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Characterization of Airborne Cotton Dust Concentrations in the Non-Textile Cotton Industry

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Workers in the "non-textile" cotton industry breathe a dust which is similar to the dust in the cotton spinning and weaving or "textile" industry. This exposure prompts the question of byssinosis prevalence and other respiratory disease in the non-textile cotton industry. NIOSH has completed a cross-sectional medical and environmental study evaluating the prevalence of byssinosis in five segments of the non-textile cotton industry. A total of 92 non-textile cotton facilities were evaluated, including cotton gins, cotton classing offices, cottonseed oil mills, cotton compress-warehouses, and waste utilization plants. This paper presents the results of the measurements of cotton dust levels and particle size distributions in these segments. Average elutriated dust concentrations for individual plants ranged from 101 to 2050 micrograms per cubic meter of air ($\mu g/m^3$) in 35 cotton gins, 81 to 376 $\mu g/m^3$ in 13 classing offices, 502 to 2041 $\mu g/m^3$ in 18 cottonseed oil mills, 39 to 831 $\mu g/m^3$ in 13 compress-warehouses, and 237 to 3968 $\mu g/m^3$ in 13 waste utilization facilities. Results tend to be lower than those reported in the literature for non-textile operations.

Background

Byssinosis is a respiratory disease that has been associated with occupational exposure to organic dusts. Originally described in flax workers, it has been characterized in hemp and cotton workers as well. The majority of research studying byssinosis prevalence has been conducted in the cotton textile industry.[1-7] Most studies suggest that the prevalence of byssinosis is higher in the early stages of textile manufacturing (such as carding) than in later stages (such as spinning). Since the dust generated in the early processes comes from cotton that has been treated through the non-textile processes the question arises about the prevalence of byssinosis in the segments comprising the non-textile cotton industry. The health status of workers in the non-textile industries is therefore subject to study considering that the properties of cotton dust, and consequently its bioactive potential, are varied among the different grades of cotton and may also vary from one segment to another.[8-10]

There have been some studies conducted to elucidate the prevalence of byssinosis in the non-textile cotton industry.[11-16] (Note: The terms "non-textile" or "secondary" are commonly used to refer to that part of the cotton industry peripheral to the textile mills that spin fibers into yarn and subsequently weave yarn into fabric. The terms are not specifically descriptive but are used here since no better have appeared.)

Larson *et al.*[11] studied a sample of cotton gins in California in which gin workers were shown not to be at increased risk for changes in pulmonary function. A large number of gins in Texas and New Mexico were studied by Palmer *et al.*[12] in which workers did not show any questionnaire-reported byssinosis symptoms although pulmonary function abnormalities were reported. No increased risk for chronic respiratory disease or byssinotic reaction was observed by Barman[13] in a group of warehouse workers from a single plant in California. Jones *et al.*[14] surveyed cottonseed oil mills in the south central United States and a survey of 172 workers showed low prevalences of byssinosis (2.3%) and chronic bronchitis (4%). The authors suggested that the overall dose-response relationship seemed to differ from that found in the cotton textile industry.

Some epidemiological studies of non-textile cotton processes have also been conducted in foreign countries.[15-20] Egyptian[4] and Sudanese[17] gin workers have demonstrated a byssinosis prevalence comparable to that of textile mill workers in the United States and Great Britain. El Batawi's study[4] showed a 38.5% prevalence of byssinosis in Egyptian gin employees. An increased prevalence (19%) of chronic respiratory disease in ginnery workers in Greece was shown by Kondakis.[18] Gilson's study[19] of Ugandan gins reported acute decrements in pulmonary function in workers exposed to cotton dust although no byssinotic symptomology was noted. Dingwall-Fordyce[20] studied the waste utilization industry in the 1950s and reported that 5% of the study population suffered "disabling" byssinosis and 25% had lesser degrees of the disease. All of these cited studies, however, have been inconclusive due to small study populations and absence of complete dose-response data.

Merchant *et al.*[7] in their study of byssinosis prevalence in North Carolina textile mills used a vertical elutriator for collecting lint-free dust with a nominal aerodynamic diameter of less than 15 micrometers (μm). Dose-response curves were developed for byssinosis prevalence versus elutriated

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dust levels and a high degree of correlation between these indices was shown. The vertical elutriator has since been widely accepted as the "standard" instrument used to collect cotton dust samples for epidemiologic studies.

