

**AN ENGINEERING ANALYSIS OF A METHOD USED TO DETERMINE PROPERTY LINE
SETBACK DISTANCES FOR COTTON GINS****J.D. Wanjura, C.B. Parnell, B.W. Shaw and R. E. Lacey****TAMU-CAAQES****College Station, TX****M. D. Buser****USDA-ARS****Lubbock, TX****D. P. Whitelock and S. E. Hughs****USDA-ARS****Mesilla Park, NM****C. B. Armijo****Mesilla Park, NM****J. Kelley Green****Texas Cotton Ginners' Association****Austin, TX****B. M. Norman****National Cotton Council****Memphis, TN****Sergio C. Capareda and Lee Hamm****College Station, TX****Abstract**

The US Environmental Protection Agency (EPA) under authority granted by the federal Clean Air Act delegates the responsibility of regulating and enforcing ambient air quality standards to the states. States are required by EPA to submit state implementation plans (SIP) detailing how a state will implement and enforce regulatory actions to ensure that the National Ambient Air Quality Standards (NAAQS) are achieved. The NAAQS list federal ambient concentration limits for six criteria pollutants including particulate matter less than or equal to 10 micrometers (μm) aerodynamic equivalent diameter (PM_{10}). The primary criteria pollutant emitted by a cotton gin is PM_{10} . State air pollution regulatory agencies (SAPRA) regulate cotton gins by requiring minor source permits under the new source review (NSR) process. When granted the NSR minor source permit, the owner/operator has permission from the state to begin construction on either a new facility or modifications to an existing facility. States have granted cotton gin pre-construction permits based on permit by rule, standard permit, or individual facility permit. Recently, the state of New Mexico developed a new tool to use in permitting cotton gins. This new tool involves a property line setback distance. The property line setback distance is the distance from the emission point to the nearest property line. The results of field sampling and dispersion modeling taken from four days identified as worst case scenarios were used to determine the required setback distance for a New Mexico gin. The ratio of the modeled concentrations to the measured concentration (using FRM PM_{10} samplers) was determined for the four days and used to correct the concentration predictions from the model. The required setback distance for the gin was determined to be 41 meters corresponding to a 12 lb/hr PM_{10} emission rate. The method used to determine this setback distance did not account for the sampler errors that occur when using FRM PM_{10} samplers to measure concentrations of PM emitted from agricultural sources. The purpose of this manuscript is to evaluate the methods used by the NMED to determine the required property line setback distance and to provide guidance based on sound science and engineering for all parties involved in the permit application process for a "permit by rule" via a minimum property line setback distance regulation. The method described in this manuscript shows that a gin emitting 24 lbs/hr PM_{10} would have a required setback distance of 58 meters if only modeling errors were accounted for. The same gin would have a required setback distance of 13 meters if both modeling errors and sampler errors were accounted for. Accounting for modeling and sampling errors results in a more appropriate minimum setback distance for cotton gins.

Background

New Source Review

In the 1977 amendments to the Federal Clean Air Act (FCAA), Congress instituted the new source review permitting program for stationary sources emitting regulated pollutants. Under the NSR requirements, states are required to include state implementation plans (SIP) for permitting new and modified stationary sources in both attainment and non-attainment areas. The EPA defines an attainment area as *an area considered to have air quality as good as or better than the national ambient air quality standards as defined in the Clean Air Act* (USEPA, 1997). Within NSR there are permitting processes for both major and minor sources. Major sources are required to obtain a prevention of significant deterioration (PSD) permit. A major source, in reference to PSD, is defined by EPA as a stationary source with the potential to emit (PTE) 250 tons per year of any regulated pollutant in an attainment area or 100 tons per year in a non-attainment area (USEPA, 1997). Cotton gins are not PSD major sources. Cotton gins, in most states, are required to obtain some type of minor source NSR permit before construction or modifications may begin on the facility.

In addition to NSR permitting, EPA requires sources to obtain a federal operating permit (a Title V permit) if the source meets or exceeds the Title V major source threshold. The PM₁₀ Title V major source classification threshold is 100 tons per year (PTE) if the facility is located in a PM₁₀ attainment area or 70 tons per year (PTE) for locations in non-attainment areas (USEPA, 1996a). Under the Title V permitting guidelines, states are required to assess fees for every ton of regulated pollutant that a facility has been permitted to emit. Most gins are not subject to Title V permit requirements.

