CHARACTERIZATION OF COTTON GIN PARTICULATE MATTER EMISSIONS – FINAL YEAR OF FIELDWORK

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Abstract

Due to EPA's implementation of more stringent standards for particulate matter (PM) with an effective diameter less than 2.5 microns (PM2.5), the cotton ginners' associations across the cotton belt agreed that there is an urgent need to collect gin emission data. The primary issues surrounding PM regulations for cotton ginning industry are the limited or lack of available PM2.5 data, that current dispersion models can potentially over-predict property-line PM concentrations at cotton gins, and that federal reference method PM samplers may over-predict emissions or concentrations when sampling in agricultural environments. In response to the gin associations' requests, a cotton gin PM emissions sampling project was planned and begun in 2008. During 2011, the fourth year of the sampling campaign, a gin was extensively sampled in North Carolina and lab analyses were conducted on more than 3000 samples. This paper highlights the individual sampling campaign and summarizes the progress made toward processing, compiling, and validating the information collected at the seven gins sampled.

Introduction

In 2006, the U.S. Environmental Protection Agency (EPA) implemented of more stringent standards for particulate matter with an effective diameter less than 2.5 microns ($PM_{2.5}$) (CFR, 2006). The national and state cotton ginners' associations across the cotton belt agreed that there was an urgent need to collect gin emission data, because of three main issues surrounding implementation of the $PM_{2.5}$ standards. The first was that there is very little scientifically based $PM_{2.5}$ emissions data for gins or any industry available. Second, many states, including Missouri, North Carolina, South Carolina, and New Mexico, rely on EPA recommended dispersion models that were not developed for low-level point sources such as cotton gins to estimate property-line PM_{10} (particles less than 10 microns in diameter) concentrations and compare with National Ambient Air Quality Standards when issuing air permits for cotton gins. Studies have shown that these models can over-predict cotton gin property-line concentrations by a factor of 10 (Zwicke, 1998; Fritz, 2002). Third, some recent research shows that EPA federal reference method (FRM) samplers, used to selectively sample $PM_{2.5}$ and PM_{10}, may not perform as designed under conditions normally encountered at cotton gins, where the average particulate size is often larger than the design cut-point of the sampler, and may over-estimate cotton gin $PM_{2.5}$ and PM_{10} emissions and ambient concentrations (Buser et al., 2006a; Buser et al., 2006b; Buser et al., 2006c).

In response to these issues, a four year study to evaluate cotton gin particulate matter (PM) emissions at several gins at locations across the cotton belt was planned and begun in 2008, by researchers at the USDA-ARS Ginning Laboratories at Lubbock, Texas; Mesilla Park, New Mexico; and Stoneville, Mississippi; and the Biosystems Engineering Department at Oklahoma State University in Stillwater, Oklahoma.

The four overall objectives of the study were:

1) Develop $PM_{2.5}$ emission factors and verify current PM_{10} emission factors for cotton gins through FRM stack sampling.
2) Develop a robust data set that can be used in the design, development, and evaluation of current and future air quality low-level dispersion models consisting of combined stack and ambient sampling data.

3) Characterize the PM emitted from cotton gins in terms of particle size distributions, particle density, and particle shape.
4) Collect field data to further quantify federal reference method ambient and stack PM_{10} and $PM_{2.5}$ over-sampling rates.

This report summarizes the project work during the final year of fieldwork.

Project Methodology & Accomplishments

The bulk of the project planning was conducted in 2008, and was detailed by Buser et al. (2009). Two different advisory groups, Cotton Gin and Air Quality, were formed with membership consisting of people from the national and state gin associations, university researchers, industry representatives, and state and federal regulatory agencies. These advisory groups were important to the planning process and essential to the success of the project, providing valuable insight in their areas of expertise and ensuring industry and regulatory agency acceptance of the results.

To develop estimates of PM emissions (i.e. pounds of $PM_{2.5}$ or PM_{10} emitted per bale of cotton produced) from cotton gin process stream exhausts, seven gins from across the Cotton Belt were to be sampled (Figure 1). Whitelock et al. (2010) summarized the project work during the first full year of sampling, 2009, and Buser et al. (2011) described the project progress for the following year. Specific project goals for 2011 were:

1) Plan and prepare for and conduct the 2011 sampling campaign.
2) Complete the laboratory analyses of samples from the previous sampling campaigns.
3) Process the stack sampling data from previous sampling campaigns.
4) Make significant progress in processing the ambient data from previous sampling campaigns.

