Emissions Benefit Analysis

October 6, 1999

Executive Summary

The Emission Benefit Study was funded by local and state governmental agencies, equipment manufacturers and material vendors to investigate the emissions benefits of alternative sanding materials and sweeping technologies currently used in the metro region. A contractor, AlphaTRAC Inc., was hired by the Regional Air Quality Council to collect silt loading data during four winter storm events during the 1998-99. The Regional Air Quality staff has used the collected data to analyze alternative sanding materials and sweeping technologies and calculate PM_{10} emissions benefits. The significant points of the Emission Benefit Analysis are summarized as follows:

The current methodology of assuming a 50% reduction in applied material when using Ice Slicer versus Sand/Salt at a 1:2 application rate is confirmed. The actual tons of Ice Slicer applied will be used to calculate percent reduction from 1989 baseline sand application rates.

Silt loading data of applied Ice Slicer is 50% greater than swept Sand/Salt, therefore no additional credit is justified for an unswept Ice Slicer roadway.

The current methodology for Realite is based on an application of equal volumes of Realite and Sand/Salt resulting in a 40% reduction in Realite tons applied. Realite also has a 10% weight penalty added to the reported tons applied when calculating percent reduction from 1989 baseline sand application rates. Unfortunately, due to road conditions, the study did not replicate the required loading protocol. Although a reduced emissions benefit was calculated from the silt loading data, the data is not sufficient to confirm or change the current methodology. The actual tons of applied Realite will continue to be multiplied by 1.1.

All geologic material applied during winter “sanding operations” is subject to sweeping to the extent necessary to achieve emissions reduction goals. However, from this study it is apparent that Sand/Salt roadways should be the first priority for sweeping.

The current emissions benefit of various sweeper technologies appears to be under estimated based on this study. Current methodology has only applied an emission benefit to the Sand & Residual Sand fraction of the Paved Road Dust. The emissions reductions calculated from the study data are based on reductions to the total uncontrolled PM_{10} Sand & Paved Road Dust emissions. This study indicates that the tested sweeping equipment, under a variety of actual storm conditions, ranges from 150% to three times as effective as currently assumed.

Overview

An Emissions Benefit Study was funded by local and state governmental agencies, equipment manufacturers and material vendors to determine the emissions benefit of alternative sanding materials, Ice Slicer (IS) and Realite (R), versus Sand/Salt (S/S) and various sweeping technologies. Mechanical Broom, Vacuum, Combination Mechanical/Vacuum and Regenerative Air.

The data collection portion of the study was conducted by AlphaTRAC, Inc. under contract to the Regional Air Quality Council. Total Loading (TL) and Silt Loading (SL) data in grams/meter ^{2} was collected before sweeping, after sweeping and a week after sweeping during four (4) storm events, which occurred during the winter seasons 1997/98 and 1998/99. The results of the data collection in terms of changes in silt loading and total loading (g/m^2) is included in the report, Emissions Benefit Study, AlphaTRAC, August 1999.

The RAQC staff has reviewed the collected data, performed an Emissions Benefit Analysis and has made recommendations concerning the various materials and equipment tested. The gutter and travel lane data has been combined, where collected separately, into a weighted average loading for the roadway area test sections. Where multiple storm data is available to compare materials or equipment, average and weighted average silt loadings have been calculated and reviewed to better understand the impact of the material or equipment. The silt loading data was used to calculate the percent Particulate Matter (PM_{10}) emissions reduction achieved by the use of alternative materials and the sweeping equipment by raising the silt loading values to be compared to the power 0.65 and performing a simple % reduction calculation as follows:

$$((SL_I)^{0.65} - (SL_F)^{0.65} / (SL_I)^{0.65}) * 100 = \%\ PM_{10}\ \text{Emissions Reduction}$$

In terms of alternative materials compared to applied sand, the % PM_{10} Emissions Reduction calculated from the study data was compared to the reduction calculated using current methodology. Based on this study, the current methodology appears to adequately reflect the emissions reduction capability of Ice Slicer and Realite.

The current emissions benefit of various sweeper technologies appears to be under estimated based on this study. Current methodology has only applied an emission benefit to the Sand & Residual Sand fraction of the Paved Road Dust (PVRD). The emissions reductions calculated from the study data are based on reductions to the total uncontrolled PM_{10} Sand & Paved Road Dust emissions. This study indicates that the tested sweeping equipment, under a variety of actual storm conditions, ranges from 150% to three times as effective as currently assumed.

