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WORKER EXPOSURE TO DUST IN THE GRAIN INDUSTRY

A Research Project
Sponsored By:

National Grain and Feed Association
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FINAL REPORT

CONFIDENTIAL

Prepared at the request of counsel for NGFA
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EXECUTIVE SUMMARY

Although considerable research has been done on grain dust exposure and health effects, past studies have had significant limitations. The objective of this study was to conduct the most comprehensive examination of this issue to date focusing on grain dust exposure, the prevalence of respiratory disease in grain workers, and an analysis of whether a dose-response relationship exists.

This study consisted of environmental measurements and employee health medical screenings conducted in 1989 and 1990 at 43 grain elevators, including country elevators, terminal and export facilities, throughout the U.S. The elevators included were handling all types of grain, with corn, wheat and soybeans being the most dominant. Median dust exposure level for 455 personal and area samples, the majority taken for more than five hours during the workshift, was 1.8 mg/m^3. Over 80 percent of all personal dust exposures were less than 10 mg/m^3 (OSHA's standard for wheat, oats, and barley), but 51% of the 43 facilities were found to have at least one measurement exceeding 10 mg/m^3. There was significant day-to-day variability in the dust levels to which individual employees were exposed. The types of grain handled and the presence of engineering controls had a measurable impact on exposure levels. No significant differences were apparent in dust exposure levels for different regions of the U.S.

Medical evaluations consisting of a respiratory questionnaire, job and health history, examination of the chest, examination of the upper respiratory system, and pulmonary function testing were conducted on 427 grain elevator workers. Comparison of the health of grain elevator workers with community and industrial data showed that the rates of chronic bronchitis and abnormal pulmonary function were not higher than usually encountered in other populations. The prominent factor affecting the prevalence of symptoms and abnormal pulmonary function findings was smoking history. There was a high correlation of prevalence of symptoms of cough, chronic bronchitis, chest tightness, and shortness of breath with smoking. Current dust exposure level appeared to have no relationship to pulmonary function decline during the shift. Likewise, levels of endotoxins, bacteria and fungi were found to be insignificant.

To measure the potential long-term effects of dust exposure, an exposure index, representing years worked and estimated exposure levels for past job functions was used. To our knowledge this is the first such study to develop an exposure index for large numbers of employees based upon actual environmental sampling and job history. It was found that long-term grain dust exposure may result in mild chest symptoms, especially tightness and a mild decline in pulmonary function. There appeared to be little evidence of influence of grain dust on respiratory health until the higher exposure indices were reached, and these may be due to higher exposures in the past.

SECTION 1

INTRODUCTION

Over the last twenty-five years considerable research has been done on the health effects of grain dust, particularly as it affects the respiratory system. While these studies have added to our knowledge about the health effects of grain dust, they have significant limitations. Most have been conducted at large export elevators and did not include workers at inland terminal and country elevators where conditions and exposures may be different. Much research on grain dust has been done outside the U.S. or in limited geographic areas within the U.S., and has not addressed the potential for regional differences. Most research to date has involved worker exposure to a limited number of grains, particularly wheat, and has not considered the variety of grain which may be encountered by elevator workers. No cross-sectional studies have been conducted to determine the levels of dust to which elevator workers are exposed and the variation of these dust levels with elevator parameters. Finally, very few studies have attempted to correlate respiratory effects with dust exposure levels.

To address some of these limitations and to better understand dust exposure and related health effects in the grain handling industry, the National Grain and Feed Association (NGFA) sponsored a study of worker exposure to grain dust in the U.S. The overall goal of this study was to obtain current, objective information on the levels of dust to which grain elevator employees are exposed and the health status of such employees with emphasis on pulmonary function. The scope of the study was limited to grain elevators and did not include grain dust exposure in other settings such as farming or processing. It involved visits to randomly selected grain elevators in the U.S., during which exposure and medical monitoring were done. All types of grain were included.

Primary scientific objectives of the study were:

1. To determine the prevalence of respiratory disease in grain workers for comparison with the general population and between industry segments.

2. To measure grain dust exposure as a function of job category in different industry segments and, if possible, by type of grain handled.

3. To establish a dose-response relationship, if any, between level of dust exposure and acute and chronic respiratory effects.

Secondary scientific objectives were:

1. To assess the variability in dust exposure level, acute respiratory response, or prevalence of respiratory disease among workers handling different grains.

2. To examine the variation of dust exposure level with work habits and engineering controls at different facilities.

3. To determine whether there is regional variability in dust exposure level and prevalence of respiratory disease within the U.S. and between the U.S. and other countries where similar data are available.

Other objectives included establishing a reference database so individual facilities and companies can compare their situation to the industry profile.

SECTION 2

METHODS

2.1 Selection of Elevators

To meet study objectives, statistically valid comparisons of respiratory health status among various exposure groups and industry segments were necessary. It was also essential to account for confounding factors such as smoking. Based on these considerations it was estimated that approximately 600 grain workers should be included in the study. Elevator selection methodology was designed to try to obtain this response level.

The Occupational Safety and Health Administration (OSHA) has estimated that as of 1981, there were approximately 14,000 grain elevators with 85,500 full-time equivalent employees in the U.S. The numbers by industry segment were estimated as follows:

Elevator type	Facilities	Employees
Country elevators	13,200	70,800
Inland terminals	700	9,800
Export terminals	75	4,950

Based on these estimates and approximately equal number of employees selected from each industry segment, the necessary number of elevators for inclusion in the study was calculated to be:

Country elevators	38
Inland terminals	14
Export elevators	3

Specific grain elevators were selected from the following lists:

1. Export terminals were randomly selected from the list of 82 facilities contained in the Export Elevator Directory dated January, 1989 published by the U.S. Department of Agriculture, Federal Grain Inspection Service. Fifteen elevators were chosen. Of these, two did not meet the selection criteria since they were floating elevators and four were not currently operating. Of the remaining nine, six were contacted and three agreed to participate.

2. Inland terminals were selected from the list of facilities contained in the 1989 Grain Guide -- North American Grain Yearbook published by Milling & Baking News, Shawnee Mission, Kansas. This list contained port, river, terminal, and subterminal elevators. After deletion of export terminals, twenty-nine terminal elevators were randomly selected from a universe of 786 facilities. Of these, twenty seven were contacted and fifteen agreed to participate.

3. Country elevators were selected from the most complete list of grain elevators *publicly available* - the Grain Directory -1989 Directory of U.S. Grain elevators published by the Grain Journal, Decatur, Illinois. After elimination of duplications from the above lists of export and inland terminal elevators, 8570 facilities remained from which 104 elevators were randomly selected. Of these, eighteen were primarily feed mills and sixteen were not currently operating or had only a single, part-time employee. Seventy country elevators were contacted and twenty-three agreed to participate.

Initial contacts with selected elevators were made by NGFA representatives through corporate members, state grain and feed associations, and directly by telephone. The initial contact was followed by a letter describing the study along with a question-and-answer flyer and employee brochure. Counsel for the NGFA assured the association and all participants that the study was being conducted at his request, that each elevator's results were confidential, and that the entire study may also be confidential. As the study progressed it became apparent that a lower number of employees were being found at each elevator than expected. This became particularly problematic with export elevators. In consultation with NGFA, two additional export elevators willing to participate in the study were identified and included. A total of 43 elevators ultimately participated in the study, including fewer country elevators and more inland terminal and export elevators than initially sought. The distribution by industry segment is shown in Table 2-1. Although overlaps in capacity and number of employees occurred between industry segments, the trend in average storage capacity and number of employees was as expected. The average number of employees per elevator was less than the OSHA estimate in all three industry segments, particularly in terminal and export elevators. The geographical distribution of elevators included in the study is shown on Table 2-2. Regional distribution was representative of the U.S. distribution. More facilities than expected were included from the Central and Southwest regions and slightly fewer from other regions. The method used for selecting elevators did not permit selection by type of grain handled. The wide regional distribution of elevators selected did ensure that a variety of grains would be included.

2.2 Scheduling

All elevator visits were scheduled for Mondays or for the day after a holiday. The reason was to increase the likelihood that employees would have a period away from grain dust exposure prior to pulmonary function testing. For elevators operating seven days per week, the best possible day was scheduled based on a pre-visit telephone contact.

Smaller grain elevators are highly seasonal in their work. An attempt was made to visit each elevator during peak harvest season. Where corn was the primary grain handled visits were made during the fall. Wheat visits were made during the summer. Larger elevators which operate all year were scheduled as convenience would allow.

2.3 Medical Evaluations

Medical evaluations consisted of a questionnaire, pre-exposure and post-exposure pulmonary function testing, and a limited examination by a nurse. These evaluations were done on all employees present at the elevator on the day of the visit who were willing to participate. By industry segment the participation of grain workers was as follows:

	Number of employees present	Number of employees evaluated	%
Country elevators	117	106	90.6
Terminal elevators	120	106	88.3
Export elevators	312	215	68.9
TOTAL	549	427	77.8

The lower participation rate in export elevators was due to not evaluating all office employees, higher refusal rates, and not being able to test third shift employees at one facility. The participation of employees who actually handled grain was higher than the percentages shown above.

An information packet was provided to each elevator just prior to the scheduled visit (Appendix A). This included an instruction sheet for employees which management was asked to distribute. Employees were instructed not to eat or smoke for one hour prior to reporting to work. A pulmonary function test site was identified and employees were asked to report to this site for testing prior to beginning their daily activities. Medical consents were obtained and pre-exposure pulmonary function tests administered. Employees were then permitted to proceed to their work areas. Four to six hours into the work shift employees were asked to return to the test site one at a time. Post-exposure pulmonary function tests were done and respiratory questionnaires completed until all employees participating had been tested.

The questionnaire used is shown as Appendix B. It is a modified version of the questionnaire recommended by the British Medical Research Council. An effort was made to obtain a complete work history and to identify other lifestyle factors which could affect pulmonary function status. The questionnaire was administered one on one by a nurse or technician trained in the technique.

Questionnaire responses were graded as follows:

Cough

1. Do you usually cough (on getting up) first thing in the morning?

2. or, Do you usually cough during the day or at night?

   If either was answered yes - then

3. Do you cough like this on most days for as much as three months a year?

If either 1 or 2, and 3 were answered yes, the person was graded as having a chronic cough, herein identified as "cough".

Chronic Bronchitis

1. Do you usually bring up any phlegm from your chest first thing in the morning?
2. Do you bring up phlegm from your chest during the day or at night?

If either 1 or 2 was answered yes, then ...

3. Do you bring up phlegm like this on most days for as much as three months each year?

4. How long have you had this phlegm?

A "yes" answer to 1 or 2 and a "yes" answer to 3 with question 4 answered two years or longer constituted a designation of chronic bronchitis. Cough or chronic bronchitis was designated for those who had either a chronic cough or chronic bronchitis.

Tightness

Chest tightness was graded yes or no in response to the question "Does your chest ever feel tight or your breathing become difficult?"

In addition, the person was asked if the tightness was present on any particular day of the week, and if so, which day?

Dyspnea

Dyspnea or shortness of breath was graded as follows:

1. Are you ever troubled by shortness of breath when hurrying on the level or walking up a slight hill?

   If "No", grade as 1. If "Yes", proceed to next question.

2. Do you get short of breath walking with other people at an ordinary pace on the level?

   If "No", grade as 2. If "Yes" proceed to next question.

3. Do you have to stop for breath when walking at your own pace on the level?

   If "No", grade as 3. If "Yes", proceed to next question.

4. Are you short of breath on washing or dressing?

   If "No", grade as 4. If "Yes", grade is 5.

Smoking

Smoking questions were graded as follows:

1. Do you smoke? Record "Yes" if a regular smoker up to one month ago - "Yes" designates "current" smoker. "No" is a non-smoker, and "ex-smokers" are those stopped for at least one month and who have smoked as much as one cigarette per day, or one ounce of tobacco a month for as long as one year. Pack years were obtained by multiplying the current number of packs per day by the years of smoking cigarettes.

Other questions pertaining to health, occupation, years exposure on grain elevator jobs, chest illness, and physical examination are listed on the questionnaire and were answered appropriately.

Pulmonary function tests were administered by technicians or nurses who had successfully completed a NIOSH-approved spirometry course. Puritan Bennett Model 900 microprocessor spirometers were used. The spirometers were calibrated prior to use each day with a Puritan Bennett 3-liter calibration syringe. The best of three efforts, the best two of which had to be within ten percent of each other, were used to evaluate the pulmonary function status of each employee. Pre-exposure test results were compared with general population data (Knudson data) as a function of age, height, sex, and race for indications of chronic respiratory disease. Post-exposure test data were compared with pre-exposure data for the same individual for indications of acute effects from dust exposure during the work shift. A ten percent change between pre- and post-exposure test data was considered significant.

Pulmonary function test parameters obtained were as follows:

FEV1B - Forced expiratory volume in one second before shift

FEV1A - Forced expiratory volume in one second 4-6 hours after start of shift

FVCB - Forced vital capacity before shift

FVCA - Forced vital capacity 4-6 hours after start of shift

FEV1BCOR - FEV1 before shift corrected to age 40

FEV1PPB - FEV1 predicted percent before shift
FEV1B ÷ FEV1 predicted (Knudsen) x 100

FEV1PPA - FEV1 predicted percent 4-6 hours after start of shift
FEV1A ÷ FEV1 predicted (Knudsen) x 100

FVCPPB - Forced vital capacity predicted percent before shift
FVCB ÷ FVC predicted (Knudsen) x 100

FVCPPA - Forced vital capacity predicted percent 4-6 hours after start of shift
FVCA ÷ FVC predicted (Knudsen) x 100

RatioB - Ratio of FEV1/FVC before shift
FEV1B ÷ FVCB x 100

RatioA	-	Ratio of FEV1/FVC 4-6 hours after beginning of shift FEV1A ÷ FVCA x 100
FEF2575B	-	Percent predicted maximum mid expiratory flow during the middle half of the FVC before shift FEF2575 ÷ FEF2575 predicted (Knudsen) x 100
FEF2575A	-	Percent predicted maximum mid expiratory flow during the middle half of the FVC 4-6 hours after the beginning of the shift FEF2575 ÷ FEV2575 predicted (Knudsen) x 100
DFEV1	-	The change in FEV1 before shift compared to 4-6 hours after the beginning of the shift FEV1A - FEV1B
DFEV1P	-	The percentage change in the FEV1 before shift compared to FEV1 after beginning of shift DFEV1P = ((FEV1A - FEV1B)/FEV1B) x 100

Initial data collection at each elevator was followed with a visit by an occupational health nurse. The purpose of this visit was to review the results of pulmonary function testing and to conduct a limited medical examination. This examination consisted of observations of the nose and throat, listening to the heart and lungs, measuring blood pressure, and soliciting additional information as necessary. Particular attention was paid to signs of chronic respiratory disease such as wheezing and rales. Responses to the questionnaire were reviewed. Employees were provided with a summary report of the findings.

2.4 Dust Exposure Monitoring

Employees were selected randomly for dust exposure monitoring. In smaller facilities with fewer than ten employees all were included. At larger facilities one employee in each job category and duplicates up to ten were selected at random. Full-shift, personal, total dust measurements were the sample type of choice in this study since the focus was on health effects rather than engineering controls and permissible exposure limits for grain dust are based on total rather than respirable dust. Sampling devices, consisting of a collection filter in a closed-face cassette connected to a portable air sampling pump, were placed on employees immediately after pulmonary function testing and removed just prior to the end of the work shift. Stationary area samples were used to represent employee dust exposure in offices and control rooms where mobility was limited.

Grain dust measurements were made in a manner similar to NIOSH Method 0500 for total nuisance dust. Metricel VM-1 polyvinyl chloride filters were preweighed to the nearest microgram on a Mettler M3 microbalance. These filters were then placed in three-piece cassettes. During sampling air was drawn through the filters with the cassettes in a closed-face configuration using Gilian or SKC sampling pumps at flow rates of approximately 2.0 L/min. These pumps have electronic feedbacks which compensate for flow reductions caused by dust accumulation during sampling. Flow rates were calibrated both before and after sampling with a representative filter in line using an M30 miniBuck calibrator. After sample collection the filters were returned to the laboratory, equilibrated overnight, and reweighed. Five filters through which no air was drawn were weighed and reweighed with the samples. The average weight change of these filters - generally less than 20 micrograms - was used as a blank correction in calculating dust levels.

Size selective dust measurements were made using a 4-stage Marple cascade impactor. This device provides cut-points of 20, 15, 10, and 3.5 micrometers. One measurement per elevator was made, and the employee expected to have the highest dust exposure was generally selected to wear this sampler. As recommended by the impactor manufacturer, Mylar plates were sprayed with silicone before preweighing and placement in the impactor. The final stage was a preweighed filter. A flow rate of 2.0 L/min was used and calibration was done using a sealed can with the miniBuck calibrator. After collection the plates and filter were reweighed and percentage of dust in each size range calculated.

2.5 Operating Characteristics and Observations

Operational characteristics of each elevator were determined by interviewing the facility manager. Observations and judgments were made on work practices, engineering controls, and respiratory protection during each visit for correlation with dust level measurements. The data were collected on the forms in Appendix C.

2.6 Detailed Exposure Studies

At twelve facilities - three country elevators, five inland terminals, and four export elevators -detailed exposure studies were done. This included taking consecutive-day samples to determine interday variability of dust levels and short-term peak samples for intermittent operations. One direct reading instrument - the Handheld Aerosol Monitor (HAM) from PPM, Inc., Knoxville, TN -was evaluated in comparison to personal and area samples. Administrative and engineering controls used to reduce employee exposure to grain dust were carefully reviewed.

