DEVELOPMENT OF AN AIRBORNE FIBER SIZE SPECIFIC JOB-EXPOSURE MATRIX (JEM) BASED ON TRANSMISSION ELECTRON MICROSCOPY (TEM) DATA

CHARLESTON, SOUTH CAROLINA ASBESTOS TEXTILE COHORT

Final Report of Data Analyses and JEM Development

June 11, 2005

NIOSH Purchase Order No. 0000158283

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INTRODUCTION

This report is submitted in fulfillment of requirements of NIOSH Purchase Order No. 0000158283 dated September 17, 2001. The methods used for analyses of the TEM data and development of the Job-Exposure Matrix (JEM) are based on the Task 1 report (Protocol Development) submitted to NIOSH and modified on May 31, 2003 based on comments and recommendations by NIOSH investigators.

BACKGROUND

The National Institute for Occupational Safety and Health (NIOSH) is currently extending the follow-up period for a cohort of chrysotile asbestos workers previously employed in an asbestos textile plant located in Charleston, South Carolina. This plant has many unique features that make further study and analyses important in order to provide new information concerning exposure-response relationships for asbestos related pulmonary fibrosis and lung cancer. Unique features of this plant and worker cohort include: 1) use of almost entirely chrysotile for a period of approximately 50 years, 2) availability of historical exposure measurements from the 1930's until asbestos textile production ceased in 1977, 3) availability of archived membrane filter samples for more detailed transmission electron microscopy (TEM) analyses of airborne fiber size, and 4) a cohort of sufficient size and with sufficient follow-up to allow meaningful analyses of exposure-response.

Previous studies of mortality among the Charleston asbestos textile cohort have demonstrated significant excess mortality due to asbestos related fibrotic lung disease and a steep exposure-response relationship for lung cancer [Dement, 1980; Dement et al., 1981; Dement et al, 1983a; Dement et al, 1983b]. Both cohort and nested case-control study designs were used to investigate exposure-relationship relationships and to control for potential confounders. Chrysotile exposure levels, expressed as fibers longer than 5 micrometer per cubic centimeter of air by phase contrast microscopy (PCM), by plant areas (department and operations), specific textile jobs, and calendar years were estimated based on historic data and were used in connection with detailed worker job histories to calculated cumulative lifetime exposures [Dement et al 1981; Dement et al, 1983]. Individual lifetime cumulative exposures were calculated and used for estimating exposure-response relationships. The overall lung cancer SMR for this cohort was 1.97 (95% CI=1.69-2.28) while the risk for pneumoconiosis was 3.11 (95% CI=2.52-3.80). The risk of lung cancer was higher for white males (SMR=2.30; CI=1.88-2.79) and white females (SMR=2.75; CI=2.06-3.61).

Using data for the most recent follow-up of this cohort through 1990, Stayner et al. [1997] evaluated alternative exposure-response models for lung cancer and asbestosis with Poisson regression. These analyses evaluated evidence of a threshold response. A highly significant exposure-response relation was found for both lung cancer and asbestosis. The exposure-response relation for lung cancer seemed to be linear on a multiplicative scale; however, the exposure-response relation for asbestosis seemed to be nonlinear on a multiplicative scale. There was no significant evidence for a threshold in models for either lung cancer or asbestosis. The excess lifetime risk for white men exposed for 45 years at the recently revised OSHA standard of 0.1 fiber/ml was predicted to be about 5/1000 for lung cancer, and

2/1000 for asbestosis. A non-linear relationship between pulmonary fibrosis and chrysotile exposure in this cohort also has been suggested by pathological analyses of parenchymal lung tissues [Green et al., 1997].

The slope of the exposure-response relationship observed in Charleston is among the highest seen in asbestos exposed cohorts, irrespective of fiber type or industry. Independent study of these same chrysotile asbestos textile workers has corroborated the results obtained by Dement et al. and Stayner et al. [McDonald et al, 1983b]. Subsequent nested case-control analyses of this population were conducted to examine possible confounding effects from the use of mineral oil in the process of textile manufacturing [Dement, 1991; Dement et al, 1994]. These analyses concluded that mineral oil exposure was not a plausible explanation for the observed risk and confirmed the role of chrysotile exposure as the most likely cause for the increase in lung cancer and the strong exposure-response pattern observed. Similar lung cancer exposure-response patterns have been observed in other asbestos textiles [McDonald et al., 1983b; Peto et al, 1985].

In contrast to the risks observed for chrysotile workers in textiles, the lung cancer exposure-response pattern observed among chrysotile miners and millers has been less dramatic [McDonald et al 1980], suggesting possible differences in airborne fiber exposures characteristics between mines and mills versus production plants. Prior transmission electron microscopic (TEM) analyses of airborne fibers collected in plants using chrysotile have shown reasonably large differences in the distribution of fibers by both length and diameter with airborne fibers in textile plants tending to be longer and thinner [Dement and Wallingford, 1990]. Airborne fiber size measurement data for chrysotile mining and milling demonstrate a significantly greater proportion of fibers (95-98%) less than five micrometers in length compared to data from textile plants using chrysotile [Gibbs and Hwang, 1980; Dement et al., 1994], providing some support for increased pathogenicity for fibers produced in textile operations.

In addition to differences in airborne particle size by type of plant, TEM data show considerable variation in fiber size distributions among different operations within the same plant [Dement and Harris, 1979; Dement, 1980; Dement and Wallingford, 1990; Dement et al.,1994]. For these analyses, airborne fibers collected on membrane filters were analyzed by TEM using direct filter preparation methods in order to determine the bivariate distributions of airborne fibers. Due to the high magnification required to resolve the smallest diameter fibers, the maximum length of fiber that could be measured was 10 μm. While limited, these data suggest differences in particle size by plant operation that might be of biological significance. Further support for differences in the risk of lung cancer by plant operation is provided in the nested case-control analyses of Dement et al. [1994] where spinning operations were found to have a higher risk after controlling for confounders and cumulative lifetime asbestos exposures by PCM. Limitations of these data include: 1) no analyses by jobs within plant operations, and 2) no information on the bivariate distribution of airborne fiber longer than 10 μm. The current research expands upon these studies by: 1) analyzing archived filters by TEM in order to further determine the airborne fiber sizes (length and diameter) with lengths greater than 10 μm, and 2) using these airborne fiber data to develop a TEM airborne fiber size specific job-exposure matrix (JEM). The size-specific JEM will be used in updated mortality analyses of the Charleston cohort extended with additional years of follow-up.

REVIEW OF ALTERNATIVE EXPOSURE METRICS AND JEMS

Alternative Fiber Exposure Metrics

Measures of asbestos dust exposures in U.S. industries have changed over many years. The impinger method for measurement of airborne dusts was developed by the U.S. Public Health in the 1920's and measured all particles less than 10 um in diameter (i.e. those considered respirable) by low power, optical microscopy. Impinger dust concentrations were expressed as millions of particles per cubic foot of air (mppcf) [Greenburg and Bloomfield,1932]. Dreessen et al. [1938] conducted a cross-sectional chest x-ray study of asbestos textile workers in North Carolina and related the prevalence of changes to impinger dust measurements made in the same plants. This study formed the basis for the 1946 Threshold Limit Value (TLV) recommendation of 5 mppcf for asbestos containing dusts by the American Conference of Governmental Industrial Hygienists (ACGIH). In the 1960's the impinger began to be replaced by the membrane filter sampling method with counts of fibers longer than 5 μm being done by phase contrast optical microscopy (PCM) and with fiber concentrations being reported as fibers longer than 5 um per cubic centimeter of air (fibers/cc) [Lynch and Ayer, 1966]. Several reports from the 1964 New York conference entitled "Biological Effects of Asbestos" describe historical developments in measurement methods for airborne asbestos dust and development of the PCM membrane filter method [Holmes, 1964; Addingley, 1964; Roach, 1964]

Current risk assessments for occupational asbestos exposures are based on measures of airborne fiber concentrations by PCM. PCM fiber exposures integrated over a working lifetime have been shown to be strong predictors of asbestosis and lung cancer risks within a given industry. These measures are thus internally valid for a given industry; however, differences in risk between sectors (e.g. mining and textiles) have not been reconciled by the PCM measurement method. This may be due to problems inherent with the PCM method as well as the exposure metric (i.e. fibers > 5 μm). For example, the PCM has a limit of resolution of approximately 0.2-0.3 μm which means that many airborne asbestos particles will not be counted, even though many of these fibers may be longer than 5 μm.. In addition, animal data strongly suggest that longer-thinner fibers may be more biologically active; therefore, the risk may be better predicted by the airborne concentrations of these fibers [Pott, 1974; Stanton et al., 1981; Berman et al, 1995]. Also, risk in relationship to fiber dimensions may vary by disease endpoint (i.e. asbestosis, lung cancer, mesothelioma) [Lippmann,1988].

Recognizing the limitations of PCM, several investigators have recommended alternative exposure metrics. Lippmann [1988] reviewed published data from experimental studies in animals exposed by injection and inhalation to fibers of defined size distributions as well as data from studies of fiber distributions in lungs of exposed humans in relation to the effects associated with the retained fibers. Lippmann concluded that asbestosis is most closely related to the surface area of retained fibers, that mesothelioma is most closely associated with numbers of fibers longer than approximately 5 μm and thinner than approximately 0.1 μm, and that lung cancer is most closely associated with fibers longer than approximately 10 μm and thicker than approximately 0.15 μm.

Berman et al. [1995] and Berman and Crump [1999] reviewed data from inhalation studies in which AF/HAN rats were exposed to nine different types of asbestos dusts (13 separate experiments by Davis). Maximum likelihood statistical analyses were used to develop linear models which related the probability of developing tumors to different measures of asbestos exposure (expressed as concentrations of structures with defined sizes, shapes and mineralogy). No univariate measure of exposure (e.g. concentrations of any one fiber size) was found to provide an adequate description of the lung tumor responses observed among the inhalation studies. Multivariate measures of exposure were identified which more adequately described the lung tumor responses. Structures most predictive of to lung tumor risk appeared to be long (∃5 µm) thin (<0.3 µm) fibers and bundles, with a possible contribution by long and very thick (∃ 5 µm) complex clusters and matrices. Potency appeared to increase with increasing length, with structures longer than 40 µm being about 500 times more potent than structures between 5 and 40 µm in length. Structures < 5 µm in length did not appear to make any contribution to lung tumor risk. This analysis did not find a difference in the potency of chrysotile and amphibole for the induction of lung tumors. Based on these analyses, Berman and Crump suggested an exposure index for asbestos expressed as follows:

$$\text{Exposure} = 0.0017C_1 + 0.853\ C_2 + 0.145\ C_3$$

where:

C_1 is the concentration of structures between 5 and 40 µm in length that are thinner than 0.3 µm.

C_2 is the concentration of structures longer than 40 µm in length that are thinner than 0.3 µm.

C_3 is the concentration of structures longer than 40 µm in length that are thicker than 5 µm.

While the models developed by Berman and Crump appear to adequately predict the risk of lung tumors in experimental animals, caution is needed in extrapolating these results to humans. First, their analyses were based on a single animal species in a single laboratory. Secondly, the models are based on fibers sizes that are respirable by rats, which is different than for humans. Lastly, the model appears to assign weights to some fiber size categories that are not respirable, thus raising questions about model validity.

Based on their analyses of data concerning exposures to man-made vitreous fibers, Quinn et al. [2000] suggested alternative exposure metrics based fiber size and composition. These indices were collectively called the Hypothetically Active Fiber (HAF) Indices and are based on three basic principles of proposed biologic activity: (1) the fibers must be able to cause the cellular changes associated with tumor formation; (2) the fibers must be sufficiently durable to remain at the target site long enough to cause carcinogenic cellular changes; and (3) the fibers must be able to reach the target tissues in the respiratory tract. These authors calculated various HAF indices based on biologically important fiber sizes suggested by Stanton, Pott, and Lippmann and compared these to PCM fiber measures. Using airborne data from the man-made vitreous industry, no consistent relationship among these measures was observed and the index of fibers hypothesized to be relevant for a study of lung cancer risk was not found to equate to the standard fiber PCM concentration measures. Quinn at al. suggested a method to Aadjust@ standard fiber concentration measures to the biologically relevant HAF concentrations using proportions from bivariate fiber size distributions.

In summary, most investigators consider longer and thinner asbestos fibers to be more active in the production of asbestosis as well as lung cancers; however, there is currently no one fiber exposure index which is universally agreed upon. The proposed fiber exposure indices have largely been based on animal inhalation data and not human epidemiology. For these reasons, it is important that the job-exposure matrix allow maximum flexibility in calculation of exposure metrics based on airborne particle size parameters.

Job-Exposure Matrices

A number of strategies have been developed for summarizing and categorizing occupational exposure information for epidemiologic studies. A job-exposure matrix (JEM) is often used to define the presence or absence of specific exposures within a given industry or job title [Acheson, 1983; Coggon et al., 1984; Hoar et al., 1980; Plato and Steineck, 1993]. In general, a JEM can be organized as an array of information which relates industry and/or job titles with occupational exposures. Each cell entry in the array then contains a measure of exposure for the job title/chemical pair. Entries can be quantitative when sufficient exposure measurement data are available, semi-quantitative (e.g., categories of exposure), or qualitative (e.g., exposed or unexposed). If exposures vary with time period, a third dimension can be added to the JEM to account for temporal variations. More elaborate JEMs can sometimes be developed if jobs are analyzed at the task level. Any given job may be further thought of as being composed of a specific number of tasks each with a given potential for exposure and associated exposure level [Nicas and Spear, 1993a, 1993b].

Job-exposure matrices (JEM) have been used effectively to combine observational or direct exposure measurements with past work histories to derive a measure of overall exposure for both surveillance and etiologic research. JEMs provide a global evaluation of a job category which can be used, through data linkages, to estimate exposures of anyone who worked in that job, or task, with their cumulative exposures based on length of employment in that job. Clearly there is some loss of precision compared to direct expert assessment and personal exposure measurements, but there can be very significant cost savings thus making it possible to study larger groups of workers than would be possible if individual longitudinal exposure assessments were needed [Dosemici, 1990]. In addition to their value for etiologic research, JEMs provide a useful tool for surveillance where potential exposures to many substances or work circumstances can be evaluated.

JEMs have been developed using many different techniques and in varying degrees of detail [Bouyer and Hemon, 1993]. Population based JEMs may use broad definitions of exposures based on industry SIC codes and occupational codes [Hoar et al., 1980; Sieber et al.,1991; Siemiatycki et al., 1981]. While JEMs have largely been used for studies of chemical or physical hazards, more recent efforts have extended the JEM concept to include a wider spectrum of hazards including physical, chemical, biological, ergonomic, and psychosocial factors [Kauppinen et al., 1998]. Industry specific JEMs can often provide a much greater degree of detail and precision in defining exposures [Astrakianakis et al., 1998a; Dement, 1980].

Dement [1980; 1981; 1983a] developed a JEM which was used to link PCM exposure estimates with individual job histories in order to estimate cumulative asbestos exposures for each cohort member. Airborne dust samples (n=5952) covering the period 1930-1975, we used to fit parameters of statistical models to predict PCM exposure levels by department, job, and time period. For purposes of model development, the plant was divided into 10 Aexposure zones@. Exposure zones are physical plant locations, which are thought to produce more homogeneous asbestos exposures based on similarity of processes, physical location, and control measures. These exposure zones were constructed *a priori* based on the similarity of jobs and characteristics of exposures. Within each exposure zone, jobs were further divided into 4 or more Auniform job categories@ (UJC). Models for each exposure zone included covariates for UJC, process changes, and changes in engineering controls. Mean PCM exposures and 95% confidence intervals for these exposure zones were calculated [Dement et al., 1983a].

