CALCULATING EMISSION INVENTORIES OF FIELD OPERATIONS IN TEXAS

A. R. Pargmann, B. K. Fritz,
C. B. Parnell and B. W. Shaw
Agricultural Engineering,
Texas A&M University
College Station, TX

Abstract

The development of a more exact state emissions inventory is critical from the aspect of regulatory issues. Emissions inventory are used to determine the state's biggest contributors to the ambient concentration of pollutants. The Clean Air Act Amendments of 1990 require all nonattainment areas for PM_{10} to incorporate available control methods. With the improvement of the emissions inventory for field operations, unfair regulatory actions can be decreased.

Introduction

The emissions inventory is one means used by the state to assess the level of pollutants released into the air from point, area, and mobile sources. A group of common air pollutants regulated by the Environmental Protection Agency (EPA) are called criteria air pollutants. Criteria pollutants are determined based on their health and/or environmental effects. A major criteria pollutant included in the emissions inventory is particulate matter less than 10 microns (PM_{10}).

Texas Natural Resource Conservation Commission (TNRCC) uses the emissions inventory produced annually in their strategic planning. TNRCC can examine the amount of pollutants released from sources and determine who is the biggest contributor of PM_{10}. In response, TNRCC will look at that contributor as the main focus of regulation. More exact emission factors and emission estimation methods will decrease unfair regulatory actions.

Emission inventories for field operations are dependent on several variables. To calculate these inventories, it was necessary to establish the emission factor for each field operation, the number of times each of these operations occurs, the season they occur in, and the total acreage for each operation.

Discussion

Emission Factors

Several studies have been done on emissions from field operations associated with cotton production. Flocchini (1995) reported emission factors ranging from about 18-80 kg/km^2. As a conservative estimation, 0.5 lb/acre (50 kg/km^2) was chosen to represent cotton field operations. Coates (1995), however, reported emission factors a hundred times higher. When Coates compared his measured values to those predicted by the AP-42 emission factor equation, the accepted EPA procedure, he found the predicted values were 1.5 to 2.5 times higher. If these numbers are incorrect, cotton farmers will see undue restrictions because of erroneous reported emissions inventories for cotton field operations due to the use of the AP-42 equation.

Coates reported his emission factors in total suspended particles (TSP), instead of PM_{10}. A typical soil particle size distribution was developed using a mass median diameter (MMD) of 25, and a geometric standard deviation (GSD) of 2.0. (The MMD and GSD were chosen due to the close proximity of the sampling in relation to the implement.) A log normal distribution was used, and a PSD was generated. The PSD shows that particulate matter with a diameter of ten microns or less composes only ten percent of the total suspended particles. Figure 1 shows the mass fraction versus the aerodynamic particle diameter of the developed PSD. Even if ten percent of Coates' emission factor is taken to get an emission factor in terms of PM_{10}, the number is still 10 times higher than Flocchini's reported emission factor.

The answer to this may lie in the process Coates used to calculate his emission factors. His sampling set-up uses four Hi-Volume Samplers, which sample directly from the plume by way of 16 inlets (four per sampler). The inlets are set up in a four-by-four grid and are located 1.5 meters behind the implement. One problem with this set-up is the small distance between the samplers and the implement does not allow for the settling out of particulate matter that would normally occur. Coates assumed the plume was 2.42 meters in height and 5.64 meters across. Since plume area sampled by one Hi-Vol is 48 times that the area of the inlets, Coates multiplied the amount of dust on the filter by that number for each sampler. He then added the four values together to obtain the total particulates in the plume. He then calculated his emission factor by dividing the total mass by the area tilled by the implement for each run. However, he does not include in his paper the length of the runs or the area covered, so it impossible to achieve the same results.

The data that was available from Coates' paper was used to figure out an emission factor using the box model, as Flocchini used when calculating his emission factors for cotton field operations. The EPA requires that the flow for any high volume sampler must be kept above 40 cubic feet per minute (cfm). The maximum amount that can be collected on a filter without dropping below the minimum flow rate is two grams. In this calculation, the maximum of two grams per filter was used, along with a flow rate of 1.13

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m^3/min (40 cfm). The following equation was used to calculate the mass flow rate of particulate into the sampler:

$$\dot{m} = \frac{m}{t * Q}$$

where

m = mass captured on filter,
t = sampling time, and
Q = flow rate.