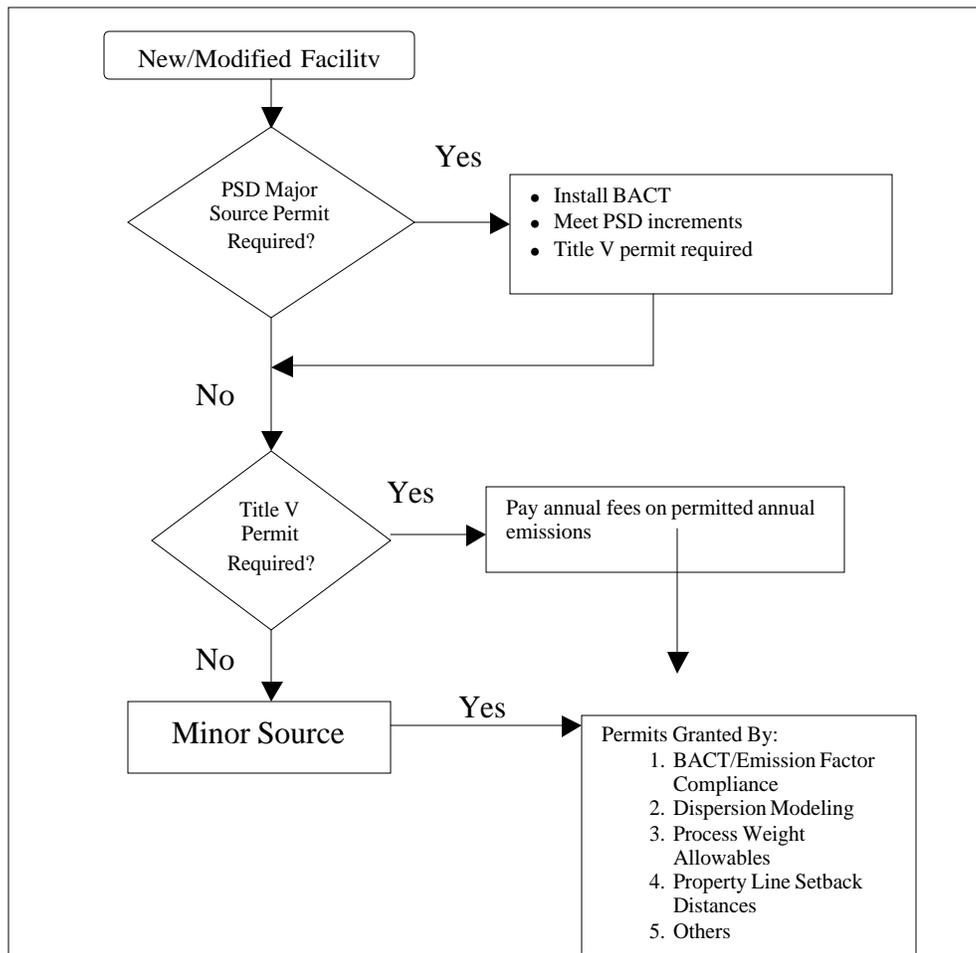


Figure 1. The basic permitting process for a new or modified stationary source of PM₁₀.*Minor Source NSR Permits*

Stationary sources of emissions are typically required to obtain minor source NSR permits or other similar authorization. A facility must obtain a minor source NSR permit if the facility has the potential to emit over 25 and less than 250 tons per year of a regulated pollutant. The purpose of a minor source NSR permit is to ensure that the construction or modification of a minor source will not preclude the state's ability to maintain air quality levels in attainment areas or improve air quality in non-attainment areas. The NSR permit also ensures that installed pollution abatement devices meet the required equipment standards. Generally, a permit allowable emission rate is stated on the permit. To be federally enforceable, an emission limit must be included in the permit.

A minor source NSR permit must be granted to a new facility prior to construction unless the facility is able to meet the requirements of a standard permit or general permit. Existing facilities proposing renovations resulting in an increase in the amount or a change in the type of emissions must obtain an amendment to their minor source NSR permit, or meet the requirements of a standard or general permit before the renovation project can begin. Facilities constructed prior to the implementation of state permitting rules are referred to as "grandfathered" facilities and historically have been exempt from state permitting requirements. Some states have eliminated the grandfathered status and require un-permitted existing facilities to obtain permits.

The criteria used to determine compliance with minor source NSR permits differ from state to state. These criteria have included (but are not limited to) any combination of the following:

- equipment standards (BACT) with published emission factors,
- visible emission limitations (opacity),
- process weight allowable tables, and
- dispersion modeling (property line concentrations).

Equipment Standards and Emission Factors

Commonly, states use equipment standards with published emission factors to determine the permit allowable emission rate. The emissions inventory is calculated by multiplying the annual number of bales ginned by the emission factor and is used to determine the maximum allowable emission rate for the source. Emission factors are specific to the type and configuration of control equipment used. AP-42 lists emission factors for TSP and PM₁₀ emissions for two cotton gin control system configurations (USEPA, 1995). The first control system configuration has high efficiency cyclones (1D3D or 2D2D cyclones) on all of the centrifugal fan exhausts and screened drums or cages on the lint cleaner and battery condenser exhausts. The second control system configuration has high efficiency cyclones on all exhausts. Table 2 shows the TSP and PM₁₀ emission rates corresponding to control system configurations.

Table 2. AP-42 emission factors for gin control system configurations one and two.

Control System Configuration	Emission Factor	
	TSP lbs./bale	PM ₁₀ lbs./bale
Configuration 1	3.1	1.2
Configuration 2	2.4	0.8

The NSR process in Texas uses equipment standards (BACT) and process weight allowable regulations to grant minor source permits. In Texas, the minimum or Baseline BACT (BBACT) equipment requirements are defined as 1D3D or 2D2D cyclones on all centrifugal (high pressure) exhausts and fine mesh screens on lint cleaner and battery condenser drum exhausts (TNRCC, 2000). The Texas BBACT configuration is similar to configuration one in table two. Texas uses emission factors that were developed for the type of cotton ginned. AP-42 emission factors are default numbers and any state is free to use their own factors, if they have emission factor numbers that they believe are more appropriate. Additional controls may be needed to meet BACT depending upon the proximity to residences, schools, businesses, etc (TNRCC, 2000). Texas emission factors account for any additional controls that may be installed.

Serious PM₁₀ non-attainment area classifications for several of the air pollution control districts in California caused many of the districts to impose strict regulations on both major and minor sources through the NSR permitting process. The San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) uses the following requirements in its NSR permitting process for cotton gins:

- daily record keeping requirements (SJVUAPCD Rule 1070, 1992),
- exhaust specific control device requirements (SJVUAPCD Rule 2201, 2002),
- exhaust specific allowable PM₁₀ emission rates (SJVUAPCD Rule 2201, 2002),
- gin total allowable PM₁₀ emission rates (SJVUAPCD Rule 2201, 2002),
- emission opacity regulations (SJVUAPCD Rule 4101, 2001),
- nuisance emissions regulation (SJVUAPCD Rule 4102, 1992),
- total particulate emissions regulation (SJVUAPCD Rule 4201, 1992), and
- process weight allowable regulations (SJVUAPCD Rule 4202, 1992).

The Federal Clean Air Act mandates BACT on all significant stationary sources of PM₁₀ in serious non-attainment areas. Cotton gins have been identified as significant sources of PM₁₀ in the SJVUAPCD. SJVUAPCD Rule 2201§3.9 defines BACT as the most stringent of the control strategies contained in any EPA approved SIP, contained in an applicable New Source Performance Standard (NSPS) or any other control strategy found to be cost effective and technologically feasible. The BACT requirements of the SJVUAPCD mandate the use of 1D3D cyclones with 2D2D inlets and D/3 trash outlets on all cotton gin exhaust points.

The emission factors used in the permitting process for the SJVUAPCD may come from any of the following sources:

- California Cotton Ginners Association Emission Factor Handbook,
- Source testing of gins applying for a permit, and
- Source testing performed by other gins with control system configurations similar to that of the gin applying for the permit.

