Evaluation of Sources and Controls of Fugitive Dust from Agricultural Operations

D.A. Michalewicz, J.D. Wanjura, B.W. Shaw, C.B. Parnell

The Center for Agricultural Air Quality Engineering and Science
Department of Biological and Agricultural Engineering
Texas A&M University
College Station, TX

Abstract

Air pollution regulations are forcing many producers and processors of agricultural products to implement control practices for fugitive particulate matter (PM) emissions. Often the effectiveness of the required practices is unknown. USDA conservation programs offer cost sharing opportunities for producers to implement environmental control practices. An accurate estimation of environmental benefits is needed for prioritization of conservation resources. There is a need to understand and quantify fugitive PM control methods and their effectiveness to ensure that environmental improvement resources yield maximum benefit. This paper evaluates the common sources and the most effective control methods based on available literature. This paper also identifies areas where data is missing and discusses the ramifications of regulating with scarce data.

Introduction

Historically, fugitive dust emissions from ground level area sources (GLAS) have been unregulated for sources not exceeding Title V thresholds for major sources. Recently California and Arizona passed laws that require farm operations to submit dust management plans for all agricultural operations. Both of these states have PM_{10} non-attainment areas as defined by the Environmental Protection Agency (EPA). An area is classified as non-attainment by the EPA when the ambient air concentration of PM_{10} exceeds 150 $\mu g/m^3$. During the late summer and fall over fifty percent of the PM_{10} in California's San Joaquin Valley is attributed to primary geologic material or soil dust. This time period coincides with the harvest season of the three major crops: cotton, almonds, and tomatoes (Holmen et al, 2001). The allowed emission rate is determined for each operation during the new source review (NSR) process using emission factors published by the EPA in AP-42. PM_{10} emissions are regulated based upon the facility's potential to emit. California's new law requires agricultural operations to submit a dust control plan showing the Conservation Management Practices (CMP) the operation plans to implement to control fugitive dust emissions. Another method of regulating emissions uses nuisance based standards. Currently in most states, air emissions from agricultural operations are regulated on a nuisance basis. Nuisance violations occur when a citizen files a complaint with a state air pollution regulatory agency (SAPRA) stating that the given emissions are interfering with the enjoyment of his or her property. Even though producers in California and Arizona are being forced to control fugitive dust emissions due to regulations, the control of these emissions is important environmentally and in terms of public health everywhere. Emissions from agricultural operations come from five main sources:

- Agricultural Field Operations – all operations associated with tilling the soil, planting, and harvesting of crops,
- Agricultural Processing Facilities – including but not limited to grain elevators, feed mills, cotton gins, oil mils,
- Environmental Sources – Wind blown soils,
- Unpaved Road Emissions, and
- Concentrated animal feeding operations (CAFO) – examples include cattle feed yards and dairy operations.

The purpose of this paper is to discuss the first four sources and the control measures that can be used to help meet both federal and state regulations. Unpaved roads and environmental sources are the main two sources of fugitive dust from agricultural operations. Most of the PM_{10} produced by agricultural processing facilities comes from point sources with minimal production of fugitive dust produced by vehicles entering and leaving the facilities.

Agricultural Sources and Controls

Agricultural Field Operations

The EPA, in addition to establishing the National Ambient Air Quality Standards (NAAQS), has also compiled a list of accepted emission factors to use in the regulatory process in AP-42(USEPA 1995). AP-42 provides emission factors for many sources. In the fifth edition of AP-42, the EPA excluded the emission factor calculation procedures for tillage operations. The method used previously for tillage operations was based upon the method used to calculate emission rates from unpaved roads. Equation 1 was used to calculate the dust emission factor for tillage operations.

$$E = k * (4.80) * (s)^{0.6} \qquad \text{Equation 1}$$

where: E = emission in lb/acre
s = silt content (percent) of surface soil (default value of 18 percent)
k = particle size multiplier (dimensionless).