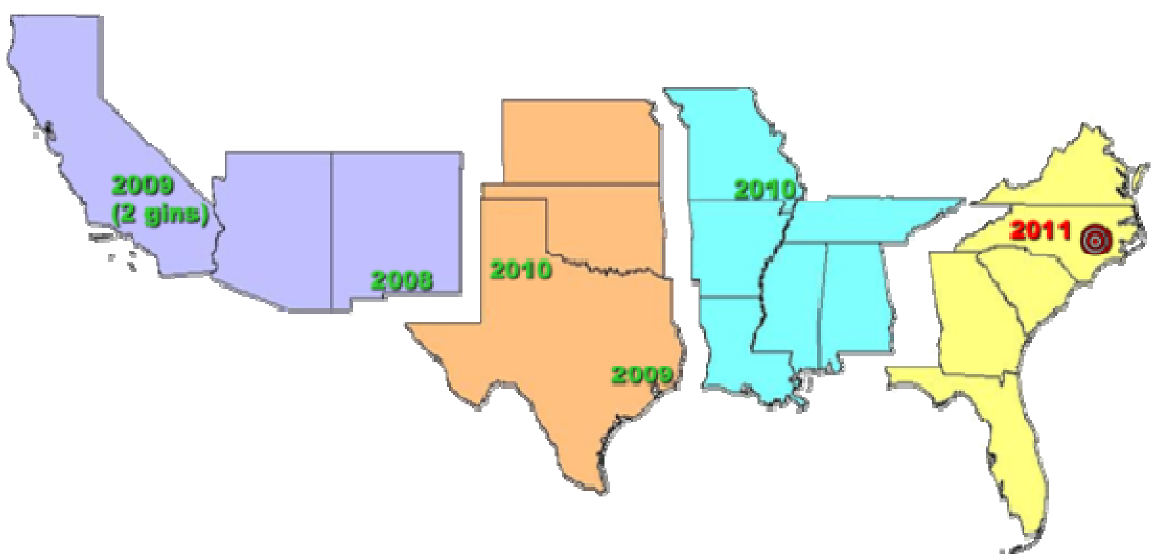

Figure 1. Completed and target gins.

2011 Sampling Campaign

Preparations for the 2011 sampling campaign included maintenance, repair, and calibration of the sampling and associated equipment, gin selection, and preparations specific to the selected gin. Besides the support equipment used during the previous campaigns, such as generators and electrical equipment, vehicles, trailers, and tools that must be checked, serviced, and repaired, there were 125 ambient samplers serviced and calibrated. After each sampling campaign, the samplers were checked using a flow meter and calibration software. Repairs were made as needed and then each was calibrated and flow coefficients were developed across its full range of operation (Figure 2).