Visible Emission Limitations (Opacity)

As an additional layer of compliance determination, some states set a visible emission limitation on the exhaust points of a cotton gin. A typical opacity limitation would be expressed in percentage of blocked visibility. Limitations from 10 to 20% opacity are common in states using this method.

Process Weight

Process weight allowable tables under SJVUAPCD Rule 4202 limit PM emissions from gins in the San Joaquin Valley. The values in the table are described by equations 1 and 2.

$$E = 3.59 * P^{0.62} \quad P \leq 30 \text{ tons per hour} \quad \text{equation 1}$$

$$E = 17.31 * P^{0.16} \quad P > 30 \text{ tons per hour} \quad \text{equation 2}$$

where:

E = rate of TSP emission in pounds per hour, and

P = process weight rate in tons per hour.

As defined in rule 4202, these equations may be used to determine the upper limit of total PM emission rates.

The SJVUAPCD also regulates total PM emissions through Rule 4201 which states that emissions concentrations may not exceed 0.1 grains per dry standard cubic foot.

In Texas, process weight allowable tables are used to establish an upper limit of the allowable emission rate for a facility. The emission rate determined using the process weight tables is compared to the predicted emissions using the emission factors calculated for the individual facility. The allowable emission rate (AER) for the facility must be lower than the limit calculated from the process weight equation. The process weight allowable tables used in Texas are described by equations 3 and 4 (TAC, 1989).

$$E = 3.12 * P^{0.985} \quad \text{for } P \leq 20 \text{ tons/hr} \quad \text{equation 3}$$

$$E = 25.4 * P^{0.287} \quad \text{for } P > 20 \text{ tons/hr} \quad \text{equation 4.}$$

The amount and type of cotton ginned impacts the level of required emissions reduction implemented at a gin. For example, it takes approximately 2200 lbs. of stripper harvested seed cotton or 1500 lbs of spindle picked seed cotton to produce one 500 lb bale of lint. Both types of cotton contain approximately 800 lbs of seed but spindle picked cotton only contains about 200 lbs of trash where stripper harvested cotton contains approximately 900 lbs of trash (Parnell et al, 1994). In Texas, a facility ginning 24 bales per hour (ginning rate) will process approximately 26.4 tons of stripper harvested seed cotton per hour and would be allowed to emit up to 65 lbs per hour (TSP). A gin (also in Texas) operating at the same ginning rate would process approximately 18 tons of spindle picked seed cotton per hour and would be allowed to emit 53.8 lbs per hour (TSP).

Under this scenario, the gin processing stripper harvested cotton would have to add control equipment such that their calculated emission rate would be less than 65 lbs/hr or 2.7 lbs/bale. Similarly, the gin processing spindle picked cotton would have to install controls such that their calculated emission rate would be less than 53.8 lbs/hr or 2.24 lbs/bale.

Dispersion Modeling

Dispersion modeling is typically used to verify that allowable emission rates from a facility will not result in off property concentrations that exceed ambient air quality standards. However, inaccuracies in the concentration predictions often dissuade regulators from using these modeling techniques. Williams et al (1996) reported that the concentration predictions down wind from low level point sources (such as cotton gins) could be in error by as much as 2.5 times.

The dispersion model recommended by the EPA for use in modeling sources such as cotton gins is the Industrial Source Complex Short Term version 3 (ISCST3). ISCST3 requires the following basic inputs:

- facility/source dimensions,
- property boundaries,
- meteorological data, and
- source emission rates.

The emission rate and predicted concentrations are directly related. Thus, the emission rate resulting in off property concentrations at the regulatory limit is the maximum emission rate that the facility is allowed to emit if dispersion modeling is used as the indication of compliance. This indicates that even if the ginning rate increases, the emission rate must stay constant for the gin to meet off property concentration limits. The effect of these results is that as the ginning rate increases, the emission factor (lbs of TSP or PM₁₀ per bale) decrease to meet regulatory concentration limits. The use of dispersion modeling often results in unrealistic emission rates from low level point sources.

Objectives

The objectives of this manuscript are 1) evaluate the methodology used by the NMED in the development of the required property line setback relationship, and 2) provide guidance based on sound science and engineering to all parties involved in the permitting process using required property line setbacks.

New Mexico

In 2003, there were only six gins operating in New Mexico. Most of these gins were constructed prior to the New Mexico Air Quality Control Act of 1978. New Mexico does not have a “grandfather” clause exempting facilities that existed prior to 1978 nor does the State require operating permits. The 1978 Act only requires permits for new construction. In 1991, a new gin was constructed south of Las Cruces, NM that required a construction permit that showed compliance with state and federal particulate emission regulations. The emission factors used in the engineering analysis for the permit were incorrect and resulted in the 18 bale per hour gin being permitted for 9.8 lbs/hr TSP and 4.6 lbs/hr PM₁₀. In 1994, the State of New Mexico conducted stack sampling to determine the gin’s compliance with the construction permit and determined that the gin was in violation of its permitted particulate emission rate. The permit

allowable emission rate (using AP-42 TSP emission factors) should have been 55.8 lbs/hr corresponding to a 18 bale per hour ginning rate. Using this corrected emission rate, the off property concentration predictions (using ISCST3) were in excess of the state AAQS. The gin's PM₁₀ emission rate (using AP-42 emission factors) was 21.6 lbs/hr. The off property PM₁₀ concentration predictions using ISCST3 were in excess of the NAAQS. The facility was found to be in violation of its construction permit and was issued a notice of violation. In 1995, the gin then applied for a revised permit using AP-42 emission factors. Subsequent dispersion modeling by the State of New Mexico showed that the gin plant's revised emission factors resulted in a predicted exceedence of state and federal emission concentrations at the boundary line using ISCST3. Several years of negotiation between the state and the ginning industry on how to permit the gin and show compliance with state and federal particulate emission requirements then followed.

