PM-10 CERTIFIED STREET SWEEPERS

"PM-10 Efficient Street Sweepers" is a committed measure in the Five Percent Plan for PM-10 (MAG, 2007b). Street sweepers certified in accordance with South Coast Air Quality Management District Rule 1186 reduce PM-10 on paved roads, which reduces reentrainment of PM-10 by vehicles traveling on the road. Therefore, the purchase of PM-10 certified street sweepers is eligible for CMAQ funds. Emission reductions for this type of project will be calculated for PM-10 only.

The emission reductions are addressed as two separate components: the reduction in reentrained dust from vehicles traveling on the roadways cleaned by the sweeper and the reduction in dust from the actual sweeping process. These components will be combined to determine the total emissions reduction associated with a PM-10 certified street sweeper. Each component is described in a separate section below.

Reduced Reentrained Dust from Vehicles Traveling on Roadways. If the sweeper is being purchased to replace an existing conventional sweeper, the emission reduction will be based on a comparison of the emissions from the base silt loading on a paved road after using a conventional sweeper versus emissions from the reduced silt loading attributable to a PM-10 certified sweeper. The reduced silt loading results in lower emissions of reentrained dust from vehicles traveling on the road. If the sweeper is being purchased to replace an older PM-10 certified sweeper, the emission reduction will be based on a comparison of the utilization rates of the new PM-10 certified sweeper versus the older certified sweeper.

If the street sweeper is being purchased to increase the frequency of sweeping, the emission reduction will be based on a comparison of emissions using a PM-10 certified sweeper with the new cycle length **(*daysnew*)** versus the same sweeper with the existing cycle length **(*days*)**. If the street sweeper is being purchased to expand coverage, the emission reduction will be based on the difference between the emissions from an unswept road (using the initial emission factors in Tables 1 and 2) and the emissions after sweeping with a PM-10 certified unit for the expanded area **(*milesnew*)**.

The emission factor for reentrained dust varies depending upon how often a street is swept. It will be assumed that requested PM-10 certified street sweepers use the same sweeping schedule as the conventional street sweepers they replace. To be consistent with the Five Percent Plan for PM-10, it will be assumed that the silt loading on a street returns to its initial level nine days after the street is swept by a PM-10 certified sweeper and six days after being swept by a conventional sweeper. The initial unswept emission factors derived from the Five Percent Plan are 0.18 grams per vehicle mile of travel for freeways and 0.92 grams per vehicle mile of travel for arterials. The latter represents a VMT-weighted average of the low ADT (1.70 g/vmt) and high ADT (0.65 g/vmt) emission factors for arterials outside the Salt River Area.

In the Salt River Area, Sierra Research recommends that a paved road PM-10 emission factor of 3.44 g/vmt for all arterials (MAG 2008). As defined in the Five Percent Plan, the Salt River Area has boundaries of: Van Buren Street on the north, 7th Street on the east, Baseline Road on the south, and 59th Avenue on the west. The higher paved road emission rate in the Salt River Area is due to the

heavier weight (i.e., 4.1 tons) of vehicles traveling on paved roads in this industrial area, compared with the average vehicle weight of 3.18 tons in the rest of the region. Emission reduction credit for PM-10 street sweepers to be purchased with CMAQ funds for use in the Salt River Area will be calculated using this higher paved road emission rate.

The Five Percent Plan also indicates that the PM-10 certified sweepers reduce the initial silt loading by 86 percent (i.e. the silt loading is reduced to 14 percent of the initial level), while conventional sweepers reduce the initial silt loading by 55 percent. The schedule in the Five Percent Plan for percent of initial silt loading on days after PM-10 certified street sweeping is as follows: day of sweeping - 14 percent, 1 day after - 24 percent, 2 days after - 34 percent, 3 days after - 44 percent, 4 days after - 54 percent, 5 days after - 64 percent, 6 days after - 74 percent, 7 days after - 84 percent, 8 days after - 94 percent, and nine days or more after - 100 percent of initial silt loading. Similarly, the silt loading at varying days after sweeping with a conventional sweeper is as follows: day of sweeping - 45 percent, 1 day after - 55 percent, 2 days after - 65 percent, 3 days after - 75 percent, 4 days after - 85 percent, 5 days after - 95 percent, and 6 days or more after - 100 percent of initial silt loading.