The average tractor velocity was given as 5.8 kph (1.61 m/s) and the average inlet air velocity was given as 5.1 kph (1.42 m/s) for Coates' sampling runs. The average length of field traveled by the implement can be calculated by multiplying the average velocity of the tractor by the sampling time. Multiplying the length of field traveled by the assumed length of the implement (4 m) results in the total area covered by the implement. The height of the plume at 1.5 meters behind the implement was determined using stability class C and was found to be 0.5 meter. The box (from the box model) would then be 0.5 meters in height and 4 meter wide (the width of the implement). Using the following equation, the total volume of air sampled can be calculated:

$$V = v_{inlet} * t * h_{box} * w_{box}$$

where

v_{inlet} = average air velocity at inlet,
h_{box} = box height, and
w_{box} = box width.

Once the volume of air that was sampled was determined, multiplying the mass flow rate of particulates by the total volume of air sampled could generate the total mass of particulates. Once that is established, the emission factor can be figured by dividing total mass by the area covered by the implement. (This emission factor would be in TSP. Ten percent of that number would give the PM_{10} emission factor. Since no data was given on sampling time, test lengths were assumed. For one, two, and five minute tests, the resulting emissions factors were 78.1 kg/km^2, 39 kg/km^2 and 15.4 kg/km^2, respectively. It can be seen that the ratio of two tests is approximately inversely proportional to the ratio of the sampling times. The resulting emission factors using the box model are near the numbers Flocchini reported for cotton field operations (18-80 kg/km^2). Therefore, 0.5 lb/acre was chosen as a conservative estimate for the purposes of the development of the Texas Emissions Inventory for Field Operations.

Crop Acreage

The total cotton acreage in the state is necessary to calculate the emission inventory. (The emissions inventory for field operations in the state of Texas includes six crops: cotton, hay, wheat, rice, sorghum, and corn. These crops make up nearly all of the farmland in the state and therefore contribute most to the emission of particulate matter. This paper will concentrate solely on cotton.) The total acreage of cotton in each county was found in the 1997 Agricultural Census on the Texas Agricultural Statistics Service web page. This census is the most recent one available and contains information on both livestock and crops, including acreage and yield sorted by county for each of the six major crops. Of the six major crops that make up nearly all of the farmland in the state, 28% of that acreage is cotton. Crop acreage is essential, since emission factors are given in mass of particulate emitted per unit area (i.e. lb/acre).

Entries into Field and Emitting Factors

The average number of entries into the field was needed in order to determine the number of emission events for cotton. Since the number of entries can vary, depending on the region of the state in which the crop is grown, it was necessary to have a number for each region. The number of entries for cotton was found in the Crop Enterprise Budgets (CEB) published by the Texas Agricultural Extension Service (TAES). TAES divides the state into twelve districts, and the CEB contains a listing of all inputs for a given crop, including the number of entries into the field and their respective dates for each district.

These dates were used to calculate the mass of particulates emitted by season. The time periods for the seasons were chosen according to the calendar dates for the first day of winter, spring, summer, and autumn. The winter season runs from December 22 to March 19; spring is March 20 through June 20; the summer season is June 21 to September 22; and autumn corresponds to the period between September 23 and December 21.

Some of the twelve districts did not have data for cotton. When this occurred, data for the missing crop was utilized from the closest district's inputs. Some districts had several listings for cotton that were dependent on such things as irrigation and soil types. We analyzed this information and developed the following procedure: After examination of the listings for each district, our decision was to either to choose the one listing that would best overall represent the cotton crop for the district or to average several together. We used both of these decision criterions for this task. The cotton crop for District One (Panhandle) can be used to illustrate this decision process. The average listings for sprinkler irrigated cotton and furrow irrigated cotton were taken to represent cotton for the entire district. We justified this with the knowledge that both applications are practiced almost evenly throughout the district.