2.7 Endotoxin Measurements

Endotoxin levels were measured on approximately one-half of the personal and area dust samples taken. Samples were submitted to the University of North Carolina School of Public Health where they were analyzed under the direction of Dr. Janet Fisher. The limulus amoebocyte lysate (LAL) method was used to determine lipopolysaccharide (LPS) content. Filters were suspended in endotoxin-free water, mixed, and serially diluted into microliter plates with LAL. The plates were incubated at 37 C for 60 minutes before toluidine blue dye was added. Changes in the color of the dye were read after five minutes. No change indicated a positive test. Titration of a lysate of known sensitivity provided a measure of the endotoxin content. Both positive and negative controls were run with the samples.

These samples were also analyzed for bacteria and fungi by inoculating appropriate growth media in Petri dishes with serially diluted filter extracts. After incubation counts were obtained for non-thermophylic Actinomycetes, Bacillus species, Gram-positive bacteria except Bacillus, Gram-negative bacteria (rods only), and fungi.

2.8 Quality Assurance

A quality control manual was prepared prior to initiation of data collection for the study. It detailed the forms, techniques, and questionnaire to be used; how data were to be obtained, processed, and reported; what corrective actions would be taken if problems were encountered; and who had responsibility for each aspect of the study. A preliminary visit was made to an elevator not included in the study to familiarize field personnel with the processes and terminology they would encounter. Initial field visits were made by teams of two or more until each person was thoroughly familiar with the study requirements.

2.9 Confidentiality

All elevators and grain workers were promised confidentiality. A system was established to assure that medical records were maintained in a confidential manner. All data are aggregated for reporting purposes and individual elevators are identified only by numbers.

2.10 Data Analysis

All data obtained during the study were entered into a computer data base. Entries were checked and rechecked for accuracy and completeness. Statistical analyses were performed using the ABstat statistical analysis software package from Anderson-Bell Corporation, Parker, Colorado. Descriptive statistics, correlations, T-tests, analysis of variance, cross-tabulations with Chi square test, simple and multiple regression analysis were obtained directly from the data.

SECTION 3

RESULTS - DUST LEVEL MEASUREMENTS

3.1 Number/Type of Samples

A total of 455 dust level measurements were made during this study. The majority of these were personal samples (63%) or stationary area samples (25%). Almost all of the samples (87.9%) covered more than 300 minutes of the work shift. The samples were evenly distributed by industry segment (Table 3-1). Samples taken in each job category are shown on Table 3-2. Area samples were used extensively in office areas to represent employee exposures. For other job categories personal samples were emphasized.

3.2 Distribution of Dust Level Measurements

As shown on Figures 3-1 and 3-2 results of personal and area samples collected during the study were distributed lognormally. Simple arithmetic means could not be used for data analysis since they tended to be influenced greatly by a small number of high level measurements. The median, or geometric mean, is a more descriptive measure for lognormally distributed data and was determined for each data set. Also, since the Threshold Limit Value (TLV) for wheat, oats and barley is 4.0 mg/m^3; the OSHA permissible exposure limit (PEL) for wheat oats, and barley is 10 mg/m^3; and the PEL for corn and other grain dusts is 15 mg/m^3, the cumulative percentages of samples exceeding each of these levels were determined. Finally, two distribution parameters, the mean and standard deviation, were estimated using the following formulas:

$$\text{Estimated mean} = \hat{u} = \exp\left(y + s^2/2\right)$$

$$\text{Estimated standard deviation} = \hat{u}\left(\exp\left(s^2\right) - 1\right)^{1/2}$$

$$\text{where } y = \frac{1}{n} \sum_{i=1}^{n} \ln x_i$$

$$s^2 = \frac{1}{n-1} \sum_{i-1}^{n} \left(\ln x_i - y\right)^2$$

x_i = dust level for i th sample

The data are summarized by type of sample in Table 3-3.

Area samples had a smaller range and lower median level than personal samples. This was due to the large number of area samples taken in offices and control rooms which tended to be less dusty than other areas of the elevators. Total dust measurements using impactors had a systematic high bias when compared to filter cassette samples (see Section 3-9), so these were not used for data analysis.

3.3 Dust Level by Industry Segment

The results of dust level measurements by industry segment are shown on Table 3-4. Median dust levels were approximately the same in each segment when only personal samples are considered. When both personal and area samples are considered, median dust levels in export elevators are higher than those in country and terminal elevators. This is an artifact attributable to sample selection. More area samples were taken in office areas at country and terminal elevators, whereas more area samples were taken in grain handling areas at export elevators as part of detailed studies. Thus, it appears that there is little, if any, significant difference in median exposure levels among industry segments.

When estimated mean levels were compared, terminal elevators showed significantly lower dust levels than country and export elevators regardless of sample type. This appeared to be due to a smaller number of high level measurements in terminal elevators compared to other industry segments. The percentage of dust level measurements greater than 10 and 15 mg/m^3 was significantly greater in country elevators than in terminal or export elevators. The reason for this is unclear.

3.4 Dust Level by Job Category

As shown on Table 3-5, median dust levels by job category ranged from 0.18 mg/m^3 for Control Room Operators to 8.88 mg/m^3 for Basement Floor Operators. As expected, those jobs with limited grain contact - Clerical/QA/Laboratory, Control Room, and Manager - had the lowest dust exposures. Supervisors/Foremen had significantly higher dust exposure levels than Elevator Managers. This is because Supervisors/Foremen generally had some responsibilities in the elevator itself whereas Elevator Managers do most of their work in the office. Receiving/Inspection and Maintenance/Electrical employees tended to have the lowest dust exposures of employees working in and around the elevator. Receiving/Inspection included employees who work in booths and others who work in open areas, both of which reduce potential exposures. Maintenance/Electrical employees are highly mobile and often move to areas with lower dust levels for portions of the work day. The significance of high dust levels found for Basement Floor Operators is limited by the small number of samples. A substantial number of Grain Handlers - General employees have exposures above 10 and 15 mg/m^3.

A breakdown of dust levels by job category in various industry segments is shown on Table 3-6. Due to the small number of employees at each facility, grain handlers were generally not assigned to specific jobs in country and terminal elevators. Specific assignments which permitted breakdown by job category were made in export elevators.

Relationships in each segment are the same as those noted for the study as a whole. It is interesting to note that the median dust level for Basement Floor Operators in export elevators (Table 3-6) is lower than the industry as a whole (Table 3-5). This is due to a single high sample from a terminal elevator. Very high dust levels were seen in Grain Handlers - General in export elevators. However, the 40% of this category of workers having exposures above 15 mg/m^3 represents only four workers. Employees in this category in large elevators are frequently laborers who are assigned to a variety of tasks, many of which involve significant dust exposures. Considering all grain handlers, export facilities had 13.3% with exposures above 10 mg/m^3 and 10% with exposures above 15 mg/m^3.

3.5 Dust Level by Type of Grain Handled

The type of grain handled by the elevators was divided into two basic groups which depended upon the geographic location and season of the year in which an elevator was visited. The first group - 23 elevators - handled corn only, soybeans only, corn and soybeans, or both along with milo. The second group - 14 elevators - handled wheat only or wheat in combination with oats, barley, or milo. Five elevators handled both types of grain during the visit. One facility was not handling grain during the visit.

Dust levels by type of grain handled are shown on Table 3-7. Dust levels for elevators handling corn/soybeans appear to be slightly higher than for those handling wheat. Corn tends to release starch and "bees wings" which may cause airborne dust. Elevators which handled both types of grain had significantly higher dust levels. This is probably related to larger volumes of grain handled in these elevators.

3.6 Dust Level and Engineering Controls

Engineering controls found at the elevators visited ranged from "none" to very extensive. Each elevator was classified on the basis of the engineering controls for dust as follows:

None	No cyclone or fabric filter present
Limited	Cyclone or baghouse dust collector with exhausted elevator legs and/or receiving pit. May have remote control for truck dump.
Extensive	Above plus covered conveyor belts, exhausted transfer points, and enclosed control booths.

There are other dust control techniques such as building enclosures and choked feeding that are not considered in this analysis. Dust levels in relation to the above three classifications are shown on Table 3-8. Elevators with no dust control equipment have a slightly higher percentage of dust measurements exceeding 4, 10, and 15 mg/m^3 and higher estimated mean dust levels. These data do not reveal the interaction of dust level, engineering controls, and volume of grain handled. It may be that in larger elevators engineering controls are necessary to counteract larger dust emissions caused by handling larger volumes of grain. This observation is confirmed by the trends seen in Table 3-9. The percentage of dust measurements exceeding 4 mg/m^3 and estimated mean dust levels are reduced in country elevators which have limited engineering controls in comparison to those with none. Terminal elevators with more extensive engineering controls had a lower percentage of samples exceeding 4 mg/m^3 and estimated mean dust levels. Export elevators with extensive controls were similar to terminal elevators with limited engineering controls and country elevators with no controls relative to median, estimated mean, and cumulative percentage greater than 4 mg/m^3 dust levels.

3.7 Dust Level and Oil Additive Usage

Thirteen of the 43 elevators studied used an oil additive to control dust. Mineral oil was the oil of choice in all cases and application rates were approximately 1.0 gallons per 1000 bushels of grain. The effect of oil usage on dust levels is shown on Table 3-10. When all elevators are considered together no effect was apparent. For country and export elevators considered separately use of an oil additive did appear to reduce dust levels. However, the reverse trend was seen in terminal elevators.

The combined effect of oil additive usage and engineering controls was examined (Table 3-11). Where engineering controls were not present or were limited, oil additive usage appeared to reduce median and estimated mean dust levels. The effect was pronounced for those elevators without engineering controls. However, oil additive usage did not appear to be beneficial where extensive engineering controls were present.

3.8 Respirable Fraction of Dust

A total of 59 impactor samples were taken during the study to determine the respirable fraction of the dust collected. The percentage of grain dust less than 10 micrometers in aerodynamic diameter is summarized by industry segment on Table 3-12. An average of 20 to 25 percent of the dust was found to meet this criterion as the respirable fraction. There was little variation of the respirable fraction by the type of elevator from which samples were taken. As shown on Table 3-13 there was significant variation in respirable fraction of the dust for different types of grain. Wheat and related products tended to be more respirable.

3.9 Impactor Total Dust Measurements

Total dust exposures from impactor measurements were determined by adding together the quantity of dust collected on each impactor plate with that found on the backup filter. In 34 cases simultaneous measurements were made by having an employee wear two samplers, one with a filter cassette for dust collection and the other an impactor. Data from these 34 measurements are shown on Table 3-14. There was a high degree of correlation between the two methods of total dust measurement (Correlation coefficient = 0.85) and a low probability that this correlation was due to chance (<0.0001). However, the data indicate that there is a systematic bias with the impactor samples showing higher total dust levels in 28 out of the 34 measurements. For this reason, and considering the fact that filter cassette sampling is considered to be the standard method, impactor total dust measurements were not used for exposure monitoring data analysis. In seventeen cases, however, the only measurements of employee dust exposure available were impactor sampling results - no simultaneous filter cassette samples were taken. In these cases, impactor results were used in analyzing the relationship between exposure and pulmonary data. (Sections 4.3 and 4.6)

3.10 Interday Variability of Dust Levels

In many cases during detailed studies at the elevators, the same individual wore a sampling device for two or three consecutive days. The results of these measurements are shown on Table 3-15. They indicate that for a wide variety of jobs in grain elevators there is significant day-to-day variability in the dust levels to which an individual employee is exposed. In most cases, variations by a factor of 2 to 5 were found, but occasionally it was one to two orders of magnitude.

3.11 Regional Variability of Dust Levels

One of the secondary objectives of the study was to see if there were regional variations in dust levels and employee health status. The regional variability of dust levels is shown on Table 3-16. In two regions - Northwest and Northeast - the number of samples was too small to draw conclusions. Although some differences were seen in the other three regions, factors such as the type of grain handled and the presence of engineering controls were probably more important than region in determining dust exposure levels.

3.12 Dust Level and Activity Level

No data were gathered during the visit on the actual quantity of grain handled on the days measurements were taken. It was apparent that exposure levels could vary according to the activity level at the elevator (see Section 3.10). Follow up telephone calls were made to each elevator visited. The total volume of grain handled on the first day of the visit was obtained for 42 of the 43 facilities. This was compared to the average dust level of personal samples taken that day at those facilities. A statistically significant correlation was found (Correlation coefficient = 0.43, Prob = 0.0047) although individual data points were widely scattered.

Elevator capacity was examined as a surrogate for activity level and compared to the average dust level at the elevator. A positive correlation coefficient (0.21) was found, but there was a high probability that this was due to chance (Prob=0.175). These data suggest that elevator capacity is not a useful surrogate for activity level.

3.13 Dust Levels at Individual Elevators

Dust level measurements for individual elevators are summarized on Table 3-17. The median and arithmetic mean of all samples taken at the elevator are shown. In addition, the median, arithmetic mean, and the number of samples exceeding 4, 10, and 15 mg/m^3 are shown for all personal samples taken.

These data show that many individual elevators had low dust levels at the time of the visit. Twelve had no personal samples with dust levels greater than 4 mg/m^3. The converse is also shown. Certain elevators (e.g. Numbers 42, 46, 58, 68 and 85) were "hot spots" with significant numbers of personal samples exceeding 10 and 15 mg/m^3. Although more than eighty five percent of all samples were below 15 mg/m^3 and eighty percent below 10 mg/m^3, seventeen or 40% of the elevators had one or more personal samples exceeding 15 mg/m^3 and twenty-two or 51% of the elevators had one or more personal samples exceeding the OSHA permissible exposure limit for wheat, oats, and barley dust of 10 mg/m^3. Thirty-one elevators or 72% had one or more personal samples exceeding the TLV for wheat, oats, and barley dust of 4 mg/m^3.

3.14 High Dust Levels

Eighteen personal samples taken during the study showed dust levels greater than 25 mg/m^3. These were examined to see if there was any pattern (Table 3-18). High dust levels were not limited to one segment of the industry. However, a few elevators had a higher percentage of such samples than others. Several job categories were represented although general grain handlers predominate. Certain activities such cleaning out bins and repairing dust collectors, occur sporadically whereas others, such as receiving at rail and truck dumps, are routine. These data do not reflect whether dust masks or other respirators were being used to control actual exposure during these work activities.

3.15 Endotoxin Levels

Levels of endotoxin found on samples taken during the study are summarized on Table 3-19. There was no consistent relationship between endotoxin level and industry segment or type of grain handled. Area samples appeared to have lower endotoxin levels than personal samples. This may be due to the fact that many area samples were taken in offices where dust levels were lower. There was a positive correlation between endotoxin and total dust levels (Correlation coefficient 0.41, Prob = <0.0001) and higher endotoxin levels were associated with higher dust levels.

3.16 Handheld Aerosol Monitor Readings

The Handheld Aerosol Monitor or HAM provides a direct reading of dust level in milligrams of dust per cubic meter of air (mg/m^3). In several elevators it was used to make half-hourly or hourly readings at locations where stationary area samples were being collected. The objective was to see if the HAM readings correlated with average dust levels as determined by filter cassettes. In general, no correlation could be found. For example, at Elevator 31 hourly HAM readings at a truck dump were 0.05, 0.09, 0.10, 0.05, 0.16, and 0.10 mg/m^3 compared to an area sample result of 2.22 mg/m^3 at the sample location. Similar results were obtained at other locations at Elevator 31 and at other elevators.

Instruments such as the HAM provide instantaneous readings and are useful in examining the effects of engineering control changes or different work practices. However, they may not be useful in obtaining exposure measurements for compliance purposes.

3.17 Respirator Usage

Respirator usage in elevators was assessed by asking each employee tested if they typically used a respirator and, if so, what type and how many hours per day; by asking the elevator manager if respirators are typically worn at the facility and if there is a written program; and by observing actual respirator usage on the day of the visit. Of the employees tested, 287 or 67.2% indicated that they typically wear a respirator. The most popular types were disposable dust masks (e.g., 3M 8710, Moldex 2200). Employees claimed to wear the respirators up to eight hours per shift with an average of 2-3 hours for those responding positively. The majority (53%), however, stated that they used their respirator one hour or less per day. This was collaborated by management responses and observations. Most elevator managers indicated that their employees typically wore respirators only while doing dusty jobs.

SECTION 4

RESULTS - MEDICAL EVALUATIONS

4.1 General Observations

Employees from 43 elevators throughout the United States participated. Altogether 427 employees participated of 549 total employees in the elevators, for a participation rate of 78%. Of the number participating, 51 (11.9%) were females and 376 (88.1%) were males, 77 (18%) were black and 350 (82%) were white. The mean age was 39.8 years; minimum age was 16 years and maximum age was 72 years. The employees were distributed among elevator types as follows: Country - 106, Terminal -106, Export - 215,

Table 4-1 lists the answers to various medical history questions. It includes the number and percent with a positive history of the listed condition.

The prevalence of cough three months per year, chronic bronchitis, as identified by production of sputum three months per year for two years, cough or chronic bronchitis, chest tightness, and dyspnea by grade is tabulated in Table 4-2.

By smoking habit the participating employees included 155 non-smoking employees (36.4%), 103 ex-smokers (24.2%), and 168 current smokers of cigarettes, cigars, or pipes (39.4%). For cigarettes the frequency distribution of pack years by number of employees is summarized in Table 4-3.

Table 4-4 provides the mean of the pulmonary function measurements of those upon whom a valid measurement for that particular test was obtained. To be included, the test had to have the two best FEV1 tracings within 10 percent. If either the before or after test did not meet this criteria, the pair was not included. Altogether 407 pairs of tests were used. A separate analysis, not shown in the tables, revealed little difference when all tests were used.

