Improved Activity Levels for National Emission Inventories of Fugitive Dust from Paved and Unpaved Roads

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ABSTRACT

A review of source activity data sources suggests that a significant deficiency exists in the methods for gathering activity data for paved and unpaved roads. The resultant data sets are suspected of being inadequate for proper spatial and temporal representation of emission inventories. This paper presents improved methodologies to construct activity datasets for development of fugitive dust emission estimates by county and by month. The required data sets include paved road silt loading, unpaved road silt content, and unpaved road moisture content. This paper demonstrates how the new activity data sets help to improve the reliability of emission inventory calculations.

The silt loading data for paved roads have been divided into baseline contributions from ubiquitous sources and hot spot contributions from application of antiskid materials and from mud/dirt track-out. The baseline silt loading is found to be inversely proportional to the traffic volume on a paved road. The amount of antiskid material is related to the annual snowfall in a region. The hotspot contribution from mud/dirt track-out is dependent on the number of construction sites and the extent of industrial activities involving aggregate handling and transport.

Fugitive dust emissions from unpaved roads depend on the silt content that in turn is related to whether native soil or road aggregate is utilized as the surface material. The moisture content of unpaved roads is related to climatic parameters that influence moisture accumulation and moisture loss in the top surface layer. Moisture loss also is dependent on the volume of vehicle traffic because of the enhanced evaporation rate. Unpaved road traffic volume can be predicted on the basis of rural road mileage and rural population density.

INTRODUCTION

This paper reports on certain aspects of a project entitled "Activity Databases for Fugitive Dust Inventories (EPA Contract No. 68-D-01-002, Work Assignment No. 1-05)" being conducted by Midwest Research Institute. The purpose of this MRI project is to gather and analyze source activity data that would improve EPA's national county-by-county emission inventory of fugitive dust sources (for both PM-10 and PM-2.5). There is substantial evidence that the modeled air quality impacts of these sources substantially exceed observed impacts derived from source apportionment of the PM concentration levels (Countess et al., 2001).

Part of the overprediction of the air quality impacts of fugitive dust sources may be related to correction parameter values used with the predictive emission factor equations in AP-42. For example, the historical silt loading database for paved roads has placed too much emphasis on "worst case" loadings associated with the use of antiskid abrasives for snow/ice control.

With regard to the atmospheric transport, it has been proposed that this problem be resolved by separating fugitive dust emissions into two components. "Transportable" emissions are only those particles that are vertically mixed beyond a certain elevation above ground level for transport over long distances. In contrast, particle emissions that remain near the surface are quickly depleted by various physical mechanisms, mostly associated with ground roughness elements. Only the "transportable" PM emissions would be used for ambient air quality modeling purposes.

The project is divided into four tasks as described below. This paper addresses aspects of the project (under Task 2 and 3) having to do with activity levels for fugitive dust generated by paved and unpaved roads.

Task 1 addresses enhanced near-source removal mechanisms for airborne fugitive dust particles. It is believed that over the first 200 meters or so of travel distance, much of the dust from sources such as unpaved roads may be removed by surface vegetation. This removal mechanism is not adequately addressed by available atmospheric dispersion models, especially those that are designed for assessing regional air quality impacts. The product of this task will be monthly values of estimated fugitive dust deposition velocities for each county, based on seasonal conditions and prevailing surface cover for each county.

Task 2 is aimed at developing a monthly soil moisture database that would be applicable to a variety of fugitive dust sources (unpaved dirt roads, construction activities, open area wind erosion, and agricultural land preparation). This database would also be spatially resolved by county. Another part of this task calls for a national crop calendar showing the crop acreage grown at the county level and when major agricultural operations occur. This task will not be completed until we receive additional input from USDA.

Task 3 addresses emission inventory input parameters for paved and unpaved roads. For paved roads, an improved methodology is needed for assigning seasonal road surface silt loading values by county. This must take into account such factors as increases in winter/spring silt loading values due to the application of antiskid abrasives in areas with substantial snowfall. For unpaved roads, there is a need for better data on county VMT values, which are currently derived by apportioning state totals on the basis of county area (rather than population density).

