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Project Summary

Extended Evaluation of Unpaved Road Dust Suppressants in the Iron and Steel Industry

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This study involved the measurement of the long-term control effectiveness of various dust suppressants used to mitigate particulate emissions from vehicular traffic on unpaved roads in the iron and steel industry. Control effectiveness values were determined by measuring emissions, using an exposure profiling technique, before and after control application. Control effectiveness was determined for total particulate (TP) and for three particle size (aerodynamic diameter) fractions: ≦ 15μm, inhalable particulate (IP); ≦ 10μm (PM_{10}); and ≦ 2.5 μm, fine particulate (FP). Parameters affecting the cost-effectiveness of unpaved road dust suppressants were also quantified, and the trace element composition of uncontrolled unpaved road surface material and airborne dust emissions was examined.

Three dust suppressants, used to reduce unpaved road emissions, were evaluated: (1) a 20% solution of Petro Tac (an emulsified asphalt) applied at 3.2 l/m^2 (0.70 gal/yd^2); (2) water applied at 2.0 l/m^2 (0.43 gal/yd^2); and (3) a 20% solution of Coherex® (a petroleum resin) applied at 3.8 l/m^2 (0.83 gal/yd^2) followed by a repeat application of 4.5 l/m^2 (1.0 gal/yd^2) of 12% solution 44 days later. Twenty-nine tests of controlled and uncontrolled particulate emissions from vehicular traffic on unpaved roads were conducted.

A decay in control effectiveness, as a function of vehicle passes after application, was measured for the dust suppressants tested. The asphalt emulsion showed an effective lifetime ranging from about 50,000 vehicle passes for control of FP emissions to over 100,000 vehicle passes for control of TP emissions. Unlike the asphalt emulsion, the petroleum resin appeared to control particulate emissions of different size fractions consistently throughout its lifetime of about 7,500 vehicle passes for the first application. Tests of the reapplication of the petroleum resin provided strong indication of a residual effect from the initial application. The lifetime of the repeat application ranged from 17,000 passes for FP to 45,000 passes for TP. Tests of watering of unpaved roads indicated high initial control efficiency which decreased at a rate of approximately 8%/hr. The rate of control efficiency decay decreased with decreasing particle size.

Comparison of optimal cost-effectiveness values for the dust suppressants evaluated and for the road conditions tested indicates that the chemical techniques can control unpaved road PM_{10} emissions for 5-50% of the cost of using water. Essentially linear relationships were found between downwind airborne and surface aggregate mass concentrations for most of the trace elements detected in the chemical analysis of uncontrolled, unpaved road dust emissions.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, 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

Previous studies have provided strong evidence that open dust sources (e.g., vehicular traffic on unpaved and paved roads, aggregate material handling, and wind erosion) should occupy a prime position in control strategy development in the iron and steel industry. This conclusion has been based on comparisons between industry-wide uncontrolled emissions from open dust sources and typically controlled fugitive emissions from major process sources (e.g., steelmaking furnaces, blast furnaces, coke ovens, and sinter machines). In addition, preliminary cost-effectiveness (dollars expended per unit mass of reduced particulate emissions) analysis of promising control options for open dust sources has indicated that control of these sources might result in significantly improved air quality at a lower cost compared to the control of process sources.

These preliminary conclusions prompted this study to gather additional data on control performance and costs for open dust sources in the steel industry. Although testing was conducted at iron and steel plants, the control efficiencies presented in this report apply to unpaved roads in other industries, if the roads have similar traffic and surface characteristics.

Control efficiency for unpaved roads can be affected by four broad categories of variables: (a) time-related variables, (b) control application variables, (c) vehicle characteristics, (d) characteristics of the surface to be treated, and (e) particle size range being considered. The emphasis of this effort was on (a), time-related variables.

Because of the finite durability of all surface-treatment control techniques, ranging from hours (watering) to years (paving), it is essential to relate an efficiency value to a frequency of application (or maintenance). For measures of lengthy durability, the maintenance program required to sustain control effectiveness should be indicated. One likely pitfall to be avoided is using field data collected soon after control measure application to represent the average control efficiency over the lifetime of the measure.

The climate, for the most part, accelerates the decay of control performance adversely through weathering. For example, freeze/thaw cycles break up the crust formed by binding agents; heavy precipitation washes away water-soluble chemical treatments like lignin sulfonates or salts; and solar radiation dries out watered surfaces. On the other hand, light precipitation might improve the efficiency of water extenders and hygroscopic chemicals like calcium chloride.