The Occupational Safety and Health Administration (OSHA) established a Permissible Exposure Limit (PEL) for exposure to cotton dust in the non-textile industry at 500 micrograms per cubic meter ($\mu g/m^3$) in 1978.[21] For purposes of this standard, OSHA defined "respirable" dust as those particles collected using the vertical elutriator, and the PEL is therefore based on filter samples taken using the vertical elutriator as a preseparator. The National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that elutriated cotton dust levels be kept below 200 $\mu g/m^3$.[22-23]

Since these recommendations are based primarily on epidemiolical data collected in textile facilities, NIOSH initiated in 1976 a cross-sectional medical and environmental research study to evaluate the prevalence of byssinosis, bronchitis and lung function impairment in five segments of the non-textile cotton industry.

The initial epidemiological field study was conducted in 1978 and the final survey was completed in 1980. The facilities studied included 35 cotton gins, 13 cotton classification offices, 18 cottonseed oil mills, 13 cotton compress warehouses, and 13 cotton waste utilization facilities. Of the 92 non-textile cotton facilities studied, 73 were evaluated by the NIOSH Division of Respiratory Disease Studies and 19 (13 gins and 6 warehouses) were studied by SRI International under contract.

Specific objectives of the industrial hygiene study were measurement of airborne cotton dust levels, characterization of particle size distributions, assessment of employee dust exposures, and field equivalency testing of a small, battery-operated vertical elutriator. This paper presents only the results of the measurement of cotton dust levels.

Along with environmental measurements taken at each facility, pre- and post-shift pulmonary function testing and respiratory questionnaires were used to assess lung function, work history, smoking history and respiratory symptoms. These results have been reported.[24-28] The following is a report of the environmental measurements taken at these non-textile cotton facilities.

Description of the Non-Textile Cotton Industry

Gins

Cotton gins receive seed cotton after it is harvested from the field. The seed cotton is cleaned of gross trash materials and cotton fibers (lint) are mechanically separated from the cottonseed using a machine called a "gin stand". The lint is subsequently cleaned, moisturized or dried (depending on its moisture content), and then packaged into bales. Most of the cottonseed is marketed directly to a cottonseed oil mill. The lint is usually sent to a cotton warehouse for storage prior to marketing to the textile industry.

Classing Offices

Cotton classification offices are operated by the U.S. Department of Agriculture and were established under the Smith-Doxey Act to provide a consistent procedure for grading cotton samples that have been removed from a bale of cotton at the gin or warehouse. The grades are based on fiber length, fiber maturity, sample color, preparation, and trash content.

Cottonseed Oil Mills

Cottonseed oil mills receive cottonseed directly from the gins. The seeds are initially cleaned of coarse trash (*e.g.* bracts, stems, sticks, dirt) by mechanical shakers and short fibers (linters) still adhering to the seed are removed by revolving saws or abrasive blocks. The seeds are then dehulled and cottonseed oil extracted from the seed meats by press or solvent methods. The linters are packaged into bales and sold commonly to waste utilizers and cotton garnetters and other industries using cottonseed by-products. The hulls, oil, and meats are also of commercial value and are processed for storage and marketing.

Compress-Warehouses

Cotton compress-warehouses are storage facilities where the bales are also weighed and samples are removed from each bale for classing. All warehouses surveyed had compressing operations to reduce the size of the bale as received from the cotton gin to a "high-density" bale for more efficient storage and transport.

Waste Utilization Plants

Cotton waste utilization facilities (also called waste recyclers) process cotton wastes from textile mills, lint wastes (motes) from gins, and linters from cottonseed oil mills. The great majority of waste recyclers are located in the southeastern United States in close proximity to the primary textile industry. Cotton materials are processed by a combination of manual and machine operations. Different types of cotton waste are usually blended and used to produce low-grade cotton products such as batting for upholstery.

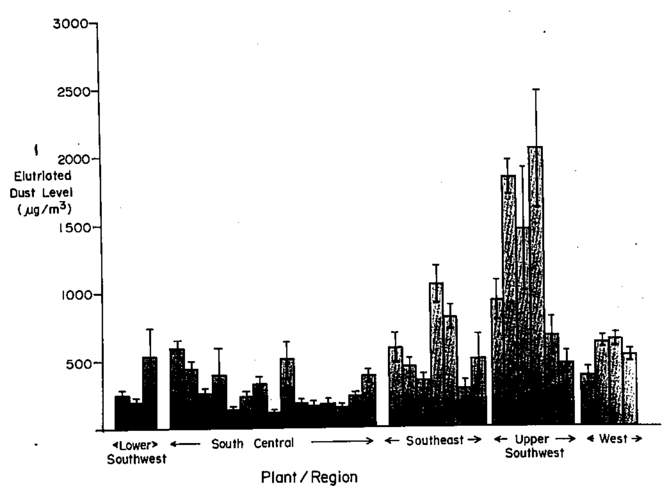

Figure 1 — Average elutriated dust levels in cotton gins (bar indicates standard error).