Table 4-5 lists pulmonary function measurements, based upon FEV1 before shift by category of impairment, with normal being $\geq$80% of predicted, mild impairment being 70 - 80%, moderate impairment 60 - 70%, and severe impairment <60% of predicted. All together 87.7% of the employees tested were in the normal category. While 12.3% had some degree of impairment, only 5 (1.2%) had an FEV1 of <60% of predicted.

The prevalence of cough, morning or day, three months out of the year, chronic bronchitis as previously defined, cough or bronchitis, tightness in the chest and dyspnea grade were evaluated by elevator type (Table 4-6). Employees at export elevators tended to have a lower prevalence of cough and bronchitis than those at country and terminal elevators, but the differences were not statistically significant. Terminal elevator employees had a higher prevalence of some grade of dyspnea, but again the differences were not statistically significant.

4.2 Symptoms and Exposure Categories

The median dust level for each job was established (Section 3.4). For each employee, this was multiplied by the number of years spent in each job and the products were added together to establish an exposure index for each individual employee.

Exposure Index = (years job 1 x med dust level job 1) + (years job 2 x med dust level job 2) .... (years job 11 x med dust level job 11)

The mean exposure index was 19.94 with the range of 0 to 248.64. The exposure indices were then categorized into groups as indicated on Table 4-7. Prevalence of cough, chronic bronchitis, cough or chronic bronchitis, tightness in the chest and dyspnea were then tabulated by exposure index category. It is seen that in the highest exposure index category (e.g. >75) the prevalence of cough, chronic bronchitis, cough or chronic bronchitis is increased. However, the differences were not statistically significant. For chest tightness there is an increased prevalence in the higher exposure index categories and the differences are significant (Prob=0.0268). The percentage of employees reporting dyspnea increased in the higher exposure index categories and these differences were highly significant (Prob=0.0002). Although the exposure index is reflective of years of exposure a separate analysis was done for the latter (Table 4-8). Chronic bronchitis was related to years exposed to a statistically significant extent. Also, tightness in the chest and dyspnea prevalence increased in the higher years exposure category to a statistically significant extent. Interestingly, the lowest years exposed category (0-5) also had a relatively high prevalence of tightness in the chest.

4.3 Symptoms in Relation to Current Dust Exposure Level

Altogether dust level measurements could be assigned to 252 employees. These dust level measurements were divided into four categories: 0 - 4, >4-10, >10-15, and 15 mg/m^3. Prevalence of cough, chronic bronchitis, cough or chronic bronchitis, tightness, and dyspnea, as a function of current dust exposure are shown on Table 4-9. There is a trend to higher prevalence of cough and cough or chronic bronchitis with dust levels over 10 mg/m^3 but these were not quite statistically significant. Interestingly, the exposure category between 4-10 mg/m^3 had a lower prevalence of all symptom categories; however the numbers in this group are low. For tightness of the chest and dyspnea there appears to be no relationship with current dust exposure level range.

4.4 Symptoms - Smoking Category and Exposure Category

The relationships of cough, chronic bronchitis, cough or chronic bronchitis, chest tightness, and dyspnea to smoking status were highly significant statistically. For example, 27% of current smokers had a cough versus 3.9% of non-smokers and ex-smokers (Table 4-10).

To evaluate the role of smoking versus grain dust exposure, the relationships between prevalence of symptoms and exposure index for non-smokers, smokers and ex-smokers were analyzed separately. For non-smokers (Table 4-11), there appeared to be no relationship of cough, chronic bronchitis, cough or chronic bronchitis with exposure index category, although the numbers in the higher exposure index categories were small. However, chest tightness was more prevalent in the higher exposure categories and this was statistically significant (Prob=0.0282). Dyspnea grade did not appear to be related to exposure category index.

For smokers (Table 4-12), there were higher prevalences of cough, chronic bronchitis, cough or chronic bronchitis, and chest tightness with higher exposure indices, but the differences were not statistically significant. For dyspnea there was a highly significant relationship amongst smokers with exposure index category. For ex-smokers (Table 4-13), there were no statistically significant relationships of symptoms with any of the exposure index categories.

Tables 4-14, 4-15, and 4-16 present prevalence of cough, chronic bronchitis, cough or chronic bronchitis, chest tightness and dyspnea by smoking category and dust level range. For non-smokers, there appeared to be no relationship of any of these symptoms with dust level range (Table 4-14). However, for current smokers (Table 4-15) prevalence of cough or chronic bronchitis was higher in the higher dust level categories, but this was not quite statistically significant (Prob=0.0630). Employees exposed to dust levels of >4-10 mg/m^3 had a relatively low prevalence of symptoms, but the numbers were few. For chest tightness and dyspnea, there appeared to be little relationship to current dust exposure. In ex-smokers there was no statistically significant relationship of any of the symptoms with dust level range, however, there was a higher prevalence of mild dyspnea amongst the ex-smokers in the high dust level category (Table 4-16).

Table 4-17 examines symptoms in non-smokers by years of exposure. For cough, chronic bronchitis, cough or chronic bronchitis there appeared to be no trend to increased prevalence of symptoms in the higher years exposed category. However, those in the higher years exposed categories had a higher prevalence of chest tightness and this was of marginal statistical significance (Prob=0.057). There appears to be no relationship of dyspnea to years of exposure in non-smokers.

For smokers (Table 4-18) there appeared to be no relationship between years of exposure and cough, chronic bronchitis, cough or chronic bronchitis, or chest tightness. However, over 50% of employees in the higher exposure year categories complain of dyspnea. This approached statistical significance (Prob=0.0798).

For ex-smokers (Table 4-19) findings were similar to non-smokers. Chest tightness was related to years of exposure category and there was an increased prevalence of dyspnea in the higher years exposure category; this approached statistical significance (Prob=0.0956).

4.5 Relationship of Symptoms to Type of Grain

Cough, chronic bronchitis, cough or bronchitis, chest tightness, and dyspnea were examined in relationship to the type of grain being processed on the day of the study. The results are listed in Table 4-20. The designation "corn" includes corn, soybeans, and milo. The designation "wheat" includes wheat, oats, barley and milo. The type of grain listed is only that type processed at the time of the testing and it does not indicate the predominant type of grain from year to year. Table 4-20 demonstrates that there was no apparent relationship of symptoms to type of grain. This may be a very limited conclusion since it has been determined that there is little, if any, short term acute effects of exposure (Section 4.6) and the fact that grain being handled was only surveyed for the day of the test.

4.6 Pulmonary Function Test Results Related to Exposure

Table 4-21 shows the category of pulmonary function impairment by exposure index category. Normal test results are those with $\geq$ 80% of predicted of FEV1 before the shift; mild impairment is 70 to < 80%; moderate is 60 to <70%; and severe is <60%. It is seen that the category of impairment is highly related to exposure index category. However, Table 4-22 shows that it is also highly related to pack year category. To differentiate the effect of smoking, non-smokers, smokers, and ex-smokers were examined independently on Tables 4-23, 4-24, and 4-25 respectively. It is seen that for non-smokers the relationship between impairment and exposure index category loses statistical significance, whereas it continues to be highly significant for smokers and ex-smokers. Table 4-26 categorizes exposure index category versus packs year category. It shows that they are highly related with Prob = 0.0002. Therefore, it appears that much of the relationship of FEV1B category of impairment with exposure index is secondary to pack years of smoking. Tables 4-23 and 4-24 indicate that ninety-six percent (96%) of non-smokers have normal lung function, but only eighty-two percent (82%) of current smokers do.

Table 4-27 shows that the relationship between category of impairment for FEV1B to all employees loses statistical significance when the exposure index is <75.

Regression analyses were done to compare FEV1B predicted and FEF2575B predicted with exposure index. Tables 4-28 and 4-29 show that for all employees there was a non-significant inverse relationship between exposure index and FEV1B predicted, and a significant inverse relationship with FEF2575B predicted (Prob=0.0099). When examined individually, for non-smokers, smokers, and ex-smokers the relationship of FEF2575B loses statistical significance.

Tables 4-30 and 4-31 present multiple linear regressions with FEV1B predicted, FEF2575B predicted as the dependent variable compared with exposure index, years exposed, and pack years. It is seen that there is very high correlation with pack years and in comparison, exposure index and years exposed are not statistically significant.

Table 4-32 presents individual regression analyses of the FEV1/FVC ratio before shift versus exposure index in all employees, non-smokers, current smokers, and ex-smokers. It is seen that for non-smokers this verges on statistical significance, but is highly significant for all employees together, and current and ex-smokers.

The ratio of FEV1/FVC before shift is analyzed as a dependent variable by multiple linear regression comparing it with exposure index, years exposed, age, and pack years (Table 4-33). It is seen that exposure index is a significant factor along with age and pack years.

Multiple regression analysis of FEV1/FVC ratio versus exposure index, years exposed, and age was also done for non-smokers. Table 4-34 shows that these are not statistically significant in non-smokers.

Table 4-35 again shows exposure index not to be independently related to FEV1/FVC ratio in smokers. However, Table 3-36 reveals exposure index to be a statistically significant relationship in ex-smokers (Prob=0.0212).

Table 4-37 compares the change in FEV1 during the shift with a number of parameters, including dust level, pack years, age, exposure index, and years exposed. Only age is related to a statistically significant extent.

Shift changes of FEV1 and FEF2575 were categorized by those with an FEV1 decrease less than 10%, and equal to or exceeding 10%, and for FEF2575 decreases of less than 10%, 10 to < 20%, and 20% or greater. The results, shown on Table 4-38 reveal no evidence that these pulmonary function parameters decrease more with higher dust level ranges. However, mean percent of FEV1 change during shift was - 0.96% for non-smokers and 0.96% and 0.32% for current smokers and ex-smokers respectively. This difference between those who never smoked and current smokers was statistically significant (Prob=0.0251 for 1 tail and 0.0514 for 2 tails).

Various pulmonary function tests were compared by regression analysis with current dust level (Table 4-39). Any employee who had a dust level measurement assigned and for whom the pulmonary function test had been done is included. It is seen that there are no significant correlations with any of the pulmonary function tests and current dust level.

Multiple linear regression was done for FEF2575, change in FEV1, and FEV2575 with endotoxin, actinomycetes, total bacteria, total fungi, gram positive bacteria, and gram negative bacteria. No statistically significant correlations were noted.

4.7 Comparison of Pulmonary Function Test Results by Job and Smoking Status

Table 4-40 presents selected pulmonary function data by job and smoking status. It shows the FEV1 percent predicted before shift, FEF2575 percent predicted before shift and the ratio of FEV1/FVC percent by job category. It is readily apparent that there are considerable differences in some of the test results between job categories. These differences were evaluated by analysis of variance, and approached statistical significance (Prob=0.0841) for the FEV1/FVC ratio when both smokers (includes ex-smokers) and non-smokers were considered together. However, when non-smokers and smokers are considered separately, these pulmonary function results do not differ by job category to a statistically significant extent.

Because it was impractical to obtain a control group of people not working in grain elevators, clerical workers are compared with all other job categories. This comparison is not ideal since 72% of the clerical workers were females, while only 2.4% of the other workers were females. However, clerical workers were the least likely to have had any significant grain dust exposure and utilization of predicted values for FEV1 and FEF2575 should overcome some of these concerns. Table 4-41 lists the comparison of the pulmonary function results of clerical workers compared to other workers and also by smoking status. It is seen that the clerical workers generally had higher values for these pulmonary function studies than other workers. However, only for ratio of FEV1/FVC for smokers and non-smokers combined is there a statistically significant difference between clerical and other workers.

Of some concern was the relatively low average percent predicted FEF2575 of 81.61% predicted (figure not shown in Table 4-41). FEF2575, however, is known to vary widely by individuals and with time. Although clerical workers had a somewhat higher average FEF2575 of 86.35% as compared with other workers who had 80.83%, the differences are not statistically significant. For clerical workers, they are still below predicted average value of 100% and even for non-smoking clerical workers the FEF2575 predicted is 90.75%, still considerably below that which would be expected. For smoking clerical workers there was virtually no difference of FEF2575 in comparison to other smoking workers.

4.8 Discussion of Health Screening Results

Overall participation was good, especially in the country and terminal elevators. Export elevators which were much larger had a lower participation rate. This was primarily due to lack of participation of a number of the clerical personnel who would normally be less exposed to dust. Therefore, if the lower participation rate of the export elevators were to bias the results, then one might anticipate that such bias would be toward having more abnormalities. In fact, export elevators had fewer abnormalities than others (Section 4.1), due to factors which are not totally understood. Therefore, if the participation rate had been higher, overall results might have shown less abnormalities.

Due to the large number of elevators surveyed and the scattered geographical locations, it was not considered feasible in this project to have control groups. However, we believe that this lack of controls is offset somewhat by the extensive dust sampling which enabled us to assign an exposure index to each individual, based both upon years of exposure in a particular job and median dust level for that job. Various symptoms and pulmonary function results could then be related to the exposure index.

An exposure index can be a valuable tool in developing dose response relationships and in the case of this study does appear to present a valid dose response relation for some parameters. However, exposure index is only based upon current studies and should be viewed with caution. In the case of country elevators where individuals work only part of the year, they may be overestimated.

It was somewhat surprising that current dust level appeared to have no relationship to pulmonary function decline during the shift; nor did levels of endotoxin, bacteria or fungi. Other studies, including those of cotton textile workers and other grain workers, have shown declines of pulmonary function during the shift. In fact, for the population included in the present study, there was generally little evidence of any shift decline since FEV1 and FEF2575 before and after, and delta FEV1 and FEF2575 indicate little overall change. Non-smokers, however, had a small mean shift decline in percent change of FEV1 which was not present in smokers. Interestingly, current smokers alone showed a small decline in FEV1 predicted during the shift.

The most prominent factor affecting the prevalence of symptoms and abnormal pulmonary function findings was pack years of cigarettes smoked. Next was exposure index and, to a lesser extent, years exposed. However, exposure index was also strongly related to pack years. Therefore, to separate the effect of smoking from exposure, separate analyses were done for non-smokers, smokers, and ex-smokers. When these analyses were done non-smokers continued to have tightness in the chest which was related to exposure index. Interestingly though, cough and chronic bronchitis were highly related to exposure index in smokers, but chest tightness was not to a statistically significant extent. Ex-smokers also had significant relationship of chest tightness to exposure index. The prevalence of symptoms in all employees together increased markedly with the higher exposure index categories, but did not generally increase much until exposure index categories reached 50 or greater. Those who smoke and have high current dust exposure levels (> 10 mg/m^3) have a greater prevalence of cough, chronic bronchitis, or the combination thereof, but this is only of marginal statistical significance.

Regression analysis revealed no significant relationship of FEV1B predicted with exposure index. However, FEF2575, and FEV1/FVC ratio were significantly related statistically to exposure index. The relationship for FEF2575 became much less prominent when smoking was considered. However, the relationship of FEV1/FVC ratio to exposure index continued to be marginally significant for non-smokers, and highly significant for smokers and ex-smokers. For smokers and ex-smokers, when considered alone, multiple regression analysis revealed the relationship of the FEV1/FVC ratio to exposure index, years exposed, and age to be non-statistically significant. For ex-smokers the FEV1/FVC ratio remained independently inversely related to exposure index, and to age. There is no relationship of any of the pulmonary function tests with current dust level, nor with levels of bacteria, fungi, actinomycetes, or endotoxin.

Grain dust exposure may result in chest symptoms, especially tightness and small decreases in FEV1 during the shift in non-smokers. There also appear to be relatively minor pulmonary function decreases, including the FEV1 predicted, FEF2575 predicted and FEV1/FVC ratio, with long-term exposure. Except in the case of the FEV1/FVC ratio, when other factors including smoking and age are considered, they are not independently related to exposure index to a statistically significant extent. There appears to be little evidence of much influence of grain dust on respiratory health until the higher exposure indices are reached, and these may be due to higher exposures in the past.

Although this study lacked a control, comparison with community[1, 2] and industrial data[3] reveal that the rates of chronic bronchitis and abnormal pulmonary function are not higher than usually encountered in other populations. For example, in a non-industrial Colorado town[1], 17% had chronic bronchitis in comparison to 7.3% in this study, while, 13% had chronic airway obstruction (FEV1/FVC ratio < 60%) in comparison to 1.4% in this study. Some of this discrepancy may be due to healthy worker effect.

Comparison of this study to other studies is difficult. To our knowledge this is the only study that selected at random from a large universe of grain elevators. Other studies have tended to concentrate on single elevators where selection of a control is much more feasible. On the other hand such selection may tend to bias the results. We may arbitrarily select those in this study with exposure index of 0-10 as being close to a control. However, the problem with this is that they tend to be younger or different occupational groups, e.g., clerical. When a suitable control is lacking, development of dose-response relationships as done in this study is an appropriate and valid means of determining effect of the exposure.

Although this was a cross sectional study, we attempted to do retrospective analysis by developing the exposure index. This is also the only large scale study to our knowledge that related dust exposure to pulmonary function studies.

In contrast to other cross sectional studies[4-8] we did not find an excess prevalence of cough, chronic bronchitis, or dyspnea in non-smokers who have higher dust exposure indices. However, it should be noted that other than DoPico[7] who used a self-administered questionnaire, the excess of symptoms of cough, sputum, and bronchitis reported by others, were generally not statistically significant. In the present study the symptom of chest tightness, which was not reported in the other studies, was *significantly increased in the higher exposure index category in non-smokers.* With smokers, the prevalence of cough showed some increase in the higher exposure categories, but this was not statistically significant. Nor was chronic bronchitis or chest tightness, which both increased in the higher exposure categories, different at statistically significant levels. Overall prevalence of dyspnea increased at higher exposure index levels to a statistically significant degree, but not for non-smokers or ex-smokers. Herbert[8] showed a marked excess of dyspnea in grain workers versus controls which would be consistent with this study in comparing higher exposure indices versus the lower or less exposed group. Other studies of smoking grain workers[4-8] have shown excesses of cough and bronchitis. With the exception of Becklake[9], only self-administered questionnaire studies showed these excesses to be statistically significant. Ex-smokers, similar to non-smokers, did not show an increased prevalence of symptoms with higher exposure indices with the exception of chest tightness. However, the increase in chest tightness with higher exposure indices in ex-smokers was not statistically significant.