Task 4 has its purpose to summarize the wind erosion algorithms currently in use by researchers in USDA and universities for estimating fine particle emissions from high wind events. The applicability of USDA Wind Erosion Prediction System for annual county-by-county emission estimates is of particular interest.

SURFACE MOISTURE CONTENT

Surface moisture is an important variable in the estimation of fugitive dust emissions due to wind, unpaved roads, tilling, land preparation, and other mechanical activities that entrain dust from crustal surface materials. For sources such as unpaved roads, a surface moisture is required, but for sources such as agricultural tilling that disturb the surface to a greater depth, the soil moisture should apply to the appropriate depth of disturbance. The lack of an available uniform set of soil moisture data for use in emission inventory preparation necessitates the evaluation of alternative data bases that can be adapted to provide the soil moisture information required.

The investigation of monthly and county resolved soil moisture data sets and methodologies began with a study of current methods for determining soil moisture content. Examples included the Wind Erosion Prediction System (WEPS) model and other predictive models that have been used to generate soil moisture datasets.

Few sources of surface soil moisture data are available that provide monthly values for each of the more than 3,000 counties in the U.S. The Global Soil Moisture Data Bank maintained by the Department of Environmental Sciences at Rutgers University is currently compiling soil moisture data sets as they are received, but currently the only two states in the U.S. that are characterized are Illinois and Iowa. The USDA-ARS is also undertaking measures to produce soil moisture values by using Synthetic Aperture Radar (SAR) as a potential means of measuring soil moisture from space or high altitude platforms. NASA is also looking at a similar method to derive soil moisture data by using the Electronically Scanned Thinned Array Radiometer (ESTAR). A recent study conducted on a 10,000 km^2 area in Oklahoma produced soil moisture percentages that account for soil temperature, vegetation type, surface roughness, soil texture, and other parameters affecting soil moisture. These measurement methods may eventually lead to methodologies for characterizing monthly soil moisture on a county basis.

CPC Soil Moisture Data

The most complete set of soil moisture values currently available is that calculated by the NOAA Climate Prediction Center (CPC) of the National Centers for Environmental Prediction. The soil moisture is calculated based on the water balance in the soil (Huang, et. al. 1996) “to the extent it participates in landsurface processes, that is, usually in the upper 1–2 m of soil.” The components of the model are precipitation, evaporation, runoff, and groundwater loss. The soil moisture over an area A is expressed by the formula:

$$dW/dt = P(t) - E(t) - R(t) - G(t)$$

where

W(t)	=	the soil water content at time t (mm)
P(t)	=	the mean areal precipitation over area A (mm)
E(t)	=	the mean areal evapotranspiration over area A (mm)
R(t)	=	the net sternflow divergence from area A (mm)
G(t)	=	the net groundwater loss (through deep percolation) from area A (mm)

The runoff parameter R(t) consists of both surface runoff and subsurface runoff. The surface runoff is based on the capacity of the soil to hold water and for the database is estimated for Oklahoma soils with a capacity of 760 mm. The evapotranspiration parameter E(t) is calculated by using Thornthwaite's Method (1948) for determining potential evapotranspiration from the observed air temperature and duration of sunlight. The CPC database of soil moisture values contains soil moisture values in mm for 344 climatic divisions in the U.S. for each month beginning in 1932.

In order to provide soil moisture values that can be applied to an emission inventory, measurements of gravimetric soil moisture percentage are needed. The saturation value of 760 mm for the Oklahoma soil is assumed to be equivalent to a 47% volumetric water content (communication with Huug van den Dool, 2001). This was verified by comparing tables of soil hydraulic parameters grouped by soil textural class (Rawls, et. al. 1982) with values given on a volumetric basis. The saturation levels for the different soil types ranged from 0.398 to 0.501 m^3/m^3. Assuming that the density of water is 1 g/cm^3 and the bulk soil density is 1.8 g/cm^3, the 47% volumetric water content corresponds to 33% gravimetric water content. This value was again verified by comparison to the saturation level of various soil types on a gravimetric basis (Rawls, et. al. 1982).