Methods

Plant Selection

Initially, a representative sample size of workers was statistically determined for each of the five identified non-textile segments. The United States' cotton belt was then divided into five major geographical regions of cotton production thus taking into consideration differences in ethnic variation, cotton types and harvesting techniques since these variables are highly correlated with geographic region. The regions include all or portions of the following states:

1. West Region: California, New Mexico, Arizona, Nevada, and the El Paso region of Texas.
2. Upper Southwest Region: Texas High Plains area, Central Texas, and Oklahoma.
3. Lower Southwest Region: Rio Grande Valley area of South Texas and Southeast Texas.
4. South Central Region: Louisiana, Arkansas, Mississippi, Missouri, Kentucky, and Tennessee.
5. Southeast Region: Georgia, Alabama, Florida, South and North Carolina, and Virginia.

To ensure representative site selection, individual plants from each non-textile segment were described by age, operational capacities, employee census, and geographic area. A multistage cluster-sampling technique was used to select specific study facilities. In four of the five non-textile cotton industry segments studied, at least one study facility was selected from each of the five regions. Waste utilization plants, which were felt to be less dependent on geographic and climatic variables, were the exception in that all 13 plants studied were located near the major textile manufacturers in the Southeast region.

Air Sampling Techniques

Airborne cotton dust concentrations were measured in each facility using the Lumsden-Lynch vertical elutriator (VE) operated at a flow rate of 7.4 ± 0.2 liters per minute (LPM) using a critical orifice.[29-34] Elutriated dust samples were collected on 37-mm diameter polyvinyl chloride filters (5 μm pore size) in open face cassettes. All samples were hand-carried to the NIOSH analytical laboratory in Morgantown, WV for gravimetric analysis. Field blanks were collected at each facility and used to correct field sample weights. Dust concentrations were calculated by dividing the corrected weight of dust collected on each filter by the volume of air sampled.

A minimum of two vertical elutriators were positioned in each work area where employees normally worked or spent a significant period of time. These samplers were placed in positions that would yield consistent results representative of actual worker exposures. Depending on where it was situated, a vertical elutriator was either supported on a tripod stand or hung on a wall, post or piece of machinery to maintain a breathing zone height (usually about 1.5 meters) representaive of the workers in the proximity of the sampler.

Sampling commenced at the start of the medical testing prior to each work shift and was stopped after the follow-up pulmonary tests were completed at the end of the shift.

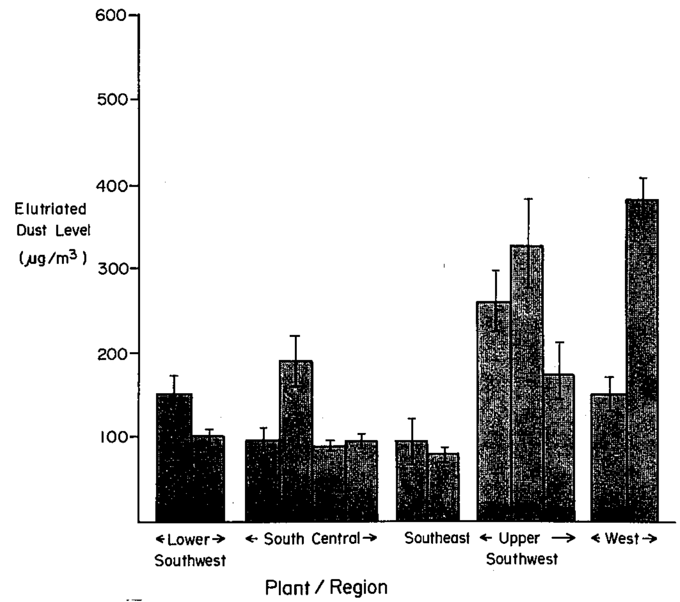

Figure 2 — Average elutriated dust levels in cotton classing offices (bar indicates standard error).

Sampling therefore varied from a minimum of 6 hours to 12 hours.

