A NEW METHOD FOR PREDICTING AMBIENT PARTICLE CONCENTRATIONS DOWNWIND FROM COTTON GINS

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Abstract

This paper will describe a dispersion model that more accurately predicts downwind concentrations of particulate from agricultural operations. The model currently approved for use by the EPA (ISC Screen3) and the proposed model, Classical Gaussian Dispersion (CGD), are based upon the Gaussian diffusion equations. A simulation program was written to develop an equation that could be used to calculate longer time averages. The CGD model incorporates this equation. With the use of this equation the one-hour and 24-hour average concentrations can be calculated once the 10-minute concentration is obtained. A procedure has also been developed to assist in the validation of the CGD model. This procedure was used to compare actual **measured** concentrations to **predicted** concentrations from the CGD and ISC. The ultimate goal of this project is to have the CGD model approved by EPA Region VI for future use in the regulation of air pollution from agricultural operations.

Introduction

Since air dispersion modeling has become such a significant part of the regulatory process, it is essential to have a model that will accurately predict the concentration of pollutants downwind from the source. One particular model being used for this purpose is the Industrial Source Complex (ISC) Screen3, which is based upon Gaussian diffusion. (EPA, 1986) All ISC programs are based upon Gaussian diffusion. The Gaussian model is the most popular basis for determining the impact of nonreactive pollutants. (EPA, 1986) This model can be used to estimate the ground level concentrations downwind in the plume from a source with a specific emission rate. (Gifford, 1975) The Gaussian plume can be used to target a point source such as a factory smokestack and predict its concentration downwind. A coordinate system is incorporated where the origin is placed at the base of the smokestack with the *x* axis aligned in the downwind direction. "The contaminated air stream (normally called a plume) rises from the smokestack and then levels off to travel in the *x* direction and spread in the *y* and *z* directions as it travels. For Gaussian plume calculations, the plume is assumed to be emitted from a point with coordinates (0,0,H) where H refers to the effective stack height, which is the sum of the physical stack (h), and the plume rise (Δh)." (De Nevers, 1995) The Gaussian dispersion equation for determining ground-level concentrations under the plume centerline is as follows:

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

where

C = ten minute concentration (μg/m^3),
Q = emission rate (μg/s),
π = 3.141593,
u = stack height wind speed (m/s),
σ_y = lateral dispersion parameter (m),
σ_z = vertical dispersion parameter (m),
z = receptor height above ground (m), and
H = plume centerline height (m).

"A major problem with the Gaussian dispersion equation is defining what the calculated concentration *C* represents when using Pasquill's dispersion coefficients. D. B. Turner states that *C* represents a 3- to 15-minute average; an American Petroleum Institute dispersion modeling publication believes *C* represents a 10- to 30-minute average; S. R. Hanna and P. J. Drivas believe *C* is a 10-minute average; and others attribute averaging times from 5 minutes to 30 minutes. Most agree on a range of 10 minutes to 15 minutes. However, many Environmental Protection Agency computer models used to determine regulatory compliance assume that the Gaussian dispersion equation yields 60-minute average concentrations. Assuming that the Gaussian dispersion equation yields 60-minute values rather than 10-minute values constitutes a built-in over-prediction error that may be as large as 2.5." (Beychok, 1996)

The most popular EPA approved computer model used by State Air Pollution Regulatory Agencies (SAPRAs) to predict downwind concentrations of nonreactive pollutants is ISC3. ISC3 includes the short term (ST), long term (LT), and Screen versions. ISC Screen3 is the model used by SAPRA permit engineers. In Screen3, the concentration estimate can be found for each of the plume heights computed. This value is considered the maximum 1-hour ground-level concentration due to emissions from the stack in question. To obtain a concentration estimate for an averaging time greater than one hour (C_p), the 1-hour value (C) is multiplied by an appropriate factor, r. (Eq. 2) "The numbers in parentheses are recommended limits to which one may diverge from the multiplying factors representing the general case. For example, if aerodynamic downwash or terrain is a problem at the facility or if the emission height is very low, it may be necessary to increase the factors (within the limits specified in parentheses). On the other hand, if the stack is relatively tall and there are no

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terrain or downwash problems, it may be appropriate to decrease the factors." (EPA, 1992)

$$C_p = r\ C \tag{2}$$

where

Averaging Time	Multiplying Factor (r)
3 hours	0.90 (± .10)
8 hours	0.70 (± .20)
24 hours	0.40 (± .20)
Annual	0.08 (± .02)

"Information in several references indicates that effects of sampling time are exceedingly complex. If it is necessary to estimate concentrations from a single source for the time intervals greater than a few minutes, the best estimate apparently can be obtained from:

$$x_s = x_k\ (t_k/t_s)^p \tag{3}$$

where x_s is the desired concentration estimate for the sampling time, t_s; x_k is the concentration estimate for the shorter sampling time, t_k, (probably about 10 minutes); and p should be between 0.17 and 0.2. However, these factors are probably best for sampling times less than 2 hours." (Turner, 1970) To obtain average concentration estimates beyond 10 minutes Hino developed the following relationship in 1968:

$$C_t = C_{10}\ (10/t).5 \tag{4}$$

where

t = averaging time (min) and

C_t = concentration for averaging time t. (Cooper and Alley, 1994)

The Hino Model has been validated for concentration estimates up to 5 hours. For example, once the 10-minute concentration (C_{10}) is obtained from Equation (1), Hino's relationship can be used to predict the concentration estimate for averaging times of 1 to 5 hours. Notice that Equations (3) and (4) are practically identical. The only difference being the power law coefficient. In Equation (4), Hino set the value of the power law coefficient to be .5. Turner states that in Equation (3) the power law coefficient can range from .17 to a value of 0.2. The State Regulatory Agencies will determine compliance based on the National Ambient Air Quality Standards (NAAQS). Currently, the NAAQS for particulate matter less than 10µm, (PM_{10}) is $150 \mu g/m^3$. There must be a method available for converting the 10 minute concentration to a 24-hour average since the NAAQS for PM_{10} is based on a 24-hour average.