With respect to pulmonary function this study showed no statistically significant increase in pulmonary impairment in non-smokers in the higher exposure index categories. Likewise, in non-smokers there was no negative correlation of FEV1 percent predicted with exposure index. Other studies[4-8] have shown slight, but usually non-statistically significant deficits of FEV1 in non-smoking grain workers. Our study also showed an increase of pulmonary impairment in smokers and ex-smokers related to exposure index, which was statistically significant. This may have been related to primarily pack year category. Regression analysis does not indicate that grain dust exposure index is an independent variable with respect to FEV1.

This study did show a decrease of FEF2575 with increasing exposure index. In independent regression analyses of non-smokers, current smokers, and ex-smokers, this was not statistically significant, but the combined group did provide enough workers to show that a statistically significant decrease. A decrease in FEF2575, of course, would relate well with the symptoms of chest tightness, which appears to increase with increasing exposure index. This study also revealed that FEV1/FVC ratio was inversely related to exposure index. Separate regression analysis revealed FEV1/FVC ratio changes to be marginally significant in non-smokers and highly significant in current and ex-smokers.

In summary, other major studies have shown some increase, although not necessarily a statistically significant increase in symptom prevalence in grain workers versus controls, and very mild pulmonary function deficits. The major finding of this study was an increase in the symptom prevalence of chest tightness, and some evidence of decline in FEF2575 and FEV1/FVC ratio with increasing exposure index largely, but not entirely correlated to smoking. It is difficult to determine from this study whether there is an interaction between grain dust exposure and smoking.

With respect to overall respiratory health of this group of workers as compared with the general population, one must consider that this study as with all cross sectional prevalence studies represents a survey of existing employees. It does not include retired or ex-employees who may have left because of respiratory symptoms. It is of interest to compare the present study population with other unexposed populations. Mueller, et al[1] found an overall rate of approximately 13.6 % chronic bronchitis versus 7.7% in the present grain elevator population. They found an overall rate of 1.5% asthmatics versus 4.4% in this study group. Farris and Anderson[10] did a study in Berlin, New Hampshire, a paper mill town, and found a 0.44% prevalence of bronchial asthma and 15% chronic bronchitis. Overall pulmonary function of the employees in the present study was within normal limits (102% predicted for non-smokers and 96% for smokers). In comparison with Discher and Feinberg's work[3] we found similar results for borderline and abnormal pulmonary function tests.

With respect to endotoxin, it was somewhat surprising that there appeared to be no dose response relationship of either acute or chronic effects. Some studies[11-14] have indicated that there may be a relationship between endotoxin and occupational lung disease. This is especially so with respect to acute effects as noted in cotton mills. The endotoxin levels were in the range that has been reported as producing a response in other studies. An explanation of why there was no acute decline in FEV1 in relationship to endotoxin levels is not readily apparent.

This is the only study to our knowledge that has developed exposure indices for large numbers of employees based upon actual environmental sampling and job history at the time of the testing. Though this study was approached somewhat differently than a number of the other studies in the literature, the results as interpreted above seem relatively consistent with these studies which have also shown generally variable and mild effects. An encouraging fact is that any adverse effects appear to be relatively minor and may have occurred largely in the past. Modern dust control measures combined with respiratory protection, efforts to control smoking, and prompt attention to respiratory symptoms should substantially reduce risks to grain workers.

SECTION 5

SUMMARY AND CONCLUSIONS

A study consisting of environmental measurements and employee medical screening was conducted in 43 grain elevators throughout the United States. Dust level measurements were made on the day of medical screening. In addition, at 12 elevators detailed exposure studies were done which included taking consecutive day samples to determine interday variability of dust levels. Endotoxin, bacteria, and fungal measurements were also made. A total of 455 dust level measurements were made, of which 63% were personal samples and 25% were area samples. Median dust levels in country, terminal and export elevators were approximately the same. Jobs were divided into 11 categories and median dust levels for job category ranged from 0.18 mg/m^3 for control room operators to 8.88 mg/m^3 for basement floor operators. Thirty percent of grain handler - general employees had uncontrolled exposures above 10 mg/m^3. Elevators were divided into two basic groups depending upon type of grain handled. The first group - 23 elevators - handled corn only, soybeans only, corn and soybeans, or both along with milo. The second group - 14 elevators - handled wheat only or wheat in a combination of oats, barley, or milo. Five elevators handled both types of grain during the visit and one handled no grain. Dust levels for elevators handling corn/soybeans appear to be slightly higher than for those handling wheat, although the number of tests and amount of the difference makes it impossible to draw any conclusions.

Control measures ranged from none (no cyclone or fabric filter) to extensive. The effectiveness of engineering controls in reducing dust levels could be seen only after breakdown by industry segment. In country elevators with limited engineering controls, dust levels were lower. Terminal and export elevators with measured exposures comparable to those in country elevators typically had more extensive engineering controls.

Where engineering controls were not present or limited, oil additive usage appeared to reduce median and estimated mean dust levels, but not where engineering controls were present. An average of 20-25% of the dust was found to be respirable (< 10 micrometers). Handling wheat and related products tended to produce more respirable dust.

There was significant day-to-day variability in dust levels to which individual employees were exposed. The type of grain handled and the presence of any engineering controls were probably more important than geographic region in determining dust exposure level.

Although over 80% of all dust samples were below 10 mg/m^3, twenty-two, or 51%, of the elevators had one or more personal samples exceeding the OSHA permissible exposure limit of 10 mg/m^3. Thirty-one, or 72%, had one or more personal samples exceeding the TLV of 4 mg/m^3. Eighteen personal samples (4%) showed dust levels of 25 mg/m^3 or more.

Endotoxin levels and bacteria measurements were taken. There was no consistent relationship between endotoxin level and industry segment or type of grain handled. Higher endotoxin levels were associated with higher dust levels.

Medical evaluations consisted of a modified respiratory questionnaire, job and health history, examination of the chest, examination of the upper respiratory system, and pulmonary function testing. Altogether 427 employees participated out of 549 eligible. An exposure index was developed by multiplying the median dust level for a job category by the number of years on that job for each job in which the employee worked. There was a high correlation of prevalence of symptoms of cough, chronic bronchitis, cough or chronic bronchitis, chest tightness, and dyspnea with smoking.

There was also a correlation of a number of these symptoms with exposure index. However, exposure index in smokers was also related to pack years. In a separate analysis done by smoking category, non-smokers and ex-smokers continued to have a statistically significant relationship of tightness in the chest to exposure index. Prevalence of cough and bronchitis symptoms in smokers appeared to be primarily related to pack years of smoking.

Pulmonary function studies were utilized from 407 employees. Multiple regression analysis revealed a significant independent relationship of FEV1/FVC ratio to exposure index for all employees and for smokers and ex-smokers. This relationship was not statistically significant for non-smokers.

Category of pulmonary function impairment was related to exposure index, but this relationship disappeared in non-smokers and appeared to be related primarily to pack years of smoking in smokers. Interestingly, there appeared to be no relationship of pulmonary function studies or decline in pulmonary function during shift with current dust level, endotoxin level, or levels of bacteria and fungi.

The prevalence of respiratory problems compares favorably with other community and industrial studies. It appears that grain workers, independent of smoking, that have probably been exposed to significant dust levels for long periods of time develop symptoms of tightness in the chest, and mild decline in FEV1/FVC ratio.

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TABLE 2-1. Grain elevators and employees included in study by industry segment

	Number of elevators	CAPACITY, THOUSAND BUSHELS		NUMBER OF EMPLOYEES		
		Range	Average	Total	Range	Average
Country elevators	23	185- 2950	860	106	2-10	4.6
Terminal elevators	15	106-10344	1865	106	4-16	7.1
Export elevators	5	1600- 7000	5375	215	18-76	43.0
TOTALS	43			427		

TABLE 2-2. Grain elevators studied by geographic region

Region[1]	Estimated % of total elevators in U.S[2]	Expected number (n=43)[3]	Number included in study
Central grain belt	70.6	30	33
Southwest	3.4	2	3
Northwest	7.2	3	1
Southeast	13.7	6	5
Northeast	5.0	2	1

NOTES:

[1] Regional division by states was as follows:
Central grain belt - IL, IA, TX, KS, MN, IN, NE, OH, MO, WI, ND OK, MI, SD, AR, LA
Southwest - CA, CO, UT, AZ, NM, NV
Northwest - WA, MT, OR, ID, WY
Southeast - NC, GA, VA, KY, MS, SC, AL, TN, FL
Northeast - PA, NY, MD, DE, NJ, WV, CT, ME, MA, NH, RI, VT

[2] Based on USDA Grain Stocks Report, January, 1983

[3] Based on equal opportunity selection by region of 43 grain elevators from OSHA estimated total of 13,975 in U.S.

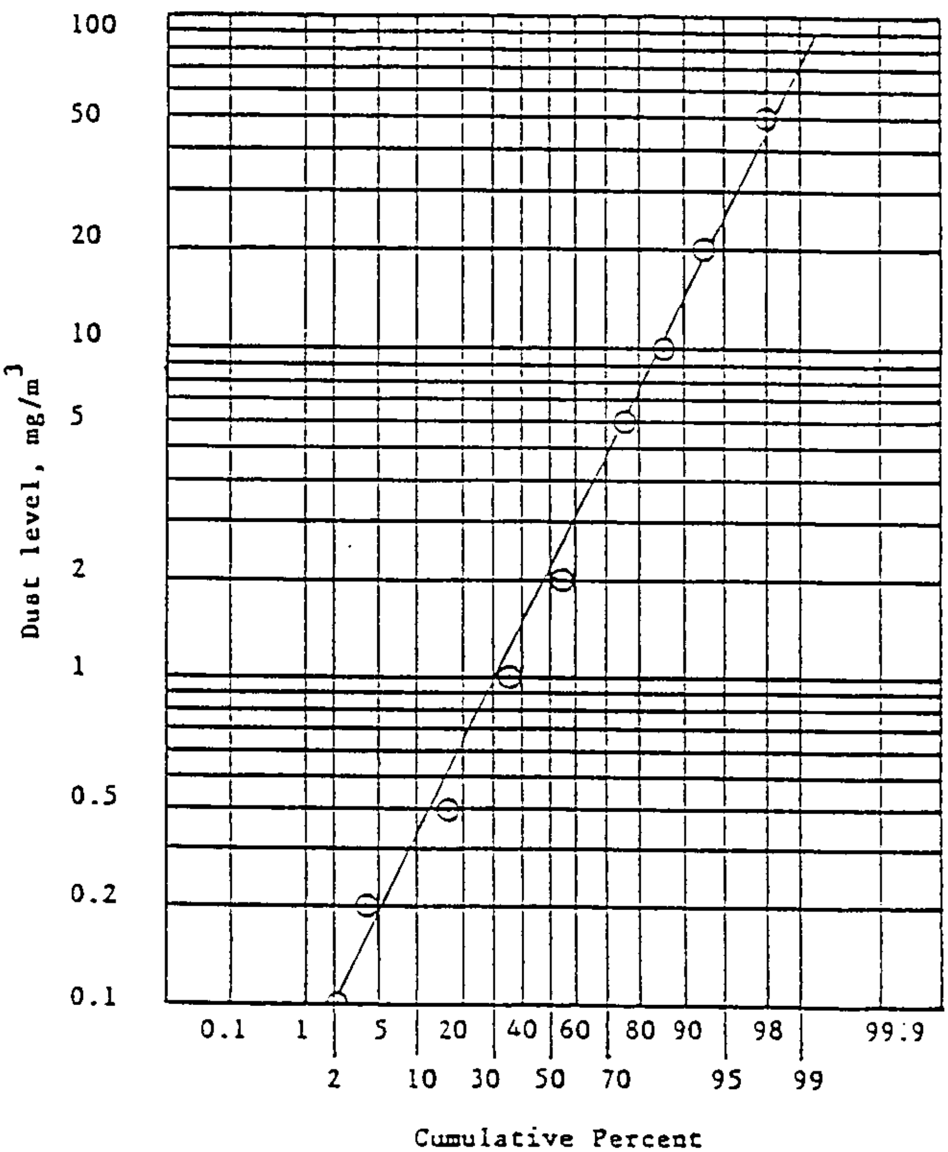

Figure 3-1. Frequency distribution of dust level measurements for personal samples

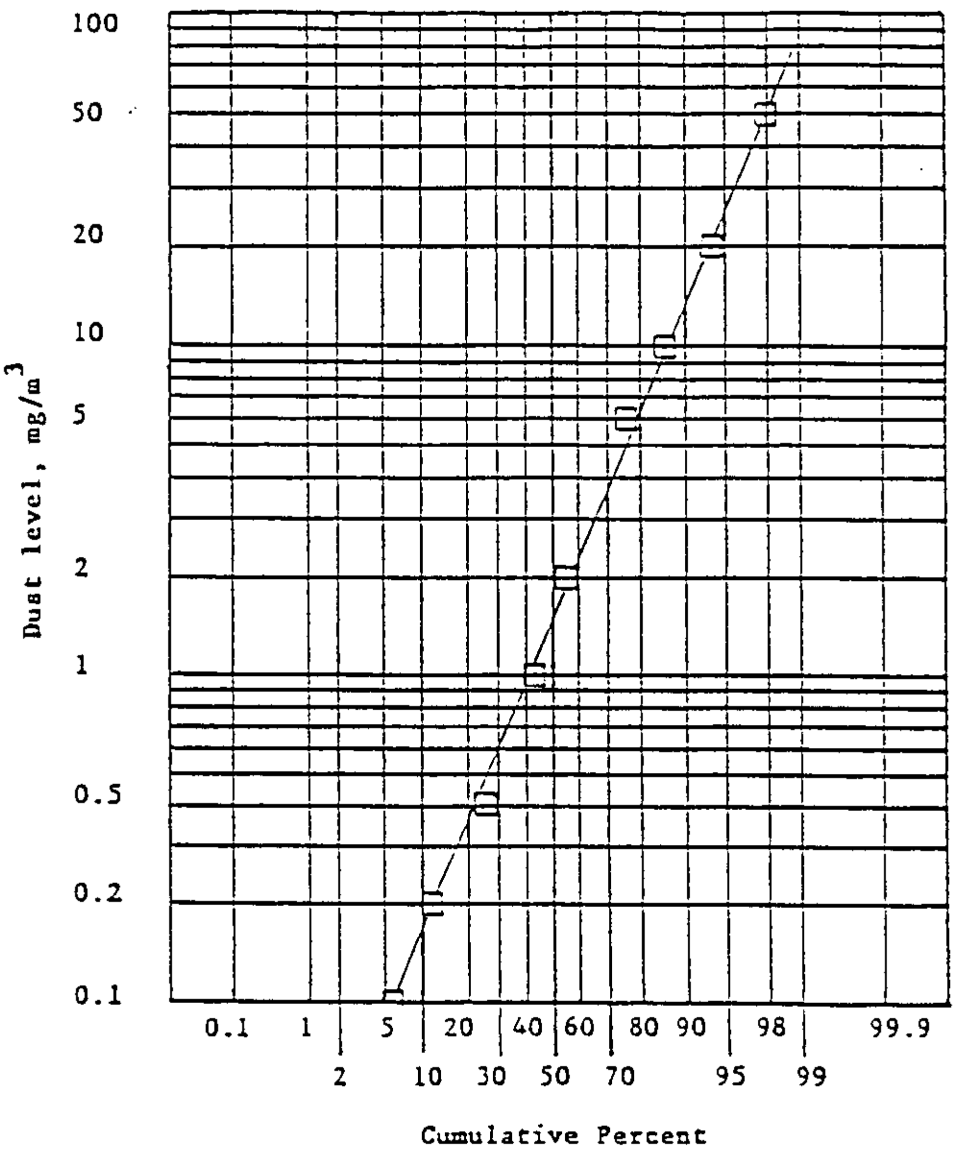

Figure 3-2. Frequency distribution of dust level measurements for personal and area samples

TABLE 3-1. Distribution of dust level measurements by sample type and industry segment

SAMPLE TYPE	INDUSTRY SEGMENT			TOTAL
	Country elevators	Terminal elevators	Export elevators	
Personal	84	110	92	286
Area	50	44	18	112
Impactor	25	22	10	57
TOTAL	159	176	120	455

TABLE 3-2. Distribution of dust level measurements by job category

JOB	NUMBER OF SAMPLES		
	Personal	Area	Impactor
Elevator Manager	28	1	1
Supervisor/Foreman	19	-	4
Clerical/QA/Laboratory	17	41	-
Grain Handler - General	108	47	35
Receiving/Inspection	47	15	6
Shipping	14	1	3
Bin Operator	15	1	5
Basement Floor Operator	4	3	1
Maintenance/Electrical	29	-	2
Cleaning/Drying	1	-	-
Control Room Operator	4	3	-
	286	112	57

TABLE 3-3 . Summary of dust level measurements by type of sample

	Number of samples[1]	Dust level, mg/m^3		Cumulative % greater than			Estimated distribution parameters, mg/m^3	
		Range	Median	4 mg/m^3	10 mg/m^3	15 mg/m^3	Mean	Std. dev.
Personal Samples	286	0.06 - 338.26	1.68	30.4	16.1	10.8	6.63	20.91
Area Samples	112	0.02 - 79.70	0.70	25.9	14.3	12.5	6.19	41.62
Personal and Area Samples	398	0.02 - 338.26	1.47	29.1	15.6	11.3	6.90	28.84
All Samples	455	0.02 - 338.26	1.83	32.7	18.5	13.2	8.11	34.06