Size characteristics of elutriated cotton dust were measured using an eight-stage Andersen cascade impactor preceeded by four VE separation chambers connected in parallel.[35] The Andersen sampler was operated at 28.4 LPM, which theoretically resulted in a flow of 7.1 LPM through each of the four elutriation chambers. It was felt that the slightly lower than optimum flow rate through each chamber would not significantly change the collection characteristics from those designed for a vertical elutriator.

Impactor samples were collected on 81-mm diameter glass fiber filters placed under each impaction stage. The corrected weight of dust collected on each stage was determined by gravimetric analysis. Mass median aerodynamic diameter (MMAD) and geometric standard deviation (GSD) were estimated from log probability plots of the impactor data.

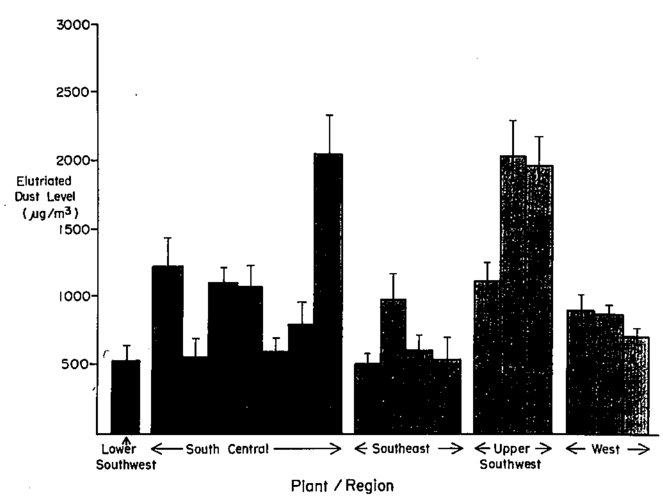

Figure 3 — Average elutriated dust levels in cottonseed oil mills (bar indicates standard error).

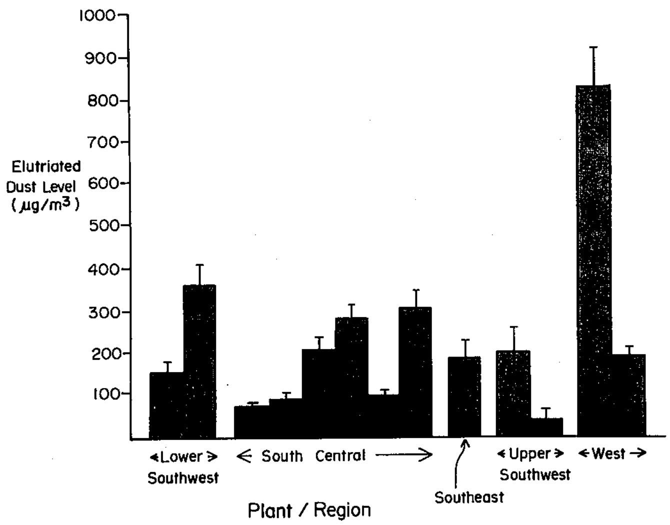

Figure 4 — Average elutriated dust levels in cotton compress warehouses (bar indicates standard error).

Results and Discussion

Figures 1-5 present the mean dust levels for all vertical elutriated samples collected at each non-textile cotton facility. Data from each plant are listed by the corresponding geographic region. Tables I-V present dust concentrations measured in different work areas for each non-textile segment; the entries are listed in the same order as the flow of material through the process.

Concentrations measured by the vertical elutriator may be influenced by variable operational parameters such as air flow patterns, condition of pneumatic conveyance and ventilation systems and work practices. Also placement of the samplers will affect measurements and is subject to the judgment of the industrial hygienist. These factors should be considered when observing results for given facilities, geographic regions and segments.

