the paved or unpaved VMT ratio from NMIM for Rural Local, Urban Local, and Rural Minor Collector roads.

$$VMT_{p/u,c,r} = VMT_{t,c,r} \times \frac{VMT_{p/u,s,r}}{VMT_{t,s,r}} \times AF_{p/u,s,r} \quad (21b)$$

Where:

$VMT_{p/u,c,r}$ = Paved or unpaved vehicle miles traveled in county *c* on FHWA road type *r*
$VMT_{t,c,r}$ = Total vehicle miles traveled in county *c* on FHWA road type *r*, from equation 1
$VMT_{p/u,s,r}$ = Paved or unpaved vehicle miles traveled in state *s* on FHWA road type *r* (from NMIM)
$VMT_{t,s,r}$ = Total vehicle miles traveled in state *s* on FHWA road type *r*
$AF_{p/u,s,r}$ = Adjustment factor for paved or unpaved vehicle miles traveled in state *s* on FHWA road (from equation 2a)

As an example, if a state paved many of its unpaved roads between 2008 and the current inventory

year, then the adjustment factor for unpaved roads would be less than 1, reducing the estimated ratio of unpaved VMT to total VMT (and, therefore, increasing the ratio of paved VMT to total VMT).

In addition, it is assumed that there is no VMT on unpaved roads for urban road types or in counties with a population density greater than 3,000 people per square mile. For these cases, all VMT is assumed to be on paved roads.

24.2.3 Allocation

The total VMT used to estimate emissions from road dust is available at the county level. The amount of paved and unpaved VMT in each county is estimated using state-level ratios, as described in the previous "Activity data" section. County level emissions were calculated by multiplying the county unpaved VMT (by road type) by the emission factors calculated in 24.2.1.1.

24.2.4 Controls

The controls assumed for unpaved roads varied by PM_{10} nonattainment area classification and by urban and rural areas. On urban unpaved roads in moderate PM_{10} nonattainment areas, paving of the unpaved road was assumed and a control efficiency of 96 percent and a rule penetration of 50 percent were applied. Controls were not applied to rural unpaved roads in moderate nonattainment areas. Chemical stabilization, with a control efficiency of 75 percent and a rule penetration of 50 percent, was assumed for rural areas in serious PM_{10} nonattainment areas. A combination of paving and chemical stabilization, with a control efficiency of 90 percent and a rule penetration of 75 percent, was assumed for urban unpaved roads in serious PM_{10} nonattainment areas. In counties currently at maintenance status, controls were assumed based on the severity (moderate or serious) of their prior nonattainment status. Some counties had multiple partial areas with differing levels of nonattainment. In these cases, controls were assumed to be applied based on the most serious level of nonattainment found within a given county.

Note that the controls were applied at the county level, and the controls differ by urban vs. rural roadway class. In the final emissions table, the emissions for all roadway classes were summed to the county level. Therefore, the emissions at the county level can represent several different control effectiveness and rule penetration levels. However, the control efficiency and rule penetration values were reported in the Controlled Emissions worksheet at the county level for urban and rural roadways separately.

24.2.5 Meteorological adjustment

After controls were applied, emissions were summed to the county level and converted to tons prior to applying the meteorological adjustment. The meteorological adjustment accounts for the reduction on fugitive dust emissions via the impact of precipitation and other meteorological factors over each hour of the year and then averaged to an annual meteorological adjustment factor for each grid cell in each county, aggregated to a single county-level factor. For example, wet roads will result in significantly lower dust emissions. The county-level meteorological adjustment factors were developed by EPA based on the ratio of the unadjusted to meteorology-adjusted county-level emissions from the SMOKE Flat Files. The county-level meteorological adjustment is a scalar between 0 and 1 that is multiplied by the

estimated emissions, where lower-values/greater-reductions are typically found in areas with more frequent precipitation.

24.2.6 Improvements/Changes in the 2020 NEI

The 2017 NEI used one county-level meteorological adjustment factors for both paved and unpaved roads. For the 2020 NEI, separate county-level meteorological adjustment factors were developed for paved roads and unpaved roads. The adjustment factors, which are updated each inventory cycle based on modeling conducted by EPA, also showed that roads generally contained less residual moisture than the factors used in 2017, and road dust emissions were higher in 2020.

24.2.7 Puerto Rico and Virgin Islands

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: Broward (state-county FIPS=12011) for Puerto Rico and Monroe (state-county FIPS=12087) for the US Virgin Islands. The total emissions in tons for these two Florida counties are divided by their respective populations creating a tons per capita emission factor. For each Puerto Rico and US Virgin Island county, the tons per capita emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

24.3 References

1. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources, Section 13.2.2, Unpaved Roads. Research Triangle Park, NC. November 2006.
2. W. Barnard, G. Stensland, and D. Gatz, Illinois State Water Survey, "Evaluation of Potential Improvements in the Estimation of Unpaved Road Fugitive Emission Inventories," paper 87-58.1, presented at the 80th Annual Meeting of the APCA. New York, New York. June 21-26, 1987
3. United States Environmental Protection Agency, 2011 National Emissions Inventory, version 2 Technical Support Document. Research Triangle Park, NC. August 2015.
4. Cowherd, C., M.A. Grelinger, C. Kies, and T.G. Pace. 2002. Improved Activity Levels for National Emission Inventories of Fugitive Dust from Paved and Unpaved Roads. Presentation at 11th International Emission Inventory Conference. Atlanta, Georgia, April 15-18, 2002.
5. Data provided to Abt Associates by Robert Rozycki, FHWA.
6. Federal Highway Administration, "Highway Statistics, 2020." Table HM-51.

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