TABLE 3-4. Dust levels by industry segment

	Number of elevators	Number of samples	Dust level, mg/m^3		Cumulative % greater than			Estimated distribution parameters, mg/m^3	
			Range	Median	4 mg/m^3	10 mg/m^3	15 mg/m^3	Mean	Std. dev.
Personal samples									
Country elevators	23	84	0.10 - 119.72	1.56	33.3	23.8	14.3	8.17	27.60
Terminal elevators	15	110	0.08 - 100.27	1.88	28.2	12.7	9.1	4.97	11.52
Export elevators	5	92	0.06 - 338.26	1.61	30.4	13.0	9.8	7.83	33.23
ALL	43	286	0.06 - 338.26	1.68	30.4	16.1	10.8	6.63	20.91
Personal & area samples									
Country elevators	23	134	0.02 - 119.72	1.37	29.9	20.9	14.9	8.72	45.11
Terminal elevators	15	154	0.05 - 100.27	1.32	25.3	11.7	8.4	4.79	15.21
Export elevators	5	110	0.05 - 338.26	1.99	33.6	14.5	10.9	8.75	41.50
ALL	43	398	0.02 - 338.26	1.47	29.1	15.6	11.3	6.90	28.84

TABLE 3-5. Dust levels by job category - all elevators

	Number of samples[1]	Dust level, mg/m^3 Range		Cumulative % greater than 4 mg/m^3	10 mg/m^3	15 mg/m^3	Estimated distribution parameters, mg/m^3 Mean	Std. dev.
		Range	Median	4 mg/m^3	10 mg/m^3	15 mg/m^3	Mean	Std. dev.
Elevator Manager	28	0.09 - 6.32	0.53	3.6	0	0	0.91	1.11
Supervisor/Foreman	19	0.21 - 34.47	1.57	31.6	10.5	5.3	5.74	18.16
Clerical/QA/Lab	58[2]	0.02 - 9.63	0.28	1.8	0	0	0.73	1.46
Grain Handler - General	108	0.31 - 338.26	3.66	47.2	30.6	20.4	11.68	28.67
Receiving/Inspection	47	0.06 - 256.37	0.92	21.3	6.4	4.3	4.24	14.10
Shipping	14	0.10 - 17.06	1.78	21.4	7.1	7.1	4.11	7.80
Bin Operator	15	0.29 - 28.08	2.02	20.0	13.3	6.7	4.12	6.51
Basement Floor Operator	4	2.00 - 21.74	8.88	75.0	50.0	25.0	12.73	18.95
Maintenance/Electrical	29	0.17 - 95.79	0.99	27.6	10.3	6.9	4.66	13.88
Cleaning/Drying	1	6.28	-	100.0	0	0	-	-
Control Room Operator	7[2]	0.05 - 1.30	0.18	0	0	0	0.31	0.46

NOTES:

1 Personal samples except as noted.
2 Personal and area samples.

TABLE 3-6. Dust level by job category and industry segment

	Number of samples[1]	Dust level, mg/m^3		Cumulative % greater than			Estimated distribution parameters, mg/m^3	
		Range	Median	4 mg/m^3	10 mg/m^3	15 mg/m^3	Mean	Std. dev.
Country elevators								
Elevator Manager	16	0.15- 3.20	0.64	0	0	0	0.95	1.01
Supervisor/Foreman	8	0.23- 14.59	1.06	25.0	12.5	0	4.27	15.06
Clerical/QA/Lab[2]	29	0.02- 9.63	0.29	3.4	0	0	0.82	1.76
Grain Handler - All[3]	52	0.34-119.72	3.30	48.1	36.5	23.1	12.70	34.99
Terminal elevators								
Elevator Manager	12	0.09- 6.32	0.36	8.3	0	0	0.89	1.31
Supervisor/Foreman	11	0.21- 34.47	2.14	36.4	9.1	9.1	7.22	21.38
Clerical/QA/Lab[2]	25	0.05- 1.93	0.24	0	0	0	0.54	0.85
Grain Handler - All[3]	80	0.08-100.27	2.35	32.5	16.3	11.3	5.75	11.11
Export elevators								
Elevator Manager	0	-	-	-	-	-	-	-
Supervisor/Foreman	0	-	-	-	-	-	-	-
Clerical/QA/Lab[2]	4	0.10- 3.40	1.37	0	0	0	3.48	20.45
Grain Handler - General	10	0.31-338.26	7.45	60.0	40.0	40.0	70.15	668.69
Receiving/Inspection	29	0.06-256.37	2.25	27.6	6.9	3.4	6.59	31.06
Shipping	10	0.10- 17.60	2.46	30.0	10.0	10.0	5.78	16.36
Bin Operator	11	0.29- 11.87	1.57	18.2	9.1	0	3.10	4.13
Basement Floor Operator	3	2.00- 13.43	4.34	66.7	33.3	0	7.73	9.47
Maintenance/Electrical	22	0.17- 95.79	0.84	27.3	13.6	13.6	6.02	24.61
Cleaning/Drying	1	6.28	-	0.0	0	0	-	-
Control Room Operator[2]	7	0.05- 1.30	0.18	0	0	0	0.31	0.46
Grain Handler - All[3]	90	0.06-338.26	1.57	31.1	13.3	10.0	7.98	34.94

NOTES:

1 Personal samples except as noted
2 Personal and area samples
3 Includes general grain handler through control room operator

TABLE 3-7. Dust levels by grain handled - all elevators

	Number of elevators[1]	Number of samples	Dust level, mg/m^3		Cumulative % greater than			Estimated distribution parameters, mg/m^3	
			Range	Median	4 mg/m^3	10 mg/m^3	15 mg/m^3	Mean	Std. dev.
Personal Samples									
Corn/Soybeans	23	117	0.08 - 119.72	1.84	29.9	14.3	10.3	6.43	18.68
Wheat	14	87	0.06 - 43.81	1.17	17.2	11.5	6.9	3.36	7.99
Both	5	80	0.10 - 338.26	3.28	46.3	23.8	16.3	12.60	48.73
Personal & Area Samples									
Corn/Soybeans[2]	23	174	0.02 - 119.72	1.43	27.0	14.4	11.5	7.11	33.44
Wheat[3]	14	123	0.05 - 43.81	1.15	20.3	11.4	8.1	3.89	12.19
Both	5	99	0.10 - 338.26	2.82	44.4	23.2	15.2	11.40	44.94

NOTES:

1 Totals only 42 since one elevator handled no grain during visit
2 Includes corn, soybeans, and milo
3 Includes wheat, milo, barley, and oats

TABLE 3-8. Dust level and engineering controls - all elevators

Controls	Number of elevators	Number of samples[1]	Dust level, mg/m^3 Range	Median	Cumulative % greater than $4\ mg/m^3$	$10\ mg/m^3$	$15\ mg/m^3$	Estimated distribution parameters, mg/m^3 Mean	Std. dev.
None	15	80	0.02 - 119.72	1.41	32.5	23.8	18.7	13.82	111.55
Limited[2]	16	121	0.05 - 100.27	1.30	29.8	16.5	10.7	6.02	22.23
Extensive[3]	12	197	0.05 - 338.26	1.57	27.4	11.7	8.6	5.72	19.87

NOTES:

1 Personal and area samples
2 Cyclone or bag house dust collector with exhausted elevator legs and/or dump pit. Remote operation for dump.
3 Above plus covered conveyor belts, exhausted transfer points, and enclosed control booths.

TABLE 3-9. Dust level and engineering controls by industry segment

	Number of elevators	Number of samples[1]	Dust level, mg/m^3 Range	Median	Cumulative % greater than $4\ mg/m^3$	$10\ mg/m^3$	$15\ mg/m^3$	Estimated distribution parameters, mg/m^3 Mean	Std. dev.
Country Elevators									
None	14	74	0.02-119.72	1.50	35.1	25.7	20.3	15.19	116.33
Limited[2]	9	60	0.07- 29.27	1.25	23.3	5.0	8.3	4.33	13.35
Extensive[3]	0	-	-	-	-	-	-	-	-
Terminal Elevators									
None	1	6	0.06- 3.70	0.24	0	0	0	0.88	2.62
Limited	7	61	0.05-100.27	1.93	36.1	18.0	13.1	8.43	36.76
Extensive	7	87	0.07- 34.47	1.45	19.5	8.0	5.7	3.30	7.45
Export Elevators									
None	0	-	-	-	-	-	-	-	-
Limited	0	-	-	-	-	-	-	-	-
Extensive	5	110	0.05-338.26	1.99	33.6	14.5	10.9	8.75	41.50

NOTES:

1 Personal and area samples
2 Cyclone or bag house dust collector with exhausted elevator legs and/or dump pit. Remote operation for dump.
3 Above plus covered conveyor belts, exhausted transfer points, and enclosed control booths.

TABLE 3-10. Dust level and usage of oil additive

	Number of elevators	Number of samples[1]	Dust level, mg/m^3		Cumulative % greater than			Estimated distribution parameters, mg/m^3	
			Range	Median	4 mg/m^3	10 mg/m^3	15 mg/m^3	Mean	Std. dev.
Country elevators									
Oil additive used	6	45	0.02- 29.27	1.05	24.4	15.6	8.9	5.17	22.06
Oil additive not used	17	89	0.07-119.72	1.58	32.6	23.6	18.0	11.07	61.31
Terminal elevators									
Oil additive used	4	39	0.06- 34.47	2.27	41.0	20.5	15.4	8.54	33.74
Oil additive not used	11	115	0.05-100.27	1.11	20.0	8.7	6.1	3.86	11.09
Export elevators									
Oil additive used	3	66	0.13-256.37	2.05	28.8	13.6	12.1	7.80	28.61
Oil additive not used	2	44	0.05-338.26	1.58	40.9	15.9	9.1	10.48	73.01
All elevators									
Oil additive used	13	150	0.02-256.37	1.58	30.7	16.0	12.0	7.16	28.46
Oil additive not used	30	248	0.05-338.26	1.34	28.2	15.3	10.9	6.77	29.21

NOTE:

[1] Personal and area samples

TABLE 4-1. Number and percentage of employees reporting various medical conditions

Type of medical condition	No. of employees reporting condition	Percentage (%)
Asthma	19	4.4
Hayfever	29	6.8
Sinusitis	66	15.5
Emphysema	4	0.9
Bronchitis	33	7.7
Respiratory problems	17	4.0
Allergies	61	14.3
Diabetes	12	2.8
Cancer	7	1.6
High blood pressure	81	19.0
Heart problems	21	4.9
Other	12	2.8

TABLE 3-11. Dust levels by engineering control and oil additive usage

	Number of elevators	Number of samples	Dust level, mg/m^3 Range	Median	Cumulative % greater than $4\ mg/m^3$	$10\ mg/m^3$	$15\ mg/m^3$	Estimated distribution parameters, mg/m^3 Mean	Std. dev.
No engineering controls									
Oil additive used	3	13	0.02 - 19.32	0.31	15.4	7.7	7.7	4.38	35.03
Oil additive not used	12	67	0.07 - 119.72	1.57	35.8	26.9	20.9	15.29	109.26
Limited engineering controls									
Oil additive used	5	42	0.07 - 29.27	1.19	26.2	19.0	11.9	5.80	22.53
Oil additive not used	11	79	0.05 - 100.27	1.66	31.6	15.2	10.1	6.33	23.07
Extensive engineering controls									
Oil additive used	5	95	0.13 - 256.37	2.25	34.7	15.8	12.6	7.63	25.00
Oil additive not used	7	102	0.05 - 338.26	1.23	20.6	7.8	4.9	3.97	13.16

TABLE 3-12. Percentage of grain dust less than 10 micrometers in aerodynamic diameter by industry segment

	No. Samples	% less than 10 micrometers Range	Mean
Country elevators	26	1.4 - 55.9	19.7
Terminal elevators	23	2.3 - 59.5	23.9
Export elevators	10	2.0 - 62.3	26.0

TABLE 3-13. Percentage of grain dust less than 10 micrometers in aerodynamic diameter by type of grain handled

	No. Samples	% less than 10 micrometers Range	Mean
Corn/soybeans[1]	28	1.4 - 55.9	17.8
Wheat[2]	15	4.6 - 62.3	29.8
Both	4	2.0 - 57.8	21.6

NOTES:

[1] Includes corn, soybeans, and milo
[2] Includes wheat, oats, barley, and milo

TABLE 3-14. Comparison of total dust measurements using filter cassette and impactor worn by same employee

Elevator	Filter	Impactor
10	7.13	8.56
11	2.14	2.18
12	1.40	2.82
13	0.49	0.83
21	16.84	18.88
29	2.27	2.97
30	26.08	21.83
33	10.01	13.68
	5.19	10.93
	2.03	6.67
35	1.58	3.95
36	2.69	2.83
40	3.49	6.81
41	2.23	3.62
42	46.75	48.78
	19.46	24.52
	4.56	8.59
44	0.53	0.47
49	3.96	1.56
52	11.08	13.48
55	0.77	1.60
56	14.93	15.05
58	12.95	13.99
	15.74	17.06
59	12.02	15.53
65	9.22	10.83
69	0.21	0.21
77	2.44	2.68
78	1.17	1.45
90	1.56	1.41
	2.48	4.63
	1.72	2.43
96	2.95	4.29
98	44.95	13.81

Correlation	
N = 34	
Correlation coefficient	0.85
Probability of chance occurence	<0.0001
Linear regression	
Regression coefficient	0.72
Standard error	0.08
Probability of chance of occurence	<0.0001

TABLE 3-15. Interday variability of dust exposure levels as measured by personal samples on the same individual

Elevator	Job	Day 1	Day 2	Day 3
33	Grain handler	10.01	5.19	2.03
	Grain handler	15.38	3.46	1.47
	Grain handler	16.18	4.70	1.82
42	Grain handler	31.30	19.46	119.72
	Grain handler	46.75	12.36	4.56
49	Grain handler	3.96	3.75	-
	Receiving	0.61	0.81	-
50	Grain handler	1.92	2.81	-
	Receiving	0.50	0.88	-
	Receiving	3.39	1.07	-
58	Supervisor	3.17	2.06	7.05
	Inspection	0.71	0.93	0.52
	Inspection	0.54	1.15	1.02
	Grain handler	100.27	0.86	0.67
60	Clerical	0.79	0.32	0.51
	Grain handler	1.29	2.95	9.63
85	Receiving	13.92	5.95	-
	Shipping	8.21	0.60	3.93
	Maintenance	-	1.47	1.83
88	Receiving	0.20	2.54	0.55
	Receiving	5.39	2.65	-
	Bin Operator	2.10	2.50	1.57
	Maintenance	0.40	0.33	0.61
90	Manager	0.38	0.35	0.26
	Grain handler	2.00	3.23	5.24
	Grain handler	1.21	3.57	0.68
	Grain handler	0.31	0.47	0.54
	Receiving	0.64	0.83	0.93
	Bin Operator	2.02	1.06	2.44
	Maintenance	1.45	0.67	0.98

TABLE 3-16 . Dust levels by region

Region	Number of elevators	Number of samples[1]	Dust level, mg/m^3 Range		Cumulative % greater than 4 mg/m^3	10 mg/m^3	15 mg/m^3	Estimated distribution parameters, mg/m^3 Mean	Std. dev.
			Range	Median	4 mg/m^3	10 mg/m^3	15 mg/m^3	Mean	Std. dev.
Central Grain Belt	33	317	0.02 - 338.26	1.55	31.5	17.4	12.9	8.17	38.39
Southwest	3	20	0.15 - 43.81	1.23	25.0	20.0	10.0	5.28	15.64
Northwest	1	4	0.34 - 2.49	1.44	0	0	0	1.74	2.56
Southeast	5	51	0.08 - 26.08	1.44	19.6	5.9	3.9	3.34	8.51
Northeast	1	6	0.14 - 4.17	1.08	16.7	0	0	1.82	3.69

TABLE 3-17. Summary of dust level measurements for *individual elevators*

Elevator	All samples			Personal samples					
							No. greater than		
	No.	Median mg/m^3	Mean mg/m^3	No.	Median mg/m^3	Mean mg/m^3	4 mg/m^3	10 mg/m^3	15 mg/m^3
10	5	7.13	5.82	3	7.13	6.77	2	1	-
11	7	2.14	3.98	5	2.14	5.12	2	1	1
12	6	2.07	1.87	1	-	1.40	-	-	-
13	7	0.28	0.81	4	0.38	1.19	-	-	-
15	11	1.98	10.35	9	2.25	12.56	2	1	1
19	5	2.24	6.02	2	8.24	8.24	1	1	1
20	5	4.51	11.75	4	12.47	13.56	2	2	2
21	5	1.22	7.47	3	1.22	6.10	1	1	1
22	4	3.37	3.41	1	-	1.66	-	-	-
23	5	1.13	12.26	2	22.47	22.47	1	1	1
28	6	1.08	1.43	3	1.57	1.33	-	-	-
29	9	2.97	6.68	6	5.81	9.38	4	1	1
30	7	6.32	10.16	4	6.88	11.03	4	1	1
31	28	1.16	3.69	15	0.57	1.23	2	-	-
33	24	4.94	6.02	9	4.70	6.69	5	3	2
35	9	0.82	1.65	6	1.20	1.78	1	-	-
36	7	2.69	3.02	5	1.84	3.10	1	-	-
40	6	2.29	2.78	4	2.29	2.34	-	-	-
41	10	0.86	1.16	6	0.70	0.91	-	-	-
42	17	21.80	31.27	6	25.38	39.03	6	5	4
44	8	0.41	0:70	5	0.53	0.98	-	-	-
46	21	4.56	27.20	14	4.41	29.21	8	4	2
49	13	3.35	4.02	5	3.75	2.83	1	-	-
50	12	0.80	2.58	6	1.49	1.76	-	-	-
52	6	2.42	5.02	3	1.21	4.23	1	1	-
53	6	0.40	0.43	5	0.52	0.51	-	-	-
55	5	1.60	2.20	4	1.72	2.35	1	-	-
56	8	8.95	12.46	5	1.42	12.77	2	2	1
58	28	2.07	10.74	23	2.06	9.54	9	5	3