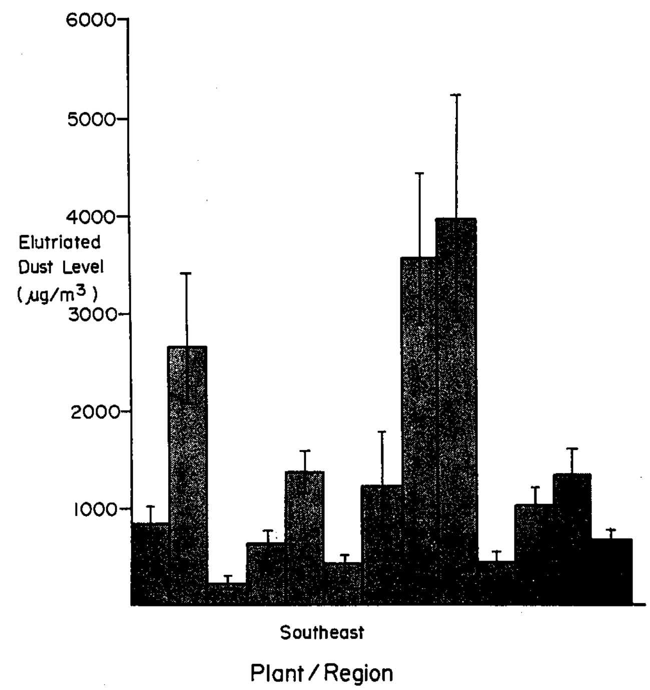

Figure 5 — Average elutriated dust levels in waste utilization plants (bar indicates standard error).

TABLE I
Elutriated Dust Levels at Cotton Gins by Plant Area

Area	Samples	Mean	S.D.	Min.	Max.
	Dust Levels in Micrograms per Cubic Meter				
Background	49	123	119	0	652
Seed Unload	61	202	261	0	1405
Gin Stand	209	634	579	39	3417
Lint Cleaning	48	478	528	42	3444
Bale Press	201	565	753	13	8389
Yard	25	165	112	18	392
Office	13	259	327	45	1206

Ginning

Figure 1 summarizes the average dust levels measured at each ginning facility. The average dust levels for all samples collected at each cotton gin ranged from 101 to 2050 $\mu g/m^3$. When comparing the results on a regional basis, the Lower Southwest and South Central regions appear to be the cleanest.

Differences between dust concentrations in different geographic regions may be attributed to various harvesting methods and/or climatic conditions encountered during the survey periods. For instance, Hersh *et al.*[36] have shown that raw cottons from locations where the crop is machine-stripped generate a greater quantity of elutriated particulate than does cotton from locations where harvest is by machine-picking. Environmental phenomena such as freezing and precipitation encountered during or immediately prior to harvesting may also affect plant part friability and therefore dust levels

Further, weather conditions during the survey period may influence the amount of atmospheric air allowed to circulate through the gin buildings and therefore the degree of dilution in dust concentrations. The variability of dust concentrations between gins may also be associated with such factors as: the type and number of lint cleaners; the type of gin stand (saw versus roller); the condition of machinery and equipment; and the use of air cleaning systems.

Palmer *et al.*[12] studied 29 gins in the Texas Rio Grande area and New Mexico. The reported overall mean was 930

TABLE II
Elutriated Dust Levels at Cotton Classing Offices by Plant Area

Area	Samples	Mean	S.D.	Min.	Max.
	Dust Levels in Micrograms per Cubic Meter				
Background	13	100	99	0	390
Receive/Ship	36	290	249	6	1194
Warehouse/Stor	7	105	48	45	183
Micronaire	87	265	211	23	1382
Classing	127	135	121	0	531
Snake	31	180	126	42	518
Yard	5	58	39	7	113
Office	18	79	20	36	112

TABLE III
Elutriated Dust Levels at Cottonseed Oil Mills by Plant Area

Dust Levels in Micrograms per Cubic Meter					
Area	Samples	Mean	S.D.	Min.	Max.
Background	39	81	59	10	240
Seed Receiving	53	604	519	16	2079
Seed Sampling	7	77	57	12	147
Seed House	37	1469	1686	34	9037
Seed Shaker	6	934	714	37	1833
Seed Cleaning	124	1339	1176	14	6072
Seed Delint	257	1232	957	1	5622
Bale Press	140	883	865	26	5542
Warehouse/Stor	3	110	77	47	196
Hull/Separate	137	1677	1470	231	7989
Hull House	9	541	1006	28	3117
Yard	69	157	215	11	1310
Office	3	279	68	229	356