In 2003 the 1978 New Mexico Air Quality Control Act was amended by law to state that New Mexico may not deny an application for a cotton gin construction permit if the applicant proposes, "use of the best system of emissions reduction currently in use by cotton gins in the United States, as specified by regulation of the environmental improvement board", and the cotton gin emits 50 tons per year or less of a pollutant subject to ambient air quality standards. Also in 2003, field sampling at the gin during the ginning season was conducted using federal reference method (FRM) PM₁₀ samplers. The field sampling study plan was reviewed and approved by the EPA. Four FRM PM₁₀ samplers were deployed, one to the north, south, east, and west of the gin to measure 24-hour PM₁₀ concentrations on a one in three day schedule. A meteorological data station was located at the south sampler location to gather weather data during the sampling periods. The meteorological station recorded wind data (speed and direction) at 2 meters above the ground.

In 2004, in response to the amended 1978 New Mexico Air Quality Control Act and the 2003 boundary line emissions study, the NMED developed a new regulation (NMAC, 2004) to permit gins using property line setback distances as one of the permit conditions. The regulation states that a gin meeting the prescribed control equipment and operational requirements, and achieving a pre-defined minimum setback distance between the gin and the property line cannot be denied a permit. This regulation can be applied to regulate gins that emit up to 50 tons of PM₁₀ per year.

The method used to develop the relationship between the required property line setback distance and the ginning rate was carried out under the following assumptions (NMED, 2004):

- concentrations measured at the sampler locations represent the maximum impact of the gin emissions and are most likely over estimations due to the inclusion of background concentrations,
- the dispersion model may not accurately predict the short term concentrations at the sampler locations, but may still be used to estimate the change in concentration over some area,
- concentrations measured on days with high wind events are not representative of normal conditions,
- only concentration data from the south and east samplers is used because those samplers are generally considered to be downwind, and
- the background concentration used in the analysis is 18 µg/m³ representing the average concentration measured at the east sampler when the gin is not in operation.

After the field sampling study was completed, an analysis of the meteorological data indicated that there were twelve days from the ginning season considered to be calm days. The PM₁₀ emission rate from the gin (calculated using AP42 emission factors and the average daily ginning rate) for each of the twelve days was used in ISCST3 to model the concentrations down wind from the gin. The background concentration (18 µg/m³ PM₁₀) was added to the modeled concentrations. Plotting the concentrations versus downwind distance, the maximum concentrations at each downwind distance were identified. A regression analysis of the maximum concentrations versus distance indicated that an exponential best-fit line yielded the highest correlation. The general form of the equation is shown by equation 5.

$$Y = C_1 + C_2 * \exp\left(\frac{-X}{C_3}\right) + C_4 * \exp\left(\frac{-X}{C_5}\right) \quad \text{equation 5}$$

where:

Y = concentration at down wind distance X ($\mu\text{g}/\text{m}^3$ PM₁₀),
 C_{1,2,3,4,5} = day specific regression coefficients,
 X = downwind distance (meters).

A listing of the regression coefficients for the four days is available in the Air Quality Monitoring Study Report for Cotton Gins (NMED, 2004).

ISCST3 is known to over estimate true PM concentrations from low-level point sources (cotton gins). A correction for this over estimation (using field data) was made by the NMED by dividing the concentration found using equation 5 by the correction ratio defined in equation 6.

$$\tau = \frac{C_{ISCST3}}{C_{SAMPLER}} \quad \text{equation 6}$$

where:

τ = model over prediction correction factor,
 C_{ISCST3} = PM₁₀ concentration predicted by ISCST3 at the sampler location ($\mu\text{g}/\text{m}^3$),
 C_{SAMPLER} = PM₁₀ concentration measured by the sampler ($\mu\text{g}/\text{m}^3$).

The correction ratios for each of the twelve days were calculated. The four days with the highest correction factor were chosen for further analysis. The four days identified were November 2, 5, 23, and December 17, 2003. The correction ratios for each of these days were 1.5, 3, 7, and 2.5 respectively.

Using the corrected model concentrations, the required setback distance was determined as the distance at which the concentration down wind from the gin does not exceed $150 \mu\text{g}/\text{m}^3$ (PM₁₀). The required setback distance for the gin was determined to be 41 meters using equation 5 with the coefficients from November 2. The required setback distance for the other days was zero. Figure 2 shows the PM₁₀ concentrations versus downwind distance for November 2, 5, 23, and December 17.

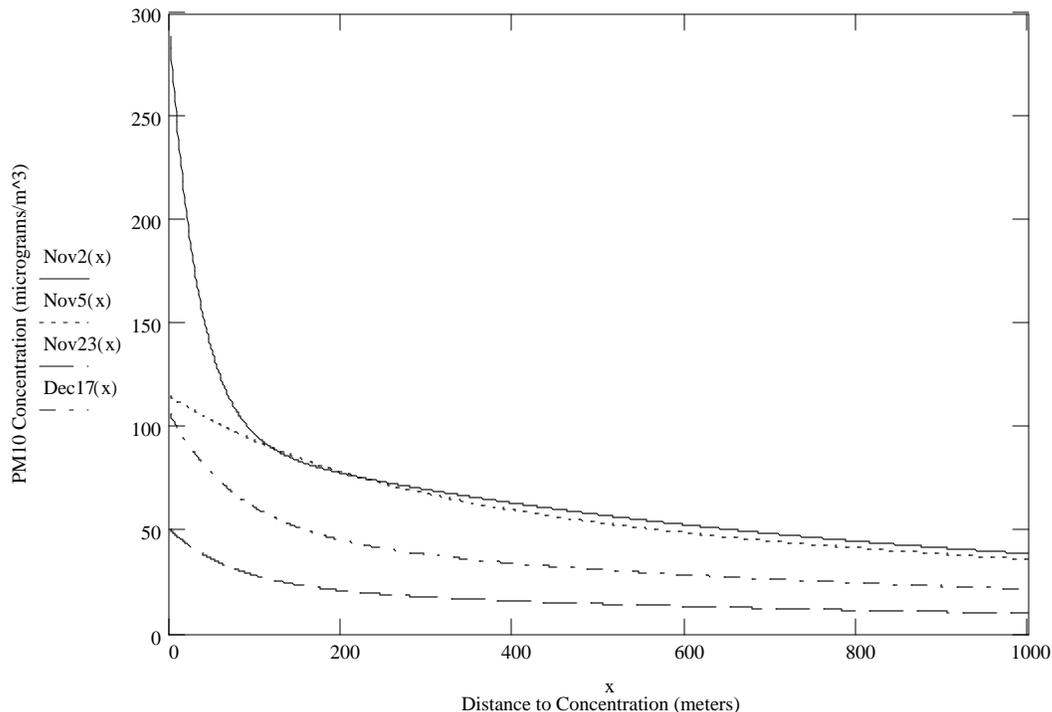


Figure 2. PM₁₀ concentration versus down wind distance for November 2, 5, 23, and December 17, 2003. The required setback distance for the gin is 41 meters based on November 2. The concentration contribution from the gin on the other three days was negligible resulting in a zero required setback distance.