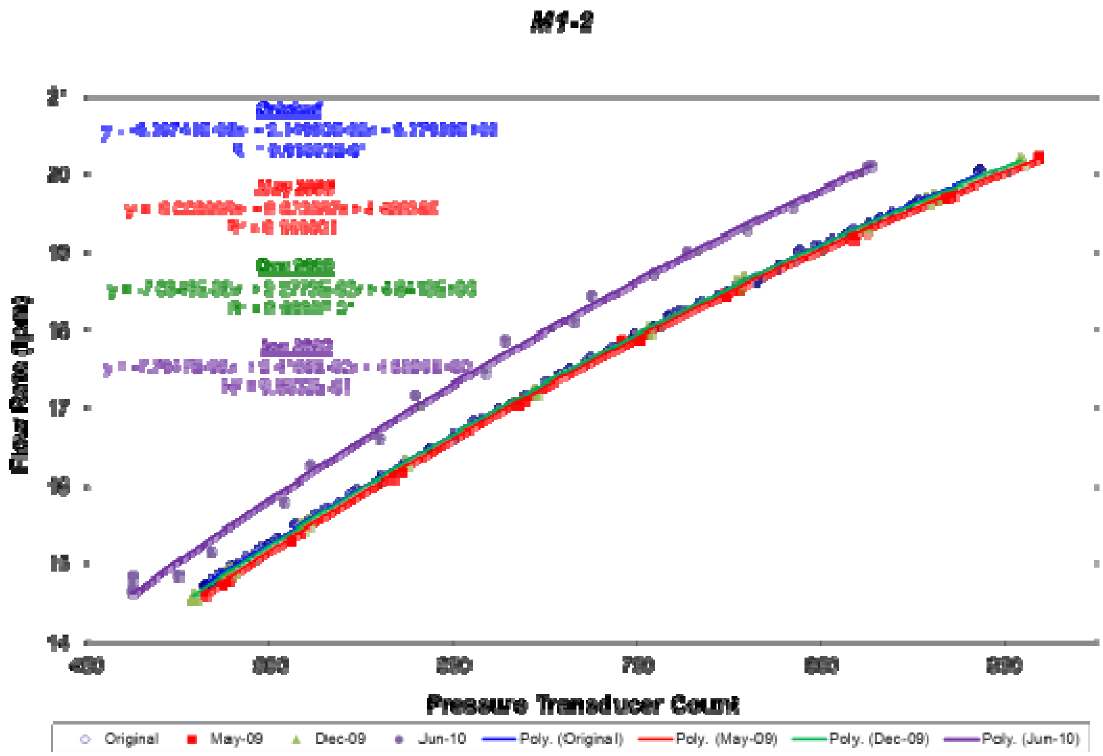

Figure 2. Ambient sampler calibration curve.

The 2011 sampling campaign specifically targeted a North Carolina gin to represent the Southeastern cotton growing region. The gin was to be similar to an average US gin with the main criteria for gin selection including:

1) Process rate of approximately 30-40 bales per hour.
2) Standard process streams - unloading, no. 1 pre-cleaning, no. 2 pre-cleaning, overflow, lint cleaning, mote fan, mote trash fan, battery condenser, and master trash.
3) High efficiency cyclones on all exhausts, preferably 1D3D type.
4) Large, clear gin yard for the ambient sampler array.

With the aid of the Southeastern Cotton Ginners Association, aerial photos, and site visits, the gin was selected from the approximately 40 cotton gins in North Carolina. The selected gin, located on a large, open yard and processing cotton at approximately 35 bales per hour with 1D3D cyclones, fit the selection criteria well. All of the standard process streams were represented, except for unloading, which was apparently typical of North Carolina gins.

Prior to all testing, each unique process stream exhaust cyclone was fitted with a 10-foot long exit stack extension containing straightening vanes to provide a sampling port and minimize cyclonic flow of the exiting air (Figure 3). These stack extensions were left on the cyclones for the duration of all testing and sampling to maintain constant exit heights for all exhausts. Each process stream was sampled using EPA test methods for $PM_{2.5}$ – OTM 27 (EPA, 2008), PM_{10} – Method 201A (CFR, 1990), and total suspended particulate (TSP) – Method 17 (CFR, 1978). The gin was sampled in October 2011. Seven unique systems with cyclones, including no. 1 pull, no. 2 pull, lint cleaner condenser, mote cleaner, mote cleaner trash, battery condenser, and main trash/overflow, were stack sampled with all three EPA methods (three replications per method).

Figure 3. Stack sampling.

Ambient sampling was conducted concurrently with the stack sampling. A uniform sampling array of 125 ambient samplers located on three rings at radial distances of 300, 600, and 900 feet centered approximately on gin's main cyclone bank was sited (Figure 4). This sampling array allowed for flexibility and limited the impact of moving or deleting some of sampling points altogether to account for site restrictions. The number and order of ambient samplers located at each site varied and sampling equipment was located to maximize data quality and minimize the effects of changing wind direction. Single stand-alone TSP samplers were deployed at each site on the inner and outer rings (Figure 5). Ten-meter tall towers with TSP sampler inlets at 1, 2, 3, 4.5, 7.25, and 10 meters were deployed at each of the middle ring sites (Figure 6). In addition to the towers at the middle ring sites, six additional sampler configurations with different combinations of FRM samplers including tapered element oscillating microbalance sampler with TSP inlet (Thermo-Scientific, East Greenbush, NY), stand-alone samplers with ambient PM_{10} sampler heads (Thermo-Scientific, East Greenbush, NY), stand-alone samplers with $PM_{2.5}$ very sharp cut cyclone heads (Thermo-Scientific, East Greenbush, NY), and stand-alone samplers with $PM_{2.5}$ WINS heads (BGI Incorporated, Waltham, MA) were used (Figure 6). Ambient samplers were run each day for approximately 22 hours. Ambient sampling was conducted over ten days. A total of 1460 samples were collected (63 stack sampling filters, 147 stack sampling washes, and 1250 ambient sampling filters). ARS and OSU researchers were on site for approximately 3 ½ weeks.