$\mu g/m^3$ which is considerably higher than the overall mean for gins in this study (521 $\mu g/m^3$) and higher than the mean from plants within the Lower Southwest region (509 $\mu g/m^3$) and the West region (611 $\mu g/m^3$). Larson *et al.*[11] reported concentrations ranging from 380 to 1400 $\mu g/m^3$ with a mean of 740 $\mu g/m^3$ for 12 gins located in California. Figure 1 indicates that mean values for the four gins in the West region were lower with a range of 356 to 611 $\mu g/m^3$. Wesley *et al.*[37] studied five high capacity gins in the Mississippi Delta in which average plant values ranged from 170 to 1060 $\mu g/m^3$. This range is broader than the 101 to 573 $\mu g/m^3$ range reported in our study of gins in the South Central region. Bethea *et al.*[38] surveyed 14 West Texas gins processing stripper-harvested cotton and arithmetic means were 260 $\mu g/m^3$ for the bale press area and 400 $\mu g/m^3$ for the gin stand area. These results can be compared to the results for the Upper Southwest region in Figure 1 in which our data indicate average plant values in excess of 450 $\mu g/m^3$ for all six plants. Bethea's study results for the gin stand and bale press areas can also be compared to Table I in which we report mean dust levels of 634 $\mu g/m^3$ for the gin stand area and 565 $\mu g/m^3$ for the bale press area. These area values were averaged from all gins surveyed and so direct comparison to area values from gins in one specific region cannot be easily interpreted.

Few foreign studies have collected vertical elutriated samples in ginning facilities. In one such study, Noweir[16] has reported mean airborne concentrations ranging from 3200 to 6020 $\mu g/m^3$. However, the "ginning" process in Egypt requires more manual labor practices resulting in higher dust generation than those observed in gins in the United States. The lowest value (3200 $\mu g/m^3$) is approximately 30% higher than the highest arithmetic mean value (2050 $\mu g/m^3$) for any of the 35 gins reported in Figure 1. In general then, the levels reported here are lower than those reported previously for both domestic and foreign gins.

TABLE IV
Elutriated Dust Levels at Cotton Compress Warehouses by Plant Area

Dust Levels in Micrograms per Cubic Meter					
Area	Samples	Mean	S.D.	Min.	Max.
Background	14	67	55	0	190
Receive/Shipping	16	170	259	0	963
Bale Sampling	85	314	343	0	1887
Dinky/Compress	173	213	229	0	1011
Warehouse/Stor	37	176	172	15	757
Yard	3	62	12	49	72
Office	2	87	21	72	102

TABLE V
Elutriated Dust Levels at Waste Utilization Plants by Plant Area

Dust Levels in Micrograms per Cubic Meter					
Area	Samples	Mean	S.D.	Min.	Max.
Background	16	51	47	10	176
Receive/Shipping	34	132	102	34	399
Opening/Feeding	132	2602	4885	206	31968
Machine Process	62	2556	2935	158	14281
Hand Process	36	1287	741	272	2933
Bale Process	116	935	942	135	5090
Warehouse	85	168	141	22	748
Office	18	77	40	22	165

Classification Offices

The mean dust levels for samples collected at each cotton classing office ranged from 81 to 376 $\mu g/m^3$. In evaluating this segment on a regional basis, the Lower Southwest, South Central, and Southeast regions have the lowest average values. Conversely, the Southwest and West regions have the highest values with four of five classing offices having average values which are higher than the highest value in the remaining three regions.

Hodgkins[39] has reported elutriated dust levels ranging from 200 to 1900 $\mu g/m^3$ in 15 classing offices surveyed from 1973-77 during the initial phase of the USDA effort to implement control technology in its classing facilities. The lower dust concentrations reported in our study reflect the success of the continuing USDA efforts to reduce dust levels in the classing offices through engineering controls.

Cottonseed Oil Mills

The mean dust levels for samples collected at cottonseed oil mills ranged from 502 to 2041 $\mu g/m^3$. In evaluating this segment by region, the Upper Southwest has the highest values. Three of the five highest dust levels for facilities in this segment were reported for the three oil mills from this region. Of the remaining regions, the South Central and West regions have the next highest values with eight of ten oil mills having values between 715 and 2041 $\mu g/m^3$. The Lower Southwest and Southeast regions have the lowest values with only one of the five plants grouped in these regions having an average value above 603 $\mu g/m^3$.

Bethea *et al.*[40] reported results from sampling in ten oil mills throughout the U.S. Cotton Belt which ranged from 71-7927 $\mu g/m^3$. From a study of five Texas cottonseed oil mills processing stripper-harvested cotton, it was reported that averaged dust levels measured in the cleaning, delintering, hulling and baling areas ranged from 1700-6000 $\mu g/m^3$.[41]

A study of four cottonseed oil mills was reported by Jones *et al.*[14] in which mean concentrations for various work areas ranged from 300 to 7600 $\mu g/m^3$ of elutriated dust. Most of the results reported from these domestic studies are higher than the values we report in Figure 3 and Table III. A foreign study conducted by Noweir reported elutriated concentrations ranging from 3120 and 6330 $\mu g/m^3$.[16] These concentrations are also much higher than the values in Figure 3 for cottonseed mills throughout the United States.