METHODS

TEM Size Specific JEM Conceptual Model

An airborne fiber size-specific JEM was developed for this project based on the prior JEM published by Dement et al. (1980, 1983a) for the Charleston plant and incorporates the same exposure zones and UJCs. The size-specific JEM is based on the 'adjustment factor' method proposed by Quinn et al. [2000], which 'adjusts' standard fiber concentration measures by PCM to the biologically relevant size-specific fiber concentrations using proportions from bivariate fiber size distributions.

A conceptual model for any desired fiber exposure metric can be expressed as a product of three random variables for any combination of plant exposure zone and UJC. The expected value of a product of random variables is the product of each expected value; therefore, each new metric can be expressed as follows:

$$E_{ijz} = (PCM_{ijz}) * [(F_{ijz})/(FPCM_{ijz})]$$

Where:

E_{ijz}	=	New exposure metric for exposure zone >i=, UJC >j=, and time period >z= based on the proportion of fibers of selected size, fiber surface area, dimension weighted fiber exposure metric, etc.
PCM_{ijz}	=	Phase contrast fiber concentration for exposure zone >i=, UJC >j=, and time period >z= from Dement et al. [1980, 1981].

$FPCM_{ijz}$ = Fraction of all airborne fibers measured by TEM which are actually counted by PCM (>0.30 µm in diameter and >5.0 µm in length) for exposure zone >i=, UJC >j=, and time period >z=

F_{ijz} = The fraction of all TEM fibers in exposure zone >i=, UJC >j=, and time period >z= fitting the definition for the exposure metric based on TEM fiber size data.

The factor (F_{ijz}) can be estimated from the final bivariate diameter/length matrix for each exposure zone or UJC. For example, F_{ijz} for AStanton fibers@ would be the fraction of all TEM fibers < 0.25 µm in diameter and >8.0 µm in length. Since the concentration of all TEM fibers is available for a relatively small portion of the PCM samples collected in this plant, a method of adjusting PCM sample concentrations to express concentrations of all fibers by TEM is needed. The model parameter $FPCM_{ijz}$ was used for this purpose and was calculated from the diameter/length matrix by summing the fraction of all airborne fibers measured by TEM which are actually counted by PCM (>0.30 µm in diameter and >5.0 µm in length). The ratio $F_{ijz}/FPCM_{ijz}$ thus provides an estimate of the TEM equivalent fiber concentration for each exposure zone and UJC using the prior PCM exposure estimates.

Membrane Filter Samples and TEM Methods

Two data sources were used to develop the fiber size specific JEM for the Charleston, S.C. textile worker mortality study. These sources were as follows:

1) PCM exposure estimates and JEM developed by Dement (1980, 1981)

2) Bivariate fiber size distribution data by TEM to be supplied by NIOSH.

The U.S. Public Health Service (PHS) conducted industrial hygiene studies of asbestos products producing plants in the U.S. as part of an industry-wide study initiated in the mid-1960's. A number of sampling and analytical methods were employed for these industrial hygiene studies including midget impingers and membrane filter samples analyzed by phase-contrast microscopy. Membrane filter samples were collected in the Charleston plant starting in 1964. These membrane filter samples were analyzed and reported by the USPHS and portions of the unused filters were archived and have been used in previous analyses to compare PCM and TEM methods for measuring airborne fiber concentrations [Dement and Wallingford, 1990]. A total of 203 archived samples were located for the present study. These archived samples were collected over the time period 1964 to 1971; therefore, an inherent assumption in development of the JEM is that airborne fiber characteristics have remained substantially the same over a study period covering the late 1930's through end of asbestos textile production in approximately 1977. This assumption is reasonable since production methods and equipment remained essentially unchanged over this time frame and engineering controls for asbestos dust were installed in the 1930's [Dement, 1980; Dement, 1983a].

All membrane filter samples from the NIOSH archives were matched to their original sampling sheets in order to identify the plant department and job sampled. Using these department and job descriptions, archived samples were assigned to the same exposure zones and uniform job categories developed by Dement [1980, 1983a] and used in developing the original PCM exposure estimates. This *a priori* assignment is consistent with our knowledge of plant processes and exposure characteristics. Based on available resources and sample availability, a stratified random sample of the available membrane filter samples was selected with the strata consisting of exposure zones and uniform job categories. This process resulted in having 86 samples for TEM analyses. A list of the TEM samples and their respective exposure zones and UJCs is shown in Appendix I. Two of the 86 samples were determined to be unusable due to extremely low fiber densities, resulting in very few structures being counted and sized based on stopping rules for the TEM method. The two samples not used in the analyses each had only 3 structures counted in all counting strata. The resulting distribution of samples included in these analyses by exposure zone and plant department is as follows:

Exposure Zone	Department Name	Number of TEM Samples
1	Preparation	6
2	Carding	11
3	Ring Spinning	11
4	Mule Spinning	11
5	Foster Winding	5
6	Twisting	6
7	Universal Winding	9
8	Heavy Weaving	11
9	Light Weaving	11
10	Finishing Operations	3

The TEM structure/fiber counting and sizing protocol used by NIOSH [NIOSH, 2004] is a modification of the ISO Direct-Transfer Method [ISO, 1995]. For each sample, three separate analyses were performed, based on fiber length, in order to achieve greater statistical precision of the bivariate size distributions. These analyses consisted of counting all structures, structures > 5 μm and structures > 15 μm. For each counting stratum, the number of grid opening used for obtaining the desired structure count was recorded. The TEM data supplied by NIOSH consisted of four Microsoft Excel worksheets for each sample analyzed. The first worksheet contained information about the TEM grids and the grid mount quality. The second worksheet contained ISO counts and sizes for all asbestos structures, the third worksheet contained the stratified counts and sizes of asbestos structures longer than 5 μm, and the fourth worksheet contained the stratified counts and sizes of asbestos structures longer than 15 μm. Data from each Excel worksheet was imported into SAS Version 8.2 [SAS, 1999] for statistical analyses. The SAS file for each sample was compared with the original Excel files to assure that all structures were successfully extracted and that the counts of structures by type were consistent with the raw Excel data.

TEM Data Reduction and Combining TEM Stratum Counts for Each Sample

The initial task in analyzing each sample was to combined the separate TEM counts of all structures, with counts for structures > 5 μm and structures > 15 μm. Available data suggest that the best predictor of risk using TEM data collected by ISO procedures is the concentration of primary structures with resolution of complex structures into component fibers and bundles [Berman et al., 1995]. For the new exposure measures, all component structures (fibers and bundles) were selected from the three Excel spreadsheets for each sample and imported into SAS for analyses. Using the length and diameter data, each structure was placed into one of 24 diameter/length categories. The cut points for the diameter/length categories were chosen based on measurement limits and precision for diameter and length specified in the NIOSH TEM protocol [NIOSH, 2004] and possible biological relevance based on published exposure metrics (previously reviewed). The actual structure length and diameter categories for the all structures count and the >5 μm count differ slightly for a given even centimeter measurement due to the different calibrations at 10,000X and 20,000X magnification. For example, the smallest structure diameter for the all structure count is #0.27 μm whereas the smallest structure diameter for the >5 μm count is #0.25 μm. In addition, some slight differences in actual calibrated magnification were observed; therefore, the smallest diameter category for the combined data was set at #0.30 μm. A similar approach was used for all other size groupings in order to assure proper structure assignment. Length categories were chosen to assure cuts at 5 μm and 15 μm for purposes of combining the stratified data. Six length categories and four diameter categories were established, resulting in a bivariate diameter/length matrix consisting of 24 cells.

Our approach to combining the all structures count with the counts of structures >5 μm and > 15 μm for each sample involved direct calculation of the proportion of airborne fibers in the 24 cells of the diameter/length matrix based on relative filter densities (fibers per TEM grid opening). The three strata (all structures, structures > 5 μm, and structures > 15 μm) all have fiber counts that are usually based on counting structures in a differing number of grid openings. For example, for all structures, only one grid opening was sometimes need to reach the stopping rule specified in the TEM protocol, however, many more grid opening were usually need to achieve the TEM stopping rules for the >5 μm and > 15 μm counting strata. In order to combine these data to form the overall bivariate distribution of diameter and length, the proportion of fibers in each cell of the diameter/length matrix was calculated as a relative fiber density, taking into account the number of grid openings used for each stratum. Cut points for fiber length in the bivariate matrix coincided with the TEM counting strata cut points of structures > 5 μm, and structures > 15 μm, which allowed direct calculation of the point estimate for the proportion of airborne fibers in each cell of the bivariate matrix. >Bootstrapping= was then used to estimate the variances of the bivariate diameter/length cell proportions.

All structures (fibers and bundles) in each TEM counting stratum were selected and assigned to the appropriate category for diameter and length. For each combination of diameter and length, the number of structures counted as well as the number of grid openings analyzed in order to achieve the observed structure count was summed. The structure density (structures/grid opening) was calculated for each diameter/length category and summed over all 24 cells to obtain the total filter structure density. The proportion of airborne fibers by TEM was estimated for each cell in the diameter/length matrix as the cell structure density divided by the total filter density. The proportion of all airborne structures (fibers and bundles) counted by PCM was estimated as the sum of cell structures densities for structures >0.3 μm in diameter > 5 μm in length.

Our approach to estimating variability in the cell proportions of diameter/length matrix involved stratified random sampling and 'bootstrapping'. For each stratum (all structures, structures > 5 μm, and structures > 5 μm), we randomly selected structures from each TEM counting stratum, with replacement, with the stratum sampling frequency equal to the structure count in the original sample. Using the SAS Proc SurveySelect procedure, this sampling procedure was replicated 100 times for each sample with the proportion of structures in each diameter/length category of the matrix calculated for each replicate. For each replicate, an estimate of the fraction of all TEM structures countable by PCM (>0.30 μm diameter and > 5 μm in length) was also generated. Using the data from each replication, the mean proportion of fibers in each diameter/length category of the matrix and the standard deviation of each mean proportion was calculated. The size specific PCM to TEM factor (Fijz)/(FPCMijz) was calculated for each replicate and a mean value, with an estimated standard deviation, calculated for each cell in the diameter/length matrix. The PCM to TEM factor represents the multiplier, that when applied to the original PCM job-exposure matrix for the Charleston plant, provides an estimate of the TEM size specific concentration for a given exposure zone, UJC, and time period.

Combining Individual Samples for Each Exposure Zone

Before combining the individual samples within a given exposure zone, we first compared the proportional distribution of structures by diameter/length category for each sample generated from the procedures described above. The primary interest in these comparisons was meaningful differences in the TEM structure size distributions for UJCs within each exposure zone, although our ability to explore this was limited as relative few TEM samples were available within each exposure zone and no TEM data were available for some UJCs within zones. Therefore, the decision was made to combine all samples within a zone to arrive at an overall zone estimate for the bivariate diameter/length distribution. This decision was justified by our *a priori* knowledge of plant processes, jobs, and fiber characteristics within each zone and is consistent with methods and assumptions used in deriving historical PCM exposure estimates for this plant [Dement 1980; Dement et al., 1983a]. In addition, differences in disease risk possibly related to fiber characteristics by jobs within exposures zones can be tested in the mortality analyses.

Individual samples within each exposure zone were combined to provide a more stable estimate of the bivariate fiber diameter/length diameter distribution for each zone as well as more stable estimates of the size specific PCM to TEM factor (Fijz)/(FPCMijz). An approach different from that used for combining the TEM counting strata or each sample was needed. The relative fiber density approach could not be used due to: 1) the highly variable fiber densities (fibers/grid) on each sample, 2) the varied number of grid opening counted for each sample and TEM counting strata, and 3) variable stability of diameter/length cell proportions for each sample. Several approaches were considered and investigated. These included: 1) calculation of diameter/length cell proportions for the zone as the inverse variance weighted average of sample cell proportions, and 2) calculation of diameter/length cell proportions for the zone as the average of cell proportions from each sample, with bootstrapping by sample and TEM counting strata to estimate exposure zone cell variances. The inverse variance weighted average method was rejected as this assumes that cell proportions for a given sample were independent. The latter method based on bootstrapped averages by cell also was rejected as this method fails to account variable stability of sample cell proportions.

Samples within each zone were combined based on pooling the fibers counted within TEM counting strata (all structures, structures > 5 μm, and structures > 15 μm). Within each TEM counting stratum, the fiber counts can be combined and the proportional distribution by diameter/length category calculated directly as a simple proportion. For example, for the all structures stratum, fibers from each sample were placed into the 24 cells of the diameter/length matrix and summed. The bivariate diameter/length proportion was calculated as the sum of the cell counts divided by the total number of fibers counted within the TEM counting stratum. The all structure stratum thus provides an estimate of the overall bivariate diameter/length distribution whereas proportions calculated from the > 5 μm, and > 15 μm strata can be viewed as conditional probabilities, conditioned on first meeting the minimum fiber length to be counted. Realizing these relationships between the TEM counting strata, the overall bivariate diameter/length cell proportions were calculated as follows based on products of conditional probabilities derived from the pooled data for each exposure zone:

- <u>For fibers less than or equal to 5 μm in length</u>:

  Cell Proportion = Cell proportion calculated using the pooled all structures TEM counting stratum.

- <u>For fibers > 5 μm in length and up to 15 μm in length</u>:

  Cell Proportion = (Fraction > 5 μm in length calculated from the pooled all structures TEM counting stratum) * (Cell proportion calculated from the pooled > 5 μm TEM counting stratum).

- <u>For fibers > 15 μm in length</u>:

  Cell Proportion = (Fraction > 5 μm in length calculated from the pooled all structures TEM counting stratum) * (Fraction > 15 μm in length calculated from the pooled > 5 μm TEM counting stratum)*(Cell proportion calculated from the pooled > 15 μm TEM counting stratum).

This method efficiently used each successive TEM counting stratum to better estimate the bivariate proportion of longer lengths without restrictive distributional assumptions. The PCM to TEM factor (Fijz)/(FPCMijz) was calculated in the same manner previously described for individual samples. Bootstrapping was used to estimate the cell proportion variances as well as the variances in the factor (Fijz)/(FPCMijz) for each cell. For each pooled stratum (all structures, structures > 5 μm, and structures > 5 μm), we randomly selected structures from each TEM counting stratum, with replacement, with the stratum sampling frequency being equal to the pooled structure count for the exposure zone. Using the SAS Proc SurveySelect procedure, this sampling procedure was replicated 500 times for each sample with the proportion of structures in each diameter/length category of the matrix calculated for each replicate as described above. For each replicate, an estimate of the fraction of all TEM structures countable by PCM (>0.30 μm diameter and > 5 μm in length) was also generated.

Using the data from each of the 500 replications, the mean proportion of fibers in each diameter/length category of the matrix and the PCM to TEM factor (Fijz)/(FPCMijz) was calculated. The distribution of the parameter estimates from the 500 replications was used to construct lower 5% and upper 95% confidence intervals. While the standard deviation of each mean proportion and PCM to TEM factor was calculated and as is provided with results, the percentile method is preferred for confidence interval estimation several reasons, with the most important being that the underlying distribution of the estimator is unknown [Mooney and Duval, 1993]. Non-normality was confirmed by examining the bootstrap distribution of the cell proportions, especially when the number of structures in the cell was low. The bootstrap percentile method allows the bootstrap estimate of the distribution of the statistic to conform to any shape that the data suggest, which allows confidence intervals to be asymmetrical around the expected value of estimate.