The paved road emission factor for reentrained dust is exponentially related to the silt loading[1]. Therefore, the change in emission factors over time after sweeping does not follow the same linear relationship as percent reductions in silt loadings. The PM-10 emission factors for sweeping freeways and non-freeways with a PM-10 certified unit are listed in Table 1 for various days following street sweeping. Similar factors for a conventional sweeper are provided in Table 2. In both tables, the emission factors for sweeping non-freeways in the Salt River Area are based on a higher initial unswept emission rate from the Five Percent Plan, as recommended by Sierra Research (MAG, 2008).

Based on sweeping frequency, the emission factors in Tables 1 and 2 will be combined to create a weighted average emission factor as shown in the formulas below. Separate weighted emission factors will be estimated to reflect the impact of sweeping with PM-10 certified sweepers and conventional sweepers. The difference between these two emission factors is the incremental reduction in emissions achieved by replacing a conventional street sweeper with a PM-10 certified unit. The difference between the initial unswept emission factor and the PM-10 certified sweeper emission factor when applied to the new area being swept (***milesnew***) represents the reduction in emissions achieved by expanding the area of sweeping. The difference between the PM-10 certified emission factors for the old (***days***) and new (***daysnew***) cycle lengths represents the reduction achieved by increasing the frequency of sweeping.

To calculate the benefits of a new PM-10 certified sweeper that will replace an older certified unit, the utilization rate of the new and older sweepers will be compared. The requestor will provide the percent of time that the older unit was not utilized during the previous year due to maintenance and repair downtime. The average daily benefit of the new sweeper based on the emission factors in Table 1 will be reduced by the difference between 95 percent (the assumed utilization rate for a new sweeper) and the utilization rate (1.0 - percent downtime) for the older sweeper.

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[1]The AP-42 equation for paved road PM-10 emission factors is calculated by raising the silt loading to the power of 0.65.

Table 1. PM-10 Emission Factors as a Function of Days After Sweeping with a PM-10 Certified Sweeper

	Freeway	Non-freeway	Salt River Area Non-freeway
day of sweeping (k=1)	0.05 g/vmt	0.26 g/vmt	0.96 g/vmt
1 day after sweeping (k=2)	0.07 g/vmt	0.36 g/vmt	1.36 g/vmt
2 days after sweeping (k=3)	0.09 g/vmt	0.46 g/vmt	1.71 g/vmt
3 days after sweeping (k=4)	0.11 g/vmt	0.54 g/vmt	2.02 g/vmt
4 days after sweeping (k=5)	0.12 g/vmt	0.62 g/vmt	2.30 g/vmt
5 days after sweeping (k=6)	0.13 g/vmt	0.69 g/vmt	2.57 g/vmt
6 days after sweeping (k=7)	0.15 g/vmt	0.76 g/vmt	2.83 g/vmt
7 days after sweeping (k=8)	0.16 g/vmt	0.82 g/vmt	3.07 g/vmt
8 days after sweeping (k=9)	0.17 g/vmt	0.88 g/vmt	3.30 g/vmt
9 days after sweeping (k>9)	0.18 g/vmt	0.92 g/vmt	3.44 g/vmt

Table 2. PM-10 Emission Factors as a Function of Days After Sweeping with a Conventional Sweeper

	Freeway	Non-freeway	Salt River Area Non-freeway
day of sweeping (k=1)	0.11 g/vmt	0.55 g/vmt	2.05 g/vmt
1 day after sweeping (k=2)	0.12 g/vmt	0.62 g/vmt	2.33 g/vmt
2 days after sweeping (k=3)	0.14 g/vmt	0.69 g/vmt	2.60 g/vmt
3 days after sweeping (k=4)	0.15 g/vmt	0.76 g/vmt	2.85 g/vmt
4 days after sweeping (k=5)	0.16 g/vmt	0.83 g/vmt	3.10 g/vmt
5 days after sweeping (k=6)	0.17 g/vmt	0.89 g/vmt	3.33 g/vmt
6 days after sweeping (k>6)	0.18 g/vmt	0.92 g/vmt	3.44 g/vmt

Reduced Emissions During the Sweeping Process. The reduction in PM-10 from the actual sweeping process will be based upon the California Air Resources Board estimate that a PM-10 certified street sweeper entrains 0.05 pounds per mile less PM-10 than a conventional sweeper during the sweeping process (CARB, 2005). For this analysis, the emissions reduction is converted to kilograms per vehicle mile, resulting in an emission reduction factor of 0.023 kilograms per vehicle mile traveled by the PM-10 certified sweeper. This estimate will be combined with the estimate of miles traveled per day by the PM-10 certified sweeper to produce a total reduction in emissions in kilograms for an average day. This reduction will only be applied when a PM-10 certified sweeper will replace a conventional sweeper.