The current method of using ISC Screen3 results in inaccurate (excessively high) predictions of downwind concentrations. Any method used to model air quality should be conservative in nature. However, an extremely conservative prediction of property line concentrations used as a permitting tool could result in unjustified, mandated controls on an industry. Therefore, it is essential that a new model be developed for the purpose of **accurately** predicting downwind concentrations when compared to ISC Screen3.

EPA (1986) states that, "The 1980 solicitation of new or different models from the technical community and the program whereby these models are evaluated, established a means by which new models are identified, reviewed and made available in the guideline. There is a pressing need for the development of models that more realistically simulate the physical and chemical process in the atmosphere and that more reliably estimate pollutant concentrations. Thus, the solicitation of models is considered to be continuous."

Objectives

A method or model known as Classical Gaussian Dispersion (CGD) was developed for predicting ambient concentrations of particulate downwind from cotton gins. This model simply uses the well known Gaussian dispersion equation to estimate the 10-minute concentration and incorporating appropriate power law coefficients (Eq. 4) to estimate concentrations for averaging time t. The need to obtain a longer time average from the models predicted 10 minute concentration still remained once the model was developed. One of the ultimate goals of this research is to have the completed CGD model approved by EPA Region VI for future use in the regulation of air pollution from agricultural operations. This CGD model could be used by SAPRA permit engineers to support the current methods of regulating air pollution from cotton gins. Therefore, the direct objectives for this research were:

(1) To determine an appropriate time average concentration equation that can be used to estimate the 24-hour concentrations of PM_{10} and

(2) To develop a method for validation of the new model.

Procedures

Development of Power Law Coefficient Utilized in CGD

"A longer time-averaged concentration would be expected to be less than a short time-average, owing to wind shifts and turbulent diffusion." (Cooper and alley, 1994) This variability in wind speed and wind direction accounts for a 10 minute concentration being larger than a 1-hour average and the 1-hour average being larger than a 24-hour average. This variability is the concept upon which Hino developed his power law coefficient of .5 in Equation (4). However, since Hino's power law coefficient has only been validated up to 5 hours, a power law coefficient that could be used to calculate concentrations up to 24 hours in length was required. Therefore, the variability in wind speed and wind direction was utilized to develop power law coefficients for CGD.

This variation of wind speed and wind direction was a key factor in the development of the power law coefficients. Equation (1) can be used to estimate the 10 minute downwind concentration (C_{10}) based on the assumptions of constant wind speed and wind direction. This means that for 10 minutes the wind speed and wind direction will not change. Therefore, any particulate being released over the period of 10 minutes will travel directly downwind.

A record of how the wind speed and the wind direction varied over different periods were obtained through the use of a weather station. Most cities have agencies that collect this data throughout the year. With this data, they are able to generate a wind rose. A wind rose depicts the frequency of occurrence of winds in 16 direction sectors for a given location and time period. The wind rose also includes the percent frequency of calm winds. Wind roses can graphically depict the dominant (prevailing) transport direction of the wind for an area. An example of a wind rose can be seen in Figure 4.

The assumption of constant wind speed and wind direction is quite conservative. The weather data obtained from Texas A&M's Riverside campus was collected every minute. This data was analyzed to get an understanding of how the wind speed and wind direction would vary over particular intervals of time. It was determined that in a 10 minute interval the wind speed varied between .5 m/s to 5 m/s and the wind direction varied by a span of 30° (plus or minus 15° on average). During the period of an hour the wind speed varied between .5 m/s to 10 m/s and the wind direction varied by a span of 60° (plus or minus 30° on average). This variation is much different than the original assumption of constant wind speed and wind direction. Constant wind direction relates to variation with a span of 0°.

The effect of this variation of wind direction can be demonstrated with a wind rose. The wind rose is separated into 16 sectors. The prevailing wind direction for the College Station area, based on a year of data, is from the south (wind vector equals 180°) for 24.2% of the year. Since it was determined that in 10 minutes the wind direction varied by a span of 30°, the wind direction over a 10 minute interval varied between the following wind vectors, 157.5° and 180°. Since it was determined that in 1 hour, the wind direction varied by a span of 60°, the wind direction over a 1-hour interval varied between the following vectors, 157.5° and 202.5°. In a 24-hour period, the wind direction varied by a span of 360°. All of this information was vital for developing the power law coefficients to be utilized in CGD's time average equation.

It was determined that the development of simulation programs (PowerLaw I & II) would be the most effective approach for determining these power law coefficients. These simulation programs were used to calculate 10-minute average concentrations for specific intervals of time, which made it possible to obtain averages for both 1-hour (PowerLaw I) and 24-hour (PowerLaw II) intervals of time. The core of the programs center around the Gaussian dispersion equation (Equation 1). Part of the program's code contains information from a wind rose depicting the College Station, Texas area. This particular part of the code can be altered to accommodate any area of the country for which a wind rose is available.

PowerLaw I calculates 10-minute concentrations for a 1-hour interval. The wind rose of the College Station area depicts the frequency of the wind along 16 different vectors for one year. Once the wind vectors for the 1-hour interval were determined, they were weighted to correspond to the windrose data. For example, in 1-hour the wind encompassed three vectors: 157.5°, 180°, & 202.5°. Utilizing the wind rose data, these vectors had the following frequencies, respectively, 13%, 24.2%, & 8.5%. Therefore, the method for weighting these vectors was as follows:

$$13\% + 24.2\% + 8.5\% = 45.7\% \text{ or } .457$$

13%/.457 = 28.4% of the time the wind travels along the 157.5° vector
24.2%/.457= 53.0% of the time the wind travels along the 180° vector
8.5%/.457 = 18.6% of the time the wind travels along the 202.5° vector

This analysis suggests that in a 1-hour interval, the wind traveled in the prevailing or downwind direction (180°) for 53.0% of the time. Therefore, the PowerLaw I program calculated 10 minute concentrations along that vector for 32 minutes. (60 minutes X .530 = 32 minutes) For the remaining 28 minutes, the program calculated concentrations resulting when the wind was traveling along the other two vectors. The program looped through this process to simulate a period of 30 days. A total of 720 1-hour average concentrations were generated. The average of these values yielded an average 1-hour concentration over the interval of one month.