Final Emission Factors for Field Operations

For the purposes of this project, the entries were grouped into three categories: low emitting (0.1 lbs/acre), medium (0.25 lbs/acre) emitting, and high emitting (0.5 lbs/acre). This was accomplished utilizing the knowledge and experience of the principle investigators and was a subjective decision. The justification of this approach was that no information was available from the literature on emission factors for all the various operations with the exception of the high emitting field operation (0.5 lbs/acre). For example, field operations such as planting produce little dust and trips involving operations like disking produce large amounts of dust. Familiarity with the field operations was used to determine the correct placement into one of the three categories of emission factors. Those operations determined to have zero dust emissions, such as spraying, were not included in this project.

Emissions from Cotton

Tables were constructed in EXCEL listing the field operations that occurred during each season for every district. All of the emitting field operations were listed, and the number of times a field operation was performed per season was entered, ranging from zero to five. These numbers were multiplied with the emission factor for the respective field operation, and the sum of all of these products for each crop input was taken. If there were several inputs per cotton crop for a district, an average was taken in order to determine the final emission factor per season.

The acreage data by county was divided up into the twelve TAES districts in EXCEL. For each district, the cotton acreage was multiplied by the final emission factor calculated for the crop according to season. For example, the respective cotton acreage for each of the counties in District Two were multiplied by the calculated emission factor of 1.73 (lb PM_{10}/acre) for the spring season to determine the emissions from cotton crop field operations in the time frame of March 20 through June 20 (see Table 1). After this was accomplished, the 254 counties and their field operation emissions were sorted alphabetically. Along with the seasonal total emissions (in pounds of PM_{10}), the yearly total emissions were calculated. Table 2 shows the seasonal total emissions.

The approximate yearly totals of PM_{10} emissions for each of the individual crops, statewide, were as follows: corn (1800 tons), cotton (8800 tons), sorghum (3300 tons), soybeans (280 tons), wheat (3100 tons), and hay (2000 tons). It can be seen that cotton is the crop with the largest amount of PM_{10} emissions, contributing 46% to the state's total emissions (19,280 tons) due to field operations. There are an estimated 400 cotton gins in the state of Texas, with four million bales produced annually. For each bale produced, 3.05 pounds of total suspended particulates (TSP) are emitted, with fifty percent of that being PM_{10}. Cotton gins emit 3,050 tons of PM_{10} per year, which is nearly one third of the calculated emissions from cotton field operations. Notice, however, if the AP-42 equation would have been used to calculate emissions, 900,000 tons of PM_{10} would be reported as being emitted from cotton field operations annually. This is one example of why better emission factors and estimation methods are needed.

Clean Air Act

The 1990 federal Clean Air Act Amendments brought about a dramatic change in the regulation of air pollution. The section having the most impact on cotton growers is that which deals with particulate matter. The Amendments contain additional provisions for PM_{10} nonattainment areas. The National Ambient Air Quality Standards (NAAQS) were established to protect the public's health and well being. The standard for PM_{10} is set at 150 g/m^3. Currently, if an area exceeds this standard more than three times in three years, the area is initially classified as moderate nonattainment. Those areas classified as moderate have six calendar years after the area's designation as nonattainment to reach attainment. The [EPA] Administrator has the power to reclassify an area as serious by two methods: before the attainment date and upon failure to attain. If the Administrator determines that the area cannot practicably attain the standard for PM_{10} by the attainment date, he can reclassify the area as serious. Also, if at the end of six years, the area has not yet reached attainment, it will be reclassified as serious. A serious area has ten calendar years to reach attainment.

If an area fails to reach attainment by the deadline, the state in which the area is located must submit plan revisions that provide for attainment of the PM_{10} NAAQS, as well as annual five percent reductions in PM_{10}. If the EPA finds a state has failed to submit an approvable state plan, EPA can choose to cut off federal highway funds or to require additional emissions offsets of at least two to one for new or modified sources seeking permits until the state complies. Other penalties a state can be subjected to is the withholding of any support grants for air pollution planning and control programs and Federal Implementation Plans (FIPs).

In moderate nonattainment areas, all source agricultural operations that are perceived to contribute to the ambient concentration of PM_{10} will be required to implement Reasonably Available Control Methods (RACM). In serious nonattainment areas, implementation of Best Available Control Methods (BACM) is required. However, there is no current guideline on RACM and BACM for agricultural field operations. This is another area where the emissions inventory is important.