The New Mexico ambient air quality standards (AAQS) limit TSP concentrations as well as PM₁₀ (NMAC, 2002). The TSP AAQS limit in New Mexico is $150 \mu\text{g}/\text{m}^3$. In order to determine the TSP concentrations

from the measured PM₁₀ concentrations, the TSP/PM₁₀ concentration ratio was taken at an elementary school several miles from the gin. The TSP/PM₁₀ ratio was found to be 1.32:1. Similar plots to those seen in figure one were developed by scaling the PM₁₀ concentrations by the TSP/PM₁₀ ratio.

Setback distances for emission rates other than the original emission rates from the four days selected for further analysis were determined by scaling the corrected model concentrations by the emission rate adjustment factor (ER_A/ER_O). Equation 7 is used to determine the corrected downwind PM₁₀ concentrations from a gin.

$$Y' = \frac{Y}{\tau} * \frac{ER_A}{ER_O} \quad \text{equation 7}$$

where:

Y' = adjusted concentration down wind from a gin (µg/m³),

ER_{A, o} = actual and original gin emission rates (lbs PM₁₀/hr).

The original emission rates from the gin were calculated by multiplying the AP-42 PM₁₀ emission factor of 1.2 lbs per bale by the average hourly ginning rate from the gin. The original emission factors for November 2, 5, 23, and December 17 were 12, 16.8, 21.6, and 10.8 lbs PM₁₀/hr respectively.

The results from November 2nd yield the largest setback distances for any of the four days, for any emission rate. Therefore, the November 2nd results may be considered to represent the upper range of the possible setback distances that the NMED could include in the regulation. Figure 3 shows the setback distance versus PM₁₀ emission rate relationship resulting from solving equation 7 with the regression constants listed in the NMED report (NMED, 2004) for November 2nd. The relationship presented in figure 3 was not presented by NMED, but is included here to illustrate the process (used by NMED) of determining the setback distance versus PM₁₀ emission rate. At this time the regulation has not been finalized.

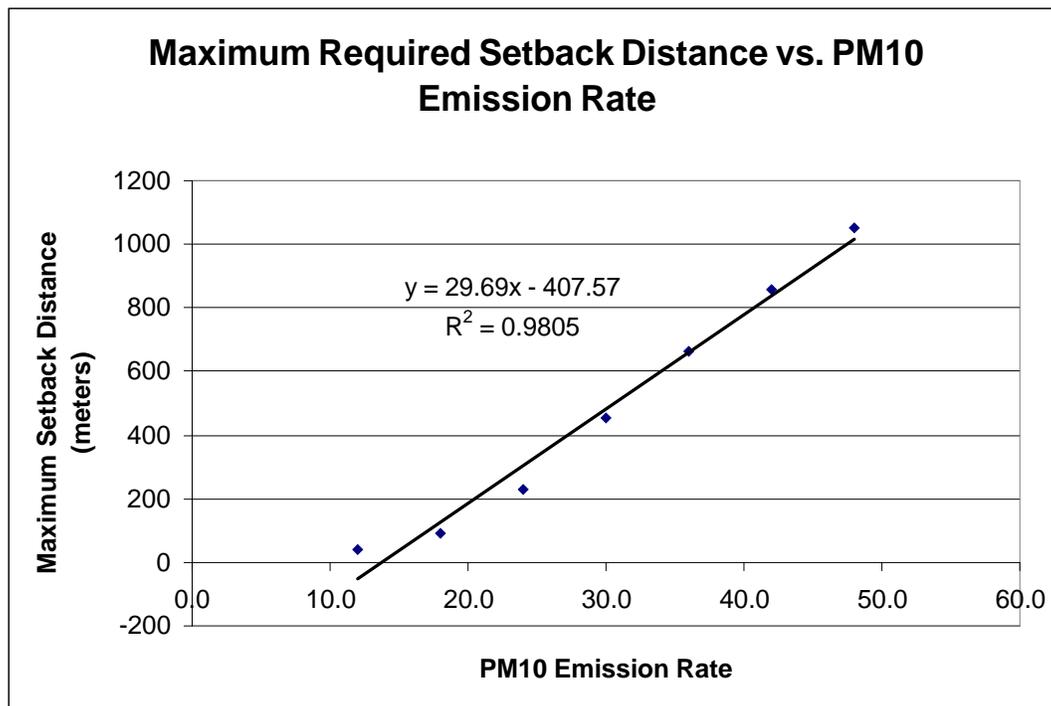


Figure 3. The setback distance (meters) versus PM₁₀ emission rate (lbs. PM₁₀/hr) relationship established from November 2nd data.

Gins which do not require a setback distance because of a low emission rate will be required to comply with a 10-foot (3.05 meters) minimum setback.

Analysis and Recommendations

TSP versus PM₁₀ Regulation

The NAAQS set the 24-hour average ambient PM concentration limit at 150 $\mu\text{g}/\text{m}^3$ PM₁₀. This primary national standard was established to protect public health. The New Mexico AAQS limiting ambient TSP concentrations to 150 $\mu\text{g}/\text{m}^3$ is an effectively much more stringent regulation than the NAAQS. The particle size distributions of PM emitted from agricultural sources typically have mass median diameters (MMD) that range from 15 to 25 μm AED with geometric standard deviations (GSD) ranging from 1.5 to 2.0 (Redwine et al, 2001). This means that, at most, 25 percent of the PM emitted from agricultural sources is PM₁₀. If a cotton gin were to be held to a TSP concentration limit of 150 $\mu\text{g}/\text{m}^3$, in effect, it would be held to a 38 $\mu\text{g}/\text{m}^3$ PM₁₀ ambient concentration limit. This excessively stringent regulation would result in the closure of many gins due to the inability to meet air quality regulations. Thus states should be judicious when setting PM concentration limits to levels more restrictive than the national standards.