For particle sizes smaller than ten microns the particle size multiplier, k, is equal to 0.21(Cowherd et al.). Holmen et al. found in his research that this method over estimates the emission factors for most crops when a high soil silt content such as that found in California is used. California has discontinued the use of this method however many other states still use it in their regulatory process.

The fifth edition AP-42 does contain emission factors for the harvesting of cotton and grain crops. However these emission factors were established in 1979 and 1980 respectively. The emission factors listed in AP-42 were developed using equipment typically used during the time period. Today's equipment is much larger and operates at much faster speeds. Little research has been conducted to develop updated emission factors.

While little is known about the emissions from agricultural field operations, even less in known about the effectiveness of the controls being implemented in California and Arizona to reduce fugitive emissions. Both California and Arizona have generated a list of best available control measures (BACM) for farmers to use. California requires producers to implement a control strategy for each of the following categories:

- unpaved roads,
- parking and equipment storage areas,
- land preparation,
- harvest, and
- other (such as burning, wind blown dust, etc.).

The University of California at Davis has been researching the emissions from agricultural land preparation operations since 1990. Much of the data produced from this research is currently being used by the California Air Resources Board (ARB) in quantifying emission factors for these operations. Considering the number of tillage/land preparation operations for each crop type grown in California makes the job of quantifying emission factors a daunting task. Over thirty tilling operations are commonly used to produce the three major crops grown in California. Research at UC Davis focused on the five main tillage operations associated with cotton and wheat. These operations are root cutting, discing, ripping and subsoiling, land planning and floating, and weeding (ARB 2003). A list of emission factors from these crops are listed in Table 1 below.

Table 1. Land Preparation Operation Emission Factor (ARB 2003)

Land Preparation Operations	Emission Factor (lbs PM_{10}/acre-pass)
Root Cutting	0.3
Discing, Tilling, Chiseling	1.2
Ripping, Subsoiling	4.6
Land Planning & Floating	12.5
Weeding	0.8

California uses these emission factors to determine emission factors for other operations. The ARB established a series of "best fit factors" to modify the base emission factors. The adjusted emission factors are referred to as potential to emit factors. Working with producers, the ARB has identified specific farming practices and the frequency of use for each practice used in the production of crops. Using this data and the potential to emit factors discussed above, the ARB has created an emission factor for each crop on a per-acre basis. Emissions inventories can be calculated using the reported acreage planted and the emission factors (on a per acre basis) for each crop . A complete listing of emission factors for each crop is published in the ARB's Emission Inventory report (ARB 2003).

Research at UC-Davis has established a foundation to build upon in terms of emission factors; however, little is known about the effectiveness of the control measures used to reduce fugitive emissions. The control measures can be grouped into four categories including:

- conservation tillage – using reduced tillage system or no-till,
- combination of operations – applying chemicals through irrigation etc.,
- monitor soil moisture in timing field operations, and
- time operations to reduce emissions – night farming and restriction of activity during high winds.

Research focusing on the effectiveness of control measures has not been conducted. Generalizations about the effectiveness of the control measures were made from meteorological, soil moisture, and implement data taken for studies to develop emission factors. The generalizations made indicate the following:

- there was no correlation between wind speed and reduced emissions,
- emissions increased with a decrease in relative humidity,
- emissions increased with a decrease in soil moisture, and
- emissions increased with increases in vertical temperature differential.

This information does not quantify the reductions that would occur from implementing the practices mentioned (Holmen etc).

<u>Unpaved Roads</u>

Unpaved road emissions are one of the largest sources of fugitive PM emissions. Fugitive dust from unpaved roads is entrained in the air when a vehicle travels down an unpaved road. Emissions from unpaved roads tend to be the highest in rural areas. Roads often remain unpaved in rural regions due to light traffic and long road lengths. Unlike paved roads, the source of emissions from unpaved roads is the road material and not surface loading (Cowherd et al 1988).