The CPC monthly soil moisture values in mm were converted to percent gravimetric water content by assuming 0 mm corresponded to 0% moisture by weight and 760 mm corresponded to 33% moisture by weight. A linear interpolation was made between the two points to produce a conversion factor of 0.04.

The yearly soil moisture values were averaged for each national climatic division and month to produce a database of average soil moisture values in mm for each month. These values were then multiplied by the conversion factor to produce the soil moisture content by weight.

The CPC provides state maps of the state climatic divisions, as seen in Figure 1 for Nevada counties. These maps locate the state climatic divisions relative to the county lines. The latitude and longitude of each of the national climatic divisions is used to relate the state climatic divisions to the national climatic divisions. The county lines do not always follow the climatic divisions, so a county was assigned to the climatic division, encompassing the highest fraction of the county area.

As a result of this work, two soil moisture databases were produced. The first database lists the average monthly 1-m soil moisture values (by weight) by state name and county name. The second lists the values by the county FIPS code.

A list of the on-line documents used to create the soil moisture database is listed below:

- Description of soil moisture files: **ftp://ftp.ncep.noaa.gov/pub/cpc/wd51jh/readme**
- Soil moisture values in mm (1932-2000): **ftp://ftp.ncep.noaa.gov/pub/cpc/wd51jh/w3100.friendly**
- State climatic divisions showing county lines:

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/CLIM_DIVS/states_counties_climate-divisions.html

- Latitude and longitude of national climatic divisions: **ftp://ftp.ncep.noaa.gov/pub/cpc/wd51jh/cdlalo.dat**

Surface Soil Moisture

Soil moisture to a depth of 1 m is appropriate for dust-generating activities such as soil excavation and may be appropriate for certain agricultural operations such as tilling. However, surface moisture to a depth of about 1 cm is more appropriate for vehicle traffic on unpaved roads or other unpaved travel surfaces.

Surface moisture can be increased by natural precipitation or by watering as a dust control method. During daytime hours when most traffic on unpaved surfaces occurs, evaporation from the surface (which is enhanced by vehicle traffic) is likely to reduce the surface moisture significantly below the value in the subsurface soil or road base material.

USEPA's current emission factor for vehicle travel on unpaved roads (EPA, 1995) contains a multiplicative term for the residual effects of surface moisture (raised to the -0.3 power). However a much stronger (inverse square) dependence on moisture can be used to represent the control effectiveness of an unpaved road watering program (USEPA, 1988).

The soil moisture database developed by Pleim and Xiu (2001) provides information on model-predicted surface (1-cm) soil moisture values as well as 1-m soil moisture values for 32 km grid cells that encompass the entire U.S. These results are limited to a 6-week observation period (June 15, 1999, to July 26, 1999). Ratios of 1-cm to 1-m moisture values developed by Pleim and Xiu may be useful in adjusting the monthly 1-m soil moisture values determined from the NOAA Climate Prediction Center data for 1932 through 2000.

Unpaved Road Surface Moisture

Actual unpaved road surface moisture and silt values obtained by MRI during emission testing are given in Tables 1 and 2. The test reports that contain these data are identified by Cowherd et al.(2002).

These values provide potential ground truth data that might be useful in developing a broader spectrum of unpaved road surface moisture values by county and month. For example, the CPC modeled 1-m soil moisture values, after adjustment to modeled 1-cm values using the Pleim and Xiu ratios, could be "calibrated" against moisture values for the months and locations where the actual measurements were made.

Table 1. Measured Surface Moisture Values for Gravel Roads

East of 97th Meridian

Location	EPA Region	Test Date	Moisture (%)
Grandview, MO	7	Nov 95 Nov 95 Nov 95 Dec 95 Dec 95	0.93 0.65 0.54 1.38 1.12
Raleigh, NC	4	Apr 96 Apr 96 Apr 96 Apr 96	0.10 0.10 0.07 0.09
Kansas	7	Aug 81 Aug 81 Sep 81 Sep 81 Sep 81	0.25 0.30 0.27 0.40 0.37
Franklin Co., KS	7	Apr 73 Apr 73	3.80 1.40
West of 97th Meridian			
La Grande, OR	10	May 91 May 91 May 91 May 91 May 91 May 91 May 91 May 91 May 91 May 91 May 91	1.52 2.40 1.73 1.94 1.81 1.61 1.29 1.59 1.50 1.54 1.34
Klamath Falls, OR	10	Jun 91 Jun 91 Jun 91 Jun 91 Jun 91 Jun 91 Jun 91 Jun 91 Jun 91 Jun 91 Jun 91	0.90 0.88 0.97 1.05 0.63 0.78 0.78 0.42 0.48 1.20 0.38
Grants Pass, OR	10	Jun 91 Jun 91 Jun 91 Jun 91	0.38 0.18 0.14 0.27
Colorado	8	Apr 82	0.26