Concentration Prediction Errors by ISCST3

ISCST3 is a Gaussian dispersion model that uses the Pasquill-Gifford atmospheric stability classification system to describe the plume spread characteristics downwind from the source. Equation 8 is the Gaussian equation used by ISCST3 to predict downwind PM concentrations.

$$C = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{1}{2} \frac{y^2}{\sigma_y^2}\right) \left\{ \exp\left(-\frac{1}{2} \frac{(z-H)^2}{\sigma_z^2}\right) + \exp\left(-\frac{1}{2} \frac{(z+H)^2}{\sigma_z^2}\right) \right\} \quad \text{equation 8}$$

where:

- Q = steady state concentration at a point (x, y, z) ($\mu\text{g}/\text{m}^3$);
- ER = PM emission rate ($\mu\text{g}/\text{sec}$),
- u = average wind speed at stack height (m/s);
- y = horizontal distance from plume centerline (m);
- z = height of receptor with respect to ground (m);
- H = effective stack height (H=h+ Δ h, where h = physical stack height and Δ h = plume rise)(m);
- σ_y , σ_z = horizontal and vertical plume dispersion coefficients, m.

The plume dispersion coefficients (σ_y and σ_z) are a function of the atmospheric stability and the distance from the source to the receptor. Turner (1994) states that the data used to develop the plume spread parameters were developed using ten-minute average data. This implies that the concentrations found using equation 8 are ten-minute average concentrations. ISCST3 assumes that the concentrations are sixty-minute average concentrations. This assumption by the developers of ISCST3 results in the over-prediction of downwind concentrations by an average factor of 2.5 (Zwicke, 1998; Beychok, 1996). Work by Stiggins et al (2003) indicate that the over prediction factor is a function of atmospheric stability class. Wanjura et al (2003) showed that the over prediction factor is a function of both atmospheric stability class and downwind distance. For regulatory purposes, an over prediction factor of 2.5 is appropriate to yield accurate yet conservative estimates of downwind PM concentrations using ISCST3.

FRM PM₁₀ Sampler Errors

A number of samplers have been designated as PM₁₀ reference or equivalent method samplers (USEPA, 2001). Mass concentration measurements with a reproducibility close to 10% have been obtained with collocated samplers of identical design (USEPA, 1996b). However, field studies of collocated EPA approved PM₁₀ samplers have shown substantial errors under certain conditions. These errors result from: 1) allowing a tolerance of +/- 0.5 μm for the 10 μm cutpoint; 2) cutpoint deviations beyond the established tolerances associated with various field application parameters; 3) inadequate restrictions on internal particle bounce; 4) surface overloading; 5) soiling of certain types of PM₁₀ inlets; and 6) losses of semi-volatile components. According to the USEPA (USEPA, 1996b), the most significant performance flaws have combined to produce excessive (up to 60%) mass concentration errors.

Wang et al. (2003) evaluated Graseby-Andersen FRM PM₁₀ samplers in a dust chamber where the samplers were exposed to treatments of dispersed cornstarch, fly ash, and aluminum oxide. Wang et al. (2003) reported that the Graseby-Andersen FRM PM₁₀ sampler over-sampled the dispersed cornstarch, fly ash, and

aluminum oxide by an average of 89%, 41%, and 14%, respectively. Wang et al. (2003) also reported that the average cutpoint and slope for the Graseby-Andersen sampler was 12.5 μm and 1.3 when sampling cornstarch; 17.7 μm and 1.5 when sampling fly ash; and 17 μm and 1.5 when sampling aluminum oxide. Wang et al. (2003) concluded that the Graseby-Andersen FRM PM₁₀ sampler's fractional efficiency curve shifted to the right when sampling dust with smaller MMDs.

Buser (2004) conducted extensive mathematical simulations to illustrate the theoretical errors associated with EPA approved ambient PM₁₀ samplers. In this study, Buser (2004) summarized the results with a scenario that assumed EPA approved PM₁₀ ambient air samplers are setup to monitor two commercial operations. These samplers were assumed to have performance characteristics described by a d_{50} of 10.5 μm and a slope of 1.6 (both parameters are within the performance criteria defined by EPA). It was assumed that one operation was a power plant and was emitting PM (sampled by the PM₁₀ sampler) that can be described by a lognormal distribution with a MMD of 5 μm and a GSD of 1.5. The second operation was assumed to be an agricultural operation emitting PM (sampled by the PM₁₀ sampler) described by a lognormal distribution with a MMD of 20 μm and a GSD of 1.5. Further, the PM₁₀ sampler used to monitor each of the operations was assumed to measure 100 $\mu\text{g}/\text{m}^3$. Results from this scenario indicated that 96% of the PM emitted from the power plant corresponded to particles with a diameter of 10 μm or smaller (true PM₁₀) and that the PM₁₀ sampler under-estimated the true PM₁₀ concentration by 8%. For the agricultural operation, results indicated that 4.37% of the emitted PM corresponded to PM with a diameter of 10 μm or smaller and that the PM₁₀ sampler over-estimated the true PM₁₀ by 245%. Based on this scenario, Buser (2004) concluded that the two operations are not being equally regulated (i.e. 109% of the PM emitted from the power plant and measured by the PM₁₀ sampler corresponds to PM less than 10 μm ; whereas only 29% of the PM from the agricultural operation and measured by the PM₁₀ sampler corresponds to PM less than 10 μm).

Although numerous reports have discussed the errors associated with current EPA approved ambient PM₁₀ samplers, the EPA still requires the use of the Federal Reference Method (FRM) or equivalent method PM₁₀ samplers for PM₁₀ monitoring studies. Typically, the data required to determine true PM₁₀ concentrations are not available. In this situation, the true PM₁₀ concentrations can be determined by:

1. assuming MMD and GSD values that correspond to the particle size distribution of the dust being exposed to the PM₁₀ sampler and also assuming values for the cut-point and slope of the sampler to use in the theoretical model described by Buser et al (2001) to determine the over sampling rate of the FRM PM₁₀ sampler, or
2. rely on previous research results that establish a relationship between FRM PM₁₀ sampler concentrations and true PM₁₀ concentrations.