Figure 4. Layout of ambient sampler sites. Ring spacing was 300 ft and “I-“ indicates inner ring, “T-“ indicates tower (middle) ring, and “O-“ indicates outer ring.

Figure 5. Single stand-alone total suspended particulate sampler (LVTSP), PM_{10} sampler, $PM_{2.5}$ very sharp cut cyclone sampler (VSCC), and $PM_{2.5}$ WINS sampler.

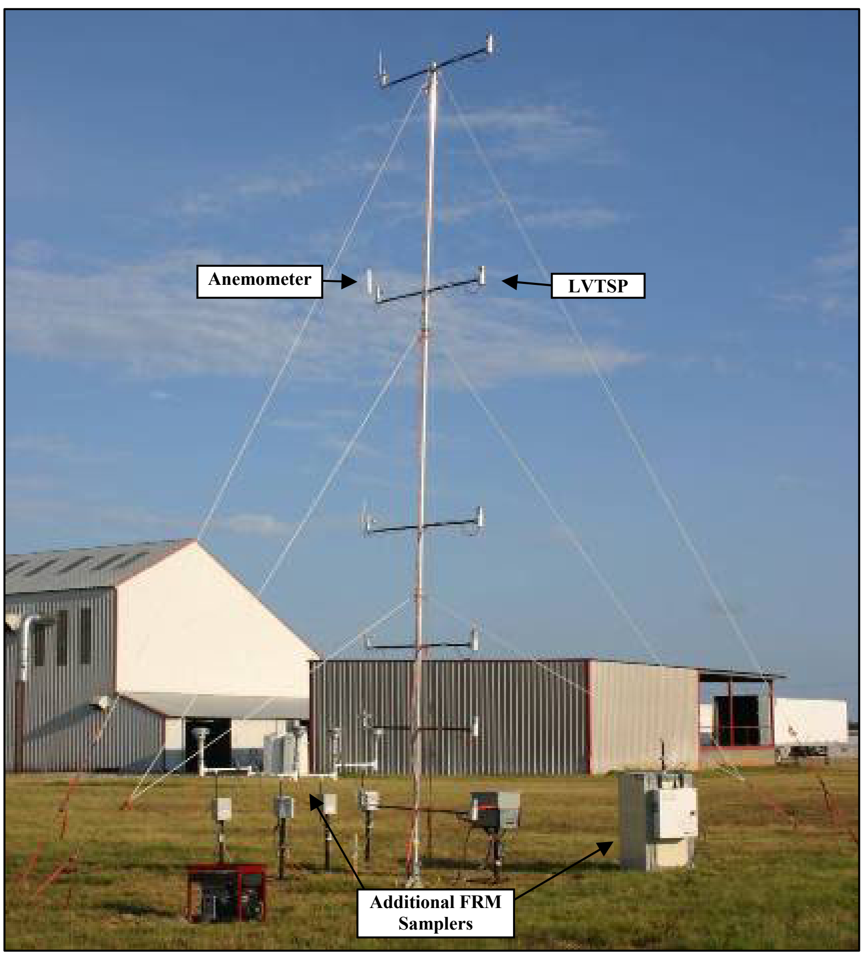

Figure 6. Configurations of ambient tower samplers with total suspended particulate sampler heads (LVTSP), wind anemometers, and additional stand-alone federal reference method samplers.

Sample Analyses

All filters and wash samples from the stack and ambient sampling were analyzed at the USDA-ARS Air Quality Laboratory (AQL) in Lubbock, Texas. These analyses included observational and photographic, gravimetric, and particle size distribution (PSD) (Figure 7). PSD analyses were conduction on a Beckman Coulter Counter Multisizer III and/or a Beckman LS230 laser diffraction system (Beckman Coulter, Inc., Fullerton, CA).

Throughout 2011, the AQL continued to process the samples collected during the 2010 campaigns and began processing the samples collected during the 2011 campaign. To date, all analyses of the samples from the previous (2008, 2009, and 2010) sampling campaigns have been completed and the gravimetric and photographic analyses of the 2011 samples have been completed (Table 1).

