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Project Summary

Characterization of Mud/Dirt Carryout onto Paved Roads from Construction and Demolition Activities

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Several urban areas of the country in violation of the National Ambient Air Quality Standard (NAAQS) for particulate matter have identified fugitive dust generated by vehicular traffic on paved streets and highways resulting from mud/dirt carryout from unpaved areas as a primary source of PM-10 (particles ≤ 10 μm in aerodynamic diameter). Since little data are currently available on the amount of mud/dirt carryout deposited on paved roads, this work characterizes the process and evaluates selected control methods. These control technologies were evaluated for effectiveness in controlling mud/dirt carryout from an unpaved construction access area onto an adjacent paved road. The first control used a street sweeper to mechanically sweep the dirt and debris from the paved road surface. The second applied a 6- to 12-in. (15- to 30-cm) layer of woodchip/mulch material onto the access area of the construction site to a distance 100 ft (30 m) from the paved road. The third applied a 6-in. layer of gravel over the access area. Street sweeping was found to be only marginally effective (approximately 20%) in reducing average silt loading on the paved road lanes. Treatment of the access area with a buffer of woodchip/mulch was moderately effective, reducing average silt loading by 38 to 46%. The gravel buffer showed the greatest effectiveness, reducing the average silt loading by 57 to 68%. These silt loading reductions result in the following calculated PM-10 reductions: street sweeping, 14%; woodchips, 27 to 33%; and gravel, 42 to 52%.

This Project Summary was developed by EPA's National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Several areas of the country that are in violation of the National Ambient Air Quality Standard (NAAQS) for PM-10 (particles ≤ 10 μm in aerodynamic diameter) have conducted studies to identify the sources of these emissions. A primary source of PM-10 in many urban areas is the fugitive dust generated by vehicular traffic on paved streets and highways.

Road dust emissions occur whenever a vehicle travels over a paved surface, such as public and industrial roads and parking lots. Particulate emissions originate primarily from the road surface material loading (measured as mass of material per unit area). The surface loading is in turn replenished by other sources (e.g., pavement wear, deposition of material from vehicles, deposition from other nearby sources, carryout from surrounding unpaved areas, and litter). Because of the effects of the surface loading, available control techniques attempt to either (a) prevent material from being deposited on the surface or (b) remove (from the travel lanes) any material that has been deposited.

According to the Environmental Protection Agency (EPA) publication, *Compilation of Air Pollutant Emission Factors* (AP-42), the quantity of dust emissions from vehicle traffic on a paved public road (per vehicle kilometer traveled or VKT) may be estimated using the empirical expression:

$$E = 4.6\ (sL/2)^{0.65}\ (W/3)^{1.5}$$

where: E = PM-10 emission factor (g/VKT),

s = surface silt content (fraction of particle < 75 µm in physical diameter),

L = total road surface dust loading (g/m²), and

W = average weight (tons) of the vehicle traveling on the road.

Activities such as construction and demolition projects can create a temporary, but substantial, increase in the amount of fine particles on the surfaces of adjacent paved roads. This increase in fine particle loading is the result of mud/dirt carryout from vehicles leaving the construction/demolition site.

Furthermore, carrying out material onto a paved road is characterized by substantial spatial variation in loading about the point of access to the site. This variation complicates the estimation of emissions caused by carryout as well as the emission reductions achievable by control of carryout. The spatial variations and the associated difficulties in estimating emissions become less important as the number of access points in an area increases.

A prior field study specifically addressed mud/dirt carryout onto urban paved roads. It was conducted in 1982 as part of a national demonstration study of construction-related dust emissions.

This report describes a field study undertaken to better understand the mechanisms of mud/dirt carryout as well as the effectiveness of measures used to control carryout. The study collected and analyzed surface material samples taken from a paved road adjacent to a construction site in the Brush Creek Flood Control Project in the metropolitan area of Kansas City, MO. The effects of mud/dirt carryout control were evaluated by monitoring the changes in paved road surface dust loading. Both *preventive and mitigative* measures for controlling carryout were considered. Preventive measures attempted to keep material from being deposited on roadways, while mitigative measures attempted to remove the material after being deposited. The mitigative control measure of interest in this study was combined water flushing and broom sweeping. The two preventive measures that were studied involved covering the access area with a coarse material (gravel and woodchips/mulch).