In addition to the TEM size specific diameter/length matrix and PCM to TEM factors for each exposure zone, we developed an exposure metric based on approximations of fiber surface areas. For this metric, we assumed that fibers and fiber bundles could be considered right cylinders and calculated the surface area (μm^2) for each structure counted. For each of the 500 replications described above, we calculated the mean surface area for each diameter/length category and a PCM to surface area factor. The distribution of the parameter estimates from the 500 replications was used to estimate the standard deviations of the surface area factor by diameter/length category and to construct lower 5% and upper 95% confidence intervals using the percentile method as described above. The surface area factor represents a multiplier to be used with PCM concentrations to express concentrations in terms of surface area (μm^2/cc). This should be viewed as only a relative measure, useful for internal comparisons within this cohort.

RESULTS AND DISCUSSION

Results of the data reduction and analyses to generate bivariate fiber diameter/length distributions by plant zone are shown in Appendix II and the surface area factors are shown in Appendix III. For each exposure zone, the bivariate diameter and length distribution of fibers and bundles is expressed as the proportion of all airborne fibers within each cell of the diameter/length matrix. Also presented for each cell is the PCM to TEM factor (Fijz)/(FPCMijz), which can be used as a multiplier to derive a TEM size specific fiber size concentration using the previous PCM data by plant department, job, and time period. As an example, suppose that the TEM concentration of long, thin fibers (< 0.3 μm diameter and > 40 μm in length is needed for zone 1. Looking at zone 1 data in Appendix I for fibers of this size (cell #6), the PCM to TEM factor is 0.03928, which would be multiplied by the previous PCM estimate to derive the appropriate TEM size specific estimate. Therefore, if the PCM concentration was 10 fibers/cc, the resulting TEM estimated concentration of fibers < 0.3 μm diameter and > 40 μm in length would be 0.39 fibers/cc. In a like manner, the surface area factors in Appendix III can be used to derive surface area specific exposure measurements, expressed as μm^2/cc, based on specific fiber size categories. Data from the 24 cells may be combined to derive fiber concentrations and surface area concentrations for combinations of fiber diameter/length represented in the data summaries.

A comparison of zone-specific PCM to TEM factors by diameter and length category is presented in Table 1. While many of the bivariate diameter/length cells have similar factors by zone, some potentially important differences are noted. For example, some zones demonstrated a greater preponderance of short, thin fibers whereas others demonstrated longer-thinner fibers. A comparison of PCM to TEM factors for long-thin fibers is shown in Figure 1. For these fiber categories, the adjustment factor is as much as 5-fold difference by zone, suggesting some potentially interesting exposure-response comparisons in the mortality analyses. Figure 2 shows univariate fiber length distributions by plant and again shows considerable differences by length category and exposure zone.

A comparison of TEM to surface area factors by exposure zone is shown in Table 2. Like to PCM to TEM conversions, considerable variability is noted by zone. A comparison the TEM count factors in Table 1 to the surface area factors in Table II demonstrates substantial differences in relative cell weights for metrics dependent on fiber counts versus fiber relative surface areas. These data suggest some interesting disease specific analyses of the cohort mortality data, especially for non-malignant lung diseases, as suggest by Lippmann [1988].

In order to facilitate maximum use of these data for exploratory exposure-response assessments of the mortality data, a Microsoft Access database was developed. This database incorporates the bivariate diameter/length data shown in Appendices II and III and allows the user to specify cells in the bivariate distribution to be included in the TEM size specific exposure measurements or for surface area specific measurements. After the desired cells are selected, a macro estimates the desired TEM fiber concentrations or surface area concentrations for each department and job included in the exposure filed used by the NIOSH PC Lifetable Analysis System (PCLTAS). The exposure file can be viewed or exported as an Excel spreadsheet. Appendix IV provides operating instructions for the 'Charleston TEM Size-Specific JEM' developed for this project. The database also includes summary reports of the bivariate diameter/length data and PCM conversion factors by exposure zone

The exposure zone approach used for the fiber size data, combined with the PCM and TEM data, provides new exposure metrics that take into account differences by job and calendar time period. The JEM provides unique data for the study of cancer and non-cancer endpoints among the Charleston cohort and for comparisons with other plants and facilities. Strengths of the data include a reasonably good number of samples for each exposure zone with additional efforts in the TEM analyses to better capture the entire fiber size spectrum, including fibers > 40 μm. A limitation is the unavailability of samples and resources to further study differences by UJC within each zone; for many jobs within exposure zones, we used all samples available within the NIOSH archive. Based on our *a priori* knowledge of plant processes, jobs, and fiber characteristics within each zone, the assumption that jobs within a given exposure zone share similar airborne fiber size characteristics appears justified [Dement 1980; Dement et al. 1983a; Dement and Wallingford, 1990]. As previously noted, differences in disease risk by jobs within an exposure zone, after accounting for exposure levels, can be evaluated in the mortality analyses as a validation of this assumption.

Given that the samples for TEM analyses do not cover the entire period for which PCM estimates are available, only a single point estimate for the PCM to TEM could be developed for each exposure zone. The implicit assumption in these estimates is stability of this parameter over calendar time. The process of making asbestos textiles at this plant changed little over the study period; therefore, this assumption also seems reasonable, as previously noted.

The primary objective of this report was to provide the size-specific JEM to allow further exposure-response analyses of the updated Charleston cohort. A more detailed report describing the TEM methods and results will be developed for publication in collaboration with NIOSH investigators. It would be most desirable if the mortality study results using the JEM data developed by this project were published in the same journal in a companion manuscript.

ACKNOWLEDGEMENTS

Ms. Leming Li and Dr. John Feaganes assisted with the statistical design for this study. We also are grateful for the many constructive comments and suggestions of Dr. Eileen Kuempel, Mr. Ralph Zumwalde, Dr. Leslie Stayner and the many other NIOSH investigators involved with this project, including development of the TEM analysis protocol. A special thank you to Anna Ristich for her tireless efforts in completing the TEM analyses and great attention to detail and data quality.

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TABLE 1

COMPARISON OF PCM TO TEM FACTORS BY ZONE FOR BIVARIATE SIZE DISTRIBUTIONS

Fiber Diameter	Fiber Length	Zone1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Overall Plant
<0.3 um	<1.5 um	3.76362	5.08917	8.53177	5.03790	6.72568	14.5784	4.42226	9.89495	9.47283	30.4891	6.80846
<0.3 um	1.5-3.0 um	2.69479	2.50762	3.01106	2.42251	4.40707	3.77380	1.96189	2.97245	3.03219	8.18130	2.77100
<0.3 um	3.0-5.0 um	1.23700	1.20208	1.20992	1.24980	1.52822	1.97840	1.02094	1.15153	1.16446	3.05550	1.23153
<0.3 um	5.0-15.0 um	0.78819	0.97250	0.84759	0.98611	0.97200	1.66600	0.85800	1.00453	1.25353	1.87820	0.96777
<0.3 um	15.0-40.0 um	0.19655	0.15464	0.36388	0.25493	0.29096	0.42060	0.22673	0.27678	0.35408	0.26920	0.26172
<0.3 um	>40.0 um	0.03928	0.02668	0.10203	0.08535	0.05484	0.08370	0.04740	0.05486	0.07934	0.00000	0.06277
0.3-1.0 um	<1.5 um	0.13036	0.24077	0.19787	0.08250	0.30598	0.05510	0.15106	0.19923	0.10959	1.19780	0.16232
0.3-1.0 um	1.5-3.0 um	0.42031	0.61683	0.34314	0.19232	0.44256	0.16410	0.25080	0.28231	0.33204	0.97880	0.34271
0.3-1.0 um	3.0-5.0 um	0.35023	0.43628	0.37080	0.29514	0.39207	0.18650	0.28471	0.25089	0.31673	0.98430	0.32419
0.3-1.0 um	5.0-15.0 um	0.44501	0.42841	0.35082	0.39047	0.40609	0.37660	0.34797	0.48220	0.46929	0.35890	0.40560
0.3-1.0 um	15.0-40.0 um	0.09412	0.08271	0.14450	0.13158	0.12949	0.15200	0.10664	0.14871	0.11087	0.40850	0.12127
0.3-1.0 um	>40.0 um	0.02727	0.01822	0.08864	0.07244	0.07653	0.11800	0.05194	0.04554	0.05192	0.08210	0.05449
1.0-3.0 um	<1.5 um	0.01953	0.01597	0.00000	0.02311	0.00000	0.03820	0.01897	0.02968	0.03764	0.37900	0.01625
1.0-3.0 um	1.5-3.0 um	0.01919	0.01598	0.01521	0.01566	0.06922	0.03680	0.03645	0.00000	0.07796	0.00000	0.02176
1.0-3.0 um	3.0-5.0 um	0.01890	0.11989	0.05037	0.00000	0.09666	0.00000	0.06058	0.01935	0.06452	0.00000	0.04295
1.0-3.0 um	5.0-15.0 um	0.26147	0.31272	0.20748	0.24744	0.18952	0.18890	0.25249	0.16989	0.20375	0.10670	0.23114
1.0-3.0 um	15.0-40.0 um	0.07121	0.07907	0.10443	0.07518	0.10598	0.10020	0.11479	0.07312	0.07391	0.00000	0.08512
1.0-3.0 um	>40.0 um	0.01189	0.01027	0.02014	0.02592	0.02348	0.01490	0.01837	0.01958	0.03522	0.00000	0.01976
> 3.0 um	<1.5 um	0.00000	0.02378	0.00000	0.00000	0.00000	0.00000	0.00000	0.01898	0.00000	0.00000	0.00428
> 3.0 um	1.5-3.0 um	0.01274	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00217
> 3.0 um	3.0-5.0 um	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
> 3.0 um	5.0-15.0 um	0.04831	0.04034	0.04293	0.03761	0.01852	0.00000	0.03493	0.03543	0.02311	0.08480	0.03538
> 3.0 um	15.0-40.0 um	0.04268	0.03568	0.04621	0.02718	0.04483	0.00000	0.06280	0.02157	0.02221	0.00000	0.03552
> 3.0 um	>40.0 um	0.00729	0.01016	0.01975	0.01221	0.00697	0.05160	0.01006	0.00396	0.00995	0.00000	0.01172

TABLE 2

COMPARISON OF PCM TO SURFACE AREA FACTORS BY ZONE FOR BIVARIATE SIZE DISTRIBUTIONS

Fiber Diameter	Fiber Length	Zone1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Overall Plant
<0.3 um	<1.5 um	3.4119	4.7083	6.8578	4.4417	6.1356	13.0402	4.1609	8.2383	8.8281	29.2457	5.9623
<0.3 um	1.5-3.0 um	4.6779	4.467	4.8261	4.2937	7.7877	6.9951	3.3981	4.8765	5.4504	15.0848	4.7799
<0.3 um	3.0-5.0 um	3.9148	3.8133	3.3139	4.0011	4.7562	6.1542	3.0681	3.2854	3.7655	12.0615	3.7751
<0.3 um	5.0-15.0 um	4.8243	6.6517	5.7116	6.8031	6.556	10.8585	5.9101	6.3165	8.4589	13.0704	6.4369
<0.3 um	15.0-40.0 um	3.6394	2.8083	6.9895	4.8976	5.6546	7.4348	4.2235	4.9737	6.7698	4.8865	4.879
<0.3 um	>40.0 um	2.2094	1.6656	6.0956	5.2009	2.5764	4.4856	2.7124	2.9096	4.6672	0	3.6253
0.3-1.0 um	<1.5 um	0.3054	0.5173	0.4643	0.1829	0.6358	0.1353	0.3698	0.4062	0.2491	3.3212	0.3621
0.3-1.0 um	1.5-3.0 um	1.7215	2.848	1.5135	0.9068	1.9031	0.6063	1.1464	1.1323	1.5652	5.3907	1.517
0.3-1.0 um	3.0-5.0 um	2.6326	3.2132	2.8501	2.248	3.1294	1.4324	2.1249	1.7566	2.4023	9.143	2.4411
0.3-1.0 um	5.0-15.0 um	7.3015	6.7796	6.0441	6.5543	7.0366	5.7864	6.0461	7.9321	8.4	7.137	6.8077
0.3-1.0 um	15.0-40.0 um	4.2171	3.4976	6.0502	6.0376	5.5468	7.0424	4.7266	6.2976	4.7979	14.7369	5.28
0.3-1.0 um	>40.0 um	3.6856	2.7008	14.7266	10.6641	13.5492	20.6264	8.2741	6.9676	8.3409	13.1083	8.6666
1.0-3.0 um	<1.5 um	0.3468	0.2093	0	0.3922	0	0.3117	0.2724	0.5308	0.5778	6.5306	0.2525
1.0-3.0 um	1.5-3.0 um	0.2961	0.1419	0.181	0.3606	0.6771	0.8117	0.832	0	1.6405	0	0.3862
1.0-3.0 um	3.0-5.0 um	0.4702	2.6007	0.9632	0	1.6685	0	1.0911	0.6073	1.593	0	0.9364
1.0-3.0 um	5.0-15.0 um	12.5139	15.3816	11.0015	10.932	8.3376	8.0897	12.4631	8.0978	8.6198	3.6578	10.9388
1.0-3.0 um	15.0-40.0 um	9.195	9.2928	13.3458	9.7648	12.8666	11.6661	14.7488	9.4497	7.3196	0	10.5467
1.0-3.0 um	>40.0 um	6.2224	3.5141	7.8872	12.578	9.0535	4.4242	5.2598	7.3011	14.9927	0	8.1472
> 3.0 um	<1.5 um	0	1.7808	0	0	0	0	0	1.1829	0	0	0.3043
> 3.0 um	1.5-3.0 um	1.4494	0	0	0	0	0	0	0	0	0	0.2354
> 3.0 um	3.0-5.0 um	0	0	0	0	0	0	0	0	0	0	0
> 3.0 um	5.0-15.0 um	5.7924	5.4302	7.9251	6.8716	3.4541	0	5.1833	13.4562	3.0004	22.9975	6.3962
> 3.0 um	15.0-40.0 um	16.8771	15.1727	19.4039	12.326	20.8491	0	21.3409	10.358	8.4886	0	15.1944
> 3.0 um	>40.0 um	8.1348	11.4977	25.2171	11.3339	10.1831	78.5648	12.5489	6.4818	18.9496	0	15.3612