Table 2. Measured Surface Moisture Values for Dirt Roads

Location	EPA Region	Test Date	Moisture (%)
East of 97th Meridian			
Lake Calumet, IL	5	Aug 87 Aug 87 Aug 87 Aug 87 Aug 87 Aug 87	0.39 0.99 0.42 0.60 0.70 1.00
Missouri	7	Mar 82 Mar 82 Mar 82 Apr 82	3.90(a) 4.50 3.20 3.10
West of 97th Meridian			
Reno, NV	9	May 96 May 96 May 96 May 96	0.48 0.44 0.45 0.38
Pinal Co., AZ	9	May 90	0.20
Pima Co., AZ	9	May 90	0.22
Yuma Co., AZ	9	May 90	0.17
Morton Co. and Wallace Co., KS	7	Jun 73	3.20(a)
Maricopa,. AZ	9	Unknown	

(a) This test road segment was selected to widen the silt content range as a basis for testing the relationship between emission rate and silt content. Because this road is not representative of typical traffic conditions, its silt and moisture content were not included in the averages presented in Table 3.

The measured road surface moisture values in Tables 1 and 2 are divided into eastern and western locations (relative to the 97th meridian). In addition, gravel roads are separated from dirt roads. Also shown are the months when the samples were taken.

A statistical summary of the components of the road surface material are given in Table 3. As expected, on average, the moisture content of roads in the east is higher than the moisture content of roads in the west. Also, the moisture content of dirt roads is higher than the moisture content of gravel roads.

Table 3. Statistical Summary of Measured Surface Moisture Values for Unpaved Roads

	Avg (%)	St. Dev (%)	No. of Tests
Site East of 97th	1.1	1.2	24
Site West of 97th	0.9	0.6	34
Road Type			
Gravel-East	0.8	1.0	13
Dirt-East	0.7	1.6	9
Gravel-West	1.0	0.6	27
Dirt-West	0.3	0.1	7
Region Number			
Region 4	0.1	0.02	3
Region 5	0.7	0.3	6
Region 7	1.5	1.4	15
Region 8	0.3	–	1
Region 9	0.3	0.1	7
Region 10	1.1	0.6	26
Gravel Overall	0.9	0.8	42
Dirt Overall	1.1	1.3	16
All Roads	1.0	0.9	58
Regions 4, 5, 7	1.1	1.2	24
Regions, 8, 9	0.3	0.1	8
Region 10	1.1	0.6	26

Typically the moisture content on an unpaved road follows a diurnal cycle. The moisture content is highest after nighttime hours, due to low evaporation rates and potential condensation. With the onset of sunlight, natural evaporation rates increase and roadway traffic enhances the evaporation rate. According to a recommended watering effectiveness model developed by Cowherd and Kinsey (1986), the rate of decrease in soil moisture is proportional to the hourly daytime evaporation rate (Class A pan evaporation) and the hourly traffic rate.

It should be noted that most of the samples collected by MRI as part of unpaved road emission factor development were collected during the driest part of the diurnal moisture cycle. The unusually low moisture values obtained on a gravel test road in Raleigh, North Carolina, probably reflect the large amount of captive traffic that was created to reduce the sampling time necessary to collect quantitative PM-2.5 emission profiles.