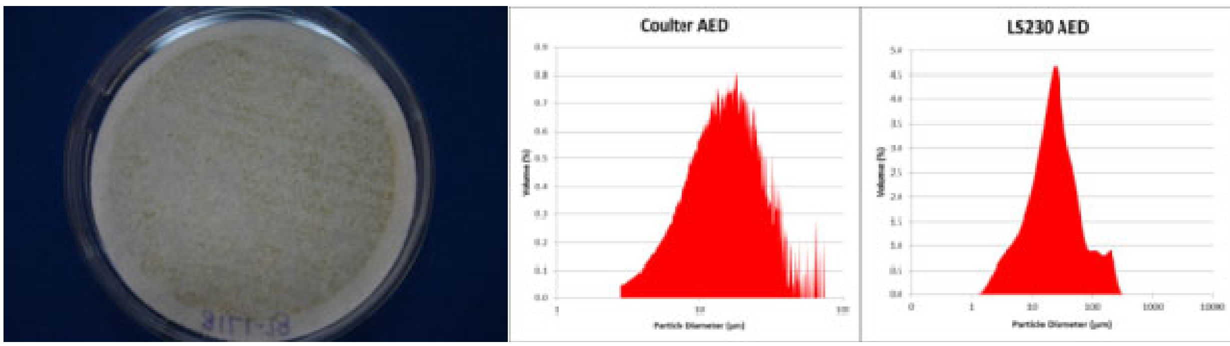

Figure 7. Example of sampling filter photograph and corresponding Coulter Counter Multisizer and laser diffraction particle size distributions.

Table 1. Summary of all samples collected and laboratory analyses completed by end of 2011.

	New Mexico 2008	South Texas 2009	California Saw 2009	California Roller 2009	Missouri 2010	West Texas 2010	North Carolina 2011
Stacks Sampled	12	9	13	13	9	10	7
Filters Collected	108	84	117	117	81	90	63
Washes Collected	252	189	273	273	189	210	147
Ambient Sampling	12 days	9 days	14 days		10 days	10 days	10 days
Filters Collected	1375	1125	1750		1250	1250	1250
Total Samples Collected	1735	1398	2530		1520	1550	1460
Lab Analyses Completed							
Photographic	100%	100%	100%		100%	100%	100%[z]
Gravimetric	100%	100%	100%		100%	100%	100%[z]
Particle Size	100%	100%	100%		100%[z]	100%[z]	---[y]

[z] Processed in 2011

[y] To be processed in 2012

Data Processing

Data processing progressed throughout 2011. For each stack test run and every day of ambient sampling conducted, there is corresponding data to be complied, checked for accuracy, and analyzed. Processing of the FRM stack sampling data from the first six gins sampled prior to 2011 was completed. This included draft stack sampling data files for 597 individual tests with gravimetric and PSD results for 597 filters and 1386 washes, and bale processing data for each test. Once the stack sampling information for the 2011 sampling campaign is processed, 219 data files containing information for 73 gin process-stream exhausts and approximately 2200 test samples will document the stack sampling effort. Ambient sampling data processing progressed with the development of template data files and significant progress compiling the ambient data from the first six gins. This is a significant and time consuming effort as the ambient data from all seven gin includes approximately 8000 individual sampler-day data-sets each containing sampler flow rate, ambient temperature, and barometric pressure (recorded every 17 seconds); filter gravimetric and PSD results; and other meteorological data (recorded every 5 minutes). At the end of the project, the authors estimate that more than 10,000 data summary sheets will be generated to document the sampling data collected.

Future Work

Work for 2012, will continue in the areas of lab analysis and data processing. Laboratory analysis for the seventh and final gin should be completed early in 2012, and processing of the FRM stack sampling data will follow closely behind. Investigators expect to have sampling draft reports for the FRM stack sampling by the end of the second quarter. Incorporation of PSD analysis data from stack sampling will require more time simply due to the volume of data to process and validate. Compiling the ambient sampling data will continue concurrently with stack data processing, but, similar to the stack PSD data, due to the great volume of information to processes (8000+ data sets) and since the need for the stack sampling results is more immediate and has been the main focus of the data processing effort, progress on processing the ambient data will likely be less significant until the stack data are complete.

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