It has been found that dust emissions from unpaved roads vary directly with the fraction of silt in the road surface materials (USEPA 1995). Silt is considered to be all particles smaller than seventy-five micrometers in diameter. Dust emission rates also vary linearly with the volume of traffic. Other factors affecting the dust emissions from unpaved roads include vehicle weight and the moisture content of the road surface (USEPA 1995).

AP-42 lists two equations to use in calculating unpaved road emissions from industrial sites and from public roads. The equations give the emissions in terms of pounds (lb) of size specific particulate emissions per vehicle mile traveled (VMT). The emission factor for unpaved industrial sites can be used in determining the emissions from equipment parking and shop sites on agricultural operations while the unpaved public road equation can be used to determine the emissions from all unpaved roads on an agricultural operation.
Equation 2 is used to calculate the emission factor for unpaved industrial-use surfaces and equation 3 is used to calculate the emissions from unpaved public roads.

$$E = k * (s/12)^a * (W/3)^b \qquad \text{Equation 2}$$

$$E = \frac{k * (s/12)^a * (S/30)^d}{(M/0.5)^c} - C \qquad \text{Equation 3}$$

where k, a, b, c, d are empirical constants and

E = size specific emission factor (lb/VMT)
s =surface mineral silt content (%)
W = mean vehicle weight (tons)
M= surface material moisture content (%)
S = mean vehicle speed (mph)
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

The values for k, a, b, c, d can be found in AP-42 (USEPA 1995).
The unpaved road emission factors calculated using equations 2 and 3 do not take into account the emissions reduction effect of rainfall. The effect on dust emissions due to rainfall can be calculated using the following equation:

$$E_{ext} = E * [(365 - P)/365] \qquad \text{Equation 4}$$

where:

E_{ext} = annual size-specific emission factor extrapolated for natural mitigation, lb/VMT
E = emission factor from above equations
P = number of days in a year with at least 0.01 inch of precipitation.

There are three categories of control methods for unpaved roads. They are vehicle restrictions, surface improvement, and surface treatment. Vehicle restrictions can include options such as limiting speed, weight or number of vehicles on the road. These options are cheap to implement and achieve moderate reductions in emission but they are often difficult to enforce.

Surface improvements alter the road surface. These improvements can include paving the road or covering the surface with a material with lower silt content. These options are often highly effective in reducing emissions but can also be costly or impractical.

The final control category is using surface treatments. These treatments include wet suppression and chemical stabilization. These options are often low cost but they require frequent re-treatment of the surface. The effectiveness of these control methods is dependent on the material of the road and the weight and frequency of travel over the surface. The effectiveness of these methods should be evaluated on a case by case basis as road types and travel will vary with geographic location.

Agricultural Processing Facilities

Agricultural processing facilities include but are not limited to the following: cotton gins, feed mills, and grain elevators. Most agricultural processing facilities are considered to be minor sources of PM_{10} and are exempt from Title V permit requirements. A minor source (for Title V) emits less than 100 tons per year of

PM_{10} in attainment areas and 70 tons per year in non-attainment areas (U.S. EPA 40 CFR Part 50). Once a source is classified as a major source for Title V, it is required to pay annual fees based on every ton of emissions that the facility has the potential to emit including fugitive emissions. Since most of these sources never reach the threshold for Title V permitting, the regulation of fugitive dust is not necessary. Typically, fugitive emissions are small in relation to point source emissions at most agricultural operations.

Environmental Sources

Wind erosion produces the highest emissions of fugitive dust from agricultural sources. Until the last decade wind erosion has been regulated based up total suspended particulate (TSP) matter. However a recent push has been made to quantify the portion of the emission under 10 microns due to ever increasing regulation from the EPA and SAPRA. Wind erosion degrades the air quality not only locally but also at significant distances down wind. Both Richland and Portland, Washington have recently been classified as non-attainment areas according to the EPA's guidelines for PM_{10} or what. It is believed by many experts that wind erosion contributes significantly to the air quality problems in these areas. The agricultural land in this area has a high sand content and is considered highly erodible (Saxton 1993).