PAVED ROAD SILT LOADINGS

Traffic entrained dust from paved roads is a major source of PM emissions in urban areas. During the past 20 years, a considerable number of emission tests have been performed to characterize the processes important in the deposition and removal of surface dust on paved roads. These reports have shown that PM emissions are positively correlated with the product of the dust loading and the silt content of the road surface material, which is referred to as the silt loading (typically in units of g/m^2). According to the predictive emission factor equation in USEPA's emission factor handbook (AP-42), PM-10 emissions are proportional to silt loading raised to the 0.65 power (USEPA, 1995). The collected data also have shown that the surface silt loading decreases with increasing traffic volume, as represented by average daily traffic count (ADT).

A combination of ubiquitous dust sources and hotspot sources contribute to paved road surface silt loadings and resulting fugitive dust emissions from paved roads. The ubiquitous sources include deposition of windblown particles, spillage, litter, deposits from undercarriages of cars and trucks, road and tire wear, material blowing off haul trucks and transport vehicles, and other sources that deposit small amounts of dust on the roadway.

Higher loadings are found on some paved roads because of hotspot contributions resulting from track-out near construction sites, quarries, junctions of paved roads with unpaved roads or parking lots, and unpaved shoulders. Wash-on is another source of hotspot loadings and occurs when road surfaces are flooded with soil-laden water. Finally, unusually high silt loadings occur when sand or other anti-skid abrasives are applied to snow- and ice-covered roads to improve vehicle traction.

Hot spot silt loadings have been measured in a number of studies. A series of field sampling tests were conducted by MRI in the Minneapolis-St. Paul area during the early 1980's and included the first data collection of hot spot silt loadings near construction sites.

Englehart, et al. (1983) defined a point where the increased silt loading on the roadway decayed to one standard deviation above the operational background from ubiquitous sources. Enhanced surface loadings associated with active construction sites were discernable out to distances of approximately 300 m in either direction from the construction site access point. The study also showed a higher track-out for commercial construction projects as compared to residential construction projects, but with the residential track-out having an influence on the ambient air quality for a longer period of time. The study noted that track-out quantities varied according to the construction phase, with highest values in the middle stages of construction corresponding to higher site activity levels.

Kinsey, et al. (1993) investigated the application of sand and salt to roadways during winter conditions of ice and snow for effect on air quality in a field study conducted in Duluth, MN. This study concluded that emission factors were generally higher than those predicted by the AP-42 equation, perhaps by as much as a factor of three.

Dirt/mud track-out from construction and demolition activities also was characterized in another field study (Raile, 1994). The field sampling program was conducted on a paved arterial road with an average daily traffic volume of ~10,000 and with track-out occurring on a 1200 ft long arterial road segment. The road was used by heavy trucks to enter and exit from a construction site. During the approximate 3-month duration of the study, more than 5,000 heavy trucks and other vehicles left the construction site. Those vehicle passes were supplemented by the normal road traffic of approximately 500,000 vehicle passes that further crushed and spread the tracked-out material along the arterial road. The study found that mean silt loadings ranged between 2 to 4 g/m^2 for uncontrolled conditions, although individual measured values ranged from 1.14 to 25.7 g/m^2 during the testing period.

An analysis of the effect of sanding on winter baseline emissions in Denver was also studied by Cowherd, et al. (1998) based on a comparison of silt loading measurements in the fall of 1996 and in the winter of 1997. These measurements were made at the Core Site (Kipling, north of Alameda, with an ADT of about 15,000), on Speer (on both sides of the intersection with Colfax) and on Jewell (on both sides of the intersection with Sheridan). By examining the pre-winter baseline silt loading and the winter baseline silt loading for roads with wintertime sanding, the fractional increase in emissions was projected. This increase in emissions represented a seasonal condition, without the enhanced impacts of individual sanding events during snowstorms.

In the Denver study, it was found that when sanded roads dry after such winter sanding events, the silt loadings (and PM-10 emissions) tend to be at a maximum. These high emission periods extend in time until the silt loading has returned to the winter baseline level. The time needed to return to the baseline condition ranges from only a few hours for high-speed limited-access roadways, to a week or more for residential roadways. For arterial roadways, which account for a substantial portion of the paved road particulate emissions, the time to return to the baseline condition is the order of a few days, depending on the amount of sand applied and the length of time for the snow melt on the roadway surface.