Site Description

The paved roadway segment that was selected for this study was the north-south section of Elmwood Avenue between Blue Parkway and Brush Creek Boulevard in east central Kansas City, MO. The roadway segment is approximately 1200 ft (365 m) long and 40 ft (12 m) wide. It carries an annual average daily traffic volume of ~ 10,000 vehicles and is classified as a minor arterial roadway. At the time of this study, a pocket of construction activity associated with the Brush Creek Flood Control Project was located on the east side of Elmwood Avenue. This activity noticeably impacted Elmwood Avenue in the mud/dirt carryover.

With the construction of a dam and other earthmoving activities, the Elmwood site was expected to provide enough truck traffic to support a field sampling program throughout the summer of 1994. Ten-wheel dump trucks carried earth from the site, south on Elmwood, and then on to their final destination. On days that it rained, the trucks could not enter the site due to an incline near the site entrance that became too muddy to support vehicles safely. On those days, the trucks were directed to other sites where they could work.

Road Surface Sampling

This field sampling program was designed to efficiently collect paved road surface material samples at various distances between 50 and 550 ft (15 and 170 m) from the construction site entrance on Elmwood Avenue over an extended time period. From previous studies of silt loading on paved roads, it was known that the loadings could vary from one lane to the next. For this reason, a sampling scheme allowed for segregation of the two southbound lanes. If necessary, at the end of the data reduction process, the data from the two southbound lanes could be integrated with each other to represent just the southbound portion of the roadway. One area of southbound Elmwood Avenue, just north of the access point, was designated for the collection of background silt loading samples that ideally would not be impacted by carryout from the construction site. Samples of the material on the road surface were collected by dry vacuuming and then analyzed for silt content according to the procedures outlined in AP-42.

Source Activity Monitoring

Source extent and activity data were also collected in the sampling program. Vehicle-related parameters were acquired using a combination of manual and automatic recording techniques. Pneumatic tube axle counters were used to obtain traffic volume data. However, because these counters recorded only the number of passing axles, it was necessary to obtain traffic mix information (e.g., number of axles per vehicle) to convert axle counts to the number of vehicle passes. Vehicle mixes were observed visually.

Daily weather data were obtained from a local newspaper, and rainfall measurements were made on site with a rain gauge. A daily log was also maintained, noting any activities that were observed at the site or any communications that were pertinent to the outcome of the project.

Study Conditions

In addition to the uncontrolled study condition, three different mud/dirt carryout controls were evaluated in the program: street sweeping, installation of a woodchip/mulch apron (buffer) at the site access point, and installation of a gravel buffer at the same point. These controls were evaluated sequentially as described below.

First, the paved road adjacent to the site (Elmwood Avenue) was cleaned to the extent practical using a combination of broom sweeping and flushing. This cleaning represented a “baseline” silt loading value for future reference. (In this context, “baseline” refers to as clean a road surface as possible.)

Once baseline levels were reached, the surface loading was allowed to increase to its “steady state” condition, with sampling conducted before and after precipitation throughout the “conditioning” period. Post-precipitation sampling was performed once the road surface became dry enough to collect surface samples. The data from these samples established both the magnitude and extent of the uncontrolled mud/dirt carryout from the site and provided a time history of the overall carryout process starting from an essentially clean surface.

When the uncontrolled tests were completed, the paved road was thoroughly cleaned again (sweeping and flushing) to baseline condition prior to evaluation of street sweeping as the first control method.

Thereafter, the road was swept periodically, using the fleet of street sweepers that were already being used to control carryout in the immediate vicinity. Sweeping occurred every other workday, except on days that it rained. Surface sampling was conducted at approximately the same time periods before and after precipitation, as was done for the uncontrolled sampling, to determine the overall reduction in silt loading.

Prior to evaluating the second control method, the paved road was again aggressively cleaned (sweeping and flushing) to reestablish the baseline condition. Coordinated with the cleaning, the woodchip/mulch material was applied in a 6- to 12-in. layer to the site access point and adjacent areas to provide a 100-ft buffer between the paved and unpaved surfaces. The buffer allowed the mud/dirt carried on the truck tires and underbodies to deposit in the buffer area, rather than on the paved road. Reductions in silt loading were then quantified by appropriate surface sampling at comparable time periods before and after precipitation.

Finally, after the paved road was cleaned again (sweeping and flushing) to the baseline condition, the previously installed woodchip/mulch buffer area was replaced with a gravel buffer (100 ft long and 6 in. deep). Comparable surface sampling was performed before and after precipitation in a manner similar to that described above.