Historically, wind erosion has been regulated more by the Natural Resources Conservation Service (NRCS) than by the EPA or SAPRA. Agricultural land was regulated under the term highly erodible land (HEL). HEL is defined by the potential of the land to erode at a rate eight times than that at which the soil can sustain productivity. According to NRCS rules a field is considered HEL is one-third or more of the field is highly erodible or if the highly erodible land in the field totals more than fifty acres (NRCS 2002). The NRCS was able to regulate these lands by withholding certain USDA benefits if the proper practices were not followed by the land owner or operator.

Traditionally the wind erosion equation has been used to calculate the amount of soil lost. However this equation determined total particulate matter lost and not just PM_{10}, which is the fraction regulated by the EPA and SAPRA. Cowherd et al (1988) describes a modification of the wind erosion equation to simplify the determination of the losses. The simplified equation is as follows:

$$E = kaIKCL'V' \qquad \text{Equation 5}$$

where: E = PM_{10} wind erosion losses of tilled fields, tons/acre/year
k = 0.5 estimated fraction of TSP which is PM_{10}
a = portion of total wind erosion losses that would be measured as suspended particulate, estimated to be 0.025
I = soil erodibility, tons/acre/year
K = surface roughness factor, dimensionless
C = climatic factor, dimensionless
L' = unsheltered field width factor, dimensionless
V' = vegetative cover factor, dimensionless.

There are many factors that affect the amount of PM_{10} produced during a wind event. The factors most affecting PM_{10} emission are:

- soil particle size distribution of the eroding field surface (percent of soil particles less than 10 microns as stated above is usually assumed to be 50 percent),
- amount of soil particle degradation,
- wind velocities and profiles, and
- vegetation interaction (Saxon).

While it is widely accepted that these factors affect PM_{10} emissions, the degree to which each one does is still relatively unknown.

As with agricultural tilling operations, little is know about the effectiveness of the control measures for limiting PM_{10} emissions. Most of the practices are effective in controlling the emissions of total suspended particles but it is unknown how well they control PM_{10}. Some of the common BACM for wind erosion include:

- vegetative cover,
- wind barriers, and
- conservation practices.

The use of vegetative cover is the easiest and most cost effective method of controlling wind erosion. The use of grasses or legumes provides the best protection because they completely cover the soil surface. These are a good choice for planting in fallow fields or following the harvest of crops. Most row crops are planted too far apart to adequately protect the soil surface. However, the residues produced by crops such as corn and sorghum form a good protective barrier and are durable enough to last long periods of time. Wind barriers can be either vegetative or man made. Wind barriers made of vegetation consist of trees or shrubs planted in one to ten rows. Man made wind barriers include solid wooden walls, rock walls, and earthen banks. These barriers provide good protection regardless of wind velocity. The use of conservation practices includes implementing strip-cropping, narrower row crop spacing and the limited irrigation of fallow fields.

Conclusion

Due to the new laws and regulations in Arizona and California, there is a need to establish emission factors and BACM for agricultural sources in the relatively near future. However, at the same time the proper research needs to be completed to find the most accurate emission factors possible and not use unsubstantiated numbers. The effectiveness of the BACM must also be determined to ensure that the practices implemented are not only the most effective in terms of reducing PM_{10} emissions but also the most effective in terms of dollars spent in the implementation.

Currently of the topics discussed above, the most is known about the emissions from unpaved roads and surfaces in terms of both emissions and effectiveness of BACM. The information from unpaved roads can be used in determining the emissions from agricultural processing facilities. The work completed by researchers at UC-Davis has established a strong foundation upon which to build on. They have established emission factors widely accepted by regulators and other researchers in the western United States. They have also made some generalizations about BACM but have not been able to determine the actual effectiveness of them. The loss of TSP due to environmental sources and the BACM for TSP are widely accepted; however, little information is available on the emissions of PM_{10} and the effectiveness of the accepted BACM on controlling PM_{10} emissions.

As research moves forward it is important to remember that the practices that reduce emissions most might not always be the most practical. Careful consideration should be given to both cost and ease of implantation.

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