San Joaquin Valley in California is a serious nonattainment area. This area is forced, by law, to reduce their emission of

PM_{10}. A voluntary compliance program n has been submitted to the Secretary of Agriculture by California's SAPRA. If this plan does not work, however, a mandatory plan will be imposed. This program will dictate when and how many times a farmer will be allowed into his fields. If California's emissions inventory had been calculated as Texas', the exact reductions of PM_{10} could be figured to see if a control measure is actually effective before it is imposed.

Summary

Texas Natural Resource Conservation Commission (TNRCC) uses the emissions inventory produced annually in their strategic planning. TNRCC can examine the amount of pollutants released from sources and determine who is the biggest contributor of PM_{10}. In response, TNRCC will look at that contributor as the main focus of regulation. Emissions inventories are also helpful when determining available control methods in response to the Clean Air Act Amendments of 1990. Therefore, more exact emission factors and emission estimation methods are important when calculating emissions inventory.

References

Coates, W. 1996. Particulates generated by five cotton tillage systems. Transactions of the ASAE, Vol 39(5): 1593-1598.

Flocchini, R. G., R. J. Southard, L. L. Ashbaugh, O. F. Carvacho. T. A. James, R. T. Matsumura. 1995. Evaluation of fugitive PM_{10} emissions from cotton production-1995 Annual Report. Cotton Incorporated Contract No. 95-189. Air Quality Group, Crocker Nuclear Laboratory, University of California, Davis, CA. 95616-8569

Texas Agricultural Extension Service. 1998. Crop Enterprise Budgets. College Station, TX.

Texas Agricultural Extension Service. 1999. Crop Enterprise Budgets. College Station, TX.

U. S. Department of Agriculture's National Agriculture Statistics Service. 1997. 1997 Agricultural Census. Washington, D. C.

Table 1. Cotton acreage for District 2 counties and the resulting PM_{10} emissions for the spring season.

County	Acreage	lbs. PM_{10}
BAILEY	73651	127048
BORDEN	24309	41933
CASTRO	58330	100619
COCHRAN	116568	201080
CROSBY	233538	402853
DAWSON	274472	473464
FLOYD	148345	255895
GAINES	278940	481172
GARZA	43986	75876
HALE	207674	358238
HOCKLEY	221358	381843
LAMB	175894	303417
LUBBOCK	279205	481629
LYNN	270283	466238
MITCHELL	60127	103719
PARMER	61293	105730
SCURRY	60374	104145
SWISHER	55056	94972
TERRY	220240	379914
YOAKUM	125427	216362

Table 2. Seasonal totals by district of PM_{10} field operations emissions due to cotton.

DISTRICT	Winter lbs PM10	Spring lbs PM10	Summer lbs PM10	Autumn lbs PM10
Panhandle	118443	80541	0	47377
South Plains	1494535	5156146	0	4483605
Rolling Plains	294415	235532	196277	588830
North	22228	17782	44456	44456
East	0	1627	6972	3486
Far West	1464030	170804	0	244005
West Central	0	128297	549843	274922
Central	0	56127	240546	120273
Southeast	0	26326	112824	56412
Southwest	2212	0	33173	0
Coastal Bend	33344	0	500162	0
South	25381	0	444168	253810
Totals	3,454,587	5,873,181	2,128,419	6,117,175

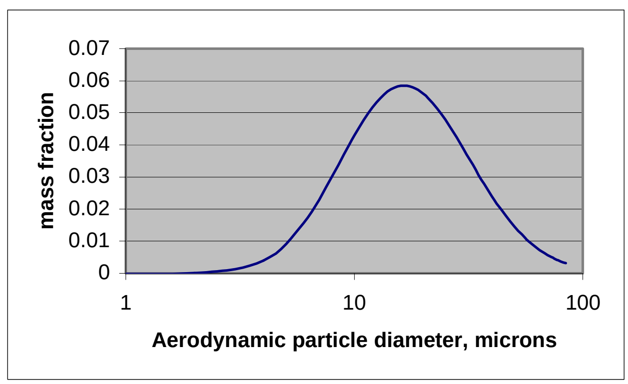

Figure 1. Graph of mass fraction versus aerodynamic particle diameter for a typical soil.