Inputs Required from Entity Requesting CMAQ Funds:

PM-10 certified street sweepers are eligible for purchase with CMAQ funds if they replace an existing unit that has not been certified by South Coast Rule 1186, replace an older Rule 1186 certified unit, increase the frequency of sweeping, expand the area that is swept, or a combination of these functions. Input requirements for each of these functions are described below. If the requested unit will perform more than one function, the requestor will need to provide all of the inputs described under each function. Note that the sweeping cycle (***days* or *daysnew***) referred to below represents the number of calendar days that elapse before the same lane of road is re-swept by the same sweeper.

For all sweeper requests:

- ***CMAQ Cost***.
- Average weekday traffic (***ADT***) per lane on streets to be swept by the PM-10 certified sweeper.
- Whether the requested unit will sweep freeways or non-freeways.

If the new sweeper will replace a non-certified sweeper:

- Current number of days per sweeping cycle (***days***) for the unit being replaced.
- Lane miles (***miles***) swept per cycle by the unit being replaced.

If the new sweeper will replace an older PM-10 certified sweeper:

- Percent of time the older certified sweeper was not utilized during the previous year as a result of maintenance and repair downtime.
- Current number of days per sweeping cycle (***days***) for the unit being replaced.
- Lane miles (***miles***) swept per cycle by the unit being replaced.

If the new sweeper will be used to increase the frequency of sweeping:

- Planned number of days per sweeping cycle (***daysnew***) for the lanes to be swept.
- Current number of days per sweeping cycle (***days***) for the lanes to be swept.
- Lane miles (***miles***) of roads to be swept per cycle.

If the new sweeper will be used to expand the area to be swept:

- Planned number of days per cycle (***daysnew***) on roads in the expanded area.
- Lane miles (***milesnew***) of roads to be swept per cycle in the expanded area.

Formulas:

Reduced Reentrained Dust from Vehicles Traveling on Roadways:

Emission factor for roads swept with PM-10 certified street sweepers:

$$PM\text{-}10\ Certified\ Sweeper\ Emission\ Factor\ (\boldsymbol{PEF}) = \frac{\sum_{k=1}^{time} (PM\text{-}10\ certified\ emission\ factor)_k}{\boldsymbol{days}}$$

Emission factor for roads swept with conventional street sweepers:

$$Conventional\ Sweeper\ Emission\ Factor\ (\boldsymbol{CEF}) = \frac{\sum_{k=1}^{time} (conventional\ emission\ factor)_k}{\boldsymbol{days}}$$

where: $(\boldsymbol{PM\text{-}10\ certified\ emission\ factor})_k$ = the emission factor on day k from Table 1
$(\boldsymbol{conventional\ emission\ factor})_k$ = the emission factor on day k from Table 2
days = current number of days per sweeping cycle

Replacing a Conventional Sweeper:

$$Daily\ Emissions\ Reduction = w4 * \boldsymbol{miles} * \boldsymbol{ADT} * 0.91 * (\boldsymbol{CEF} - \boldsymbol{PEF}) * \frac{1}{1000} = \frac{kilograms}{day}$$

Replacing an Older PM-10 Certified Sweeper:

$$Daily\ Emissions\ Reduction = w4 * \boldsymbol{miles} * \boldsymbol{ADT} * 0.91 * \boldsymbol{PEF} * (0.95 - URATE_{old}) * \frac{1}{1000} = \frac{kilograms}{day}$$

Increasing the Frequency of Sweeping:

$$Daily\ Emissions\ Reduction = w4 * \boldsymbol{miles} * \boldsymbol{ADT} * 0.91 * (\boldsymbol{PEF} - \boldsymbol{PEF}_{new}) * \frac{1}{1000} = \frac{kilograms}{day}$$