The PowerLaw II simulation model utilized a similar procedure with all 16 wind vectors. It was assumed that a typical day would involve the wind direction spanning the entire 360° range. To calculate a 24-hour average concentration, one hundred and forty-four 10-minute concentrations were simulated. Again, the program looped through this process to simulate a period of 30 days. A total of 30 24-hour average concentrations were generated. The average of these values gave an average 24-hour concentration over the interval of one month.

For PowerLaw I and PowerLaw II, the following variables were inputs: stability class, emission rate, stack height, and receptor height. The programs generated a random variable to determine the wind speed based on which stability class the user inputted. Each stability class has a range of wind speeds for which it is valid. For example, if stability class A is chosen, the random variable will input a wind speed between 1 m/s and 3 m/s. This value for wind speed is utilized in Equation (1) to aid in determining the downwind concentration. A series of tests were conducted once the simulation programs were completed. Each of the six stability classes were simulated with the emission rates of 2, 4, and 8 grams/second. This range of emission rates encompassed rated ginning capacities of 15 to 50 bales per hour.

The 1-hour (C_{60}) and 24-hour (C_{24}) average concentrations were obtained using simulation models, PowerLawI and PowerLawII. Equation (6) was developed from Equation (5). The 1-hour power law coefficient (X_{60}) and the 24-hour power law coefficient (X_{24}) were calculated for the different stability classes. The 'C_t' in Equation (5) was the C_{60} or the C_{24} that was previously determined and the 't' was 60 minutes or 1440 minutes (1440 being the number of minutes in 24 hours).

$$C_t = C_{10}\left(\frac{10}{t}\right)^x \qquad (5)$$

$$X = \frac{\ln \dfrac{C_t}{C_{10}}}{\ln \dfrac{10}{t}} \qquad (6)$$

The 'X' in Equation (6) was actually X_{60} or X_{24} depending on whether C_{60} or C_{24} was substituted into the equation for 'C_t'. These coefficients (X_{60} & X_{24}) were used to replace Hino's value of .5 in Equation (4). The X_{60} coefficient is valid for converting the 10-minute concentration to a 1-hour average concentration. The X_{24} coefficient is valid for converting the 10-minute concentration to a 24-hour average concentration.

Validation of CGD

A future goal of this research is to have the CGD model approved by EPA Region VI as an alternative model for use in regulating air pollution from agricultural operations. "There are three separate conditions under which an alternative model will normally be approved for use. Meeting any one of these three separate conditions may warrant use of the alternative model." (EPA, 1986) One of those conditions being, "if a statistical performance evaluation has been conducted using measured air quality data and the results of that evaluation indicate the alternative model performs better for the application than a comparable model" that is already approved by the EPA (i.e. Screen3). (EPA, 1986) Ultimately, this means that concentrations predicted with CGD should more accurately reflect measured concentrations when compared to Screen3. Also, the alternative model (CGD) should not be biased toward underestimating downwind concentration.

Obtaining air quality data for this validation process will involve performing downwind ambient air sampling for obtaining the **measured** concentrations of particulate matter in the air for comparison with the **predicted** concentrations that result from CGD and Screen3. Collection of air quality data requires a point source emitting particulate matter. The point source should have an elevated stack that emits the material into the atmosphere. The point source should also be capable of operating at a range of emission rates.

An emitting source was developed by Michael Demny and Linda Williams and can be seen in Figure 1 & Figure 2. The system consists of a Syntron feeding mechanism that can be adjusted to provide different feeding rates. It was determined that the Syntron feeder could be used to vary feeding rates from 2 to 8 grams per second utilizing fly ash. The feeding mechanism receives particulate matter via a hopper that is equipped with a vibration device used to prevent bridging of material inside the hopper. The Syntron was equipped with a tray that conveys the material into a funnel. This funnel was used to feed particulate into a venturi throat. The venturi throat conveyed material into a 1½" PVC pipe where the particulate then traveled up the height of the stack and was released to the atmosphere. The emitting point of the stack was located 10 meters above the ground. This height was selected to correspond to typical release points of cotton gins. The particulate was conveyed through the stack utilizing a 115V centrifugal fan. The fan provided a volume rate of flow corresponding to a conveying velocity of 3500 feet per minute. The conveying velocity was maintained by using a pitot tube to measure the static pressure and the total pressure. Velocity pressure was determined by subtracting static from total pressure. The velocity pressure was used to calculate the conveying velocity. A volumetric flow rate of 40 cubic feet per minute was required to maintain the conveying velocity of 3500 fpm. The volumetric flow rate for the system can be calculated as follows:

$$\begin{aligned} \mathbf{Q} &= \mathbf{(V)\,(A)} \\ &= \mathbf{(3500)ft/min\ (\pi^*\ (1½\div12)^2/4)\ ft^2} \qquad (7) \\ &= \mathbf{40\ ft^3/min(cfm).} \end{aligned}$$

Preliminary work has been accomplished to obtain the actual air quality data that is required for the approval process of the model. This work was performed on the runways that exist at Texas A&M University's Riverside campus. This site allowed for long distances of level open terrain with no obstructions. High Volume and PM_{10} samplers were arranged downwind in order to capture the particulate matter being released. Seven sampler stations were established. Six of the stations were downwind while one station was placed upwind to measure the background concentration. Each station consisted of a High Volume and a PM_{10} sampler powered by portable generators. The arrangement of the seven stations is shown in Figure 3. The six stations placed downwind were close enough together in the y-direction to be considered on the centerline. A weather station was erected at the test site to monitor wind speed and wind direction along with other environmental conditions to aid in obtaining predicted concentrations from CGD and Screen3. Weather station data was collected every two minutes.