FIGURE 1

COMPARISON TO PCM TO TEM FACTORS BY ZONE FOR LONG-THIN FIBERS

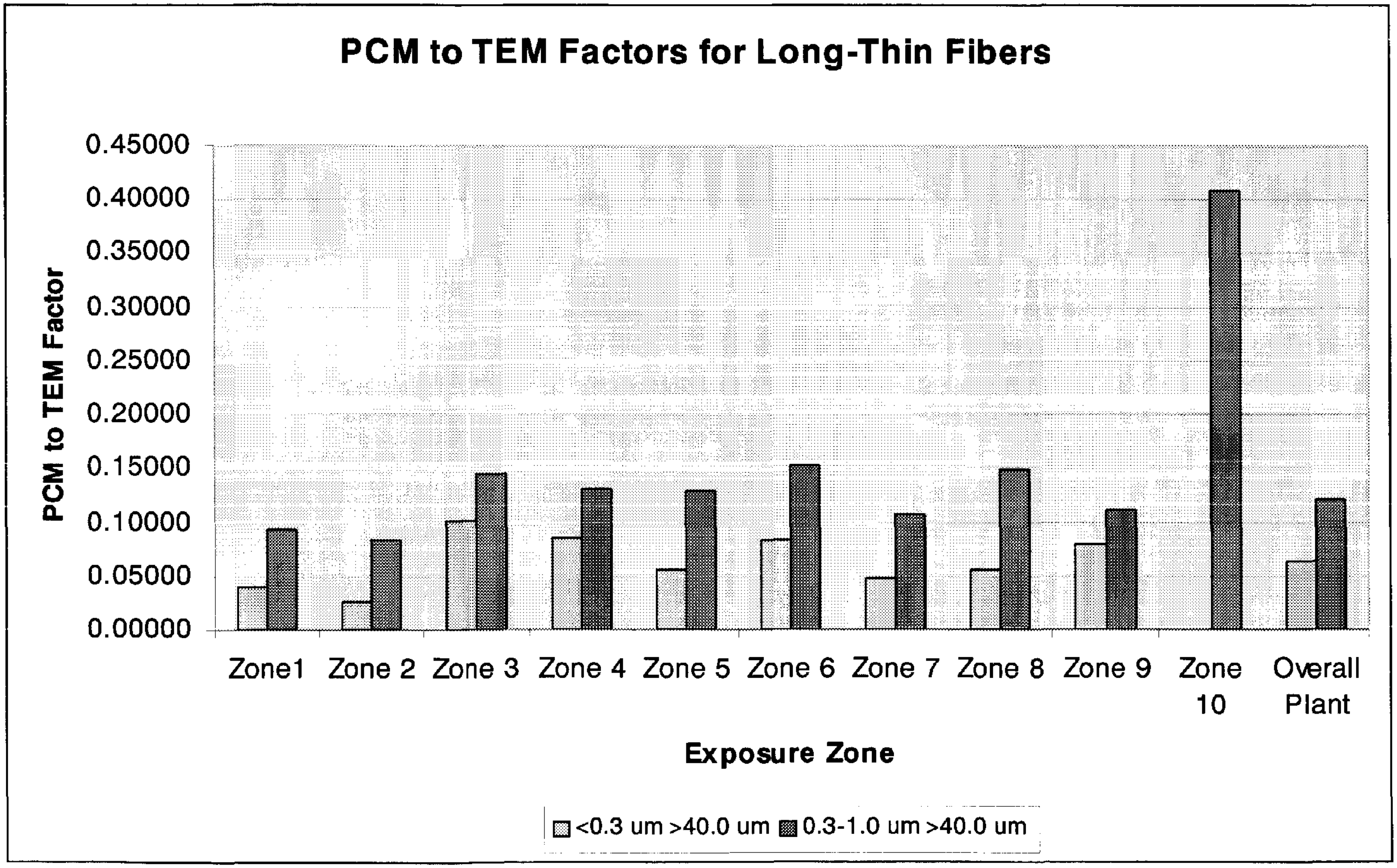
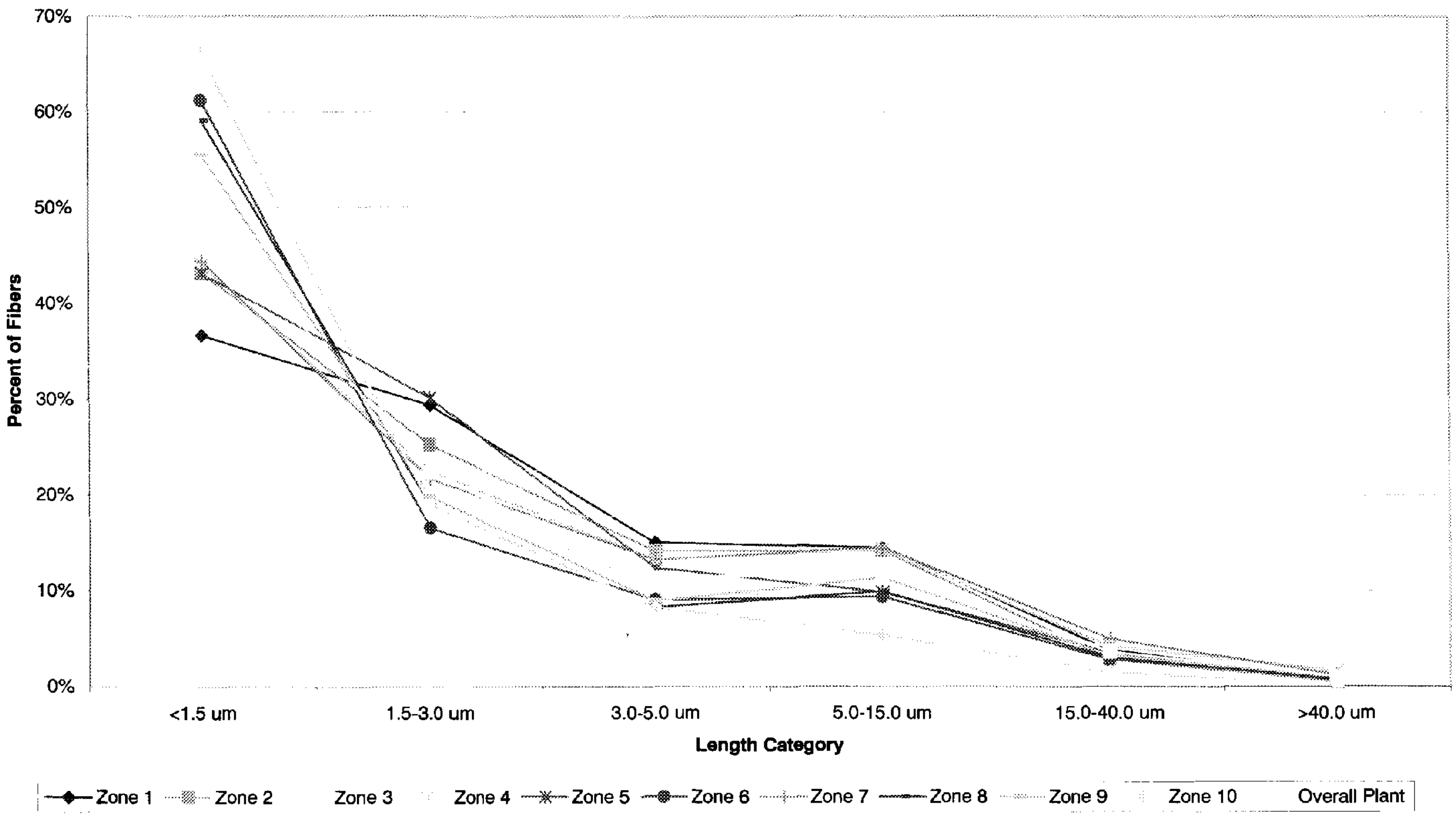


FIGURE 2

TEM FIBER LENGTH DISTRUBUTION BY PLANT EXPOSURE ZONE



APPENDIX I

CHARLESTON TEM SAMPLE LISTING BY EXPOSURE ZONE AND UJC

Sample	Exposure Zone	UJC	All and STR > 5 Sequence	STR > 15 Sequence	Comments
113-013	1	1B1	9763-CE	1675 10186-CB	
013-465	1	1B3	4947 9763-CH	1676 10186-CC	
013-467	1	1D	9763-CB	1655 10186-CA	
113-006	1	1D	4947 9763-CK	1678 10186-CE	
113-016	1	1A	4947 9763-CG	1676 10186-CC	
113-115	1	1B1	4947 9763-CL	1678 10186-CE	
013-461	2	2A	9763-CE	1675 10186-CB	
013-462	2	2B	9763-CD	1655 10186-CA	
013-500	2	2B	4947 9763-CJ	1677 10186-CD	
013-037	2	2A	4947 9763-CJ	1681 10186-CH	
013-246	2	2B	4947 9763-CJ	1680 10186-CG	
013-299	2	2B	4947 9763-CJ	1680 10186-CG	
013-326	2	2B	4947 9763-CJ	1682 10186-CI	
013-339	2	2C	9763-CF	1675 10186-CB	
113-124	2	2B	9763-CF	1683 10186-CJ	
113-155	2	2D	4947 9763-CM	1679 10186-CF	
113-204	2	2B	4947 9763-CM	1655 10186-CA	
013-050	3	3A	4947 9763-CM	1679 10186-CF	
113-150	3	3B	9763-CB, 9763-CC	1655 10186-CA	
013-006	3	3A	4947 9763-CJ	1677 10186-CD	
013-008	3	3B	4947 9763-CJ	1679 10186-CF	
013-040	3	3B	4947 9763-CI	1677 10186-CD	
013-061	3	3B	4947 9763-CI	1682 10186-CI	
013-434	3	3B	4947 9763-CI	1682 10186-CI	
113-149	3	3B	3925 9763-CS	1681 10186-CH	
113-157	3	3A	4947 9763-CH	1676 10186-CC	
113-158	3	3A	4947 9763-CH	1680 10186-CG	
113-217	3	3B	4947 9763-CH	1683 10186-CJ	
013-066	4	4A	9763-CD	1655 10186-CA	
013-452	4	4B	9763-CF	1675 10186-CB	

Sample	Exposure Zone	UJC	All and STR > 5 Sequence	STR > 15 Sequence	Comments
013-029	4	4B	9763-CF	1683 10186-CJ	
013-042	4	4B	4947 9763-CM	1679 10186-CF	
013-063	4	4A	4947 9763-CM	1680 10186-CG	
013-447	4	4A	4947 9763-CM	1681 10186-CH	
013-448	4	4A	4947 9763-CG	1676 10186-CC	
013-449	4	4B	4947 9763-CG	1681 10186-CH	
013-451	4	4B	4947 9763-CG	1679 10186-CF	
013-453	4	4A	4947 9763-CG	1682 10186-CI	
113-214	4	4B	4947 9763-CJ	1677 10186-CD	
013-606	5	5B	9763-CD	1655 10186-CA	
013-086	5	5B	9763-CF	1675 10186-CB	
013-600	5	5B	4947 9763-CK	1678 10186-CE	
013-601	5	5B	4947 9763-CI	1677 10186-CD	
013-605	5	5B	4947 9763-CH	1676 10186-CC	
013-095	6	7B	4947 9763-CI	1677 10186-CD	
013-060	6	6A	4947 9763-CI	1677 10186-CD	
013-088	6	6A	4947 9763-CJ	1677 10186-CD	
013-472	6	6B	4947 9763-CK	1678 10186-CE	
013-529	6	6B	9763-CE	1675 10186-CB	
113-196	6	6B	4947 9763-CL	1678 10186-CE	
013-068	7	7B	4947 9763-CK	1678 10186-CE	
013-090	7	7B	4947 9763-CL	1678 10186-CE	
013-097	7	7B	4947 9763-CH	1676 10186-CC	
013-296	7	7B	3925 9763-CT	1682 10186-CI	
013-455	7	7B	4947 9763-CJ	1677 10186-CD	
013-457	7	7B	4947 9763-CJ	1683 10186-CJ	
013-459	7	7B	4947 9763-CJ	1680 10186-CG	
013-470	7	7B	4947 9763-CJ	1679 10186-CF	Not used – Too few str
013-508	7	7B	4947 9763-CJ	1682 10186-CI	
013-603	7	7B	3925 9763-CR	1681 10186-CH	
013-593	8	8B3	9763-CB	1655 10186-CA	Not used – Too few str
013-621	8	8B3	9763-CB, 9763 –CC	1655 10186-CA	
013-720	8	8B4	4947 9763-CK	1678 10186-CE	
113-243	8	8B1	9763-CD	1655 10186-CA	
013-561	8	8B2	3925 9763-CV	1683 10186-CJ	

Sample	Exposure Zone	UJC	All and STR > 5 Sequence	STR > 15 Sequence	Comments
013-581	8	8B3	3925 9763-CO	1679 10186-CF	
013-617	8	8B3	3925 9763-CO	1682 10186-CI	
013-634	8	8B2	3925 9763-CW	1683 10186-CJ	
013-638	8	8B2	4947 9763-CM	1679 10186-CF	
013-650	8	8B3	4947 9763-CM	1680 10186-CG	
013-686	8	8B3	4947 9763-CL	1678 10186-CE	
013-690	8	8B2	4947 9763-CL	1681 10186-CH	
013-484	9	9B	4947 9763-CI	1677 10186-CD	
013-703	9	9B	4947 9763-CM	1679 10186-CF	
013-441	9	9B	3925 9763-CP	1680 10186-CG	
013-474	9	9B	4947 9763-CG	1676 10186-CC	
013-482	9	9B	4947 9763-CH	1676 10186-CC	
013-492	9	9B	4947 9763-CH	1681 10186-CH	
013-537	9	9B	3925 9763-CQ	1680 10186-CG	
013-538	9	9B	3925 9763-CQ	1681 10186-CH	
013-539	9	9B	3925 9763-CU	1682 10186-CI	
013-612	9	9	3925 9763-CU	1683 10186-CJ	
113-138	9	9B	9763-CE	1675 10186-CB	
013-525	10	10+	4947 9763-CL	1678 10186-CE	
013-660	10	10+	4947 9763-CG	1676 10186-CC	
013-667	10	10+	9763-CF	1675 10186-CB	

APPENDIX II

TEM BIVARIATE DIAMETER/LENGTH MATRIX

OVERALL SUMMARIES OF DATA BY EXPOSURE ZONE

Charleston Exposure Zone 1 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	453	0.35188	0.01290	3.76362	0.34272	3.25200	4.42125
2	<0.3 um	1.5-3.0 um	324	0.25189	0.01220	2.69479	0.26666	2.30215	3.15032
3	<0.3 um	3.0-5.0 um	149	0.11562	0.00891	1.23700	0.14293	1.01057	1.47020
4	<0.3 um	5.0-15.0 um	295	0.07382	0.00598	0.78819	0.07919	0.65794	0.92638
5	<0.3 um	15.0-40.0 um	139	0.01844	0.00237	0.19655	0.02524	0.15518	0.23476
6	<0.3 um	>40.0 um	34	0.00368	0.00095	0.03928	0.01032	0.02341	0.05719
7	0.3-1.0 um	<1.5 um	16	0.01219	0.00286	0.13036	0.03235	0.08166	0.18951
8	0.3-1.0 um	1.5-3.0 um	51	0.03933	0.00535	0.42031	0.06509	0.31807	0.53369
9	0.3-1.0 um	3.0-5.0 um	42	0.03274	0.00482	0.35023	0.05994	0.25706	0.45224
10	0.3-1.0 um	5.0-15.0 um	158	0.04186	0.00428	0.44501	0.03200	0.39236	0.49674
11	0.3-1.0 um	15.0-40.0 um	82	0.00884	0.00153	0.09412	0.01556	0.07134	0.12026
12	0.3-1.0 um	>40.0 um	24	0.00256	0.00077	0.02727	0.00815	0.01434	0.04124
13	1.0-3.0 um	<1.5 um	2	0.00183	0.00096	0.01953	0.01039	0.00775	0.03997
14	1.0-3.0 um	1.5-3.0 um	2	0.00179	0.00097	0.01919	0.01049	0.00770	0.03855
15	1.0-3.0 um	3.0-5.0 um	2	0.00176	0.00097	0.01890	0.01052	0.00773	0.03910
16	1.0-3.0 um	5.0-15.0 um	83	0.02460	0.00327	0.26147	0.02886	0.21593	0.31045
17	1.0-3.0 um	15.0-40.0 um	58	0.00670	0.00136	0.07121	0.01349	0.05041	0.09285
18	1.0-3.0 um	>40.0 um	17	0.00112	0.00051	0.01189	0.00527	0.00459	0.02115
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	1	0.00119	0.00065	0.01274	0.00689	0.00741	0.02655
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	14	0.00458	0.00132	0.04831	0.01331	0.02793	0.07139
23	> 3.0 um	15.0-40.0 um	27	0.00402	0.00093	0.04268	0.00953	0.02711	0.05989
24	> 3.0 um	>40.0 um	9	0.00069	0.00043	0.00729	0.00452	0.00000	0.01585