Silt Loading data from the CDOT study indicated that the Sand fraction of the Paved Road Dust is 60% in wintertime. When combined with the applied Sand, the resultant Dust/Sand fraction relationship is currently calculated as 36/64. This study supports the CDOT study by noting the Dust/Sand fraction relationship as 35/65.

Ice Slicer vs Sand/Salt

Storms 1,2 & 3 applied Ice Slicer and Sand/Salt at an approximate 1:2 ratio i.e. Ice Slicer provided a 50% reduction in applied material. Based on current calculation methodology, this reduction in applied material results in an Emissions Benefit of 27% reduction in total uncontrolled PM_{10} Sand & Paved Road Dust emissions.

The weighted Silt Loading (g/m^2) concentrations of Ice Slicer and Sand/Salt before sweeping for various combinations of Storms 1, 2 & 3 were compared and a PM_{10} Emissions Benefit range of 24% to 29% reduction in uncontrolled PM_{10} Sand & Paved Road Dust emissions was calculated. This confirms the original assumption.

RECOMMENDATION:

Retain the current practice of counting IS tons applied.

Additional Credit for Unswept Ice Slicer

The Silt Loading and Total Loading concentrations of Ice Slicer unswept are approximately 50% to 100% greater than the Sand/Salt concentrations, respectively, after sweeping for Storms 1, 2, and 3 as shown in the following table.

Storm 123	Silt Loading (g/m^2)	Total Loading (g/m^2)
IS Before Sweeping	**1.72**	**8.40**
S/S After Sweeping	**1.14**	**4.22**
Ice Slicer Before Sweep as a % of Sand/Salt After Sweep	**151%**	**199%**

The unswept Total Loading concentration ratio for Ice Slicer and Sand/Salt is approximately 1:4, i.e. 74% reduction in material on the roadway when using Ice Slicer instead of Sand/Salt, as shown in the next table. It is, therefore, reasonable to the eye to assume that Ice Slicer does not need to be swept.

Storm 123	Total Loading (g/m^2)	Reduction in Total Loading
IS Before Sweeping	**8.4**	
S/S Before Sweeping	**32.72**	**74%**

However, in terms of the Silt Load concentrations and air quality emissions benefits, there is no justification for additional credit based on an Ice Slicer unswept road appearing to be cleaner than a Sand/Salt swept road.

RECOMMENDATION:

Retain the current practice of reporting all roadways to which material is applied to combat snow and ice as part of the "sanding network", and reporting swept roadway as a percentage of that "sanded network".

The Sand/Salt roadway should be swept first.

Realite vs Sand/Salt

The current methodology, based on assumptions of equal volumes of applied material, i.e. Realite 40% less by weight, and emissions factors from upwind/down wind testing, results in a 10% penalty of additional tons to the applied Realite and a calculated emissions benefit of 20% reduction in uncontrolled PM_{10} Sand & Paved Road Dust emissions.

Storm 4 required loading of Realite and Sand/Salt tons at a ratio of 1.2:1 to maintain the safety of the roadway. The Silt Load concentrations of Realite and Sand/Salt before sweeping for Storm 4 were compared and a PM_{10} Emissions Benefit of 9% reduction in uncontrolled PM_{10} Sand & Paved Road Dust emissions was calculated.

Under the current methodology with weight penalty, the loading ratio from Storm 4 would result in no calculated emissions benefit because there was no reduction in material applied, yet with twice the expected Realite load, a reduction in silt loading was measured, resulting in a calculated emissions benefit of 9%.

Those agencies (2) that use Realite exclusively have shown reductions in applied material of 40% to 60%, have maintained safety and are achieving overall emissions reductions that exceed the new Reg 16 30% emissions reduction requirement with the current methodology. Although, there is evidence that Realite does yield an emissions benefit (albeit reduced) when it is used in equal or greater tons applied than sand, it does not overcome previous studies that support the current methodology which is applicable to loading rates (equal volumes) currently being used in the field.

RECOMMENDATION:

Retain the current practice of counting Realite tons applied with the 1.1 factor at the normal application rate.

Sweeping

Storm 1 was a weak storm and the low tonnage of material applied resulted in Silt Load concentrations on the roadway for IS and S/S that were less than or equal to the baseline. In terms of analysis this data set did not reflect an adequate or appropriate test of the equipment.