The material used in the testing process was fly ash. This fly ash had a mass median diameter (MMD) of 10 µm aerodynamic equivalent diameter (AED). This means that 50% of the material by mass was less than or equal to 10 µm in size. This MMD was determined with a Coulter Counter particle size analyzer. If 8 g/s (TSP) was being emitted, 50% of this material is PM_{10} or less. Therefore, the emission rate would actually be 4 g/s (PM_{10}).

A series of 10-minute tests as well as 1-hour tests were performed at different emission rates. Prior to testing, the 8"X 10" filters to be used on the High Volume and PM_{10} sampler filter cartridges were pre-weighed. Once the tests were completed the filters were retrieved from the sampler filter cartridges so that a post-weight could be obtained. The following equation was used to calculate the measured concentration:

$$\textbf{Concentration} = \frac{\textbf{(post-weight) - (pre-weight)}}{\textbf{flow rate} \times \textbf{sampling time}} \qquad \textbf{(8)}$$

These measured concentrations were then compared to the predicted values from CGD and Screen3.

Results

Development of Power Law Coefficients in CGD

The power law coefficients to estimate the 1-hour and 24-hour time weighted averages were obtained utilizing the simulation programs referred to as PowerLaw I & II. The programs were executed for all six stability classes. The results for each stability class were analyzed at 2, 4, and 8 g/s. The 10-minute (C_{10}), 1-hour average (C_{60}), and 24-hour average (C_{24}) concentrations were obtained at a downwind distance of 1000 meters. A relationship between the estimated concentrations was utilized to develop two power law coefficients. The first power law coefficient (X_{60}) was utilized to convert a 10-minute concentration to a 1-hour average concentration. The second power law coefficient (X_{24}) was utilized to convert a 10-minute concentration to a 24-hour concentration.

The AP-42 emission factor for cotton gins is 2.24 pounds of dust (TSP) per bale. (EPA, 1985) Utilizing the PM_{10} fraction of TSP of 50% yields a PM_{10} emission factor (EF) of 1.12 lbs per bale. In order to obtain an emission rate (ER), a typical cotton gin processing rate (PR) of 28 bales-per-hour was utilized. The following equation was utilized to calculate the emission rate of 4 g/s that was utilized for all of the modeling results:

$$ER = PR \times EF \times (454/3600) \qquad \textbf{(9)}$$

where

ER = Emission rate (g/s),
PR = Processing rate (bales-per-hour), and
EF = Emission factor (lb/bale).

Table 1 illustrates the results of utilizing Power I and II simulations for different stability classes. The following results have been selected from Table 1:

(1) The 1-hour average was 81.79 µg/m³ and the 24-hour average was 34.50 µg/m³ for class D with an emission rate of 4 g/s. The 1-hour average was 321.7 µg/m³ and the 24-hour average was 105.83 µg/m³ for class E with an emission rate of 4 g/s.

(2) The power law coefficients X_{60} and X_{24} for class D with an emission rate of 4 g/s were .47 and .34, respectively. The power law coefficients X_{60} and X_{24} for class E with an emission rate of 4 g/s were .66 and .46, respectively.

Equation (6) was used to develop power law coefficients X_{60} and X_{24} for each stability class at three different emission rates utilizing the results of the PowerLaw simulation programs. Throughout a 24 hour period, all six stability classes could be encountered. Therefore, the coefficients developed for all six stability classes and emission rates were averaged in order to obtain a single X_{60} value. This same method was utilized to obtain a single X_{24} value. The resulting X_{60} value was .55 while the X_{24} value was 0.4.

(3) The following time average concentration equations were utilized in CGD. These equations were based upon the development of the power law coefficients, X_{60} and X_{24}.

To convert the 10-minute concentration to a 1-hour average concentration

$$\mathbf{C_{60} = C_{10} \left(\frac{10}{60}\right)^{.55}.} \qquad \textbf{(10)}$$

To convert the 10-minute concentration to a 24-hour average concentration

$$\mathbf{C_{24} = C_{10} \left(\frac{10}{1440}\right)^{.40}.} \qquad \textbf{(11)}$$

Equations (10) and (11) were used to estimate the 1-hour and the 24-hour average concentrations for CGD. (Table 2) At 100 meters the 1-hour and 24-hour average concentrations, respectively, for stability class A with a wind speed of 3 meters/second were 241.0 and 88.45 µg/m³. At 100 meters the 1-hour and 24-hour average concentrations, respectively, for stability class C with a wind speed of 10 meters/second were 157.7 and 57.89

µg/m^3. CGD results of 10-minute, 1-hour, and 24-hour averages for all stability classes are found in Table 2.

(4) Equation (2) was used with the multiplying factor of .4 to estimate the 24-hour average concentration from the predicted values of Screen3. Doing so yielded 260.5 and 1.836 µg/m^3 for stability class A with a wind speed of 3 meters/second (100 and 1000 meters respectively). At 100 and 1000 meters, respectively, the values of 194.4 and 8.14 µg/m^3 were obtained for stability class C with a wind speed of 10 meters/second. Screen3 1-hour averages along with their respective 24-hour averages for all stability classes are displayed in Table 3.

(5) A comparison of Screen3's 24-hour average concentrations and CGD's 24-hour average concentrations was conducted to show how much Screen3 over predicts when compared to CGD. (Table 4) CGD's 24-hour average concentration is 62 µg/m^3 while Screen3's 24-hour average concentration is 223 µg/m^3 utilizing a wind speed of 1 m/s for stability class B at 100 meters downwind. CGD's 24-hour average concentration is 71 µg/m^3 while Screen3's 24-hour average concentration is 207 µg/m^3 utilizing a wind speed of 3 m/s for stability class F at 1000 meters downwind.

Validation of CGD

Some difficulty in collecting ambient air quality data in June and July of this past summer was experienced. The sampling went trouble free, however, there were some problems with the protocol utilized to pre-weigh and post-weigh the filters. The filter media utilized was a polyweb material that was folded inside of an 8½ X 11 sheet of paper. We determined that due to the considerably low concentrations of particulate being captured, the protocol for weighing the filters had to be ratified. To account for this, we acquired an environmental chamber that had strict controls for temperature and relative humidity. The temperature and relative humidity utilized for weighing the filter media were 70°F and 30%, respectively. The polyweb media was replaced with glass fiber filters to limit the variation in filter weights associated with hygroscopic accumulation of moisture. This resulted in a further reduction of variability in the weighing of the filters. Once the protocol for weighing of the filters was modified, additional sampling was performed.