Use of method one should be limited due to the number of assumptions required, which can lead to substantial errors when inappropriate estimates for MMD, GSD, sampler cut-point or sampler slope are used. Capareda et al. (2005) conducted a study evaluating sampler and true PM₁₀ concentrations downwind from a cotton gin. The relationship developed by Capareda et al (2005) is shown in equation 9 and is used in the analysis presented in this manuscript.

$$PM10_{true} = 0.55 * PM10_{sampler} \quad \text{equation 9}$$

where:

$$PM10_{true, sampler} = \text{true and measured concentrations of PM}_{10} (\mu\text{g}/\text{m}^3).$$

Adjusted Setback Regulation Example

Often air pollution regulations are developed from data taken from worst-case scenarios. Similarly, the four days identified by the NMED for further analysis were considered to be the days that produced the worst-case scenarios for concentration contribution by the gin. Of the four days used by NMED, November 2nd produced the most conservative estimates of required property line setback distance, from a regulatory standpoint, for any emission rate. Air pollution regulations must be conservative in nature to protect public health; however, they must not be overly conservative thereby precluding the ability for industries to operate. The following example illustrates how corrections for concentration prediction errors (resulting from modeling using ISCST3) and for over sampling errors (introduced by FRM PM₁₀ samplers) can be made resulting in an accurate yet conservative regulation based on property line setbacks.

The relationship between concentration (Y) and distance (X) for a gin with hourly PM₁₀ emission rate, ER, on November 2nd is described by equation 10.

$$Y_{Nov2} = \left(29.8 + 290.1 * \exp\left(\frac{-X}{34.3}\right) + 113.1 * \exp\left(\frac{-X}{721}\right) \right) * \left(\frac{ER}{12}\right) \quad \text{equation 10}$$

where:

Y_{Nov2} = concentration predicted at downwind distance X on November 2nd ($\mu\text{g}/\text{m}^3$),

ER = gin emission rate in lbs of PM₁₀ per hour (NMED, 2004).

The scaling of concentrations at any X distance by the ER/12 term is possible because of the direct relationship between concentration and emission rate described in equation 8. This term is used because the gin emission rate for November 2nd was 12 lbs per hour (PM₁₀).

Applying the recommended correction factor to account for concentration prediction errors from ISCST3, and applying equation 9 to account for over sampling errors, equation 11 is obtained.

$$Y_C = \left\{ \frac{Y_{Nov2}}{2.5} \right\} * 0.55 \quad \text{equation 11}$$

where:

Y_C = average concentration at downwind distance X corrected for model prediction errors and over sampling errors ($\mu\text{g}/\text{m}^3$),

2.5 = recommended correction factor for modeling over prediction errors,

0.55 = constant used in equation 12 to relate measured PM₁₀ concentrations using FRM PM₁₀ samplers to true PM₁₀ concentrations.

Figure 4 shows the plot of equations 10 and 11 along with the plot of equation 10 corrected for model errors only (EQ10MC) using an ER of 24 lbs PM₁₀ per hour.

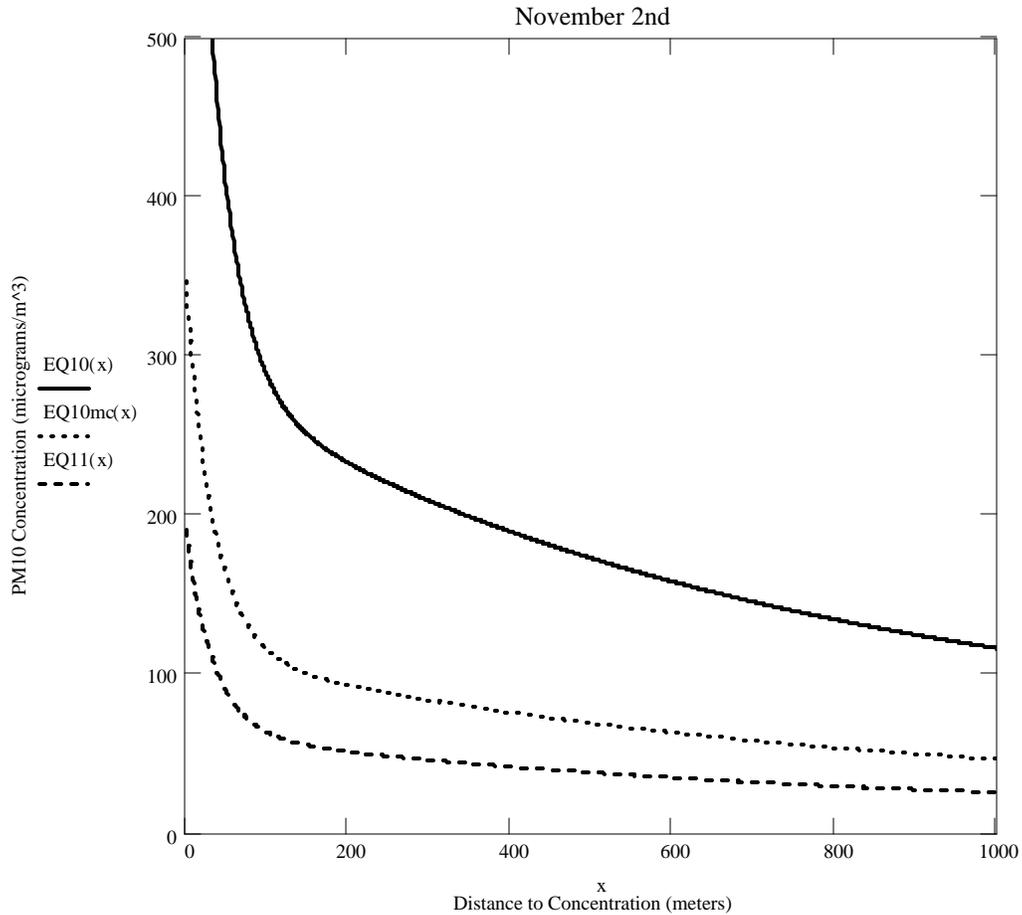


Figure 4. Concentration versus distance plots for equation 10, equation 10 corrected for model errors only, and equation 11 using the regression coefficients for November 2, 2003. The emission rate used was 24 lbs per hour (PM₁₀).