Storms 2, 3 and 4 provided adequate data for analysis. The gutter and travel lane data has been combined, where collected separately, into a weighted average silt and total loading for the roadway area test sections. The test section data was combined by technology and material for further analysis. The weighted average PM_{10} Sand & Paved Road Dust emissions reduction from sweeping within four days for all of the equipment on the applied Realite, Ice Slicer and Sand/Salt used for Storms 2, 3 and 4 (and dropping one outlier) is a 62% reduction in uncontrolled Sand & Paved Road Dust PM_{10} emissions.

Weighted average data collected from the swept roadways of Storms 3 and 4 one week later indicates a reduction in the peak PM_{10} emissions reduction from sweeping within four days of approximately 50%. The PM_{10} emissions reduction averaged over the week after initial sweeping is then approximately 75% of the peak PM_{10} emissions reduction from sweeping within four days. Applying this factor to the above weighted average PM_{10} Sand & Paved Road Dust emissions reduction within four days for all of the equipment on the materials used for Storms 2, 3 and 4 results in a 46% reduction in uncontrolled Sand & Paved Road Dust PM_{10} emissions overall.

The weighted average per cent Sand & Paved Road Dust PM_{10} emissions reduction calculated from the measured silt loading from the test sections of the roadway before and after sweeping within four days are presented by technology in the next table. Included is the averaging factor, 0.74, and the resultant emissions reduction credit available for consideration for each of the sweeping technologies as follows:

Technology	Mechanical	Vacuum	Combination	Regen. Air	All Equipment
Reduction w/i 4 days	**56%**	**79%**	**44%**	**88%**	**62%**
Averaging Factor	**0.74**	**0.74**	**0.74**	**0.74**	**0.74**
Calculated Emission Credit	**41%**	**58%**	**32%**	**64%**	**46%**

The current RAQC methodology applies the EPA allowable sweeping credits of 32% emissions reduction applied to the Sand and Sand fraction of the PVRD and results in a 20.5% reduction in uncontrolled Sand & Paved Road Dust PM_{10} emissions for sweeping equipment.

The break down of emissions reductions by technology further broken down by applied material begins to yield a less robust data set. Realite, which was only used in Storm 4, was only swept by one mechanical sweeper and two vacuum sweepers. Also, the technology demonstrates more differences in reduction than the material. The calculated emissions credit, which corresponds to the data in the table above, for all sweeping equipment broken out by material is as follows:

Realite	32%
Ice Slicer	45%
Sand/Salt	47%
All Material	46%

Currently (1998-99) approximately 5% of the network is using Realite, 20% uses Ice Slicer and the remainder receives Sand/Salt application.

The ultimate use of this analysis is the application of the emissions credits to the data reported in the annual Street Sanding/Sweeping reports. There does not appear to be much gained from requesting the reporting sanding agencies to provide percent of network swept by four technologies and three applied materials. Based on the level of this study, RAQC staff considers the calculated emissions credits in the above table for Mechanical and Combination equipment and Vacuum and Regenerative Air equipment sufficiently close to recommend that they be averaged for use in calculating the emissions reduction of a given sanding agency.

RECOMMENDATION:

Sweeping operations should include the gutter area of the roadways since the gutter acts as a feeder to the travel lane.

Sweeping credit applied to uncontrolled Sand & Paved Road Dust PM_{10} emissions for equipment as follows:

Average Mechanical and Combo Equipment	37%
Average Vacuum and Regn Air	61%

The cost savings to the region would be between $0.9 and $2.2 Million annually based on 1997 dollars.

Impact of Not Sweeping (One Week Later)

Storm 2 data provides a comparison between the loadings from an unswept portion of the roadway before the sweeping operation and an unswept portion of the roadway one week after the sweeping operation. In terms of initial Silt Loading the Ice Slicer and Sand/Salt lost 65% and 71%, respectively, presumably to the air. In terms of initial Total Loading the Ice Slicer lost 15% and the Sand/Salt lost 71% in the one week. The initial Silt & Total Loading of Sand/Salt is approximately 2 to 4 times greater than that of Ice Slicer as can be seen in in the following table.

Storm 2	Silt Loading (g/m^2)	% Silt Loading Lost	Total Loading (g/m^2)	% Total Loading Lost
Initial (Unswept) Ice Slicer	**2.59**		**12.48**	
Unswept Ice Slicer One Week Later	**0.92**	**65%**	**10.62**	**15%**
Initial (Unswept) Sand/Salt	**4.39**		**48.48**	
Unswept Sand/Salt One Week Later	**1.28**	**71%**	**14.24**	**71%**

RECOMMENDATION:

Sweeping is necessary for applied geologic materials, however, sweeping operations should be directed to streets with applied sand as a first priority.