In the summer sampling trip, 10-minute and 1-hour tests were attempted. We soon realized that an accurate 10-minute test would be difficult to obtain. We initially assumed that in a 10-minute span, the wind speed and wind direction would remain constant. This assumption did not hold. In a 10-minute span we were fortunate if we had constant wind direction for 5 minutes. In order to obtain adequate sampling data, the remaining tests were conducted at 1-hour periods.

We proceeded to perform two 1-hour tests in November. The samplers were arranged at 250, 500, and 750 meters downwind from the point source. The emission rate for test A was 4.3 grams per second. The emission rate for test B was 6.2 grams per second. Table 5 and 6 display the results for the two tests. The results are the 1-hour measured downwind concentrations of PM_{10}.

(6) The resulting concentrations were quite low. For Test A, the concentration at 250 and 750 meters downwind averaged 56 and 26 µg/m^3, respectively. For Test B, the concentration at 250 and 750 meters downwind averaged 51 and 0 µg/m^3, respectively.

(7) The actual measured 1-hour concentrations were compared to both CGD's and Screen3's 1-hour concentration. These values are displayed in Table 7 for Tests A & B.

Conclusions

The following conclusions were made after comparison of the results obtained by modeling with Screen3 and those obtained with the CGD model:

(1) The 1-hour concentration that Screen3 predicts is actually a 10 minute concentration.

(2) The 24 hour concentration that Screen3 predicts is actually a 1- hour concentration.

(3) To use the 10 minute concentration as a 1-hour concentration puts an unnecessary degree of conservatism in the Screen3 model results. Such conservatism will lead to predicted downwind concentrations that are excessively high.

Equations capable of predicting the 24-hour average play an essential role in assisting regulatory agencies in determining whether a facility is in compliance based on the NAAQS . The time average concentration equations developed for the CGD model are based upon sound engineering analysis. These equations have been implemented into the CGD model for use in estimating the 24-hour average concentrations of PM_{10}.

(4) Screen3 over predicts by a factor ranging between 3 to 4 when comparing CGD and Screen3's 24-hour average concentration. If a regulator were to utilize Screen3 with full meteorology to model the emissions from a 28 bale per hour cotton gin, the concentration 500 meters downwind that the gin would have to comply with is 253 µg/m^3. If a regulator were to utilize CGD with full meteorology to model the emissions from a 28 bale per hour cotton gin, the concentration 500 meters downwind that the gin would have to comply with is 80 µg/m^3. Since the NAAQS for PM_{10} is 150 µg/m^3, based on a 24-hour average, it

is evident that utilizing Screen3 the gin would not be in compliance. However, utilizing CGD, the gin would be in compliance.

A method was developed to assist in validation of the CGD model. Initial data suggests that CGD slightly over predicts the actual concentrations while Screen3 greatly over predicts the actual concentrations. Further tests must be conducted to complete the validation of the CGD model.

Dispersion modeling should exist for the purpose of determining whether a gin <u>is in compliance</u> with its permitted allowable emission factor (which should be calculated based on emission factors and/or process weight tables), <u>not</u> to limit production by setting allowable emission rates based on model results. If dispersion modeling continues to be used in this manner, then there should be a model available that can be used to accurately depict the downwind concentrations. The proposed CGD model will fulfill the need of a model that more accurately predicts downwind concentrations.

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Table 1. Concentrations ($\mu g/m^3$) and coefficients obtained utilizing PowerLaw I & II.

	Stability Class A			**Stability Class B**		
	2 g/s	**4 g/s**	**8 g/s**	**2 g/s**	**4 g/s**	**8 g/s**
C_{10}	6.64	13.28	26.57	37.30	74.60	149.2
C_{60}	2.85	5.79	11.48	11.27	22.51	44.98
C_{24}	1.01	2.01	4.00	3.71	7.58	15.47
X_{60}	.47	.46	.47	.67	.67	.67
X_{24}	.38	.38	.38	.46	.46	.46

	Stability Class C			**Stability Class D**		
	2 g/s	**4 g/s**	**8 g/s**	**2 g/s**	**4 g/s**	**8 g/s**
C_{10}	49.51	99.02	198.0	94.11	188.22	376.44
C_{60}	17.09	34.70	67.43	41.08	81.79	167.8
C_{24}	4.71	9.86	18.79	16.22	34.50	65.17
X_{60}	.59	.59	.60	.46	.47	.45
X_{24}	.47	.46	.47	.35	.34	.35

	Stability Class E			**Stability Class F**		
	2 g/s	**4 g/s**	**8 g/s**	**2 g/s**	**4 g/s**	**8 g/s**
C_{10}	525.0	1050	2100	1033	2065	4131
C_{60}	158.2	321.7	612.4	431.0	838.9	1699
C_{24}	57.10	105.9	206.6	150.1	277.3	540.8
X_{60}	.67	.66	.69	.49	.50	.50
X_{24}	.45	.46	.47	.39	.40	.41

Table 2. CGD 10-minute, 1-hour, and 24-hour concentrations with concentration in μg/m^3 and distance in meters.