Charleston Exposure Zone 2 TEM Data Summary

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	507	0.40935	0.01292	5.08917	0.44809	4.39696	5.88194
2	<0.3 um	1.5-3.0 um	250	0.20160	0.01110	2.50762	0.26133	2.11318	2.97696
3	<0.3 um	3.0-5.0 um	120	0.09662	0.00855	1.20208	0.15311	0.95496	1.46234
4	<0.3 um	5.0-15.0 um	488	0.07850	0.00561	0.97250	0.06756	0.86305	1.07861
5	<0.3 um	15.0-40.0 um	209	0.01248	0.00143	0.15464	0.01742	0.12759	0.18277
6	<0.3 um	>40.0 um	42	0.00215	0.00047	0.02668	0.00577	0.01791	0.03731
7	0.3-1.0 um	<1.5 um	24	0.01933	0.00400	0.24077	0.05503	0.15172	0.32563
8	0.3-1.0 um	1.5-3.0 um	61	0.04959	0.00626	0.61683	0.09530	0.46538	0.76639
9	0.3-1.0 um	3.0-5.0 um	43	0.03509	0.00501	0.43628	0.07247	0.32362	0.55716
10	0.3-1.0 um	5.0-15.0 um	215	0.03467	0.00339	0.42841	0.02707	0.38298	0.46997
11	0.3-1.0 um	15.0-40.0 um	123	0.00669	0.00093	0.08271	0.01033	0.06713	0.10089
12	0.3-1.0 um	>40.0 um	37	0.00147	0.00039	0.01822	0.00474	0.01077	0.02632
13	1.0-3.0 um	<1.5 um	1	0.00128	0.00070	0.01597	0.00884	0.00906	0.03191
14	1.0-3.0 um	1.5-3.0 um	1	0.00129	0.00072	0.01598	0.00892	0.00894	0.03278
15	1.0-3.0 um	3.0-5.0 um	12	0.00963	0.00276	0.11989	0.03608	0.06252	0.18382
16	1.0-3.0 um	5.0-15.0 um	138	0.02530	0.00263	0.31272	0.02386	0.27482	0.35128
17	1.0-3.0 um	15.0-40.0 um	110	0.00639	0.00085	0.07907	0.00944	0.06409	0.09517
18	1.0-3.0 um	>40.0 um	20	0.00083	0.00028	0.01027	0.00341	0.00489	0.01630
19	> 3.0 um	<1.5 um	2	0.00192	0.00104	0.02378	0.01307	0.00932	0.04843
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	18	0.00331	0.00081	0.04034	0.00952	0.02621	0.05744
23	> 3.0 um	15.0-40.0 um	50	0.00289	0.00052	0.03568	0.00617	0.02563	0.04573
24	> 3.0 um	>40.0 um	16	0.00082	0.00029	0.01016	0.00346	0.00483	0.01647

Charleston Exposure Zone 3 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95%Limit
1	<0.3 um	<1.5 um	858	0.53078	0.01281	8.53177	0.74904	7.39590	9.79806
2	<0.3 um	1.5-3.0 um	302	0.18729	0.00943	3.01106	0.30189	2.51302	3.54546
3	<0.3 um	3.0-5.0 um	122	0.07528	0.00678	1.20992	0.14788	0.98188	1.46743
4	<0.3 um	5.0-15.0 um	427	0.05293	0.00399	0.84759	0.06207	0.74949	0.95705
5	<0.3 um	15.0-40.0 um	361	0.02273	0.00206	0.36388	0.03132	0.31598	0.41806
6	<0.3 um	>40.0 um	100	0.00637	0.00092	0.10203	0.01420	0.07861	0.12617
7	0.3-1.0 um	<1.5 um	20	0.01231	0.00279	0.19787	0.04786	0.12371	0.28075
8	0.3-1.0 um	1.5-3.0 um	34	0.02135	0.00365	0.34314	0.06504	0.24924	0.46063
9	0.3-1.0 um	3.0-5.0 um	37	0.02306	0.00374	0.37080	0.06914	0.26551	0.49132
10	0.3-1.0 um	5.0-15.0 um	193	0.02195	0.00218	0.35082	0.02537	0.30685	0.39222
11	0.3-1.0 um	15.0-40.0 um	197	0.00904	0.00114	0.14450	0.01537	0.12034	0.17053
12	0.3-1.0 um	>40.0 um	108	0.00555	0.00087	0.08864	0.01249	0.06981	0.11054
13	1.0-3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	1.0-3.0 um	1.5-3.0 um	1	0.00095	0.00052	0.01521	0.00838	0.00893	0.03055
15	1.0-3.0 um	3.0-5.0 um	5	0.00314	0.00139	0.05037	0.02259	0.01824	0.09116
16	1.0-3.0 um	5.0-15.0 um	107	0.01298	0.00155	0.20748	0.02141	0.17308	0.24316
17	1.0-3.0 um	15.0-40.0 um	106	0.00653	0.00092	0.10443	0.01329	0.08324	0.12789
18	1.0-3.0 um	>40.0 um	34	0.00126	0.00038	0.02014	0.00597	0.01140	0.03066
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	19	0.00273	0.00066	0.04293	0.00984	0.02615	0.05978
23	> 3.0 um	15.0-40.0 um	56	0.00291	0.00054	0.04621	0.00812	0.03371	0.06055
24	> 3.0 um	>40.0 um	20	0.00124	0.00039	0.01975	0.00600	0.01054	0.03112

Charleston Exposure Zone 4 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	497	0.43189	0.01379	5.03790	0.43920	4.35711	5.80516
2	<0.3 um	1.5-3.0 um	239	0.20765	0.01131	2.42251	0.24065	2.04880	2.82944
3	<0.3 um	3.0-5.0 um	123	0.10709	0.00920	1.24980	0.15266	1.00408	1.52364
4	<0.3 um	5.0-15.0 um	488	0.08478	0.00570	0.98611	0.07231	0.87162	1.10578
5	<0.3 um	15.0-40.0 um	306	0.02194	0.00210	0.25493	0.02308	0.21693	0.29133
6	<0.3 um	>40.0 um	88	0.00734	0.00101	0.08535	0.01163	0.06718	0.10494
7	0.3-1.0 um	<1.5 um	8	0.00707	0.00258	0.08250	0.03087	0.03661	0.13146
8	0.3-1.0 um	1.5-3.0 um	19	0.01648	0.00361	0.19232	0.04511	0.12003	0.27090
9	0.3-1.0 um	3.0-5.0 um	29	0.02527	0.00461	0.29514	0.06076	0.20729	0.40645
10	0.3-1.0 um	5.0-15.0 um	194	0.03365	0.00297	0.39047	0.02530	0.34891	0.43215
11	0.3-1.0 um	15.0-40.0 um	187	0.01134	0.00137	0.13158	0.01315	0.11141	0.15405
12	0.3-1.0 um	>40.0 um	90	0.00624	0.00088	0.07244	0.00967	0.05724	0.08893
13	1.0-3.0 um	<1.5 um	2	0.00199	0.00110	0.02311	0.01279	0.00947	0.04614
14	1.0-3.0 um	1.5-3.0 um	1	0.00135	0.00075	0.01566	0.00876	0.00912	0.03433
15	1.0-3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	1.0-3.0 um	5.0-15.0 um	110	0.02134	0.00250	0.24744	0.02228	0.21208	0.28502
17	1.0-3.0 um	15.0-40.0 um	90	0.00647	0.00094	0.07518	0.01035	0.05873	0.09325
18	1.0-3.0 um	>40.0 um	39	0.00223	0.00057	0.02592	0.00640	0.01604	0.03650
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	17	0.00326	0.00085	0.03761	0.00936	0.02283	0.05315
23	> 3.0 um	15.0-40.0 um	37	0.00237	0.00057	0.02718	0.00636	0.01731	0.03753
24	> 3.0 um	>40.0 um	15	0.00106	0.00034	0.01221	0.00380	0.00633	0.01840

Charleston Exposure Zone 5 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	225	0.41270	0.02060	6.72568	0.96335	5.33637	8.31894
2	<0.3 um	1.5-3.0 um	148	0.27030	0.01942	4.40707	0.68247	3.39316	5.66165
3	<0.3 um	3.0-5.0 um	51	0.09373	0.01303	1.52822	0.29998	1.06803	2.05966
4	<0.3 um	5.0-15.0 um	195	0.06025	0.00750	0.97200	0.11005	0.79838	1.16218
5	<0.3 um	15.0-40.0 um	132	0.01808	0.00290	0.29096	0.03975	0.22642	0.35766
6	<0.3 um	>40.0 um	26	0.00341	0.00092	0.05484	0.01366	0.03355	0.07714
7	0.3-1.0 um	<1.5 um	10	0.01879	0.00572	0.30598	0.10114	0.15332	0.48077
8	0.3-1.0 um	1.5-3.0 um	15	0.02708	0.00656	0.44256	0.12927	0.26738	0.68630
9	0.3-1.0 um	3.0-5.0 um	13	0.02407	0.00643	0.39207	0.11697	0.21763	0.61109
10	0.3-1.0 um	5.0-15.0 um	85	0.02532	0.00376	0.40609	0.03428	0.34993	0.46619
11	0.3-1.0 um	15.0-40.0 um	69	0.00808	0.00165	0.12949	0.02097	0.09795	0.16394
12	0.3-1.0 um	>40.0 um	47	0.00477	0.00111	0.07653	0.01526	0.05032	0.10140
13	1.0-3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	1.0-3.0 um	1.5-3.0 um	2	0.00426	0.00236	0.06922	0.03971	0.02696	0.14943
15	1.0-3.0 um	3.0-5.0 um	3	0.00591	0.00290	0.09666	0.04953	0.02756	0.19084
16	1.0-3.0 um	5.0-15.0 um	35	0.01181	0.00223	0.18952	0.02820	0.14276	0.23703
17	1.0-3.0 um	15.0-40.0 um	54	0.00659	0.00137	0.10598	0.01914	0.07508	0.13991
18	1.0-3.0 um	>40.0 um	16	0.00146	0.00058	0.02348	0.00886	0.00999	0.03866
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	3	0.00115	0.00058	0.01852	0.00926	0.00581	0.03587
23	> 3.0 um	15.0-40.0 um	19	0.00279	0.00086	0.04483	0.01274	0.02654	0.06774
24	> 3.0 um	>40.0 um	5	0.00043	0.00030	0.00697	0.00483	0.00000	0.01620

Charleston Exposure Zone 6 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	621	0.60830	0.01518	14.57840	1.93995	11.77000	17.99620
2	<0.3 um	1.5-3.0 um	161	0.15741	0.01126	3.77380	0.57343	2.98040	4.80090
3	<0.3 um	3.0-5.0 um	84	0.08254	0.00872	1.97840	0.33446	1.47300	2.61260
4	<0.3 um	5.0-15.0 um	192	0.06965	0.00741	1.66600	0.26513	1.29430	2.18330
5	<0.3 um	15.0-40.0 um	80	0.01762	0.00338	0.42060	0.08979	0.29070	0.57980
6	<0.3 um	>40.0 um	12	0.00350	0.00147	0.08370	0.03646	0.02670	0.14720
7	0.3-1.0 um	<1.5 um	2	0.00228	0.00125	0.05510	0.03203	0.02080	0.12110
8	0.3-1.0 um	1.5-3.0 um	7	0.00685	0.00257	0.16410	0.06499	0.06770	0.27770
9	0.3-1.0 um	3.0-5.0 um	8	0.00776	0.00274	0.18650	0.07198	0.07930	0.32290
10	0.3-1.0 um	5.0-15.0 um	41	0.01597	0.00323	0.37660	0.05958	0.27780	0.47310
11	0.3-1.0 um	15.0-40.0 um	34	0.00644	0.00192	0.15200	0.04102	0.09010	0.22410
12	0.3-1.0 um	>40.0 um	19	0.00500	0.00167	0.11800	0.03734	0.06450	0.17740
13	1.0-3.0 um	<1.5 um	1	0.00159	0.00080	0.03820	0.02011	0.01990	0.07730
14	1.0-3.0 um	1.5-3.0 um	1	0.00154	0.00078	0.03680	0.01907	0.01990	0.07850
15	1.0-3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	1.0-3.0 um	5.0-15.0 um	15	0.00802	0.00228	0.18890	0.04721	0.11360	0.26590
17	1.0-3.0 um	15.0-40.0 um	15	0.00424	0.00151	0.10020	0.03419	0.04990	0.16330
18	1.0-3.0 um	>40.0 um	2	0.00063	0.00055	0.01490	0.01277	0.00000	0.03970
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
23	> 3.0 um	15.0-40.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
24	> 3.0 um	>40.0 um	11	0.00218	0.00110	0.05160	0.02560	0.01310	0.09880

Charleston Exposure Zone 7 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	372	0.42764	0.01709	4.42226	0.44359	3.79062	5.22843
2	<0.3 um	1.5-3.0 um	166	0.18966	0.01287	1.96189	0.22972	1.61405	2.34594
3	<0.3 um	3.0-5.0 um	86	0.09874	0.00974	1.02094	0.13756	0.79775	1.27173
4	<0.3 um	5.0-15.0 um	275	0.08322	0.00730	0.85800	0.08663	0.72620	1.00748
5	<0.3 um	15.0-40.0 um	108	0.02198	0.00329	0.22673	0.03683	0.17158	0.29335
6	<0.3 um	>40.0 um	24	0.00459	0.00146	0.04740	0.01543	0.02513	0.07511
7	0.3-1.0 um	<1.5 um	13	0.01461	0.00422	0.15106	0.04618	0.08044	0.22745
8	0.3-1.0 um	1.5-3.0 um	21	0.02425	0.00536	0.25080	0.06049	0.16038	0.35468
9	0.3-1.0 um	3.0-5.0 um	24	0.02753	0.00591	0.28471	0.06660	0.18901	0.39730
10	0.3-1.0 um	5.0-15.0 um	108	0.03389	0.00421	0.34797	0.03356	0.29728	0.40747
11	0.3-1.0 um	15.0-40.0 um	73	0.01038	0.00225	0.10664	0.02181	0.07093	0.14392
12	0.3-1.0 um	>40.0 um	32	0.00507	0.00154	0.05194	0.01512	0.02861	0.07773
13	1.0-3.0 um	<1.5 um	1	0.00183	0.00089	0.01897	0.00940	0.01048	0.03703
14	1.0-3.0 um	1.5-3.0 um	3	0.00352	0.00179	0.03645	0.01901	0.01113	0.07154
15	1.0-3.0 um	3.0-5.0 um	5	0.00586	0.00247	0.06058	0.02614	0.02263	0.10399
16	1.0-3.0 um	5.0-15.0 um	66	0.02460	0.00362	0.25249	0.03072	0.20182	0.30333
17	1.0-3.0 um	15.0-40.0 um	54	0.01118	0.00231	0.11479	0.02200	0.08067	0.15163
18	1.0-3.0 um	>40.0 um	15	0.00179	0.00087	0.01837	0.00881	0.00466	0.03340
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	9	0.00340	0.00121	0.03493	0.01218	0.01750	0.05628
23	> 3.0 um	15.0-40.0 um	28	0.00612	0.00171	0.06280	0.01667	0.03793	0.09312
24	> 3.0 um	>40.0 um	7	0.00098	0.00067	0.01006	0.00692	0.00000	0.02231