Compress-Warehouses

The average dust levels for all samples collected at each cotton-compress warehouse ranged from 39 to 831 $\mu g/m^3$. Evaluating this segment on a regional basis indicates that the West region had the highest individual plant value of all 13 plants studied. The Lower Southwest and South Central regions have the next highest values as one-half of the plant values in each region are among the five highest values for the segment. The single study plant located in the Southeast region had a value in the mid-range. The Upper Southwest region had values among the five lowest for all 13 plants.

A study by Wesley *et al.*[42] in three cotton-compress warehouses located in the Mississippi Delta reported average dust concentrations ranging from 120 to 420 $\mu g/m^3$ for those areas in which cotton is actively handled. The Mississippi Delta would correspond to the South Central Region in Figure 4 where mean values ranged from 60 to 301 $\mu g/m^3$.

Table IV indicates that the highest mean concentrations were found in the bale sampling and the dinky/compress areas. Since forklifts were observed to operate frequently in these areas, it is highly probable that some of the mass collected in these areas was exhaust particulate. The mass contribution of such particulate relative to the cotton dust however is thought to be negligible considering its relatively smaller size.

Waste Utilization

As seen in Figure 5, waste recyclers are characterized by relatively high dust concentrations. The mean dust levels for samples collected at each cotton waste utilization facility ranged from 237 to 3968 $\mu g/m^3$.

Chinn *et al.*[15] reported dust levels in "willowing mills" in England which use some of the same raw materials as used in U.S. cotton waste facilities. Respirable dust concentrations were reported to range from 28 000 to 140 000 $\mu g/m^3$ which are comparably much higher than levels measured in this study.

Segment Comparisons

Figure 6 presents the average of the mean dust levels for all plants within each segment. The average values for the five segments are 521 $\mu g/m^3$ for gins, 165 $\mu g/m^3$ for classing offices, 1008 $\mu g/m^3$ for cottonseed oil mills, 229 $\mu g/m^3$ for compress warehouses, and 1390 $\mu g/m^3$ for waste utilization facilities.

Reasons for the intrasegment differences are varied, but would include the type of processing (machine versus manual), type of material being processed (waste material versus cotton fiber), and availability and condition of dust control equipment. Cotton classing offices have primarily manual processing of cotton samples and were the only segment in which each individual facility had installed local exhaust ventilation equipment to control the airborne dust concentrations. These factors contributed to the fact that the cotton classing segment had the lowest average value.

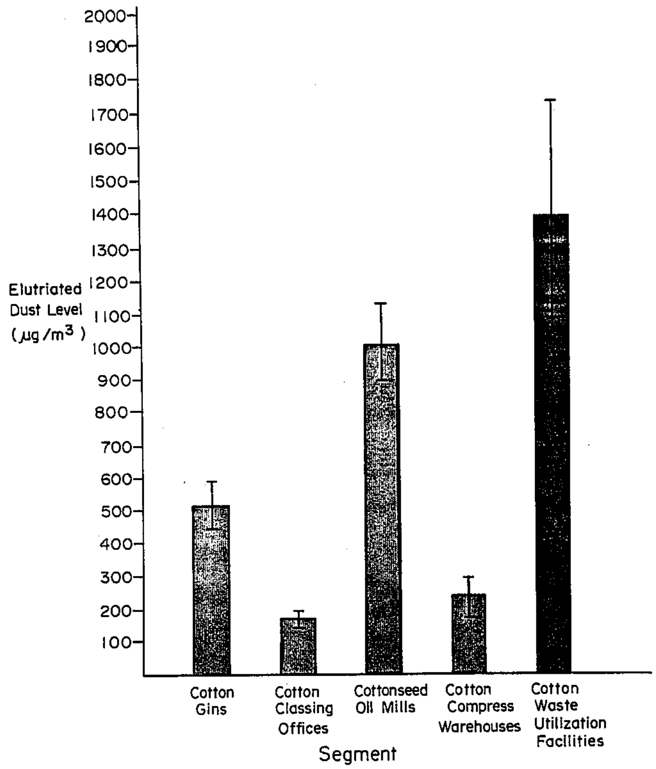

Figure 6 — Average elutriated dust levels by segment (bar indicates standard error).