Stability class A; u = 1 m/s				Stability class A; u = 3 m/s			
Distance	Concentration			Distance	Concentration		
	10-min	1-hour	24-hour		10-min	1-hour	24-hour
100	740.8	276.5	101.5	100	645.7	241.0	88.45
200	615.1	229.6	84.26	200	261.6	97.65	35.83
300	308.4	115.1	42.24	300	110.8	41.36	15.18
400	158.8	59.27	21.75	400	54.48	20.34	7.463
500	89.95	33.58	12.32	500	30.38	11.34	4.160
600	55.42	20.69	7.591	600	18.60	6.943	2.548
700	36.47	13.61	4.996	700	12.20	4.554	1.671
800	25.27	9.432	3.461	800	8.441	3.151	1.156
900	18.23	6.805	2.497	900	6.087	2.272	0.8338
1000	13.60	5.076	1.863	1000	4.538	1.694	0.6216

Stability class B; u = 1 m/s				Stability class B; u = 5 m/s			
Distance	Concentration			Distance	Concentration		
	10-min	1-hour	24-hour		10-min	1-hour	24-hour
100	454.1	169.5	62.20	100	593.6	221.6	81.31
200	809.3	302.1	110.9	200	284.2	106.1	38.93
300	577.1	215.4	79.05	300	148.6	55.47	20.36
400	387.0	144.5	53.01	400	88.96	33.21	12.19
500	268.7	100.3	36.81	500	58.61	21.88	8.028
600	194.8	72.71	26.68	600	41.32	15.42	5.660
700	146.8	54.80	20.11	700	30.61	11.43	4.193
800	114.1	42.59	15.63	800	23.54	8.787	3.224
900	91.03	33.98	12.47	900	18.65	6.961	2.555
1000	74.20	27.70	10.16	1000	15.12	5.644	2.071

Stability class C; u = 1 m/s				Stability class C; u = 10 m/s			
Distance	Concentration			Distance	Concentration		
	10-min	1-hour	24-hour		10-min	1-hour	24-hour
100	67.16	25.07	9.200	100	422.6	157.7	57.89
200	789.1	294.5	108.1	200	268.3	100.1	36.75
300	881.0	328.8	120.7	300	153.7	57.37	21.05
400	701.4	261.8	96.08	400	97.67	36.46	13.38
500	541.3	202.0	74.15	500	67.42	25.17	9.235
600	422.4	157.7	57.86	600	49.41	18.44	6.768
700	336.1	125.5	46.04	700	37.83	14.12	5.182
800	273.0	101.9	37.40	800	29.96	11.18	4.104
900	225.8	84.28	30.93	900	24.35	9.089	3.335
1000	189.7	70.81	25.99	1000	20.21	7.544	2.768

Stability class D; u = 1 m/s				Stability class D; u = 20 m/s			
Distance	Concentration			Distance	Concentration		
	10-min	1-hour	24-hour		10-min	1-hour	24-hour
100	0.0456	0.0170	0.0062	100	146.6	54.72	20.08
200	168.0	62.71	23.01	200	219.0	81.74	30.00
300	580.9	216.8	79.57	300	156.2	58.30	21.40
400	762.9	284.8	104.5	400	110.4	41.21	15.12
500	771.2	287.9	105.6	500	81.50	30.42	11.16
600	713.1	266.2	97.68	600	62.60	23.37	8.575
700	638.5	238.3	87.46	700	49.70	18.55	6.808
800	565.6	211.1	77.48	800	40.60	15.15	5.561
900	500.5	186.8	68.56	900	33.80	12.62	4.630
1000	444.0	165.7	60.82	1000	28.70	10.71	3.931

Table 2. Continued

Stability class E; u = 1 m/s				Stability class E; u = 5 m/s			
Distance	Concentration			Distance	Concentration		
	10-min	1-hour	24-hour		10-min	1-hour	24-hour
100	0.1193	0.0445	0.0163	100	40.16	14.99	5.501
200	236.0	88.09	32.33	200	488.2	182.2	66.87
300	835.2	311.8	114.4	300	594.0	221.7	81.37
400	1162	433.7	159.2	400	533.0	199.0	73.01
500	1231	459.5	168.6	500	448.0	167.2	61.37
600	1181	440.8	161.8	600	374.0	139.6	51.23
700	1088	406.1	149.0	700	314.3	117.3	43.05
800	986.2	368.1	135.1	800	267.2	99.74	36.60
900	889.0	331.8	121.8	900	229.7	85.74	31.46
1000	801.0	299.0	109.7	1000	200.0	74.65	27.40

Stability class F; u = 1 m/s				Stability class F; u = 3 m/s			
Distance	Concentration			Distance	Concentration		
	10-min	1-hour	24-hour		10-min	1-hour	24-hour
100	1.7e-07	6.3e-08	2.3e-08	100	0.0014	0.0005	0.0002
200	4.196	1.566	0.5748	200	35.63	13.30	4.881
300	128.9	48.11	17.66	300	244.3	91.19	33.46
400	445.4	166.3	61.01	400	462.8	172.7	63.39
500	774.5	289.1	106.1	500	586	218.7	80.27
600	1007	375.9	137.9	600	628.5	234.6	86.09
700	1135	423.7	155.5	700	624	232.9	85.48
800	1185	442.3	162.3	800	595	222.1	81.50
900	1183	441.6	162.0	900	556.4	207.7	76.22
1000	1151	429.6	157.7	1000	515.2	192.3	70.57

Table 3. Screen3 1-hour and 24-hour average concentrations with concentration in $\mu g/m^3$ and distance in meters.

Stability class A; u = 1 m/s			Stability class A; u = 3 m/s		
Distance	Concentration		Distance	Concentration	
	1-hour	24-hour		1-hour	24-hour
100	768.3	307.32	100	651.3	260.52
200	614.2	245.68	200	259.8	103.92
300	331.7	132.68	300	121.4	48.56
400	185.4	74.16	400	64.44	25.78
500	107.0	42.80	500	36.38	14.55
600	62.93	25.17	600	21.16	8.460
700	40.81	16.32	700	13.35	5.340
800	31.03	12.41	800	8.955	3.580
900	26.96	10.78	900	6.293	2.520
1000	24.49	9.800	1000	4.591	1.840

Stability class B; u = 1 m/s			Stability class B; u = 5 m/s		
Distance	Concentration		Distance	Concentration	
	1-hour	24-hour		1-hour	24-hour
100	557.5	223.0	100	607.6	243.04
200	834.3	333.7	200	289.0	115.6
300	583.1	233.2	300	150.8	60.32
400	393.8	157.5	400	91.32	36.53
500	272.5	109.0	500	59.71	23.88
600	197.2	78.88	600	41.95	16.78
700	148.5	59.40	700	31.04	12.42
800	115.6	46.24	800	23.88	9.550
900	92.31	36.92	900	18.94	7.580
1000	75.37	30.15	1000	15.38	6.150