The baseline silt loading results from the Denver field study are summarized as follows:

Denver Road Site	Baseline Silt Loading (g/m^2)	
	Prewinter	**Winter**
Kipling	0.05 (November 6, 1996)	0.30 (March 15, 1997)
Jewell (East of Sheridan)	0.10 (November 15, 1996)	0.70 (December 23, 1996)
Speer (South of Colfax)	0.30 (November 14, 1996)	0.50 (December 22, 1996)

The ratios of winter to prewinter baseline silt loading range from about 2 to 6. Based on the AP-42 emission factor equation, the corresponding range of PM-10 emission ratios is approximately 1.5 to 3.

Muleski, et al. (2000a) conducted field tests of the effectiveness of paved and graveled access aprons on mud/dirt track-out locations due to unpaved truck exit routes. The tests were conducted with controlled traffic consisting of light-duty vehicles. Uncontrolled total loadings ranged from 4.2 ± 1.9 g/m^2 , for a mixture of sand and native soil, to 11.0 ± 3.8 g/m^2 for native soil alone. A correlation between silt loading (sL) and moisture content (M) of the tracked-on soil was obtained:

$$sL = 0.096\ (M) - 0.027 \qquad (R^2 = 0.702) \qquad (1)$$

This correlation was based on track-on of sandy soil to a paved road after tracking first through a gravel apron designed to remove mud/dirt from vehicle tires. For moisture contents higher than about 8 percent, the gravel apron resulted in no net control, because the effect of the apron was more than offset by the increased track-on rate.

A recent study (Muleski, et al., 2001b) characterized PM emissions from paved roads with increased surface loading due to mud/dirt trackout from a large construction site in the Kansas City area. Tests of trackout emissions showed that 1400 ft of roadway was affected by trackout. Six tests gave silt loadings ranging from 0.46 to 6.41 g/m^2 at the location nearest the construction site. Approximately 6 g of PM-10 were emitted for every vehicle passing over the affected roadway and approximately 0.2 g of PM-2.5 were emitted. In terms of baseline PM-10 emissions, the 1,400 ft of roadway affected by trackon was “equivalent” to an additional road length of approximately 6 mi with the baseline silt loading, similarly the”equivalent” length for PM-2.5 emissions was slightly over 1 mi. The unexpected low trackout contribution to PM-2.5 emissions is thought to be the result of unusually high speed of the traffic on he impacted arterial roadway. This appears to have resulted in less opportunity for grinding the tracked mud/dirt into fine particles prior to the emission process.

The following sections summarize available national, regional and local sets of silt loading default values.

National Emissions Inventory (USEPA, 2001)

In the methodology used for the National Emission Inventory (NEI), paved road silt loadings are assigned to each of the twelve functional roadway classifications (six urban and six rural) based on the average annual traffic volume of each functional system by State. One of three values is assigned to each of these road classes:

- 1 g/m^2 is assigned to local functional class roads
- 0.2 g/m^2 is assigned to other road types that have an ADT less than 5,000 vehicles/day
- 0.04 g/m^2 is assigned to other road types that have an ADT greater than or equal to 5,000 vehicles/day

The average daily traffic volume (ADT) is calculated by dividing annual VMT by State and functional class (from Highway Statistics, Table VM-2) by State specific functional class roadway mileage (from Highway Statistics, Table HM-20).

AP-42 (USEPA, 1995)

In the AP-42 section on paved road dust emissions, recommended default silt loadings (g/m^2) are included in Table 13.2.1-2:

- 0.1 g/m^2 for roads with ADT greater than or equal to 5000 vehicles/day under normal conditions
- 0.5 g/m^2 for roads with ADT greater than or equal to 5000 vehicles/day under worst-case conditions
- 0.4 g/m^2 for roads with ADT less than 5000 vehicles/day under normal conditions
- 3 g/m^2 for roads with ADT less than 5000 vehicles/day under worst-case conditions

The range of silt loading values for normal conditions is 0.01 to 1.0 g/m^2 for high ADT roads and 0.054 to 6.8 g/m^2 for low ADT roads. For limited access roads, a default value of 0.015 g/m^2 is recommended. A default value of 0.2 g/m^2 is recommended for short periods of time following application of snow/ice controls to limited access roads.