The average control efficiency, C(T), is given by:

$$C(T) = \frac{1}{T} \int_{0}^{T} c(t)\, dt$$

where: C(T)=Average control efficiency during period ending T days after application (percent)

c(t)=Instantaneous control efficiency at t days after application (percent)

T=Time period over which average control efficiency is desired (days)

The overall objective of this study was to provide data that document the mass of particulate emissions (in several size ranges) generated by vehicular traffic on controlled unpaved roads in the iron and steel industry Most of the data were to provide control efficiencies for common road dust suppressants over the lifetime of each control measure. Thus, the long-term control efficiency decay function associated with each dust suppressant applied to unpaved roads formed the primary goal of this study. For emphasis, the chemical control measures were applied following the manufacturer's recommendations for dilution ratio and application intensity; as such, data presented in this report are directly applicable only to the dilution ratios and application intensities tested.

Secondary objectives of this study were: (a) calculating the cost-effectiveness of measures designed to reduce unpaved road dust emissions; (b) comparing the emission factors obtained with simultaneously operated 6-m and 10-m profiling towers; and (c) determining the trace element composition of particulate emissions from unpaved roads in the iron and steel industry.

Summary and Conclusions

The purpose of this study was to measure the long term control efficiency (effectiveness) of various dust suppressants used in the iron and steel industry to mitigate particulate emissions from vehicular traffic on unpaved roads. Control efficiency values were determined not only for total particulate (TP), but also for particles less than 15 μm in aerodynamic diameter (inhalable particulate, IP), less than 10 μm in aerodynamic diameter (PM_{10}), and less than 2.5 μm in aerodynamic diameter (fine particulate, FP). In addition to control efficiency determination, parameters affecting the cost-effectiveness of unpaved road dust suppressants were quantified, and the trace element composition of uncontrolled unpaved road surface material and airborne dust emissions was examined. Vehicular traffic on unpaved roads was the sole concern of this study because this source was estimated to contribute 56% of the open source suspended particulate emissions in the iron and steel industry.

The exposure profiling method developed by MRI was the technique utilized to measure uncontrolled and controlled emission factors for vehicular traffic on unpaved roads. Exposure profiling of roadway emissions involves direct isokinetic measurement of the total passage of open dust emissions approximately 5 m downwind of the edge of the road by means of simultaneous sampling at four points distributed vertically over the effective height of the dust plume. Downwind particle size distributions were measured at the 1.5 and 4.5 m heights using cyclone precollectors followed by parallel-slot cascade impactors. Upwind size distributions were also determined using a cyclone/impactor combination.

Twenty-nine tests of controlled and uncontrolled particulate emissions from vehicular traffic on unpaved roads were conducted. Six of these provided uncontrolled baseline emissions data necessary to determine control efficiency and cost-effectiveness.

Three dust suppressants used to reduce unpaved road emissions were evaluated.

1. A 20% solution of Petro Tac (an emulsified asphalt) applied at an intensity of 3.2 l/m^2 (0.70 gal/yd^2).
2. Water applied at an intensity of 2.0 l/m^2 (0.43 gal/yd^2).
3. A 20% solution of Coherex® (a petroleum resin) applied at an intensity of 3.8 l/m^2 (0.83 gal/yd^2), followed by a repeat application of 4.5 l/m^2 (1.0 gal/yd^2) of 12% solution 44 days later.

The results in this report are directly applicable only to these dilution ratios and application intensities. The chemical dust suppressants were applied in quantities recommended by the manufacturers. These quantities were, in general, much higher than those currently used at iron and steel plants.

Table 1 presents estimated lifetimes and source/control parameters for the dust suppressants evaluated. The lifetimes

Table 1. Control Efficiency Decay Rates

Dust suppressant	Mean vehicle weight (Mg)	Mean No. of wheels	Particle size range	Estimated lifetime (vehicle passes)
Asphalt Emulsion (initial application) 3.2 l/m² of 20% solution in water	27	9.2	TP	125,000
			IP	77,000
			PM_{10}	91,000
			FP	53,000
Petroleum Resin (initial application) 3.8 l/m² at 20% solution in water	34	6.2	TP	7,100
			IP	7,100
			PM_{10}	7,700
			FP	7,700
Petroleum Resin (reapplication) 4 5 l/m² of 12% solution in water	39	6.0	TP	45,000
			IP	26,000
			PM_{10}	23,000
			FP	17,000
Water 1.9 l/m²	44	6.0	TP	480
			IP	530
			PM_{10}	560
			FP	620

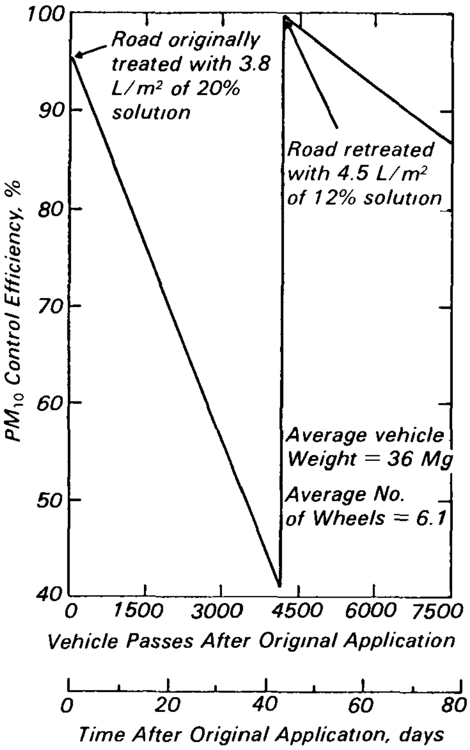

Figure 1. *Comparison of the control performance for PM_{10} of initial and repeat applications of a petroleum resin illustrating the residual effect.*

given are applicable only to situations with the same source/control parameters. (Lifetime is the time at which a sufficient number of vehicle passes have caused the control efficiency to decay to zero.)