The compress warehouse segment had the next lowest range. These facilities involve some machine processing of cotton bales such as cutting samples from the bales and compression of bales to a smaller size. However, the majority of activity involves manual processing such as manual removal of bale samples and removing and/or replacing bands and covers on bales of cotton. In addition, the facilities are spacious which allows for dispersion of airborne dust and, weather permitting, the doors and windows are left open, which may also aid in reducing airborne dust levels.

The remaining segments involve more rigorous processing of cotton materials. The application of high velocity mechanical force at several steps in processing probably results in most of the high dust concentrations reported in these segments. Waste utilization involves both manual and machine processing and involves processing of materials containing a large amount of trash. This segment had the largest diversity in dust control and processing equipment of all segments studied; this is reflected in the large standard error shown in Figure 6. Some waste utilization plants performed rigorous machine processing of cotton materials, but had no effective dust control and/or poorly maintained processing equipment. Other plants had similar processing, but better maintained dust control and processing equipment.

Intersegment variations are undoubtedly due to a number of factors. These factors would include the harvesting method used, environmental factors (humidity, temperature, wind direction), operating capacities, housekeeping practices, plant layout, and availability and maintenance of ventilation systems. These factors have been previously reported as affecting airborne dust concentrations.[43-45] The method of harvest seemed to be a consistent influence as three of the four segments, which had study plants located in all five geographic regions, had some of the highest individual plant values in the Upper Southwest Region. Cotton from this region is harvested by machine-strippers as opposed to spindle-pickers. As mentioned earlier, it has been shown that machine-stripped cotton contains considerably more trash and subsequently generates higher concentrations of airborne cotton dust during processing.[36,43]

When discussing the different dust levels for the different segments, it should be pointed out that the health hazards associated with these processes may not vary directly with the dust levels. This is because the concentrations of the etiologic agent, unidentified as yet, may vary from segment to segment. For example, cottonseed oil mill dust may have a different level of etiologic agent than gin dust. These differences may not necessarily be reflected in the elutriated dust concentrations that were measured but may be better expressed in the results of the epidemiogical surveys conducted for each segment.[24-28]

Particle Size Characterizations

Cascade impactors were used to collect at least one set of dust samples for particle size analysis from most non-textile facilities studied. For many samples, low dust concentrations and insufficient sampling times resulted in inadequate dust collections for accurate weight analysis; therefore, no size distributions could be determined from these samples. For some samples which were suitable for weighing, it was observed that fibrous material had plugged orifices in the impaction plates therefore resulting in high dust deposition on the initial stages with low deposition on the later stages of the impactor. This has been reported previously[46] and these samples were therefore voided from analysis.

Data presented in Table VI summarize the particle size characterizations determined in those segments in which suitable samples were collected. The lowest average mass median aerodynamic diameter (MMAD) was observed in the classing office segment while the highest was calculated for the cotton gin segment.

TABLE VI
Mean Particle Sizes of Cotton Dust in the Non-Textile Industry

Segment	# Samples	Mean MMAD (micrometers)	Mean GSD
Gins	9	5.3	3.5
Cottonseed Mills	10	4.5	3.5
Classing Offices	13	4.1	4.5

Thibodeaux[41] has reported results that show the mass median particle diameter to range from 11.8-26.8 micrometers (GSD range = 1.8-2.2) in various process areas of an oil mill which is much larger than the oil mill value indicated in Table VI.

Summary

A study of elutriated dust levels in the non-textile cotton industry has been completed by NIOSH. Dust concentrations were measured in 92 facilities representing the geographic distribution, process design, type of cotton processed and other operational parameters in the ginning, cottonseed oil extracting, classing, warehousing and waste utilization segments of the U.S. secondary cotton industry. Dust samples were collected in various work areas of each facility using the vertical elutriator. Dust levels measured in the work environments were found to be highly variable within and between the various non-textile cotton segments. Average elutriated dust concentrations were 521 $\mu g/m^3$ for cotton gins, 165 $\mu g/m^3$ for classing offices, 1008 $\mu g/m^3$ for cottonseed oil mills, 229 $\mu g/m^3$ for compress-warehouses, and 1390 μ b1g/m^3 for waste utilization facilities. Analysis of the data also reveals that a large majority (80%) of the facilities have mean dust concentration of 1000 $\mu g/m^3$ or less and 54% have an average of 500 $\mu g/m^3$ or less. Results from this study tend to be somewhat lower than those reported previously.

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