Note that the original test plans had called for the evaluation of street sweeping, the gravel buffer, and an asphalt buffer. However, the construction site supervisor responded to the city's request for controlling on-site fugitive dust by using a woodchip/mulch buffer. Because the woodchip/mulch buffer was an actual control measure chosen by the contractor, it was decided to evaluate this buffer's effectiveness.

By the time that the gravel buffer was to be evaluated, traffic into and out of the site had been reduced and was not expected to pick up until concrete pouring began in earnest at the dam site. Because of schedule constraints, it was jointly decided by the EPA work assignment manager and the contractor to generate "captive" traffic to complete the evaluation of the gravel buffer. The "captive" traffic that was used was a 10-wheeled truck that was identical to the type of trucks that were originally hauling material from the site. The captive truck was half-loaded to represent the average of a loaded and an unloaded condition.

Time History of the Project

The field sampling portion of the program spanned from the end of May until mid-September 1994. The long time span was the result of many delays caused by the weather. There were consecutive days when no sampling activity occurred. During those days, there was either no hauling activity at the site or it had rained the evening before. This prevented any trucks from entering the site and also prevented surface samples from being taken.

The sampling program was also affected by the trucks' originally leaving the site going south and later began exiting to the north. This change in direction caused problems in maintaining a constant flow of traffic from the test site over the southbound lanes of Elmwood. Also, because of interference from a power pole, trucks exiting north from the construction site were forced to swing into the southbound lane, thereby impacting the silt loading background area.

Traffic into and out of the site slowed after the earthmoving activities were largely completed and concrete pouring for the dam had not yet begun. Therefore, supplemental "captive" traffic was generated by hiring a truck and driver to drive into and out of the test site for the remaining portion of the field sampling program; i.e., the evaluation of the gravel buffer.

Data Analysis/Results

The silt loading data were plotted as a function of distance from the site access point. Because earlier studies found a rapid decrease in silt loading with distance, the data were plotted on a semi-logarithmic graph. The data were grouped by control technology (e.g., uncontrolled, woodchip/mulch) to construct a single plot for each control. The data were then regressed for each lane and for each control method. The uncontrolled silt loadings did not exhibit any discernible trend to increase with time. This is probably due to the fact that, because of the steep slope of the access road, no truck haulage occurred for 1 or 2 days after rainfall. Thus, at the study site, precipitation did not enhance carryout onto Elmwood, but rather rainfall at least partially cleaned the road surface. The trucks were diverted to haul from other sites in the area during these periods.

The area under the silt loading distribution curve was determined using the trapezoidal rule for each sampling event. When the resulting area was divided by 500 ft, the average silt loading ($\overline{sL}$) was found. The average silt loadings measured for the uncontrolled condition ranged from 2.6 to 8.9 g/m^2 for the "A" lane and from 1.0 to 5.8 g/m^2 for the "B" lane. These ranges correspond approximately to the upper 20th-percentile of the silt loading data base presented in AP-42. Thus, carryout clearly resulted in heavy silt loadings on Elmwood Avenue. In addition, the curb or "A" lane was roughly twice as heavily loaded as the other southbound lane ("B"). This was expected because the loaded trucks tended to travel almost exclusively in the "A" lane in preparing to turn west onto Blue Parkway.

Because of problems encountered in defining an appropriate "background value" of silt loading (as a result of the impacts of construction vehicles occasionally exiting to the north on Elmwood), the control efficiency of reduction in $\overline{sL}$ (presented in Table 1) is in terms of a range between a lower bound and an upper bound. The lower bound was obtained by assuming a background value of zero for silt loading. The upper bound was obtained by subtracting the relatively high background value of 0.5 g/m^2. This high background value was determined from an average daily traffic value of 10,000 using the relationship between silt loading and traffic volume.

The overall control efficiency for street sweeping was found to be 19 and 27% for the "A" and "B" lanes, respectively, based on the reduction in $\overline{sL}$. Street sweeping was found to be much more effective in reducing total surface loadings. Part of the poor performance for removal of silt loading can be attributed to the abrasion of coarse material left on the roadway after sweeping; i.e., the sweeper generated additional material in the silt fraction by breaking large particles into smaller ones. In addition, the same sweeper already was being used to control carryout from construction sites in the immediate vicinity.

The woodchip/mulch buffer proved to be more effective than the street sweeper in reducing average silt loading. Over the two sampling events, an average control efficiency of 33 to 37% for the "A" lane and 49 to 64% for the "B" lane was found for the woodchip/mulch buffer. This control measure is of considerable interest because it represents a "real world" solution to the problems of carryout in that the contractor constructed a buffer from waste material collected on-site. This resulted in a far more cost-effective (i.e., reduction in silt loading per unit cost) control than street sweeping.