Charleston Exposure Zone 8 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	802	0.57700	0.01309	9.89495	0.91506	8.53729	11.46080
2	<0.3 um	1.5-3.0 um	241	0.17333	0.00965	2.97245	0.31423	2.50813	3.52950
3	<0.3 um	3.0-5.0 um	93	0.06715	0.00652	1.15153	0.15194	0.92308	1.42460
4	<0.3 um	5.0-15.0 um	401	0.05882	0.00488	1.00453	0.08183	0.88182	1.15470
5	<0.3 um	15.0-40.0 um	219	0.01621	0.00172	0.27678	0.02873	0.23386	0.32580
6	<0.3 um	>40.0 um	47	0.00322	0.00065	0.05486	0.01079	0.03774	0.07460
7	0.3-1.0 um	<1.5 um	16	0.01161	0.00283	0.19923	0.05241	0.11811	0.29420
8	0.3-1.0 um	1.5-3.0 um	23	0.01645	0.00346	0.28231	0.06548	0.17608	0.40760
9	0.3-1.0 um	3.0-5.0 um	20	0.01461	0.00340	0.25089	0.06335	0.15973	0.35650
10	0.3-1.0 um	5.0-15.0 um	193	0.02832	0.00278	0.48220	0.02731	0.43743	0.52870
11	0.3-1.0 um	15.0-40.0 um	143	0.00873	0.00117	0.14871	0.01722	0.12291	0.17960
12	0.3-1.0 um	>40.0 um	46	0.00267	0.00058	0.04554	0.00928	0.03055	0.06140
13	1.0-3.0 um	<1.5 um	2	0.00174	0.00092	0.02968	0.01565	0.01157	0.05900
14	1.0-3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	1.0-3.0 um	3.0-5.0 um	1	0.00113	0.00055	0.01935	0.00931	0.01125	0.03810
16	1.0-3.0 um	5.0-15.0 um	63	0.00998	0.00150	0.16989	0.02104	0.13651	0.20720
17	1.0-3.0 um	15.0-40.0 um	68	0.00429	0.00078	0.07312	0.01213	0.05372	0.09540
18	1.0-3.0 um	>40.0 um	18	0.00115	0.00038	0.01958	0.00628	0.01028	0.03150
19	> 3.0 um	<1.5 um	1	0.00111	0.00056	0.01898	0.00962	0.01112	0.03810
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	11	0.00208	0.00064	0.03543	0.01059	0.01835	0.05290
23	> 3.0 um	15.0-40.0 um	14	0.00127	0.00041	0.02157	0.00677	0.01149	0.03340
24	> 3.0 um	>40.0 um	11	0.00023	0.00016	0.00396	0.00270	0.00000	0.00920

Charleston Exposure Zone 9 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	597	0.54727	0.01609	9.47283	1.03051	7.97461	11.45270
2	<0.3 um	1.5-3.0 um	190	0.17522	0.01154	3.03219	0.37022	2.48145	3.65260
3	<0.3 um	3.0-5.0 um	74	0.06736	0.00739	1.16446	0.16568	0.91686	1.45420
4	<0.3 um	5.0-15.0 um	408	0.07280	0.00617	1.25353	0.10842	1.08508	1.44430
5	<0.3 um	15.0-40.0 um	188	0.02058	0.00238	0.35408	0.03932	0.29132	0.42190
6	<0.3 um	>40.0 um	50	0.00461	0.00102	0.07934	0.01710	0.05340	0.10820
7	0.3-1.0 um	<1.5 um	7	0.00632	0.00242	0.10959	0.04363	0.04404	0.18500
8	0.3-1.0 um	1.5-3.0 um	21	0.01918	0.00419	0.33204	0.08035	0.21016	0.47740
9	0.3-1.0 um	3.0-5.0 um	20	0.01833	0.00396	0.31673	0.07368	0.20074	0.44210
10	0.3-1.0 um	5.0-15.0 um	159	0.02736	0.00289	0.46929	0.02962	0.41822	0.51930
11	0.3-1.0 um	15.0-40.0 um	99	0.00647	0.00119	0.11087	0.01757	0.08249	0.13900
12	0.3-1.0 um	>40.0 um	48	0.00303	0.00081	0.05192	0.01304	0.03118	0.07450
13	1.0-3.0 um	<1.5 um	2	0.00218	0.00118	0.03764	0.02068	0.01459	0.07580
14	1.0-3.0 um	1.5-3.0 um	5	0.00450	0.00187	0.07796	0.03353	0.02799	0.13650
15	1.0-3.0 um	3.0-5.0 um	4	0.00373	0.00180	0.06452	0.03190	0.01666	0.12020
16	1.0-3.0 um	5.0-15.0 um	59	0.01190	0.00185	0.20375	0.02413	0.16529	0.24350
17	1.0-3.0 um	15.0-40.0 um	50	0.00431	0.00094	0.07391	0.01456	0.04962	0.09830
18	1.0-3.0 um	>40.0 um	25	0.00205	0.00065	0.03522	0.01057	0.01871	0.05450
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	6	0.00135	0.00056	0.02311	0.00938	0.00785	0.04060
23	> 3.0 um	15.0-40.0 um	12	0.00129	0.00049	0.02221	0.00823	0.00946	0.03650
24	> 3.0 um	>40.0 um	4	0.00058	0.00033	0.00995	0.00552	0.00282	0.02020

Charleston Exposure Zone 10 TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	129	0.62900	0.03424	30.48910	11.49110	17.48610	55.12690
2	<0.3 um	1.5-3.0 um	35	0.16962	0.02684	8.18130	3.20460	4.38830	14.73740
3	<0.3 um	3.0-5.0 um	13	0.06290	0.01764	3.05550	1.46310	1.28420	5.65920
4	<0.3 um	5.0-15.0 um	43	0.04087	0.01107	1.87820	0.58410	1.13250	2.98660
5	<0.3 um	15.0-40.0 um	8	0.00578	0.00339	0.26920	0.18040	0.06700	0.56190
6	<0.3 um	>40.0 um	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7	0.3-1.0 um	<1.5 um	5	0.02482	0.01091	1.19780	0.69160	0.33950	2.53090
8	0.3-1.0 um	1.5-3.0 um	4	0.02006	0.00985	0.97880	0.63460	0.21090	2.30290
9	0.3-1.0 um	3.0-5.0 um	4	0.01998	0.00971	0.98430	0.66390	0.22750	2.24810
10	0.3-1.0 um	5.0-15.0 um	9	0.00830	0.00381	0.35890	0.11370	0.17550	0.55430
11	0.3-1.0 um	15.0-40.0 um	9	0.00942	0.00437	0.40850	0.13120	0.20300	0.62850
12	0.3-1.0 um	>40.0 um	4	0.00187	0.00188	0.08210	0.07610	0.00000	0.22220
13	1.0-3.0 um	<1.5 um	1	0.00766	0.00401	0.37900	0.26230	0.14580	0.91580
14	1.0-3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	1.0-3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	1.0-3.0 um	5.0-15.0 um	3	0.00242	0.00169	0.10670	0.06810	0.00000	0.22500
17	1.0-3.0 um	15.0-40.0 um	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
18	1.0-3.0 um	>40.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	1	0.00197	0.00117	0.08480	0.04620	0.04130	0.16670
23	> 3.0 um	15.0-40.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
24	> 3.0 um	>40.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Charleston Overall Plant TEM Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Cell Proportion	Cell Prop Std	PCM Factor	PCM Factor Std	PCM Factor Lower 5% Limit	PCM Factor Upper 95% Limit
1	<0.3 um	<1.5 um	5061	0.48561	0.00479	6.80846	0.21540	6.49323	7.17862
2	<0.3 um	1.5-3.0 um	2056	0.19764	0.00377	2.77100	0.09890	2.61574	2.92379
3	<0.3 um	3.0-5.0 um	915	0.08783	0.00270	1.23153	0.05461	1.14213	1.32231
4	<0.3 um	5.0-15.0 um	3212	0.06905	0.00191	0.96777	0.02878	0.92189	1.01479
5	<0.3 um	15.0-40.0 um	1750	0.01868	0.00073	0.26172	0.00975	0.24633	0.27754
6	<0.3 um	>40.0 um	424	0.00448	0.00030	0.06277	0.00421	0.05566	0.06937
7	0.3-1.0 um	<1.5 um	121	0.01158	0.00105	0.16232	0.01527	0.13758	0.18628
8	0.3-1.0 um	1.5-3.0 um	256	0.02445	0.00142	0.34271	0.02183	0.30831	0.38078
9	0.3-1.0 um	3.0-5.0 um	240	0.02312	0.00149	0.32419	0.02307	0.28759	0.36407
10	0.3-1.0 um	5.0-15.0 um	1355	0.02895	0.00103	0.40560	0.00927	0.39002	0.42047
11	0.3-1.0 um	15.0-40.0 um	1016	0.00866	0.00044	0.12127	0.00540	0.11269	0.13034
12	0.3-1.0 um	>40.0 um	455	0.00389	0.00029	0.05449	0.00379	0.04813	0.06066
13	1.0-3.0 um	<1.5 um	12	0.00116	0.00032	0.01625	0.00446	0.00932	0.02398
14	1.0-3.0 um	1.5-3.0 um	16	0.00155	0.00038	0.02176	0.00531	0.01299	0.03078
15	1.0-3.0 um	3.0-5.0 um	32	0.00306	0.00054	0.04295	0.00770	0.03059	0.05582
16	1.0-3.0 um	5.0-15.0 um	679	0.01650	0.00075	0.23114	0.00820	0.21795	0.24432
17	1.0-3.0 um	15.0-40.0 um	608	0.00608	0.00034	0.08512	0.00434	0.07801	0.09186
18	1.0-3.0 um	>40.0 um	186	0.00141	0.00015	0.01976	0.00212	0.01626	0.02356
19	> 3.0 um	<1.5 um	3	0.00031	0.00016	0.00428	0.00218	0.00133	0.00813
20	> 3.0 um	1.5-3.0 um	1	0.00015	0.00008	0.00217	0.00118	0.00130	0.00417
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	98	0.00253	0.00027	0.03538	0.00366	0.02909	0.04130
23	> 3.0 um	15.0-40.0 um	246	0.00254	0.00022	0.03552	0.00292	0.03087	0.04045
24	> 3.0 um	>40.0 um	98	0.00084	0.00012	0.01172	0.00171	0.00892	0.01457

APPENDIX III

TEM SURFACE AREA FACTOR SUMMARY BY BIVARIATE LENGTH/DIAMETER CATEGORY

OVERALL SUMMARIES OF DATA BY EXPOSURE ZONE

Charleston Exposure Zone 1 Surface Area Data Summary

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	453	3.41190	0.31118	2.92640	3.96180
2	<0.3 um	1.5-3.0 um	324	4.67790	0.45980	3.95340	5.49040
3	<0.3 um	3.0-5.0 um	149	3.91480	0.45783	3.19300	4.65720
4	<0.3 um	5.0-15.0 um	295	4.82430	0.51438	4.01630	5.69670
5	<0.3 um	15.0-40.0 um	139	3.63940	0.51634	2.85210	4.47140
6	<0.3 um	>40.0 um	34	2.20940	0.56616	1.29510	3.15950
7	0.3-1.0 um	<1.5 um	16	0.30540	0.08170	0.17670	0.44840
8	0.3-1.0 um	1.5-3.0 um	51	1.72150	0.29134	1.27010	2.23450
9	0.3-1.0 um	3.0-5.0 um	42	2.63260	0.48288	1.89210	3.47440
10	0.3-1.0 um	5.0-15.0 um	158	7.30150	0.56016	6.38060	8.20720
11	0.3-1.0 um	15.0-40.0 um	82	4.21710	0.66909	3.17320	5.42190
12	0.3-1.0 um	>40.0 um	24	3.68560	1.13521	2.09840	5.80710
13	1.0-3.0 um	<1.5 um	2	0.34680	0.20067	0.13100	0.72470
14	1.0-3.0 um	1.5-3.0 um	2	0.29610	0.15493	0.12170	0.56100
15	1.0-3.0 um	3.0-5.0 um	2	0.47020	0.26495	0.13800	0.97200
16	1.0-3.0 um	5.0-15.0 um	83	12.51390	1.50547	10.01380	15.17330
17	1.0-3.0 um	15.0-40.0 um	58	9.19500	1.84959	6.33780	12.16900
18	1.0-3.0 um	>40.0 um	17	6.22240	3.02444	1.86500	11.83670
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	1	1.44940	0.71767	0.83350	2.84660
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	14	5.79240	1.69753	3.25110	8.56430
23	> 3.0 um	15.0-40.0 um	27	16.87710	4.06227	10.82400	24.61540
24	> 3.0 um	>40.0 um	9	8.13480	4.73857	0.00000	16.52650

Charleston Exposure Zone 2 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	507	4.70830	0.43751	4.03620	5.44530
2	<0.3 um	1.5-3.0 um	250	4.46700	0.45602	3.72550	5.29500
3	<0.3 um	3.0-5.0 um	120	3.81330	0.44423	3.08690	4.56920
4	<0.3 um	5.0-15.0 um	488	6.65170	0.48878	5.87510	7.53420
5	<0.3 um	15.0-40.0 um	209	2.80830	0.31307	2.33860	3.36560
6	<0.3 um	>40.0 um	42	1.66560	0.43752	1.03240	2.44420
7	0.3-1.0 um	<1.5 um	24	0.51730	0.11493	0.34940	0.71490
8	0.3-1.0 um	1.5-3.0 um	61	2.84800	0.43197	2.20920	3.62520
9	0.3-1.0 um	3.0-5.0 um	43	3.21320	0.57235	2.29770	4.14240
10	0.3-1.0 um	5.0-15.0 um	215	6.77960	0.44542	6.06020	7.52970
11	0.3-1.0 um	15.0-40.0 um	123	3.49760	0.45500	2.80160	4.27650
12	0.3-1.0 um	>40.0 um	37	2.70080	0.76809	1.54480	4.03810
13	1.0-3.0 um	<1.5 um	1	0.20930	0.11821	0.11820	0.42850
14	1.0-3.0 um	1.5-3.0 um	1	0.14190	0.07573	0.08010	0.28060
15	1.0-3.0 um	3.0-5.0 um	12	2.60070	0.78585	1.38250	3.90790
16	1.0-3.0 um	5.0-15.0 um	138	15.38160	1.35922	13.26610	17.58560
17	1.0-3.0 um	15.0-40.0 um	110	9.29280	1.29777	7.37440	11.54880
18	1.0-3.0 um	>40.0 um	20	3.51410	1.32906	1.40940	5.81840
19	> 3.0 um	<1.5 um	2	1.78080	0.99911	0.59260	3.64170
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	18	5.43020	1.38737	3.25390	7.75520
23	> 3.0 um	15.0-40.0 um	50	15.17270	3.38942	9.88270	20.78990
24	> 3.0 um	>40.0 um	16	11.49770	4.29919	5.45540	19.42330