Correcting the original model concentration predictions for modeling errors and sampler errors results in a required setback distance of 13 meters for November 2nd.

Solving equation 11 for the required setback distance using several PM₁₀ emission rates ranging from 12 to 72 lbs per hour yields the following relationship between required setback distance and hourly PM₁₀ emission rate.

$$RSBD = 3.9(ER) - 100 \quad \text{equation 12}$$

where:

RSBD = required setback distance (meters).

It should be noted that for gin emission rates resulting in a required setback distance less than 3 meters, the required setback distance should be 3 meters (10 feet). Figure 5 shows the plot of the required setback distance versus PM₁₀ emission rate.

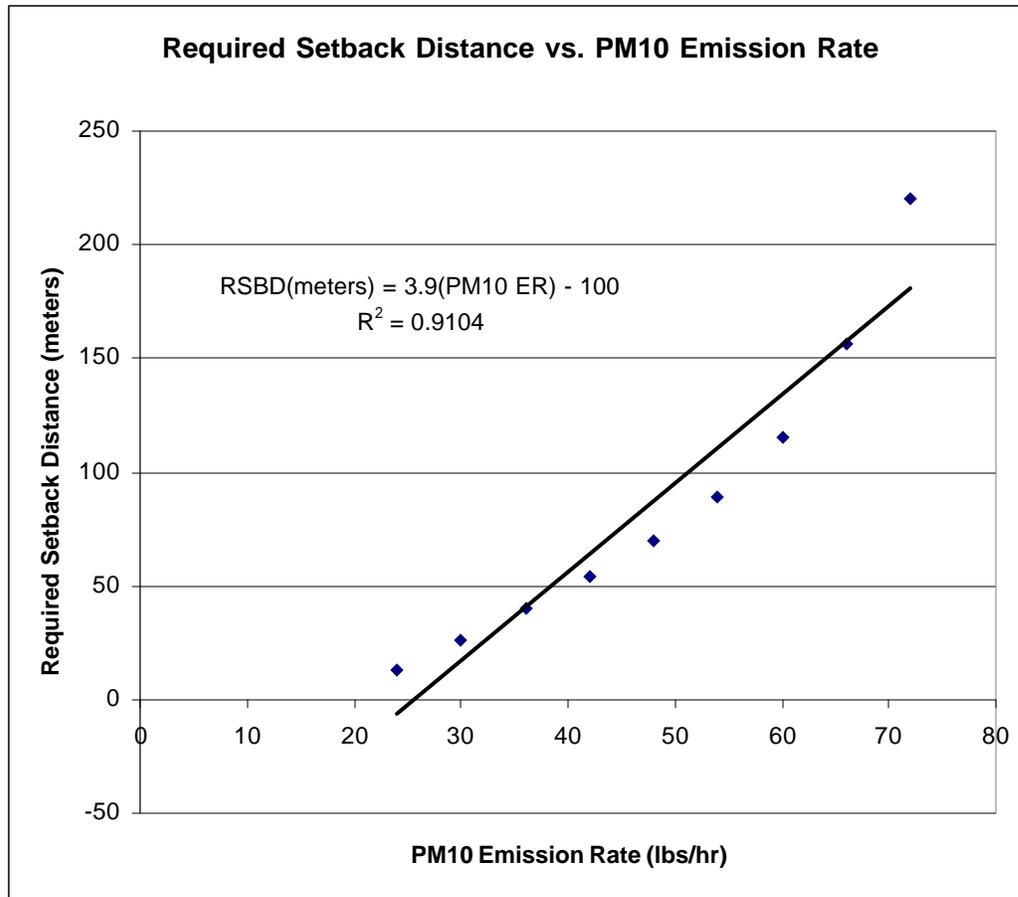


Figure 5. Plot of required setback distances versus PM₁₀ emission rates using downwind concentration predictions corrected for modeling errors and FRM PM₁₀ sampler errors.

These results indicate that a gin must emit over 26.4 lbs of PM₁₀ per hour to be required to have a setback distance over the minimum 3 meter setback. Using the AP-42 emission factor of 1.2 lbs per bale (PM₁₀), a gin emitting 26.4 lbs per hour would be ginning approximately 22 bales per hour.

Conclusions

Particulate matter concentration regulations limiting property line TSP concentrations to 150 µg/m³ impose overly stringent air quality restrictions on agricultural sources. A property line TSP concentration limit of 150 µg/m³ in effect limits property line PM₁₀ concentrations to 38 µg/m³. There is no national standard that regulates TSP concentrations and thus no basis for such a regulation.

The most common method used to grant minor source NSR permits is through the use of a combination of equipment standards along with some method to limit total emissions such as process weight allowable tables. The regulation of cotton gins based on required property line setback distances may be appropriate if the method used to determine the required setback distances is founded on sound science. The primary findings of the method analyzed in this manuscript include the following:

- The NMED recognized that the current EPA approved dispersion model for low-level point sources (ISCST3) over predicts by a factor ranging from 1.5 to 7. New Mexico is one of the few states that recognizes this problem and has attempted to correct for it.
- Worst-case results from four days (November 2, 5, 23, and December 17) were used by NMED to develop the relationship between the required property line setback distance and PM₁₀ emission rate.

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- Using a PM₁₀ emission rate of 24 lbs per hour with the recommended model correction factor of 2.5 on November 2nd, the required setback distance is 58 meters (190 feet).
- Correcting for over sampling errors, the required setback distance for November 2nd is reduced to the minimum setback of 13 meters (43 feet).
- Correcting for both modeling errors and over sampling errors, the PM₁₀ emission rate threshold at which a gin would be required to have a setback distance over the 3 meter minimum is 26.4 lbs per hour. Using the AP-42 PM₁₀ emission factor of 1.2 lbs per bale, this threshold would be reached by a gin processing 22 bales per hour.

Disclaimer

Mention of a trade name, propriety product or specific equipment does not constitute a guarantee or warranty by the United States Department of Agriculture and does not imply approval of a product to the exclusion of others that may be suitable.

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