Stability class C; u = 1 m/s			Stability class C; u = 10 m/s		
Distance	Concentration		Distance	Concentration	
	1-hour	24-hour		1-hour	24-hour
100	199.1	79.64	100	486.1	194.4
200	878.9	351.6	200	287.3	114.9
300	881.0	352.4	300	160.9	64.36
400	701.4	280.6	400	101.0	40.40
500	541.3	216.5	500	69.19	27.68
600	422.4	169.0	600	50.42	20.17
700	336.1	134.4	700	38.44	15.38
800	273.0	109.2	800	30.33	12.13
900	225.8	90.32	900	24.58	9.830
1000	189.7	75.88	1000	20.35	8.140

Table 3. Continued

Stability class D; u = 1 m/s			Stability class D; u = 20 m/s		
Distance	Concentration		Distance	Concentration	
	1-hour	24-hour		1-hour	24-hour
100	16.07	6.430	100	243.1	97.24
200	302.8	121.1	200	255.5	102.2
300	680.9	272.4	300	170.9	68.36
400	804.5	321.8	400	117.4	46.96
500	788.8	315.5	500	85.08	34.03
600	720.2	288.1	600	64.48	25.79
700	639.9	256.0	700	50.63	20.25
800	563.5	225.4	800	40.90	16.36
900	495.8	198.3	900	33.79	13.52
1000	437.5	175.0	1000	28.43	11.37

Stability class E; u = 1 m/s			Stability class E; u = 5 m/s		
Distance	Concentration		Distance	Concentration	
	1-hour	24-hour		1-hour	24-hour
100	10.47	4.190	100	60.68	24.27
200	363.2	145.3	200	489.7	195.9
300	946.3	378.5	300	601.4	240.6
400	1205	482.0	400	536.1	214.4
500	1246	498.4	500	450.3	180.1
600	1184	473.6	600	374.9	150.0
700	1086	434.4	700	314.1	125.6
800	980.4	392.2	800	265.9	106.4
900	880.6	352.2	900	227.7	91.08
1000	790.6	316.2	1000	197.1	78.84

Table 3. Continued

Stability class F; u = 1 m/s			Stability class F; u = 3 m/s		
Distance	Concentration		Distance	Concentration	
	1-hour	24-hour		1-hour	24-hour
100	.2416	.0966	100	.2172	.0869
200	42.69	17.08	200	73.58	29.43
300	278.6	111.4	300	313.1	125.2
400	639.6	255.8	400	525.4	210.2
500	951.1	380.4	500	633.7	253.5
600	1147	458.8	600	662.2	264.9
700	1240	496.0	700	646.0	258.4
800	1241	496.4	800	605.1	242.0
900	1210	484.0	900	560.4	224.2
1000	1161	464.4	1000	516.4	206.6

Table 4. Comparison of CGD and Screen3 24-hour average concentrations with concentration in µg/m^3 and distance in meters.

Stability class A; u = 1 m/s			**Stability class A; u = 3 m/s**		
Distance	24-hour concentration		Distance	24-hour concentration	
	CGD	Screen3		CGD	Screen3
100	101.5	307.32	100	88.45	260.52
200	84.26	245.68	200	35.83	103.92
300	42.24	132.68	300	15.18	48.56
400	21.75	74.16	400	7.463	25.78
500	12.32	42.80	500	4.161	14.55
600	7.591	25.17	600	2.548	8.460
700	4.996	16.32	700	1.671	5.340
800	3.461	12.41	800	1.156	3.580
900	2.497	10.78	900	0.834	2.520
1000	1.863	9.800	1000	0.6216	1.840

Stability class B; u = 1 m/s			**Stability class B; u = 5 m/s**		
Distance	24-hour concentration		Distance	24-hour concentration	
	CGD	Screen3		CGD	Screen3
100	62.20	223.0	100	81.31	243.04
200	110.9	333.7	200	38.93	115.6
300	79.05	233.2	300	20.36	60.32
400	53.01	157.5	400	12.19	36.53
500	36.81	109.0	500	8.028	23.88
600	26.68	78.88	600	5.660	16.78
700	20.11	59.40	700	4.193	12.42
800	15.63	46.24	800	3.224	9.550
900	12.47	36.92	900	2.555	7.580
1000	10.16	30.15	1000	2.071	6.150

Stability class C; u = 1 m/s			**Stability class C; u = 10 m/s**		
Distance	24-hour concentration		Distance	24-hour concentration	
	CGD	Screen3		CGD	Screen3
100	9.200	79.64	100	57.89	194.4
200	108.1	351.6	200	36.75	114.9
300	120.7	352.4	300	21.05	64.36
400	96.08	280.6	400	13.38	40.40
500	74.15	216.5	500	9.235	27.68
600	57.86	169.0	600	6.768	20.17
700	46.04	134.4	700	5.182	15.38
800	37.40	109.2	800	4.104	12.13
900	30.93	90.32	900	3.335	9.830
1000	25.99	75.88	1000	2.768	8.140

Stability class D; u = 1 m/s			**Stability class D; u = 20 m/s**		
Distance	24-hour concentration		Distance	24-hour concentration	
	CGD	Screen3		CGD	Screen3
100	0.0062	6.430	100	20.08	97.24
200	23.01	121.1	200	30.00	102.2
300	79.57	272.4	300	21.40	68.36
400	104.5	321.8	400	15.12	46.96
500	105.6	315.5	500	11.16	34.03
600	97.68	288.1	600	8.575	25.79
700	87.46	256.0	700	6.808	20.25
800	77.48	225.4	800	5.561	16.36
900	68.56	198.3	900	4.630	13.52
1000	60.82	175.0	1000	3.931	11.37