Utah Department of Environmental Quality (2002)

The Utah DEQ has specified "post-storm" default values for silt loading as follows:

- Freeway – 0.124 g/m^2
- Arterial – 0.280 g/m^2
- Collectors – 0.906 g/m^2
- Local streets – 3.402 g/m^2

California Air Resources Board (CARB, 1997)

Silt loading default values specified by CARB were determined from California tests. They are subdivided by roadway classification as follows:

- Freeway – 0.20 g/m^2
- Major – 0.035 g/m^2
- Collectors – 0.035 g/m^2
- Local streets – 0.320 g/m^2
- Local rural – 1.6 g/m^2

Clark County Department of Health (2001)

Clark County, NV observes that "local and collector streets without improved shoulders but with a minimum 15-ft wide travel lane would have a loading of 24.7 g/m^2 compared with a silt loading of 1.69 g/m^2 or 0.86 g/m^2 respectively. The silt loading for roadways with gravel shoulders was 1.34 g/m^2 compared to 1.04 g/m^2 for minor arterial roadways and 0.49 g/m^2 for major arterial roadways."

Summary

Table 4 presents default silt loading values consolidated from the NEI, AP-42, and CARB and organized by applicable range of ADT. These values are intended to be the most widely applicable to the country as a whole, with California values more representative of the southwest. The "worst case" values reflect the contributions of hot spot sources. There is a relatively good consistency between the "normal" default values categories in terms of ADT ranges. Table 4 provides an appropriate starting point for a matrix of default silt loadings related to ubiquitous sources.

Table 4. Default Silt Loading Values Based on ADT (vehicles/day)

ADT/ Source	Local < 500	Collector 500 – 10,000	< 5,000	> 5,000	Major > 10,000	Freeway > 10,000
NEI	1.0	←	0.2	0.04	→	→
AP-42	←	←	0.4 (normal) 3.00 (worst)	0.1 (normal) 0.5 (worst)	→	→
CARB	0.320 1.6 (rural)	0.035	→	→	0.035	0.02

It should be noted that according to the AP-42 emission factor equation for paved roads, doubling the silt loading increases the emissions by a factor of 1.57.

Recommended Default Silt Loadings

Table 5 presents recommended default silt loadings for normal baseline conditions and for wintertime baseline conditions in areas that experience frozen precipitation with periodic application of antiskid material. The winter baseline is represented as a multiple of the non-winter baseline, depending on the ADT value for the road in question. As shown, a multiplier of 4 is applied for low volume roads (< 500 ADT) to obtain a wintertime baseline silt loading of 4 X 0.6 = 2.4 g/m^2.

Table 5. Ubitiguous Silt Loading Default Values with Hot Spot Contributions from Anti-Skid Abrasives (g/m^2)

ADT Category	< 500	500-5,000	5,000-10,000	> 10,000
Ubiquitous Baseline g/m^2	0.6	0.2	0.06	0.03 0.015 limited access
Ubitiguous Winter Baseline Multiplier during months with frozen precipitation	X4	X3	X2	X1
Initial peak additive contribution from application of antiskid abrasive (g/m^2)	2	2	2	2
Days to return to baseline conditions (assume linear decay)	7	3	1	0.5

It is suggested that an additional (but temporary) silt loading contribution of 2 g/m^2 occurs with each application of antiskid abrasive for snow/ice control. This was determined based on a typical application rate of 500 lb per lane mile and an initial silt content of 1 % silt content. Ordinary rock salt and other chemical deicers add little to the silt loading, because most of the chemical dissolves during the snow/ice melting process.

To adjust the baseline silt loadings for mud/dirt trackout, the number of trackout points is required. It is recommended that in calculating PM-10 emissions, six additional miles of road be added for each active trackout point from an active construction site, to the paved road mileage of the specified category within the county. In calculating PM-2.5 emissions, it is recommended that three additional miles of road be added for each trackout point from an active construction site.

It is suggested the number of trackout points for activities other than road and building construction areas be related to land use. For example, in rural farming areas, each mile of paved road would have a specified number of trackout points at intersections with unpaved roads. This value could be estimated from the unpaved road density (mi/sq. mi.).

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