TABLE 3-17. Summary of dust level measurements for individual elevators

	All samples			Personal samples					
							No greater than		
Elevator	No.	Median mg/m^3	Mean mg/m^3	No.	Median mg/m^3	Mean mg/m^3	4 mg/m^3	10 mg/m^3	15 mg/m^3
59	5	1.44	5.94	2	6.73	6.73	1	1	-
60	17	1.29	4.04	10	1.04	2.13	1	-	-
64	3	8.49	9.52	2	14.23	14.23	2	1	1
65	5	9.22	7.94	1	-	9.22	1	-	-
68	5	15.67	15.32	3	15.67	19.84	3	3	2
69	3	0.21	0.36	2	0.43	0.43	-	-	-
72	6	2.77	5.08	3	2.80	3.23	1	-	-
77	5	2.44	1.68	2	1.39	1.39	-	-	-
78	13	1.33	3.49	11	1.33	3.97	3	2	-
85	34	5.25	16.99	30	4.48	16.67	15	7	6
88	26	1.32	1.51	24	1.29	1.48	1	-	-
90	30	1.02	1.46	21	1.21	1.60	1	-	-
96	6	1.75	1.82	4	1.75	1.64	-	-	-
98	7	6.92	11.69	3	14.10	19.86	2	2	1

TABLE 3-18. Personal samples with high dust levels

Elevator	Type	Job	Dust level mg/m^3	Comments
15	Export	Maintenance	95.79	Truck dump - cleaned clogged filter
20	Terminal	Bin Operator	28.08	
23	Country	Grain handler	43.81	Cleaning out corn bins
29	Terminal	Supervisor	34.47	Clean out oat bin 1-1.5 hours
30	Terminal	Grain handler	26.08	Loading rail cars
42	Country	Grain handler	31.30	
	Country	Grain handler	46.75	
	Country	Grain handler	119.72	
46	Export	Grain handler	338.26	Car dump
56	Country	Grain handler	45.21	Truck dump
58	Terminal	Grain handler	100.27	Transferring soybeans from bins
	Terminal	Grain handler	31.49	Transferring soybeans from bins
68	Country	Grain handler	29.27	Truck dump
85	Export	Grain handler	33.71	Clean up
	Export	Grain handler	38.49	Loading dust
	Export	Receiving	256.37	Unloading barge with Bobcat
	Export	Maintenance	42.14	Repaired dust collector
98	Country	Grain handler	44.95	

TABLE 3-19. Summary of endotoxin level measurements

Sample type	Number of samples	Endotoxin levels, ng/m^3			
		Range	Median	Mean	Std. dev.
Personal	155	0.79 - 6606.9	69.2	282.9	744.3
Area	51	0.26 - 1548.8	16.6	153.1	290.2
Industry segment					
Country elevators	85	0.35 - 3388.6	18.2	234.7	630.8
Terminal elevators	61	0.26 - 6606.9	77.6	366.4	936.2
Export elevators	60	0.61 - 955.0	75.9	156.0	217.2
Grain handled					
Corn	93	0.26 - 6606.9	51.3	238.7	758.7
Wheat	106	0.61 - 3388.4	79.4	271.5	591.8
Both	5	3.16 - 537.0	14.8	120.0	233.5
All samples	206	0.26 - 6606.9	65.3	250.8	663.2

TABLE 4-2. Prevalence of symptoms in grain elevator employees

Symptom/ frequency	No. of employees reporting no symptoms (percent)	No. of employees reporting symptoms (percent)	Total
Cough, am or pm 3 months per year	371 (86.9)	56 (13.1)	427
Chronic bronchitis, defined by production of phlegm, am or pm 3 months per year for 2 years	396 (92.7)	31 (7.3)	427
Cough or phlegm	364 (85.2)	63 (14.8)	427
Chest illness causing lost work within the last 3 years	395 (92.7)	31 (7.3)	426[1]
Chest tightness	331 (77.7)	95 (22.3)	426[1]
Dyspnea Grade			
1		329 (77.2)	
2		84 (19.7)	
3		10 (2.3)	
4		2 (0.5)	
5		1 (0.2)	426[1]

NOTE:

1 Some of the questions were not answered by one employee, making the total 426.

TABLE 4-3. Frequency of pack year category for cigarettes

Category pack · yrs	Number of Employees	Percentage
None	167	39.1
1-10	77	18.0
>10-20	69	16.2
>20-40	66	15.5
>40-80	37	8.7
>80	11	2.6

TABLE 4-4. Pulmonary function results

407 Cases

Variable	Mean	Std. dev.	Std. error of mean
FEV1BCOR ml	3665	771	38.20
FEV1Before ml	3642	853	42.27
FEV1After ml	3637	846	41.92
FEV1B Percent Predicted	98.46	16.65	0.83
FEV1A Percent Predicted	98.22	17.02	0.84
FVCBefore ml	4584	973	48.23
FVCAfter ml	4550	971	48.18
FEF2575Before Percent Predicted	81.61	30.26	1.50
FEF2575After Percent Predicted	80.31	29.54	1.46
Delta FEV1 ml	-5.14	278.34	13.79
DVEV1Percent	0.17	7.78	0.39
FVCB Percent Predicted	99.15	14.24	0.71
FVCA Percent Predicted	99.30	14.51	0.72
FEV1/FVC Ratio Before Percent	80.03	7.04	0.35
FEV1/FVC Ratio After Percent	79.80	7.05	0.35

TABLE 4-5. Prevalence of pulmonary function abnormalities

Predicted FEV1 before shift	Impairment	Number of Employees	Percentage
≥80	None	357	87.7
70-79.99	Mild	35	8.6
60-69.99	Moderate	10	2.5
<60	Severe	5	1.2

Predicted FVC before shift	Impairment	Number of Employees	Percentage
≥80	None	391	91.8
70-79.99	Mild	26	6.1
60-69.99	Moderate	8	1.9
<60	Severe	1	0.2

Predicted FEV1/FVC before shift	Impairment	Number of Employees	Percentage
≥75	None	347	81.5
60-75	Mild/Moderate	73	17.1
<60	Severe	6	1.4

TABLE 4-6. Symptom prevalence by type of elevator

Symptom	Elevator type: Country	Export	Terminal	TOTAL
Cough	15 14.2%	23 10.7%	18 17.0%	56 13.1%
TOTAL	106	215	106	427
Chi Square = 2.59284		DF = 2		Prob = 0.2735
Chronic bronchitis	10 9.4%	10 4.7%	11 10.4%	31 7.3%
TOTAL	106	215	106	427
Chi Square = 4.44737		DF = 2		Prob = 0.1082
Cough or bronchitis	19 17.9%	24 11.2%	20 18.9%	63 14.8%
TOTAL	106	215	106	427
Chi Square = 4.47818		DF = 2		Prob = 0.1066
Chest tightness	25 23.6%	43 20.1%	27 25.5%	95 22.3%
TOTAL	106	214	106	426
Chi Square = 1.31772		DF = 2		Prob = 0.5174
Dyspnea Grade				
1	88 83.0%	169 79.0%	72 67.9%	329 77.2%
2	16 15.1%	38 17.8%	30 28.3%	84 19.7%
3	2 1.9%	5 2.3%	3 2.8%	10 2.3%
4	0 0.0%	1 0.5%	1 0.9%	2 0.5%
5	0 0.0%	1 0.5%	0 0.0%	1 0.2%
TOTAL	106	214	106	426
Chi Square = 9.45667		DF = 8		Prob = 0.3052

TABLE 4-7. Symptom prevalence by exposure index category

Symptom	Exposure index, mg · yrs/m³ 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Cough	21 10.9%	18 14.4%	10 14.1%	2 9.5%	5 27.8%	56 13.1%
TOTAL	192	125	71	21	18	427
	Chi Square = 4.67256		DF = 4		Prob = 0.3226	
Chronic bronchitis	15 7.8%	11 8.8%	2 2.8%	1 4.8%	2 11.1%	31 7.3%
TOTAL	192	125	71	21	18	427
	Chi Square = 3.20225		DF = 4		Prob = 0.5249	
Cough or chronic bronchitis	25 13.0%	21 16.8%	10 14.1%	2 14.3%	5 27.8%	63 15.0%
TOTAL	192	125	71	21	18	427
	Chi Square = 3.7841		DF = 4		Prob = 0.4360	
Chest tightness	34 17.7%	29 23.4%	17 23.9%	6 28.6%	9 50.0%	95 22.3%
TOTAL	192	124	71	21	18	426
	Chi Square = 10.9789		DF = 4		Prob = 0.0268	
Dyspnea Grade						
1	157 81.8%	94 75.8%	52 73.2%	14 66.7%	12 66.7%	329 77.2%
2	29 15.1%	27 21.8%	18 25.4%	6 28.6%	4 22.2%	84 19.7%
3	6 3.1%	3 2.4%	0 0.0%	1 4.8%	0 0.0%	10 2.3%
4	0 0.0%	0 0.0%	0 1.4%	1 0.0%	1 5.6%	2 0.5%
5	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 5.6%	1 0.2%
TOTAL	192	124	70	22	18	426
	Chi Square = 44.2367		DF = 16		Prob = 0.0002	

TABLE 4-8. Symptom prevalence by years exposed category

Symptom	Years exposed 0-5	>5-10	>10-20	>20	TOTAL
Cough	20 14.4%	9 1.0%	15 12.2%	12 14.5%	56 13.1%
TOTAL	139	82	123	83	427
Chi Square = 0.749891		DF = 3	Prob = 0.8614		
Chronic bronchitis	17 12.2%	3 3.7%	6 7.9%	5 6.0%	31 7.3%
TOTAL	139	82	123	83	427
Chi Square = 7.90441		DF = 3	Prob = 0.0480		
Cough or chronic bronchitis	23 16.5%	10 12.2%	16 13.0%	14 16.9%	63 14.8%
TOTAL	139	82	123	83	427
Chi Square = 1.12858		DF = 3	Prob = 0.7702		
Chest tightness	28 20.1%	8 9.8%	35 28.5%	24 29.3%	95 22.3%
TOTAL	139	82	123	83	426
Chi Square = 12.8067		DF = 3	Prob = 0.0051		
Dyspnea Grade					
1	118 84.9%	66 80.5%	88 71.5%	57 69.5%	329 77.2%
2	20 14.4%	13 15.9%	29 23.6%	22 26.8%	84 19.7%
3	1 0.7%	3 3.7%	6 4.9%	0 0.0%	10 2.3%
4	0 0.0%	0 0.0%	0 0.0%	2 2.4%	2 0.5%
5	0 0.0%	0 0.0%	0 0.0%	1 1.2%	1 0.2%
TOTAL	139	82	123	83	426
Chi Square = 28.0076		DF = 12	Prob = 0.0055		

TABLE 4-9. Symptom prevalence and current dust exposure level

Symptom	Dust level, mg/m^3				TOTAL
	0-4	>4-10	>10-15	>15	
Cough	24	1	1	9	35
	13.2%	4.0%	9.1%	26.5%	13.9%
TOTAL	182	25	11	34	252
Chi Square = 6.83106		DF = 3		Prob = 0.0775	
Chronic bronchitis	16	1	0	5	22
	8.8%	4.0%	0.0%	14.7%	8.7%
TOTAL	182	25	11	34	252
Chi Square = 3.27877		DF = 3		Prob = 0.3506	
Cough or chronic bronchitis	27	1	1	10	39
	14.8%	4.0%	9.1%	29.4%	15.5%
TOTAL	182	25	11	34	252
Chi Square = 7.96469		DF = 3		Prob = 0.0467	
Chest tightness	42	6	4	7	59
	23.1%	24.0%	36.4%	20.6%	23.4%
TOTAL	182	25	11	34	252
Chi Square = 1.19645		DF = 3		Prob = 0.7539	
Dyspnea					
Grade					
1	136	22	10	25	193
	74.7%	88.0%	90.9%	73.5%	76.6%
2	39	3	1	9	52
	21.4%	12.0%	9.1%	26.5%	20.6%
3	6	0	0	0	6
	3.3%	0.0%	0.0%	0.0%	2.4%
4	1	0	0	0	1
	0.5%	0.0%	0.0%	0.0%	0.4%
TOTAL	182	25	34	11	252
Chi Square = 5.76640		DF = 9		Prob = 0.7631	

TABLE 4-10. Symptom prevalence and smoking status

Symptom	Non-Smoker	Ex-Smoker	Current Smoker	TOTAL
Cough	6	4	46	56
	3.9%	3.9%	27.4%	13.1%
TOTAL	155	103	168	426
Chi Square = 49.2344		DF = 2	Prob < 0.00001	
Chronic bronchitis	4	2	25	31
	2.6%	1.9%	14.9%	7.3%
TOTAL	155	103	168	426
Chi Square = 23.8080		DF = 2	Prob < 0.00001	
Cough or chronic bronchitis	8	5	50	63
	5.2%	4.9%	29.8%	14.8%
TOTAL	155	103	168	426
Chi Square = 49.3560		DF = 2	Prob < 0.00001	
Chest tightness	25	21	49	95
	16.1%	20.4%	29.2%	22.3%
TOTAL	155	103	168	426
Chi Square = 8.19532		DF = 2	Prob = 0.0166	
Dyspnea				
Grade				
1	135	82	112	329
	87.1%	79.6%	66.7%	77.2%
2	15	20	49	84
	9.7%	19.4%	29.2%	19.7%
3	5	0	5	10
	3.2%	0.0%	3.0%	2.3%
4	0	1	1	2
	0.0%	1.0%	0.6%	0.5%
5	0	0	1	1
	0.0%	0.0%	0.6%	0.2%
TOTAL	155	103	168	426
Chi Square = 26.0744		DF = 8	Prob = 0.0010	

TABLE 4-11. Non-smokers vs. symptom prevalence by exposure index category

Symptom	Exposure index, mg · yrs/m³ 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Cough	4 4.4%	0 0.0%	2 9.5%	0 0.0%	0 0.0%	6 3.9%
TOTAL	90	36	21	6	2	155
	Chi Square = 3.65470		DF = 4	Prob = 0.4547		
Chronic bronchitis	4 4.4%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	4 2.6%
TOTAL	90	36	21	6	2	155
	Chi Square = 2.965		DF = 4	Prob = 0.5636		
Cough or chronic bronchitis	6 6.7%	0 0.0%	2 9.5%	0 0.0%	0 0.0%	8 5.2%
TOTAL	90	36	21	6	2	155
	Chi Square = 3.6277		DF = 4	Prob = 0.4587		
Chest tightness	13 14.4%	5 13.9%	4 19.0%	1 16.7%	2 100.0%	25 16.1%
TOTAL	90	36	21	6	2	155
	Chi Square = 10.8559		DF = 4	Prob = 0.0282		
Dyspnea Grade						
1	78 86.7%	32 88.9%	17 81.0%	6 100.0%	2 100.0%	135 87.1%
2	9 10.0%	2 5.6%	4 19.0%	0 0.0%	0 0.0%	15 9.7%
3	3 3.3%	2 5.6%	0 0.0%	0 0.0%	0 0.0%	5 3.2%
TOTAL	90	36	21	6	2	155
	Chi Square = 5.12475		DF = 8	Prob = 0.7442		

TABLE 4-12. Current smokers vs symptom prevalence by exposure index category

Symptom	Exposure index, mg · yrs/m³ 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Cough	16	15	8	2	5	46
	21.6%	31.9%	25.8%	25.0%	62.5%	27.4%
TOTAL	74	47	31	8	8	168
	Chi Square = 6.74405		DF = 4		Prob = 0.1500	
Chronic bronchitis	10	10	2	1	2	25
	13.5%	21.3%	6.5%	12.5%	25.0%	14.9%
TOTAL	74	47	31	8	8	168
	Chi Square = 4.0485		DF = 4		Prob = 0.3995	
Cough or chronic bronchitis	18	17	8	2	5	50
	24.3%	36.2%	25.8%	25.0%	62.5%	29.8%
TOTAL	74	47	31	8	8	168
	Chi Square = 6.3905		DF = 4		Prob = 0.1718	
Chest tightness	18	15	8	4	4	49
	24.3%	31.9%	25.8%	50.0%	50.0%	29.2%
TOTAL	74	47	31	8	8	168
	Chi Square = 4.54247		DF = 4		Prob = 0.3375	
Dyspnea Grade						
1	54	31	20	4	3	112
	73.0%	66.0%	64.5%	50.0%	37.5%	66.7%
2	17	15	11	3	3	49
	23.0%	31.9%	35.5%	37.5%	37.5%	29.2%
3	3	1	0	1	0	5
	4.1%	2.1%	0.0%	12.5%	0.0%	3.0%
4	0	0	0	0	1	1
	0.0%	0.0%	0.0%	0.0%	12.5%	0.6%
5	0	0	0	0	1	1
	0.0%	0.0%	0.0%	0.0%	12.5%	0.6%
TOTAL	74	47	31	8	8	168
	Chi Square = 47.7221		DF = 16		Prob = < 0.0001	