Table 4. Continued

Stability class E; u = 1 m/s			**Stability class E; u = 5 m/s**		
Distance	24-hour concentration		Distance	24-hour concentration	
	CGD	Screen3		CGD	Screen3
100	0.0163	4.190	100	5.501	24.27
200	32.33	145.3	200	66.87	195.9
300	114.4	378.5	300	81.37	240.6
400	159.2	482.0	400	73.01	214.4
500	168.6	498.4	500	61.37	180.1
600	161.8	473.6	600	51.23	150.0
700	149.0	434.4	700	43.05	125.6
800	135.1	392.2	800	36.60	106.4
900	121.8	352.2	900	31.46	91.08
1000	109.7	316.2	1000	27.40	78.84

Stability class F; u = 1 m/s			**Stability class F; u = 3 m/s**		
Distance	24-hour concentration		Distance	24-hour concentration	
	CGD	Screen3		CGD	Screen3
100	2.3e-08	.0966	100	0.0002	.0869
200	0.5748	17.08	200	4.881	29.43
300	17.66	111.4	300	33.46	125.2
400	61.01	255.8	400	63.39	210.2
500	106.1	380.4	500	80.27	253.5
600	137.9	458.8	600	86.09	264.9
700	155.5	496.0	700	85.48	258.4
800	162.3	496.4	800	81.50	242.0
900	162.0	484.0	900	76.22	224.2
1000	157.7	464.4	1000	70.57	206.6

Table 5. Test A 1-hour PM_{10} concentrations (µg/m^3).

Distance	Station					
	1	2	3	4	5	6
250	65.77	56.11				
500			36.84	61.06		
750					39.39	13.00

Table 6. Test B 1-hour PM_{10} concentrations (µg/m^3).

Distance	Station					
	1	2	3	4	5	6
250	43.85	58.47				
500			75.68	20.55		
750					0	n/a

Table 7. Comparison of measured, CGD, and Screen3 1-hour concentrations ($\mu g/m^3$) at 3 downwind distances (meters).

Test A			
Distance	Measured	CGD	Screen3
250	56	144	397
500	49	61	167
750	26	34	89

Test B			
Distance	Measured	CGD	Screen3
250	51	173	478
500	48	74	200
750	0	40	107

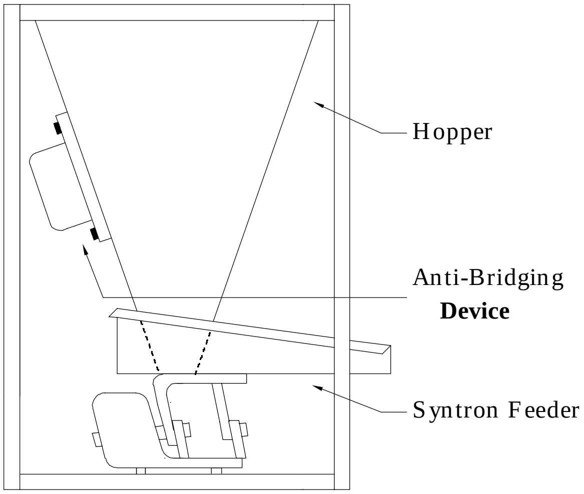

Figure 1. Side view of syntron, hopper and anti-bridging device.

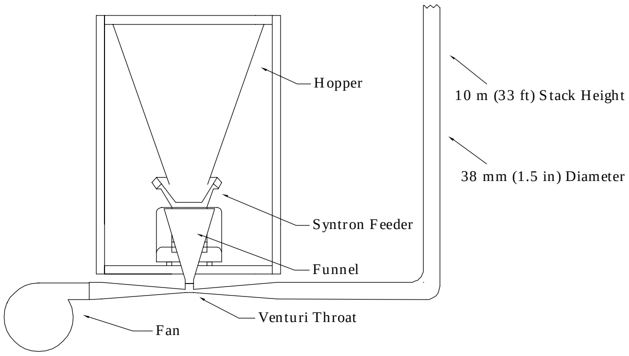

Figure 2. Front view of syntron, hopper, feed system an

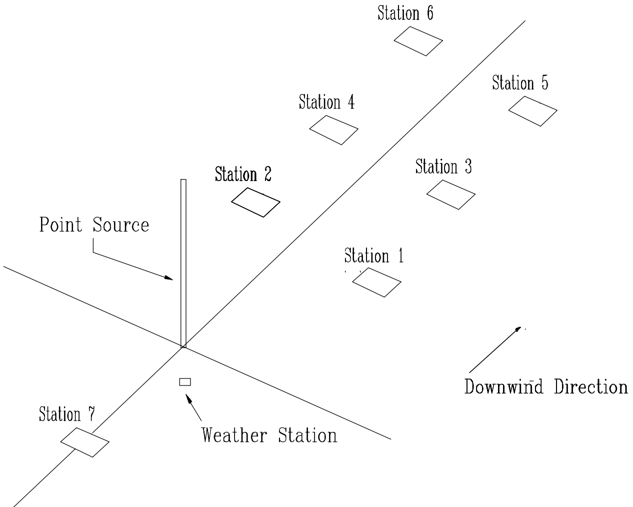

Figure 3. Arrangement of sampler stations for proposed

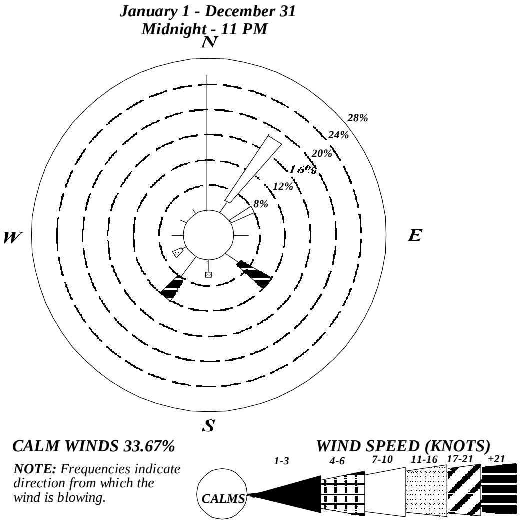

Figure 4. Example of a wind rose.