Expanding the Coverage of Sweeping:

$$\textit{Daily Emissions Reduction} = w4 * \textbf{\textit{milesnew}} * \textbf{\textit{ADT}} * 0.91 * (\textbf{\textit{IEF}} - \textbf{\textit{PEF}}_{new}) * \frac{1}{1000} = \frac{\textit{kilograms}}{\textit{day}}$$

where: ***miles*** = lane miles of street to be swept per cycle in the current area
milesnew = lane miles of streets be swept per cycle in the expanded area
ADT = average weekday traffic per through lane on streets to be swept by the requested sweeper
0.91 = factor to convert from weekday traffic to annual average daily traffic
$\textbf{\textit{PEF}}_{new}$ = PM-10 certified sweeper emission factor calculated with ***days***= ***daysnew***
IEF = the initial silt loading emission factor in Table 1 (i.e., 9 days after sweeping) or Table 2 (i.e., 6 days after sweeping)
$\textbf{\textit{URATE}}_{old}$ = percent utilization of the older PM-10 certified sweeper during the past year
w4 = the PM-10 weighting factor

<u>Reduced Emissions During the Sweeping Process</u> (This reduction is only applied if the requested sweeper replaces a non-certified unit):

$$\textit{Daily Emissions Reduction for the Sweeping Process} = w4 * (\frac{\textbf{\textit{miles}}}{\textbf{\textit{days}}}) * 0.023 = \frac{\textit{kilograms}}{\textit{day}}$$

where: **0.023** = kilograms per vehicle mile reduction in reentrained dust from the sweeping process itself.
w4 = the PM-10 weighting factor

$$\textit{Capital Recovery Factor } (\textbf{\textit{CRF}}) = \frac{(1+i)^{\textbf{\textit{life}}}\ (i)}{(1+i)^{\textbf{\textit{life}}} - 1}$$

where: ***i*** = discount rate of 3 percent
life = effectiveness period of 8 years

$$\textit{Cost-Effectiveness} = \frac{\textbf{\textit{CRF}} * \textbf{\textit{CMAQ Cost}} * 1000}{\textit{Daily Emissions Reduction} * 365} = \frac{\textit{dollars}}{\textit{metric ton}}$$

where: ***CMAQ Cost*** = the CMAQ funding requested for the project.

PM-10 Certified Street Sweepers **EXAMPLE**

A city proposes to purchase a PM-10 certified street sweeper in FY 2009 to replace a non-certified sweeper. The replacement unit will not be used to increase the frequency of sweeping or the area swept. The cost of CMAQ-eligible equipment on the sweeper is $150,000. The city proposes to pay $15,000 and requests $135,000 of CMAQ funding. The certified sweeper will be used on streets (non-freeways) outside the Salt River Area with average weekday traffic per through lane of 5,000 vehicles. Each lane mile of street is currently swept once every 14 days. During this 14-day cycle, 200 lane miles are swept using the non-certified sweeper being replaced.

Inputs Required from Entity Requesting CMAQ Funds:

- ***CMAQ Cost*** = $135,000.
- Average weekday traffic per through lane swept with the conventional sweeper to be replaced (***ADT***)= 5,000 vehicles per lane per day.
- Current number of days in the sweeping cycle using the conventional sweeper to be replaced (***days***) = 14 days.
- Lane miles of streets swept per sweeping cycle with the conventional sweeper to be replaced (***miles***) = 200 lane miles.

Calculations:

$$CEF = \frac{0.55 + 0.62 + 0.69 + 0.76 + 0.83 + 0.89 + (8 * 0.92)}{14} = 0.836$$

$$PEF = \frac{0.26 + 0.36 + 0.46 + 0.54 + 0.62 + 0.69 + 0.76 + 0.82 + 0.88 + (5 * 0.92)}{14} = 0.714$$

$$\textit{Daily Emissions Reduction for Reentrainment} = 1.0 * 200 * 5000 * 0.91 * (0.836 - 0.714) * \frac{1}{1000} = 111.02 \ \frac{kilograms}{day}$$

$$\textit{Daily Emissions Reduction for the Sweeping Process} = 1.0 * \frac{200}{14} * 0.023 = 0.33 \ \frac{kilograms}{day}$$

$$CRF = \frac{(1+0.03)^8 * (0.03)}{(1+0.03)^8 - 1} = 0.1425$$

$$\textit{Cost-Effectiveness} = \frac{0.1425 * 135{,}000 * 1000}{111.35 * 365} = 473 \ \frac{dollars}{metric\ ton}$$