TABLE 4-13. Ex-smokers vs. symptom prevalence for exposure index category

Symptom	Exposure index, mg · yrs/m³ 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Cough	1 3.6%	3 7.3%	0 0.0%	0 0.0%	0 0.0%	4 3.9%
TOTAL	28	41	19	7	8	103
	Chi Square = 2.67600		DF = 4	Prob = 0.6134		
Chronic bronchitis	1 3.6%	1 2.4%	0 0.0%	0 0.0%	0 0.0%	2 1.9%
TOTAL	28	41	19	7	8	103
	Chi Square = 1.11707		DF = 4	Prob = 0.8916		
Cough or chronic bronchitis	1 3.6%	4 9.8%	0 0.0%	0 0.0%	0 0.0%	5 4.9%
TOTAL	28	41	19	7	8	103
	Chi Square = 3.96733		DF = 4	Prob = 0.4104		
Chest tightness	3 10.7%	9 22.0%	5 26.3%	1 14.3%	3 37.5%	21 20.4%
TOTAL	28	41	19	7	8	103
	Chi Square = 3.69117		DF = 4	Prob = 0.4494		
Dyspnea Grade						
1	25 89.3%	31 75.6%	15 78.9%	4 57.1%	7 87.5%	82 79.6%
2	3 10.7%	10 24.4%	3 15.8%	3 42.9%	1 12.5%	20 19.4%
4	0 0.0%	0 0.0%	1 5.3%	0 0.0%	0 0.0%	1 1.0%
TOTAL	28	41	19	7	8	103
	Chi Square = 9.26115		DF = 8	Prob = 0.3207		

TABLE 4-14. Prevalence of symptoms for non-smokers vs. dust level range

Symptom	Dust level, mg/m³ 0-4	>4-10	>10-15	>15	TOTAL
Cough	4	0	0	1	5
	5.3%	0.0%	0.0%	7.7%	4.9%
TOTAL	75	10	5	13	103

Chi Square = 1.02925 DF = 3 Prob = 0.7942

Symptom	0-4	>4-10	>10-15	>15	TOTAL
Chronic bronchitis	3	0	0	0	3
	4.0%	0.0%	0.0%	0.0%	2.9%
TOTAL	75	10	5	13	103

Chi Square = 1.15360 DF = 3 Prob = 0.7642

Symptom	0-4	>4-10	>10-15	>15	TOTAL
Cough or chronic bronchitis	5	0	0	1	6
	6.7%	0.0%	0.0%	7.7%	5.8%
TOTAL	75	10	5	13	103

Chi Square = 1.10723 DF = 3 Prob = 0.7753

Symptom	0-4	>4-10	>10-15	>15	TOTAL
Chest tightness	13	2	1	3	19
	17.3%	20.0%	20.0%	23.1%	18.4%
TOTAL	75	10	5	13	103

Chi Square = 0.271119 DF = 3 Prob = 0.9654

Symptom	0-4	>4-10	>10-15	>15	TOTAL
Dyspnea Grade					
1	62	9	5	11	87
	82.7%	90.0%	100.0%	84.6%	84.5%
2	10	1	0	2	13
	13.3%	10.0%	0.0%	15.4%	12.6%
3	3	0	0	0	3
	4.0%	0.0%	0.0%	0.0%	2.9%
TOTAL	75	10	5	13	103

Chi Square = 2.12216 DF = 6 Prob = 0.9081

TABLE 4-15. Prevalence of symptoms for current smokers vs. dust level range

Symptom	Dust level, mg/m³ 0-4	>4-10	>10-15	>15	TOTAL
Cough	18	1	1	8	28
	25.7%	14.3%	25.0%	53.3%	29.2%
TOTAL	70	7	4	15	96
Chi Square = 5.42809		DF = 3		Prob = 0.1430	
Chronic bronchitis	11	1	0	5	17
	15.7%	14.3%	0.0%	33.3%	17.7%
TOTAL	70	7	4	15	96
Chi Square = 3.62106		DF = 3		Prob = 0.3054	
Cough or chronic bronchitis	19	1	1	9	30
	27.1%	14.3%	25.0%	60.0%	31.3%
TOTAL	70	7	4	15	96
Chi Square = 7.33091		DF = 3		Prob = 0.0621	
Chest tightness	23	2	1	3	29
	32.9%	28.6%	25.0%	20.0%	30.2%
TOTAL	70	7	4	15	96
Chi Square = 1.03475		DF = 3		Prob = 0.7928	
Dyspnea Grade					
1	43	5	4	10	62
	61.4%	71.4%	100.0%	66.7%	64.6%
2	23	2	0	5	30
	32.9%	28.6%	0.0%	33.3%	31.3%
3	3	0	0	0	3
	4.3%	0.0%	0.0%	0.0%	3.1%
4	1	0	0	0	1
	1.4%	0.0%	0.0%	0.0%	1.0%
TOTAL	70	7	4	15	96
Chi Square = 3.77610		DF = 9		PROB = 0.9255	

TABLE 4-16. Prevalence of symptoms in ex-smokers vs. dust level

Symptom	Dust level, mg/m^3 0-4	>4-10	>10-15	>15	TOTAL
Cough	2 5.4%	0 0.0%	0 0.0%	0 0.0%	2 3.8%
TOTAL	37	8	2	6	53
Chi Square = 0.898781	DF = 3		PROB = 0.8257		
Chronic bronchitis	2 5.4%	0 0.0%	0 0.0%	0 0.0%	2 3.8%
TOTAL	37	8	2	6	53
Chi Square = 0.898781	DF = 3		PROB = 0.8257		
Cough or chronic bronchitis	3 8.1%	0 0.0%	0 0.0%	0 0.0%	3 5.7%
TOTAL	37	8	2	6	53
Chi Square = 1.37514	DF = 3		PROB = 0.7114		
Chest tightness	6 16.2%	2 25.0%	2 100.0%	1 16.7%	11 20.8%
TOTAL	37	8	2	6	53
Chi Square = 8.24837	DF = 3		PROB = 0.0411		
Dyspnea Grade					
1	31 83.8%	8 100.0%	1 50.0%	4 66.7%	44 83.0%
2	6 16.2%	0 0.0%	1 50.0%	2 33.3%	9 17.0%
TOTAL	37	8	2	6	53
Chi Square = 4.33648	DF = 3		PROB = 0.2273		

TABLE 4-17. Prevalence of symptoms for non-smokers vs. years exposed category

Symptom	Years exposed 0-5	>5-10	>10-20	>20	TOTAL
Cough	3	1	2	0	6
	5.0%	2.78%	5.3%	0.0%	3.9%
TOTAL	60	37	38	20	155
Chi Square = 1.34454		DF = 3	Prob = 0.7186		
Chronic bronchitis	2	0	1	1	4
	3.3%	0.0%	2.6%	5.0%	2.6%
TOTAL	60	37	38	20	155
Chi Square = 1.5814		DF = 3	Prob = 0.6636		
Cough or chronic bronchitis	4	1	2	1	8
	6.7%	2.7%	5.3%	5.0%	5.2%
TOTAL	60	37	38	20	155
Chi Square = 0.736555		DF = 3	Prob = 0.8646		
Chest tightness	8	3	7	7	25
	13.3%	8.1%	18.4%	35.0%	16.1%
TOTAL	60	37	38	20	155
Chi Square = 7.51890		DF = 3	Prob = 0.0571		
Dyspnea Grade					
1	56	30	30	19	135
	93.3%	81.1%	78.9%	95.0%	87.1%
2	4	5	5	1	15
	6.7%	13.5%	13.2%	5.0%	9.7%
3	0	2	3	0	5
	0.0%	5.4%	7.9%	0.0%	3.2%
TOTAL	60	37	38	20	155
Chi Square = 8.60077		DF = 6	Prob = 0.1973		

TABLE 4-18. Prevalence of symptoms for smokers vs. years exposed category

Symptom	Years exposed 0-5	>5-10	>10-20	>20	TOTAL
Cough	16	8	13	9	46
	27.6%	27.6%	24.1%	33.3%	27.4%
TOTAL	58	29	54	27	168
Chi Square = 0.779938		DF = 3	Prob = 0.8543		
Chronic bronchitis	14	3	5	3	25
	24.1%	10.3%	9.3%	11.1%	14.9%
TOTAL	58	29	54	27	168
Chi Square = 6.0452		DF = 3	Prob = 0.1094		
Cough or chronic bronchitis	18	9	14	9	51
	31.0%	31.0%	25.9%	33.3%	30.4%
TOTAL	58	29	54	27	168
Chi Square = 0.61226		DF = 3	Prob = 0.8936		
Chest tightness	19	5	17	8	49
	32.8%	17.2%	31.5%	29.6%	29.2%
TOTAL	58	29	54	27	168
Chi Square = 2.50130		DF = 3	Prob = 0.4751		
Dyspnea					
Grade					
1	43	20	37	12	112
	74.1%	69.0%	68.5%	44.4%	66.7%
2	14	8	14	13	49
	24.1%	27.6%	25.9%	48.1%	29.2%
3	1	1	3	0	5
	1.7%	3.4%	5.6%	0.0%	3.0%
4	0	0	0	1	1
	0.0%	0.0%	0.0%	3.7%	0.6%
5	0	0	0	1	1
	0.0%	0.0%	0.0%	3.7%	0.6%
TOTAL	58	29	54	27	168
Chi Square = 19.3762		DF = 12	Prob = 0.0798		

TABLE 4-19. Prevalence of symptoms for ex-smokers vs. years exposed category

Symptom	Years exposed 0-5	>5-10	>10-20	>20	TOTAL
Cough	1	0	0	3	4
	4.8%	0.0%	0.0%	8.6%	3.9%
TOTAL	21	16	31	35	103

Chi Square = 4.00308 DF = 3 Prob = 0.2611

Symptom	0-5	>5-10	>10-20	>20	TOTAL
Chronic bronchitis	1	0	0	1	2
	4.8%	0.0%	0.0%	2.9%	1.9%
TOTAL	21	16	31	35	103

Chi Square = 1.96190 DF = 3 Prob = 0.5804

Symptom	0-5	>5-10	>10-20	>20	TOTAL
Cough or chronic bronchitis	1	0	0	4	5
	4.8%	0.0%	0.0%	11.4%	4.9%
TOTAL	21	16	31	35	103

Chi Square = 5.67351 DF = 3 Prob = 0.1286

Symptom	0-5	>5-10	>10-20	>20	TOTAL
Chest tightness	1	0	11	9	21
	4.8%	0.0%	35.5%	25.7%	20.4%
TOTAL	21	16	31	35	103

Chi Square = 12.2205 DF = 3 Prob = 0.0067

Symptom	0-5	>5-10	>10-20	>20	TOTAL
Dyspnea					
Grade					
1	19	16	21	26	82
	90.5%	100.0%	67.7%	74.3%	79.6%
2	2	0	10	8	20
	9.5%	0.0%	32.3%	22.9%	19.4%
4	0	0	0	1	1
	0.0%	0.0%	0.0%	2.9%	1.0%
TOTAL	21	16	31	35	103

Chi Square = 10.7740 DF = 6 Prob = 0.0956

TABLE 4-20. Prevalence of symptoms vs. type of grain handled

Symptom	Corn	Wheat	Both	None	TOTAL
Cough	19	14	23	0	56
	14.5%	11.3%	13.6%	0.0%	13.1%
TOTAL	131	123	169	3	426

Chi Square = 1.07317 DF = 3 Prob = 0.7836

Symptom	Corn	Wheat	Both	None	TOTAL
Chronic bronchitis	10	11	10	0	31
	7.6%	8.9%	5.9%	0.0%	7.3%
TOTAL	131	123	169	3	426

Chi Square = 1.1926 DF = 3 Prob = 0.7548

Symptom	Corn	Wheat	Both	None	TOTAL
Cough or chronic bronchitis	23	16	24	0	63
	17.6%	12.9%	14.2%	0.0%	14.8%
TOTAL	131	123	169	3	426

Chi Square = 1.7165 DF = 3 Prob = 0.6333

Symptom	Corn	Wheat	Both	None	TOTAL
Chest tightness	31	33	30	1	95
	23.7%	26.8%	17.8%	33.3%	22.3%
TOTAL	131	123	169	3	426

Chi Square = 3.82555 DF = 3 Prob = 0.2809

Symptom	Corn	Wheat	Both	None	TOTAL
Dyspnea Grade					
1	96	101	129	3	329
	73.3%	82.1%	76.3%	100.0%	77.2%
2	30	20	34	0	84
	22.9%	16.3%	20.1%	0.0%	19.7%
3	4	2	4	0	10
	3.1%	1.6%	2.4%	0.0%	2.3%
4	1	0	1	0	2
	0.8%	0.0%	0.6%	0.0%	0.5%
5	0	0	1	0	1
	0.0%	0.0%	0.6%	0.0%	0.2%
TOTAL	131	123	169	3	426

Chi Square = 5.91594 DF = 12 Prob = 0.9203

TABLE 4-21. Prevalence of pulmonary function impairment by exposure index category

Category of Impairment FEV1B % Predicted	Exposure index, mg · yrs/m³ 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Normal (≥ 80%)	164 90.6%	105 86.1%	62 89.9%	17 85.0%	9 60.0%	357 87.7%
Mild (≥ 70% < 80%)	12 6.6%	14 11.5%	6 8.7%	1 5.0%	2 13.3%	35 8.6%
Moderate (≥ 60% - <70%)	5 2.8%	1 0.8%	1 1.4%	2 10.0%	1 6.7%	10 2.5%
Severe (< 60%)	0 0.0%	2 1.6%	0 0.0%	0 0.0%	4 20.0%	5 1.2%
TOTAL	181	122	69	20	20	407

Chi Square = 58.1670 DF = 12 Prob < 0.0001

TABLE 4-22. Pulmonary impairment category by pack year category

Category of Impairment (FEV1B % Predicted)	Pack Years						
	None	1-10	>10-20	>20-40	>40-80	>80	TOTAL
Normal (≥ 80%)	154 96.4%	65 96.2%	57 91.5%	53 86.4%	19 81.5%	9 87.7%	357 90.0%
Mild (≥ 70% < 80%)	6 3.8%	5 7.0%	6 9.1%	8 12.3%	9 25.7%	1 8.6%	35 8.7%
Moderate (≥ 60% < 70%)	0 0.0%	1 1.4%	1 1.5%	1 1.5%	7 20.0%	0 0.0%	10 2.5%
Severe (>60%)	0 0.0%	0 0.0%	2 3.0%	3 4.5%	0 0.0%	0 0.0%	5 1.2%
TOTAL	160	71	66	65	35	10	407

Chi Square = 83.788 DF = 15 Prob = <0.0001

TABLE 4-23. Pulmonary impairment category in non-smokers by exposure index category

Category of Impairment (FEV1B % Predicted)	Exposure index, mg · yrs/m³ 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Normal (≥ 80%)	83 95.6%	33 95.4%	20 94.3%	6 100.0%	2 100.0%	144 96.0%
Mild (>70% - <80%)	4 4.6%	2 5.7%	0 0.0%	0 0.0%	0 0.0%	6 4.0%
TOTAL	87	35	20	6	2	150

Chi Square = 1.515   DF = 4   Prob = 0.8239

TABLE 4-24. Pulmonary impairment category in current smokers by exposure index category

Category of Impairment (FEV1B % Predicted)	Exposure index, mg · yrs/m^3 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Normal (≥ 80%)	59 84.3%	38 82.6%	26 86.7%	6 75.0%	2 33.3%	131 81.9%
Mild (≥ 70% - < 80%)	7 10.0%	6 13.0%	3 10.0%	1 12.5%	2 33.3%	19 11.9%
Moderate (≥ 60% - < 70%)	4 5.7%	1 2.2%	1 3.3%	1 12.5%	1 16.7%	8 5.0%
Severe (< 60%)	0 0.0%	1 2.1%	0 0.0%	0 0.0%	1 16.7%	2 1.3%
TOTAL	70	46	30	6	8	160

Chi Square = 21.1666 DF = 12 Prob = 0.0480

TABLE 4-25. Pulmonary impairment category in ex-smokers by exposure index category

Category of Impairment (FEV1B of predicted)	Exposure index, mg · yrs/m^3 0-10	>10-25	>25-50	>50-75	>75	TOTAL
Normal (≥ 80%)	22 91.7%	33 82.5%	16 84.2%	5 83.3%	5 71.4%	81 84.4%
Mild (≥ 70% - < 80%)	1 4.2%	6 15.0%	3 15.8%	0 0.0%	0 0.0%	10 9.8%
Moderate (≥ 60% - < 70%)	1 4.2%	0 0.0%	0 0.0%	1 16.7%	0 0.0%	2 2.1%
Severe (< 60%)	0 0.0%	1 2.5%	0 0.0%	0 0.0%	2 28.6%	3 3.1%
TOTAL	24	40	19	6	7	96

Chi Square = 27.9809 DF = 12 Prob = 0.0056

TABLE 4-26. Exposure index category vs. pack year category

	Exposure index					
Pack Years	0-10	>10-25	>25-50	>50-75	>75	TOTAL
1-10	33 18.2%	21 17.2%	12 17.4%	2 10.0%	3 20.0%	71 17.4%
>10-20	22 12.2%	29 23.8%	10 14.5%	4 20.0%	1 6.7%	66 16.2%
>20-40	21 11.6%	20 16.4%	16 23.2%	1 5.0%	7 46.7%	65 16.0%
>40-80	10 5.5%	11 9.0%	7 10.1%	6 30.0%	1 6.7%	35 8.6%
>80	3 1.7%	3 2.5%	2 2.9%	1 5.0%	1 6.7%	10 2.5%
None	96 50.8%	38 31.1%	22 31.9%	6 30.0%	2 13.3%	160 39.3%
TOTAL	181	122	69	20	15	407