An important potential drawback was observed during the use of woodchip/

***Table 1**. Silt Loading Control Efficiencies*

Control	*A Lane*	*B Lane*	*Both Lanes*
		(lower limit/upper limit)	
Street sweeping	19/22%	21/27%	20/24%
Woodchip/mulch application	33/37%	49/64%	38/46%
Gravel application	56/64%	58/76%	57/68%

mulch. Because woodchip/mulch is soft and easily compressed by vehicles, the weight of a passing vehicle will displace the air contained in the buffer. This effect caused substantial fugitive dust clouds that could be seen when a vehicle traveled over the buffer. Although the buffer was effective in controlling the carryout of materials from the site, on-site reentrained fugitive dust vehicular emissions may have increased due to the woodchip/mulch buffer.

The gravel buffer was found to be the most effective control studied in this report, reducing average silt loadings by 56 to 64% in the "A" lane and 58 to 76% in the "B" lane. In addition, unlike the woodchip/mulch material, the gravel buffer probably reduced on-site reentrained fugitive dust vehicle emissions by covering the travel surfaces with a coarser material.

Quality Assurance (QA) Results

Eight sets of co-located surface samples were collected (using the "embedded" sampling approach) and analyzed. The regular and the QA samples yielded comparable results for total loading, silt loading, and overall silt content (as determined by dividing the total loading by the silt loading). The silt loading range percent values fell well within the ±50% guideline set forth in the test plan, with an overall mean of 17% in absolute value of range percent.

A total of 24 QA samples were obtained by riffle splitting of field samples of road surface loading. Each subsample was taken through sieve analysis. The QA statistic (relative value, RV) for 17 of the 24 pairs (71%) fell within the ±0.05 guideline established in the test plan, with an absolute maximum of 0.154 for Sample 2-B-R-593 (i.e., having a "regular" silt content of 10.5% contrasted with a QA value of 9.3%). In general, larger absolute values of the QA statistic are associated with lower silt fractions.

Conclusions

The testing and evaluation program that was conducted led to several conclusions.

- A broad range of paved road silt loadings were measured near the construction site access point under the uncontrolled condition and each controlled condition, but no condition exhibited clearly discernible time trends. In other words, silt loadings did not tend to increase with time. This may be the result of rainfall partially cleaning the surface between different sampling events and largely reducing access road traffic until the steep slope had dried. Once access point traffic was restored to its normal level, reentrainment and displacement to nontraveled parts of the road (i.e., curb) offset the additional loading from carryout so that a new "equilibrium" was established.
- Street sweeping was found to be only marginally effective (approximately 20%) in lowering average paved road silt loading values in carryout areas. In general, total loadings were reduced far more effectively, but the street sweeper appears to have abraded the remaining material, thus "creating" additional material in the silt fraction.
- The 6- to 12-in. layer of woodchip/mulch was moderately effective in controlling carryout, with average paved road silt loadings being reduced 38 to 46%. This control measure was implemented by the construction contractor at the request of Kansas City officials. Furthermore, the control made use of material that was available on-site at no cost. Although the woodchip/mulch buffer was moderately effective in controlling off-site emissions, it was noted that this buffer may have increased on-site PM-10 emissions. The buffer was fairly "soft" and was readily compressed by vehicles traveling over it. This compression displaced the trapped air, and puffs of fugitive dust were observed.
- The 6-in. layer of gravel was found to reduce average paved road silt loadings by 57 to 68%. This was the highest efficiency found in the present study. Unlike the other buffer material, gravel formed a far stronger surface that did not yield under vehicular traffic, and no on-site increase in fugitive dust emissions was noted.
- Based on these measured reductions in silt loading and using the PM-10 emission equation, the following calculated PM-10 reductions would result: street sweeping would reduce PM-10 by approximately 14%; treatment of the access area with woodchips/mulch would moderately reduce PM-10 by 27 to 33%; the gravel buffer would result in the largest reduction of PM-10, by 42 to 52%; and the PM-10 control efficiencies are somewhat lower than the silt loading reductions, because of the 0.65 power on silt loading in the PM-10 emission equation.

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The complete report, entitled "Characterization of Mud/Dirt Carryout onto Paved Roads from Construction and Demolition Activities," (Order No. PB96-129028; Cost: $28.00, subject to change) will be available only from:
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