Charleston Exposure Zone 3 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	858	6.85780	0.60527	5.93470	7.97320
2	<0.3 um	1.5-3.0 um	302	4.82610	0.51448	4.08730	5.77330
3	<0.3 um	3.0-5.0 um	122	3.31390	0.42889	2.65590	4.05590
4	<0.3 um	5.0-15.0 um	427	5.71160	0.46626	4.95350	6.44940
5	<0.3 um	15.0-40.0 um	361	6.98950	0.65195	6.00940	8.06130
6	<0.3 um	>40.0 um	100	6.09560	0.91973	4.69660	7.68710
7	0.3-1.0 um	<1.5 um	20	0.46430	0.11048	0.29760	0.65870
8	0.3-1.0 um	1.5-3.0 um	34	1.51350	0.33588	1.00390	2.10980
9	0.3-1.0 um	3.0-5.0 um	37	2.85010	0.54844	2.05290	3.74740
10	0.3-1.0 um	5.0-15.0 um	193	6.04410	0.45792	5.29960	6.81030
11	0.3-1.0 um	15.0-40.0 um	197	6.05020	0.65415	4.98330	7.20870
12	0.3-1.0 um	>40.0 um	108	14.72660	2.23675	11.22980	18.85400
13	1.0-3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
14	1.0-3.0 um	1.5-3.0 um	1	0.18100	0.09691	0.10570	0.38780
15	1.0-3.0 um	3.0-5.0 um	5	0.96320	0.47065	0.31600	1.79960
16	1.0-3.0 um	5.0-15.0 um	107	11.00150	1.12229	9.22040	12.84080
17	1.0-3.0 um	15.0-40.0 um	106	13.34580	1.90433	10.29320	16.39340
18	1.0-3.0 um	>40.0 um	34	7.88720	2.37912	4.24660	11.91480
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	19	7.92510	2.00946	4.81020	11.24290
23	> 3.0 um	15.0-40.0 um	56	19.40390	3.93492	13.34020	26.30100
24	> 3.0 um	>40.0 um	20	25.21710	7.78400	13.77100	38.90450

Charleston Exposure Zone 4 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	497	4.44170	0.42148	3.83415	5.14820
2	<0.3 um	1.5-3.0 um	239	4.29370	0.44216	3.62914	5.02700
3	<0.3 um	3.0-5.0 um	123	4.00110	0.47720	3.24888	4.78390
4	<0.3 um	5.0-15.0 um	488	6.80310	0.47495	6.08453	7.60290
5	<0.3 um	15.0-40.0 um	306	4.89760	0.45566	4.17399	5.69690
6	<0.3 um	>40.0 um	88	5.20090	0.74092	3.99787	6.46960
7	0.3-1.0 um	<1.5 um	8	0.18290	0.06560	0.08497	0.29690
8	0.3-1.0 um	1.5-3.0 um	19	0.90680	0.23480	0.54758	1.29140
9	0.3-1.0 um	3.0-5.0 um	29	2.24800	0.45994	1.51494	3.02150
10	0.3-1.0 um	5.0-15.0 um	194	6.55430	0.47240	5.75550	7.31360
11	0.3-1.0 um	15.0-40.0 um	187	6.03760	0.63736	5.07007	7.13140
12	0.3-1.0 um	>40.0 um	90	10.66410	1.47901	8.29643	13.26480
13	1.0-3.0 um	<1.5 um	2	0.39220	0.21360	0.15413	0.78060
14	1.0-3.0 um	1.5-3.0 um	1	0.36060	0.17339	0.21242	0.71920
15	1.0-3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
16	1.0-3.0 um	5.0-15.0 um	110	10.93200	1.05781	9.14954	12.66160
17	1.0-3.0 um	15.0-40.0 um	90	9.76480	1.45811	7.46926	12.32320
18	1.0-3.0 um	>40.0 um	39	12.57800	2.90472	8.11201	17.53630
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	17	6.87160	2.09201	3.32275	10.33060
23	> 3.0 um	15.0-40.0 um	37	12.32600	3.27179	7.60981	18.46560
24	> 3.0 um	>40.0 um	15	11.33390	3.72682	6.01994	16.99580

Charleston Exposure Zone 5 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	225	6.13560	0.89123	4.78030	7.66880
2	<0.3 um	1.5-3.0 um	148	7.78770	1.21421	6.01288	10.02520
3	<0.3 um	3.0-5.0 um	51	4.75620	0.90179	3.41696	6.40230
4	<0.3 um	5.0-15.0 um	195	6.55600	0.68922	5.48671	7.69930
5	<0.3 um	15.0-40.0 um	132	5.65460	0.73050	4.51017	6.96870
6	<0.3 um	>40.0 um	26	2.57640	0.69994	1.56435	3.70370
7	0.3-1.0 um	<1.5 um	10	0.63580	0.22416	0.31804	1.04020
8	0.3-1.0 um	1.5-3.0 um	15	1.90310	0.54559	1.11125	2.94440
9	0.3-1.0 um	3.0-5.0 um	13	3.12940	0.96611	1.75470	4.82920
10	0.3-1.0 um	5.0-15.0 um	85	7.03660	0.70111	6.00347	8.21090
11	0.3-1.0 um	15.0-40.0 um	69	5.54680	0.90809	4.11570	7.12260
12	0.3-1.0 um	>40.0 um	47	13.54920	3.23809	8.86115	19.62220
13	1.0-3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
14	1.0-3.0 um	1.5-3.0 um	2	0.67710	0.38837	0.20714	1.37930
15	1.0-3.0 um	3.0-5.0 um	3	1.66850	0.96198	0.39272	3.45810
16	1.0-3.0 um	5.0-15.0 um	35	8.33760	1.41294	6.01327	10.66960
17	1.0-3.0 um	15.0-40.0 um	54	12.86660	2.53913	9.03884	17.23750
18	1.0-3.0 um	>40.0 um	16	9.05350	3.50560	3.49943	15.11070
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	3	3.45410	1.83688	0.79002	6.80590
23	> 3.0 um	15.0-40.0 um	19	20.84910	8.57672	9.49591	36.28760
24	> 3.0 um	>40.0 um	5	10.18310	8.20171	0.00000	25.12350

Charleston Exposure Zone 6 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	621	13.04020	1.90800	10.41100	16.87500
2	<0.3 um	1.5-3.0 um	161	6.99510	1.13700	5.40930	8.93500
3	<0.3 um	3.0-5.0 um	84	6.15420	1.06160	4.65790	8.29300
4	<0.3 um	5.0-15.0 um	192	10.85850	1.85520	8.24370	14.14400
5	<0.3 um	15.0-40.0 um	80	7.43480	1.61890	4.85260	10.32900
6	<0.3 um	>40.0 um	12	4.48560	1.98830	1.60390	8.14900
7	0.3-1.0 um	<1.5 um	2	0.13530	0.07380	0.05320	0.27200
8	0.3-1.0 um	1.5-3.0 um	7	0.60630	0.24090	0.24330	1.02500
9	0.3-1.0 um	3.0-5.0 um	8	1.43240	0.62460	0.54740	2.51000
10	0.3-1.0 um	5.0-15.0 um	41	5.78640	0.97120	4.17610	7.41700
11	0.3-1.0 um	15.0-40.0 um	34	7.04240	1.95700	4.11200	10.59400
12	0.3-1.0 um	>40.0 um	19	20.62640	7.62380	8.23460	33.53900
13	1.0-3.0 um	<1.5 um	1	0.31170	0.17150	0.16330	0.64800
14	1.0-3.0 um	1.5-3.0 um	1	0.81170	0.41390	0.44690	1.66100
15	1.0-3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
16	1.0-3.0 um	5.0-15.0 um	15	8.08970	2.31310	4.37200	12.06400
17	1.0-3.0 um	15.0-40.0 um	15	11.66610	4.19990	5.59960	19.16100
18	1.0-3.0 um	>40.0 um	2	4.42420	4.16400	0.00000	11.84100
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	0	0.00000	0.00000	0.00000	0.00000
23	> 3.0 um	15.0-40.0 um	3	0.00000	0.00000	0.00000	0.00000
24	> 3.0 um	>40.0 um	11	78.56480	41.91920	21.99740	154.9460

Charleston Exposure Zone 7 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	372	4.16090	0.45679	3.43630	5.01210
2	<0.3 um	1.5-3.0 um	166	3.39810	0.42526	2.75010	4.14750
3	<0.3 um	3.0-5.0 um	86	3.06810	0.43313	2.41660	3.84790
4	<0.3 um	5.0-15.0 um	275	5.91010	0.59605	5.01840	6.91620
5	<0.3 um	15.0-40.0 um	108	4.22350	0.67604	3.21640	5.49680
6	<0.3 um	>40.0 um	24	2.71240	0.98685	1.31370	4.49180
7	0.3-1.0 um	<1.5 um	13	0.36980	0.11185	0.20400	0.58090
8	0.3-1.0 um	1.5-3.0 um	21	1.14640	0.27833	0.73290	1.63270
9	0.3-1.0 um	3.0-5.0 um	24	2.12490	0.50745	1.34860	3.05460
10	0.3-1.0 um	5.0-15.0 um	108	6.04610	0.55861	5.12630	6.97460
11	0.3-1.0 um	15.0-40.0 um	73	4.72660	0.96515	3.18340	6.36750
12	0.3-1.0 um	>40.0 um	32	8.27410	2.50078	4.40260	12.60520
13	1.0-3.0 um	<1.5 um	1	0.27240	0.13480	0.15940	0.55480
14	1.0-3.0 um	1.5-3.0 um	3	0.83200	0.42479	0.27560	1.64650
15	1.0-3.0 um	3.0-5.0 um	5	1.09110	0.52447	0.28260	2.00550
16	1.0-3.0 um	5.0-15.0 um	66	12.46310	1.66007	9.90300	15.28760
17	1.0-3.0 um	15.0-40.0 um	54	14.74880	2.81044	10.20010	19.79850
18	1.0-3.0 um	>40.0 um	15	5.25980	2.50133	1.39400	9.57190
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	9	5.18330	1.92115	2.14580	8.39350
23	> 3.0 um	15.0-40.0 um	28	21.34090	6.28063	11.55990	33.23910
24	> 3.0 um	>40.0 um	7	12.54890	9.01557	0.00000	28.03700

Charleston Exposure Zone 8 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	802	8.23830	0.75691	7.02925	9.48200
2	<0.3 um	1.5-3.0 um	241	4.87650	0.51109	4.05774	5.72990
3	<0.3 um	3.0-5.0 um	93	3.28540	0.44423	2.60539	4.00710
4	<0.3 um	5.0-15.0 um	401	6.31650	0.52264	5.53570	7.25230
5	<0.3 um	15.0-40.0 um	219	4.97370	0.54374	4.14588	5.82790
6	<0.3 um	>40.0 um	47	2.90960	0.62485	1.95673	4.01450
7	0.3-1.0 um	<1.5 um	16	0.40620	0.10712	0.23901	0.59990
8	0.3-1.0 um	1.5-3.0 um	23	1.13230	0.25163	0.74316	1.56150
9	0.3-1.0 um	3.0-5.0 um	20	1.75660	0.45625	1.04711	2.51240
10	0.3-1.0 um	5.0-15.0 um	193	7.93210	0.51849	7.07766	8.80860
11	0.3-1.0 um	15.0-40.0 um	143	6.29760	0.70006	5.17111	7.52600
12	0.3-1.0 um	>40.0 um	46	6.96760	1.69253	4.46731	9.87400
13	1.0-3.0 um	<1.5 um	2	0.53080	0.29978	0.19724	1.16220
14	1.0-3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
15	1.0-3.0 um	3.0-5.0 um	1	0.60730	0.28892	0.35010	1.20500
16	1.0-3.0 um	5.0-15.0 um	63	8.09780	1.10958	6.28849	9.87790
17	1.0-3.0 um	15.0-40.0 um	68	9.44970	1.63690	6.89274	12.25660
18	1.0-3.0 um	>40.0 um	18	7.30110	2.70069	3.20610	12.38120
19	> 3.0 um	<1.5 um	1	1.18290	0.63381	0.67909	2.63830
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	11	13.45620	9.25312	2.75440	31.74430
23	> 3.0 um	15.0-40.0 um	14	10.35800	3.42291	5.11278	16.67050
24	> 3.0 um	>40.0 um	11	6.48180	4.90202	0.00000	15.86780

Charleston Exposure Zone 9 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	597	8.82810	0.91340	7.54574	10.49850
2	<0.3 um	1.5-3.0 um	190	5.45040	0.67000	4.44725	6.55020
3	<0.3 um	3.0-5.0 um	74	3.76550	0.59730	2.92464	4.73310
4	<0.3 um	5.0-15.0 um	408	8.45890	0.73900	7.38612	9.79980
5	<0.3 um	15.0-40.0 um	188	6.76980	0.75990	5.56610	8.10520
6	<0.3 um	>40.0 um	50	4.66720	1.04300	3.02815	6.45490
7	0.3-1.0 um	<1.5 um	7	0.24910	0.10620	0.09894	0.43390
8	0.3-1.0 um	1.5-3.0 um	21	1.56520	0.39350	0.99730	2.24140
9	0.3-1.0 um	3.0-5.0 um	20	2.40230	0.58020	1.47076	3.36880
10	0.3-1.0 um	5.0-15.0 um	159	8.40000	0.58440	7.44114	9.39060
11	0.3-1.0 um	15.0-40.0 um	99	4.79790	0.80050	3.48466	6.18380
12	0.3-1.0 um	>40.0 um	48	8.34090	2.18790	5.01349	12.07590
13	1.0-3.0 um	<1.5 um	2	0.57780	0.32890	0.23166	1.16890
14	1.0-3.0 um	1.5-3.0 um	5	1.64050	0.75230	0.51723	3.00160
15	1.0-3.0 um	3.0-5.0 um	4	1.59300	0.82180	0.48556	3.06280
16	1.0-3.0 um	5.0-15.0 um	59	8.61980	1.25180	6.71216	10.78270
17	1.0-3.0 um	15.0-40.0 um	50	7.31960	1.56910	5.02606	10.05480
18	1.0-3.0 um	>40.0 um	25	14.99270	5.34460	7.41390	25.01230
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	6	3.00040	1.23060	1.07207	5.37350
23	> 3.0 um	15.0-40.0 um	12	8.48860	3.02720	3.80507	13.87900
24	> 3.0 um	>40.0 um	4	18.94960	13.08290	3.78441	42.63720

Charleston Exposure Zone 10 Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	129	29.24570	13.20810	14.69790	57.48050
2	<0.3 um	1.5-3.0 um	35	15.08480	7.24000	7.43320	30.34940
3	<0.3 um	3.0-5.0 um	13	12.06150	6.27280	4.85560	24.24360
4	<0.3 um	5.0-15.0 um	43	13.07040	5.01360	7.60040	22.94550
5	<0.3 um	15.0-40.0 um	8	4.88650	3.46500	1.00930	11.21850
6	<0.3 um	>40.0 um	1	0.00000	0.00000	0.00000	0.00000
7	0.3-1.0 um	<1.5 um	5	3.32120	2.20900	0.70820	7.47320
8	0.3-1.0 um	1.5-3.0 um	4	5.39070	3.69050	1.26020	13.20550
9	0.3-1.0 um	3.0-5.0 um	4	9.14300	6.70520	2.26790	19.65920
10	0.3-1.0 um	5.0-15.0 um	9	7.13700	2.81470	3.25950	11.85340
11	0.3-1.0 um	15.0-40.0 um	9	14.73690	5.24520	6.77570	23.80370
12	0.3-1.0 um	>40.0 um	4	13.10830	12.05570	0.00000	35.70840
13	1.0-3.0 um	<1.5 um	1	6.53060	5.22240	2.22880	16.31140
14	1.0-3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
15	1.0-3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
16	1.0-3.0 um	5.0-15.0 um	3	3.65780	2.47370	0.00000	7.79580
17	1.0-3.0 um	15.0-40.0 um	3	0.00000	0.00000	0.00000	0.00000
18	1.0-3.0 um	>40.0 um	0	0.00000	0.00000	0.00000	0.00000
19	> 3.0 um	<1.5 um	0	0.00000	0.00000	0.00000	0.00000
20	> 3.0 um	1.5-3.0 um	0	0.00000	0.00000	0.00000	0.00000
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	1	22.99750	12.47690	11.70170	46.23610
23	> 3.0 um	15.0-40.0 um	0	0.00000	0.00000	0.00000	0.00000
24	> 3.0 um	>40.0 um	0	0.00000	0.00000	0.00000	0.00000