The asphalt emulsion was tested over a period of about 4 months and nearly 50,000 vehicle passes. Although TP emissions showed the lowest initial control efficiency, the control efficiency values associated with particulate emissions in the smaller size ranges showed a much greater rate of decay than that for TP. For example, initial FP control efficiency was substantially greater than that of TP, but the FP control efficiency decay rate was much greater, so that FP emissions nearly matched the uncontrolled state at a time when TP emissions were still controlled at the 50% level.

The tests of watering of unpaved roads indicated high initial control efficiency, which decreased at a rate of approximately 8% per hour. The rate of control efficiency decay was found to decrease with decreasing particle size.

The tests of an initial application of a petroleum resin product did not indicate significant variation in the control efficiency decay rate as a function of particle size range. During each test in the 41 day period after application, the measured control efficiency increased with decreasing particle size. Unlike the asphalt emulsion, the petroleum resin appeared to control particulate emissions of different size fractions consistently throughout its lifetime. In other words, the decay rate for the initial application of the petroleum resin was nearly identical regardless of the particle size.

The tests of the reapplication of the petroleum resin provided strong indication of a residual effect from the initial application. Figure 1 compares the PM_{10} control efficiency decay functions for those associated with the initial and repeat applications. The rate of decay for the repeat application was found to be roughly one order of magnitude less than that associated with the initial application. Comparison of the surface aggregate size distribution before and after chemical retreatment suggests that the bonding characteristics of the reapplication are enhanced by a residual effect of the initial treatment.

Comparison of optimal cost-effectiveness values for the dust suppressants evaluated indicates that the chemical techniques are capable of controlling unpaved road PM_{10} emissions for 5-50% of the cost of using water. However, note that direct comparisons between suppressants are difficult at best, even when tests are conducted at the same site, because of changes in vehicle characteristics, traffic rate, etc. Comparisons between suppressants evaluated at different sites are even more formidable because there are additional uncontrollable variations in road structure and surface characteristics. Consequently, there are situations where watering, for example, may be more cost-effective than chemical dust suppressants.

Essentially linear relationships were found between downwind airborne and surface aggregate mass concentrations for most of the trace elements detected in the chemical analysis of uncontrolled, unpaved road dust emissions. Because of these relationships, it appears possible to economically estimate airborne elemental mass concentrations by examining the corresponding concentrations in the surface material. However, more data are required to substantiate this approach.

In a comparison designed to accentuate the variation between measurement-based emission factors using 10 m and 6 m profiling towers, the percent difference was 10-17%. Because the small differences found in this worst-case comparison are within the experimental accuracy of the profiling method, the difficulties in erecting and operating a 10 m tower at a 5 m distance from the edge of the road are not justified.

Additional work in the area of open dust control evaluation would be helpful. To truly optimize the cost-effectiveness of a control program designed to meet a minimally acceptable level of average control, a range of application intensities and dilution ratios should be examined. Ideally, enough data should be collected to support a mathematical relationship between average control efficiency and application parameters. The values of application parameters tested should span the ranges commonly employed in the iron and steel industry for the most prevalent dust suppressants. To provide optimization of control performance for a given dust suppressant, each control efficiency decay function should be based on a minimum of three application intensities.

Identifying readily quantifiable source parameters, which can be used as measures of control effectiveness, would reduce the expense of the field investigations required to characterize dust suppressant performance in the iron and steel industry. This would permit tracking control performance without labor-intensive source testing.

Another way to reduce the amount of costly field tests would be developing and implementing a laboratory screening procedure, perhaps involving wind tunnel exposure of representative samples of aggregate materials. In addition to wind forces, the tests could involve simulating the forces of vehicle tire/road surface contact. Control performance could be measured as resistance to loss of exposed surface materials. Ideally, if a program adopted for the laboratory simulation produced the same effectiveness ranking for the typical chemicals as that determined by field tests of these chemicals, it would establish the usefulness of the laboratory-based ranking for application to field conditions.

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The complete report, entitled "Extended Evaluation of Unpaved Road Dust Suppressants in the Iron and Steel Industry," (Order No. PB 84-154 350; Cost: $16.00, subject to change) will be available only from:
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