Charleston Overall Plant Surface Area Data

Matrix Cell #	Fiber Diameter	Fiber Length	Fibers Sized	Surface Area Factor	Surface Area Factor Standard Deviation	Surface Area Factor Lower 5% Limit	Surface Area Factor Upper 95% Limit
1	<0.3 um	<1.5 um	5061	5.96230	0.17786	5.68690	6.26720
2	<0.3 um	1.5-3.0 um	2056	4.77990	0.16292	4.52490	5.04400
3	<0.3 um	3.0-5.0 um	915	3.77510	0.15753	3.52570	4.04710
4	<0.3 um	5.0-15.0 um	3212	6.43690	0.18602	6.14530	6.74520
5	<0.3 um	15.0-40.0 um	1750	4.87900	0.19164	4.57720	5.22430
6	<0.3 um	>40.0 um	424	3.62530	0.25337	3.21870	4.04590
7	0.3-1.0 um	<1.5 um	121	0.36210	0.03472	0.30370	0.41980
8	0.3-1.0 um	1.5-3.0 um	256	1.51700	0.11032	1.34740	1.71550
9	0.3-1.0 um	3.0-5.0 um	240	2.44110	0.18986	2.12160	2.75910
10	0.3-1.0 um	5.0-15.0 um	1355	6.80770	0.18028	6.50090	7.09960
11	0.3-1.0 um	15.0-40.0 um	1016	5.28000	0.24740	4.89470	5.69210
12	0.3-1.0 um	>40.0 um	455	8.66660	0.63529	7.62440	9.76610
13	1.0-3.0 um	<1.5 um	12	0.25250	0.07085	0.13910	0.36600
14	1.0-3.0 um	1.5-3.0 um	16	0.38620	0.10626	0.21980	0.57860
15	1.0-3.0 um	3.0-5.0 um	32	0.93640	0.16564	0.67680	1.21170
16	1.0-3.0 um	5.0-15.0 um	679	10.93880	0.44294	10.26070	11.71060
17	1.0-3.0 um	15.0-40.0 um	608	10.54670	0.61575	9.51990	11.61790
18	1.0-3.0 um	>40.0 um	186	8.14720	0.99633	6.58840	9.84520
19	> 3.0 um	<1.5 um	3	0.30430	0.16254	0.08350	0.61070
20	> 3.0 um	1.5-3.0 um	1	0.23540	0.12406	0.14560	0.45720
21	> 3.0 um	3.0-5.0 um	0	0.00000	0.00000	0.00000	0.00000
22	> 3.0 um	5.0-15.0 um	98	6.39620	1.12503	4.71890	8.34270
23	> 3.0 um	15.0-40.0 um	246	15.19440	1.51540	12.77520	17.84950
24	> 3.0 um	>40.0 um	98	15.36120	2.47447	11.62000	19.64610

APPENDIX IV

CHARLESTON TEM SIZE-SPECIFIC JEM

MICROSOFT ACCESS DATABASE

DOCUMENTATION AND INSTRUCTIONS

DATABASE DOCUMENTATION

DATABASE NAME: CHARLESTON TEM SIZE-SPECIFIC JEM.MDB

DATA TABLES

Table: Charleston Exposure Zones

Description: Provides a look-up table that describes the plant processes associated with each exposure zone.

Properties

Date Created:	5/14/2005 9:22:11 PM	GUID:	Long binary data
Last Updated:	5/16/2005 10:34:09 AM	NameMap:	Long binary data
OrderByOn:	False	Orientation:	0
RecordCount:	11	Updatable:	True

Columns

Name	Type	Size
ID	Long Integer	4
Department Name	Text	50
Exposure Zone	Long Integer	4

Variable Descriptions

Table Variable Name	**Variable Description**
ID	Table Record Key
Department Name	Textile Department Description
Exposure Zone	Assigned Exposure Zone for Plant Process

Table: JD2EXP

Description: This file contains the PCM job-exposure matrix developed by Dement et al. (1980, 1983a) and used for prior exposure-response analyses. The data fields are consistent with NIOSH PCLTAS input requirements as a dose file. The PCM fiber concentrations in this table are adjusted by the PCM to TEM factor to estimate size-specific metrics of exposure.

Properties

Date Created:	5/14/2005 1:12:47 PM	GUID:	Long binary data
Last Updated:	5/14/2005 1:13:10 PM	NameMap:	Long binary data

OrderByOn:	False	Orientation:	0
RecordCount:	340	Updatable:	True

Columns

Name	Type	Size
Start Date	Double	8
End Date	Double	8
f/cc	Double	8
Plant	Double	8
Dept	Text	255
Oper	Text	255
Zone	Long Integer	4

Variable Descriptions

Table Variable Name	Variable Description
Start Date	Start Date for Exposure Level Assignment
End Date	End Date for Exposure Level Assignment
f/cc	PCM or TEM Exposure Level
Plant	Always 13 for the Charleston Plant
Dept	Department Designation [Dement, 1980]
Oper	Operation (Job) Designation [Dement, 1980]
Zone	Exposure Zone Designation [Dement, 1980]

Table: JEM Cells for TEM Factor

Description: This table contains information used by macros and queries to generate the size-specific exposure estimates. Each cell in the diameter/length matrix is represented in this table with a designation of '0' or '1' in the field 'Include in TEM Conc'. These values are updated by the user based on the desired size-specific exposure metric. In addition to the '0' or '1' designation, other values can be used to derive size weighted exposure metrics. For example, the Berman and Crump [1999] exposure metric based on animal data would be generated using the weights from their formula applied to the appropriate cells in the length/diameter matrix. The sum of the cell weights should equal 1.0.

Properties

Date Created:	5/14/2005 1:12:47 PM	GUID:	Long binary data
Last Updated:	5/14/2005 1:22:11 PM	NameMap:	Long binary data

OrderByOn:	False	Orientation:	0
RecordCount:	24	Updatable:	True

Columns

Name	Type	Size
Cell	Double	8
Fiber Diameter	Text	255
Fiber Length	Text	255
Include in TEM Conc	Double	8

Variable Descriptions

Table Variable Name	Variable Description
Cell	Diameter/Length Matrix Cell Number (1-24)
Fiber Diameter	Fiber Diameter Category (μm)
Fiber Length	Fiber Length Category (μm)
Include in TEM Conc	"0" for Exclude Cell in JEM or "1" for Include in the JEM. This can also be weighting factor

Table: TEM Factors All Zones

Description: This file is generated by the macro 'Export TEM JEM to Excel File' or 'Generate TEM Size-Specific JEM for LTAS' and represents the PCM to TEM multiplier to be applied to the PCM data for each exposure zone. The values in this table are updated based on the diameter/length cells chosen for the desired exposure metric.

Properties

Date Created:	5/28/2005 11:13:31 PM	GUID:	Long binary data
Last Updated:	5/28/2005 11:14:00 PM	RecordCount:	11
Updatable:	True		

Columns

Name	Type	Size
Zone	Long Integer	4
TEM_Multiplier	Double	8

Variable Descriptions

Table Variable Name	Variable Description
Cell	Diameter/Length Matrix Cell Number (1-24)
Zone	Exposure Zone Designation [Dement, 1980]
TEM Multiplier	PCM to TEM Multiplier for JEM Concentrations

Tables: Zone 1 Summary through Zone 99 Summary

Description: These tables contain the bivariate fiber diameter/length data for each exposure zone and the PCM to TEM multiplier factors. These data were developed using the sum of all samples for a given zone. In addition to point estimates for the cell proportions and PCM to TEM factors, standard deviations and percentile ranges (P5 and P95) from the bootstrapping procedures.

Properties

Date Created:	5/14/2005 8:58:58 PM	GUID:	Long binary data
Last Updated:	5/27/2005 1:16:13 PM	NameMap:	Long binary data
OrderByOn:	False	Orientation:	0
RecordCount:	24	Updatable:	True

Columns

Name	Type	Size
Cell	Double	8
Zone	Long Integer	4
Fiber Diameter	Text	255
Fiber Length	Text	255
Fibers Sized	Double	8
Cellprop	Double	8
CellProp_std	Double	8
Cellprop_P5	Double	8
Cellprop_P95	Double	8
PCMfactor	Double	8
PCMfactor_std	Double	8
PCMfactor_P5	Double	8
PCMfactor_P95	Double	8

Variable Descriptions

Table Variable Name	Variable Description
Cell	Diameter/Length Matrix Cell Number (1-24)
Zone	Exposure Zone Designation [Dement, 1980]
Fiber Diameter	Fiber Diameter Category (μm)
Fiber Length	Fiber Length Category (μm)
Fibers Sized	Number of Total Fibers Sized for Zone
Cellprop	Proportion of Fibers in Each Cell of Bivariate Diameter/Length Distribution
CellProp_std	Standard Deviation of Cell Proportion (Bootstrap)
Cellprop_P5	Lower 5th Percentile of Cell Proportion (Bootstrap)
Cellprop_P95	Upper 95th Percentile of Cell Proportion (Bootstrap)
PCMfactor	PCM to TEM Multiplier (f/cc)
PCMfactor_std	Standard Deviation of PCMfactor (Bootstrap)
PCMfactor_P5	Lower 5th Percentile of PCMfactor (Bootstrap)
PCMfactor_P95	Upper 95th Percentile of PCMfactor (Bootstrap)

Tables: Zone 1 Surface Area Summary through Zone 99 Surface Area Summary

Description: These tables contain the bivariate fiber diameter/length data for each exposure zone and the PCM to surface area multiplier factors. These data were developed using the sum of all samples for a given zone. In addition to point estimates for the cell proportions and PCM to surface area factors, standard deviations and percentile ranges (P5 and P95) from the bootstrapping procedures.

Properties

Date Created:	6/7/2005 2:06:07 PM	GUID:	Long binary data
Last Updated:	6/7/2005 2:09:19 PM	NameMap:	Long binary data
OrderByOn:	False	Orientation:	0
RecordCount:	24	Updatable:	True

Columns

Name	Type	Size

Cell	Double	8
Zone	Long Integer	4
Fiber Diameter	Text	255
Fiber Length	Text	255
Fibers Sized	Double	8
Surface_factor	Double	8
Surface_factor_std	Double	8
Surface_factor_P5	Double	8
Surface_factor_P95	Double	8

Variable Descriptions

Table Variable Name	**Variable Description**
Cell	Diameter/Length Matrix Cell Number (1-24)
Zone	Exposure Zone Designation [Dement, 1980]
Fiber Diameter	Fiber Diameter Category (μm)
Fiber Length	Fiber Length Category (μm)
Fibers Sized	Number of Total Fibers Sized for Zone
Surface_factor	PCM to Surface Area Multiplier ($\mu m^2/cc$)
Surface_factor_std	Standard Deviation of Surface_factor (Bootstrap)
Surface_factor_P5	Lower 5^{th} Percentile of Surface_factor (Bootstrap)
Surface_factor_P95	Upper 95th Percentile of Surface_factor (Bootstrap)

MACROS

Macro: Export TEM JEM to Excel File

Description: Exports the size-specific JEM to an Excel file for use with the NIOSH PCLTAS. The default location of the exported file is the root directory of the 'C:' drive. The file location for export can be edited in the macro to specify a different location. Also, the file format (e.g. ASCII, TXT, etc.) can be modified within the macro.

Properties

Container:	Scripts	Date Created:	5/14/2005 4:37:10 PM
Last Updated:	5/14/2005 4:37:10 PM	Owner:	admin
UserName:	admin		

Macro: Generate TEM Size-Specific JEM for LTAS

Description: Generates the size-specific JEM to an Excel file for use with the NIOSH PCLTAS for review prior to exporting. The file generated may be printed or exported using the Access export function in the file menu.

Properties

Container:	Scripts	Date Created:	5/14/2005 3:37:40 PM
Last Updated:	5/14/2005 3:37:40 PM	Owner:	admin
UserName:	admin		

GENERAL OPERATING INSTRUCTIONS

DATABASE NAME: CHARLESTON TEM SIZE-SPECIFIC JEM.MDB

General Overview: This Access database serves to:

1. Store and report on the TEM bivariate diameter/length data by Charleston exposure zone.
2. Interactively select fiber sizes to be included in the calculation of a user defined exposure metric (i.e. any combination of the 24diameter/length matrix cells).
3. Generate and export a JEM for use with the NIOSH PCLTAS based on the selected size-specific exposure metric.

The system is menu driven and has several predefined reports that can be selected by the user.

User Inputs:

All exposure zone bivariate fiber size data are predefined in the system and no user data input is required for these parameters. The Main Menu selections are as follows:

Enter/View TEM Matrix Cell for JEM

Preview Summary Reports for Plant Zones 1-5

Preview Summary Reports for Plant Zones 6-10

Preview Summary Report – Overall Plant

Generate and View Size-Specific JEM – NIOSH LTAS

Before generating a size-specific exposure matrix, the user must select the diameter/length cells to be included in the metric. These values are input by selecting 'Enter/View TEM Matrix Cell for JEM' at the main menu. The input screen used to select cells for the JEM is shown on the following page. A value of '0' in the column 'Include in TEM Size-Specific JEM" excludes the cell in the JEM and value of '1' includes the cell. In addition to the '0' or '1' designation, other values can be used to derive size weighted exposure metrics. For example, the Berman and Crump [1999] exposure metric based on animal data would be generated using the weights from their formula applied to the appropriate cells in the length/diameter matrix. The sum of the cell weights should equal 1.0. The data are save when this screen is closed.

Reports:

After selection of fiber size cells for the exposure metric, the JEM for the NIOSH PCLTAS can be generated by selecting the menu item 'Generate and View Size-Specific JEM – NIOSH LTAS'. This menu allows the JEM to be viewed and printed or exported as a Microsoft Excel spreadsheet. The default location for file export is the 'C:' drive root directory. To choose a different directory, open the macro in design mode and edit the designated file location in the 'Transfer Spreadsheet' Action column.

The other Main Menu items allow the user to view and print the TEM bivariate diameter/length and PCM to TEM factors for each zone.

USER INPUT SCREEN

Select TEM Fiber Diameter/Length Matrix Cells for JEM

Matrix Cell #	Fiber Diameter	Fiber Length	Include in TEM Size-Specific JEM (1=Yes, 0=No)
1	<0.3 um	<1.5 um	0
2	<0.3 um	1.5-3.0 um	0
3	<0.3 um	3.0-5.0 um	0
4	<0.3 um	5.0-15.0 um	0
5	<0.3 um	15.0-40.0 um	1
6	<0.3 um	>40.0 um	1
7	0.3-1.0 um	<1.5 um	0
8	0.3-1.0 um	1.5-3.0 um	0
9	0.3-1.0 um	3.0-5.0 um	0
10	0.3-1.0 um	5.0-15.0 um	0
11	0.3-1.0 um	15.0-40.0 um	1
12	0.3-1.0 um	>40.0 um	1
13	1.0-3.0 um	<1.5 um	0
14	1.0-3.0 um	1.5-3.0 um	0
15	1.0-3.0 um	3.0-5.0 um	0
16	1.0-3.0 um	5.0-15.0 um	0
17	1.0-3.0 um	15.0-40.0 um	0
18	1.0-3.0 um	>40.0 um	0
19	> 3.0 um	<1.5 um	0
20	> 3.0 um	1.5-3.0 um	0
21	> 3.0 um	3.0-5.0 um	0
22	> 3.0 um	5.0-15.0 um	0
23	> 3.0 um	15.0-40.0 um	0
24	> 3.0 um	>40.0 um	0

Note: Enter a '0" if the cell is not to be included in the size-specific JEM for the NIOSH PCLTAS and a '1" if the cell is included. Use the TAB key to move through the cells.