Chi Square = 50.0417 DF = 20 Prob = 0.0002

TABLE 4-27. Prevalence of pulmonary impairment category by exposure index category <75

Category of Impairment (FEV1B % predicted)	Exposure index, mg · yrs/m^3				TOTAL
	0-10	>10-25	>25-50	>50-75	
Normal	164	105	62	17	348
(≥ 80%)	90.6%	86.1%	89.9%	85.2%	88.8%
Mild	12	14	6	1	33
(≥ 70% - < 80%)	6.6%	11.5%	8.7%	5.0%	8.4%
Moderate	5	1	1	2	9
(≥ 60% - < 70%)	2.8%	0.8%	1.4%	10.0%	2.3%
Severe	0	2	0	0	2
(< 60%)	0.0%	1.6%	0.0%	0.0%	0.5%
TOTAL	181	122	69	20	392

Chi Square = 13.6781 DF = 9 Prob = 0.1342

TABLE 4-28. Regression analysis of FEV1B % predicted and exposure index

	N	Regr Coeff	Std. error	T	Prob
All	407	- 0.0419	0.0308	- 1.36	0.1741
Non-Smokers	150	0.0443	0.0456	0.969	0.3338
Current Smokers	160	- 0.0546	0.0478	- 1.139	0.2563
Ex-Smokers	96	- 0.0638	0.0727	- 0.879	0.3819

TABLE 4-29. Regression analysis of FEF2575B and exposure index

	N	Regr Coeff	Std. error	T	Prob
All	405	- 0.1478	0.0570	- 2.59	0.0099
Non-Smokers	150	- 0.0855	0.0842	- 1.02	0.3110
Current Smokers	158	- 0.1214	0.0917	- 1.32	0.1874
Ex-Smokers	96	- 0.2158	0.1305	- 1.65	0.1016

TABLE 4-30. Multiple linear regression analysis of FEV1B % predicted with exposure indices

	407 Cases			
	Reg Coeff	Std. error	T	Prob
Exposure index	- 0.0192	0.00360	- 0.536	0.5925
Years exposed	0.0941	0.1025	1.918	0.3591
Pack years	- 0.2440	0.0367	- 6.651	<0.0001

TABLE 4-31. Multiple linear regression analysis of FEF2575B with exposure indices

	405 Cases			
	Reg Coeff	Std. error	T	Prob
Exposure index	- 0.0625	0.0660	- 0.947	0.3440
Years exposed	- 0.0528	0.1851	- 0.285	0.7757
Pack years	- 0.4288	0.0666	- 6.44	<0.0001

TABLE 4-32. Regression analysis of FEV1/FVC ratio before shift and exposure index

	N	Regr Coeff	Std. error	T	Prob
All	407	- 0.0621	0.0127	- 4.89	<0.0001
Non-Smokers	150	- 0.0354	0.0200	- 1.769	0.0790
Current Smokers	160	- 0.0542	0.0195	- 2.77	0.0062
Ex-Smokers	96	- 0.084	0.0283	- 2.97	0.0038

TABLE 4-33. Multiple linear regression of FEV1/FVC ratio before shift with exposure indices for all employees

	407 Cases			
Variable	Reg Coeff	Std. error	T	Prob
Exposure Index	- 0.0339	0.0143	- 2.365	0.0185
Years exposure	0.0510	0.0513	0.994	0.3209
Age	- 0.1292	0.0391	- 3.301	0.0010
Pack Years	- 0.0951	0.0153	- 6.228	<0.0001

TABLE 4-34. Multiple linear regression of FEV1/FVC ratio before shift with exposure indices for non-smokers

Variable	Reg Coeff	Std. error	T	Prob
Exposure Index	- 0.0175	0.0232	- 0.753	0.4529
Years exposure	0.0116	0.0866	- 0.134	0.8939
Age	- 0.0995	0.0615	- 1.616	0.1081

TABLE 4-35. Multiple linear regression of FEV1/FVC ratio before shift with exposure indices for smokers

Variable	Reg Coeff	Std. error	T	Prob
Exposure Index	- 0.0166	0.0220	- 0.753	0.4524
Years exposure	0.0080	0.0818	- 0.098	0.9218
Age	- 0.0821	0.0654	- 1.254	0.2117
Pack years	- 0.1383	0.0272	- 5.084	<0.0001

TABLE 4-36. Multiple linear regression of FEV1/FVC ratio before shift with exposure indices for ex-smokers

Variable	Reg Coeff	Std. error	T	Prob
Exposure Index	- 0.0754	0.0322	- 2.346	0.0212
Years exposure	0.1661	0.1036	1.603	0.1123
Age	- 0.3111	0.0847	- 3.673	0.0004
Pack years	- 0.0411	0.0278	- 1.479	0.1427

TABLE 4-37. Multiple linear regression of decrease in FEV1 during work shift with various indices of exposure

Variable	Regr Coeff	Std. Error	T	Prob
Dust level	0.2621	0.5911	0.4433	0.6578
Pack years	0.0670	0.6710	0.0997	0.9206
Age	3.915	1.7218	2.2737	0.0235
Exposure index	- 0.5673	0.6387	- 0.8883	0.3749
Years exposed	- 0.1395	2.257	- 0.0618	0.9507

TABLE 4-38. Pulmonary function decrease during work shift as a function of current dust exposure level

FEV1 Change	Dust level mg/m^3 < 4	> 4 - 10	>10-15	>15	TOTAL
< 10% decrease	168 (94.9%)	22 (91.7%)	10 (90.9%)	31 (93.9%)	231 (94.3%)
≥ 10% decrease	9 (5.1%)	2 (8.3%)	1 (9.1%)	2 (6.1%)	14 (5.7%)
TOTAL	177	24	11	33	245

Chi Square = 0.675884 DF = 3 Prob = 0.8789

FEF2575 change				
< 10% decrease	149 (84.2%)	21 (87.5%)	9 (81.8%)	27 (81.8%
≥ 10%<20% dec.	18 (10.2%)	2 (8.3%)	5 (11.4%)	
≥ 20% decrease	10 (5.6%)	1 (4.2%)	3 (6.8%)	
TOTAL	177	24	44	

Chi Square = 0.603405 DF = 6 Prob = 0.9963

TABLE 4-39. Individual linear regressions at current dust level and pulmonary function test parameters

Test	N	Regr Coeff	Std. error	T	Prob
DFEV1	245	0.0117	0.5724	0.0204	0.9837
DFEF2575	243	0.0304	0.0263	1.158	0.2481
Ratio B	245	0.0079	0.0157	0.506	0.6130
FEF2575B Pred	243	- 0.0020	0.6606	- 0.033	0.9736
FEF2575A Pred	245	- 0.0329	0.0625	0.526	0.5993
FEV1B	245	0.8679	1.911	0.454	0.6502
FEV1B Pred	245	0.0057	0.0347	0.164	0.8699
FEV1A Pred	245	0.0035	0.0369	0.0959	0.9237

TABLE 4-40. Comparison of before shift FEV1 percent predicted, FEV/FVC ratio, and FEF2575 percent predicted by job and smoking status

	TOTAL			NON-SMOKERS			SMOKERS		
	FEV1 % Pred	Ratio FEV1/FVC	FEF2575	FEV1 % Pred	Ratio FEV1/FVC	FEF2575	FEV1 % Pred	Ratio FEV1/FVC	FEF2575
All jobs	98.46	80.03	81.61	102.26	82.11	87.45	96.40	78.90	78.16
Elevator Manager	97.02	77.82	74.87	101.09	81.27	84.45	95.32	76.39	70.70
Supervisor/Foreman	98.53	77.75	77.78	104.30	79.30	82.60	95.91	77.05	75.59
Clerical/QA/Lab	101.21	82.16	86.35	104.72	82.97	90.75	95.19	80.76	78.81
Grain Handler-Gen'l	98.00	80.22	82.51	100.81	81.71	85.48	96.18	79.25	80.56
Receiving/Inspection	95.33	79.22	76.45	101.86	81.93	87.71	93.67	78.60	72.86
Shipping	99.00	80.11	80.95	99.50	79.75	77.50	98.64	80.36	83.45
Bin Operator	105.89	81.94	94.78	113.25	86.50	106.00	103.79	80.64	91.57
Basement Floor Operator	106.60	81.60	89.60	106.50	82.00	87.00	106.67	81.33	91.33
Maintenance/Electrical	97.95	80.51	83.07	98.38	83.56	88.44	98.32	79.59	80.98
Control Room Operator	96.71	79.71	79.57	104.00	82.57	92.14	90.86	76.86	67.00
Prob (ANOVA)	0.4398	0.0841	0.3860	0.5854	0.4370	0.7438	0.7719	0.5445	0.6511

TABLE 4-41. Before shift comparison of FEV1 percent predicted, FEV1/FVC ratio, and FEF2575 percent predicted of clerical workers with other workers by smoking status - numbers in ()

All Employees	Clerical	Other	Prob 1 tail	Prob 2 tail
FEV1 percent predicted	101.2 (57)	98.02 (350)	0.0898	0.1796
FEF2575 predicted	86.35 (57)	80.83 (348)	0.1011	0.2023
Ratio FEV1/FVC	82.16 (57)	79.75 (350)	0.0069	0.0137

Non-Smoking Employees	Clerical	Other	Prob 1 tail	Prob 2 tail
FEV1 percent predicted	104.91 (36)	101.48 (114)	0.0882	0.1764
FEF2575 predicted	90.75 (36)	86.41 (114)	0.1636	0.3272
Ratio FEV1/FVC	82.97 (36)	81.83 (114)	0.1415	0.2831

Smoking	Clerical	Other	Prob 1 tail	Prob 2 tail
FEV1 percent predicted	95.19 (21)	96.34 (236)	0.3914	0.7828
FEF2575 predicted	78.81 (21	78.11 (234)	0.4637	0.9274
Ratio FEV1/FVC	80.76 (21)	78.64 (236)	0.1091	0.2182

APPENDIX

A

Health & Hygiene, Inc.

October 19, 1990

Dear Mr. ___________:

This is to confirm our telephone conversation and arrangements for the research project sponsored by the National Grain and Feed Association. Materials are enclosed for distribution to your employees. Staff from Health & Hygiene will arrive at your elevator on _________________. It is extremely important that participating employees come directly to the testing area prior to entering the elevator for their initial breathing test.

Selected employees will be asked to wear a dust sampling device during their workshift. Approximately 4-5 hours into the workshift employees will return to complete a questionnaire and repeat their breathing test. Dust sampling devices will be removed after 6-7 hours.

A conference will be held with management to review the day's procedures. A brief medical examination will be conducted and employees will be given the results of their examination.

After all testing has been completed you will receive a summary report of medical examinations and dust sampling results.

Sincerely,

David Rice, RN

/jc

Enclosure

420 Gallimore Dairy Road • Greensboro, North Carolina 27409 • (919) 665-1818

ATTACHMENT 2-2

EMPLOYEE INFORMATION

Our company has agreed to be part of a national study sponsored by the National Grain and Feed Association on grain dust. A representative from Health & Hygiene, Inc., Greensboro, North Carolina will be at our facility on ________________ to conduct this study. All employees are asked to participate by having a breathing test done and completing a questionnaire. Some employees will be asked to wear a sampling device which measures dust exposure on the job.

To get the best possible test results, a few simple rules should be followed. First, it is extremely important that you have your breathing test before going to your regular job. Report direct to __________________________, Second, we ask that you

DO NOT SMOKE
DO NOT EAT A HEAVY MEAL
DO NOT USE MEDICINE TO HELP YOUR BREATHING

for one hour before you are tested.

A nurse or physician from Health & Hygiene will visit our facility later to follow-up the tests. Your test results will be discussed with you at that time. There is no cost to you for this service. Our company and the grain industry, as well as each of you, will benefit from this research. We encourage your participation. If you have questions, please contact __________________________.

A Research Study on Employee Exposure to Grain Dust

...And How You Can Help...

Our company is cooperating in a major research project on employee exposure to grain dust sponsored by the National Grain and Feed Association.

As a valued employee, we want to share with you information on this research and how you can help.

What are the Purpose and Goals of the Project?

To help answer questions about grain dust and its effect on workers exposed to it. We know dust can be an irritant and nuisance in heavy concentrations and can bother individuals with allergies or respiratory problems. But it is not known if there are significant effects on normal healthy workers.

The project has two major goals:

▲ To determine actual levels of employee exposure to grain dust.

▲ To find out whether health effects on the respiratory system happen more often among grain workers than the general population.

With better information, the industry and our company can decide what, if any, additional protective measures are needed to reduce grain dust exposure. Since the health of our workers is of vital concern to us, we believe participation in this project is important.

Who Will Do the Tests?

Health and Hygiene Inc., of Greensboro, N.C., a respected health research organization.

How Can You Help?

By cooperating with the medical doctor or nurse and industrial hygiene technician who will visit our facility soon as part of the research team. Of course, your participation is voluntary and there is no cost to you. Ask your manager any questions you may have before or during the project.

What's Involved in the Testing?

If you participate, you'll be asked to take part in three ways:

▲ By showing how well your lungs function by blowing into a device that measures how much and how fast you can expel air from your lungs.

▲ By answering questions about your general health and any allergies you may have.

▲ By taking a limited medical examination done by the doctor or nurse at our plant. Only your nose and throat will be examined, and your heart and lungs will be listened to through a stethescope.

You may also be asked to wear a small collection device located on your shirt that samples the air you are breathing for a few hours while you work.

Are Test Results Confidential?

Yes! Researchers will discuss your test results with you and will not release the results to anyone else – even your employer – without your written permission. Results obtained from monitoring employees in our plant will be combined with data from hundreds of other workers in our industry to provide more grain dust exposure information than has ever been available before.

Will You Help?

Although grain dust exposure has not been a major problem at our facility, we need to learn more. This project is a good way to do it. It will involve a minimum of time and inconvenience on your part. Yet the results hopefully will provide real benefits for our employees and our industry. We hope as many of our employees as possible will participate.

Thanks for your help!

APPENDIX

B

Health & Hygiene, Inc.

MEDICAL CONSENT FORM

NAME (please print) ______________________________________

I agree to participate in a research study sponsored by the National Grain and Feed Association and conducted by Health & Hygiene, Inc. I understand that my medical evaluation will consist of a breathing test, respiratory questionnaire, and limited physical examination. I also understand that this evaluation will be maintained in a confidential manner by Health & Hygiene, Inc. and released only with my written permission, but that the data, without identifying me, may be used in reports to the National Grain and Feed Association.

Signed: ______________________

Date: ______________________

Witness: ___________________________

420 Gallimore Dairy Road • Greensboro, North Carolina 27409 • (919) 665-1818

RESPIRATOR USER'S QUESTIONNAIRE

DATE ______________

A. IDENTIFICATION

Plant (site) ______________ Job ______________
Current Work Schedule ______________

Name ______________ SS# ______________

DOB ________ Ht ______ Wt ______ Race _____ Sex ______

B. MEDICAL HISTORY

Have you ever been told you had or been treated for: (please explain yes responses)

1. Asthma, hayfever or sinusitis ______________
2. Emphysema, bronchitis or respiratory problems ______________
3. Allergies ______________
4. Diabetes ______________
5. Cancer ______________
6. High blood pressure ______________
7. Heart problems ______________
8. Emotional illness ______________
9. Fainting or seizures ______________
10. Ruptured eardrum ______________
11. Defective vision (wear glasses or contacts) ______________
12. Defective hearing ______________
13. Are there other conditions which may interfere with respirator use or result in limited work activity? ______________

C. OCCUPATIONAL HISTORY

1. How long with current employer? ______________
2. How long with present job? ______________
3. How many hours of exposure per day? ______________
4. Present or previous work exposures to: (please circle)

Wood Dust	Y	N	Chromium	Y	N
Silica	Y	N	Sand blasting	Y	N
Foundry	Y	N	Solvents	Y	N
Asbestos	Y	N	Cotton, flax, hemp	Y	N
Formaldehyde	Y	N	Urethane foam	Y	N

Other (identify) ______________

5. Exposure to dusts or chemicals at home or on 2nd job? ______________

6. Is there a dust or chemical at work that causes breathing problems?

____

D. RESPIRATORY HISTORY

1. Cough
Do you usually cough (on getting up) first thing in the morning? (Count a cough with first smoke or on "first going out of doors." Exclude clearing throat or a single cough.) Yes _____ No ___

Do you usually cough during the day or at night? (Ignore an occasional cough) Yes _____ No _____

If "Yes" to either question:

Do you cough like this on most days for as much as three months a year? Yes _____ No _____

Do you cough on particular day of the week? Yes _____ No ___

2. Phlegm

Do you usually (on getting up) bring up any phlegm from your chest first thing in the morning? (Count phlegm with the first smoke or on "first going out of doors." Exclude phlegm from the nose. Count swallowed phlegm). Yes _____ No _____

Do you usually bring up any phlegm from your chest during the day or at night? Accept twice or.) Yes _____ No _____

If "Yes" to either question:

Do you bring up phlegm like this on most days for as much as three months each year? Yes _____ No _____

If "Yes" to question:

How long have had this (cough) phlegm? (Write in number of years)

__________ 2 years or less
__________ More than 2 years - 9 years
__________ 10-19 years
__________ 20+ years

3. Chest illnesses

In the past three years, have you had a period of (increased) *cough and phlegm lasting for 3 weeks or more?

No ____
Yes, only one period ____
Yes, two or more periods ____

* For subjects who usually have phlegm

During the past 3 years have you had any chest illness which has kept you off work, indoors at home or in bed? (for as long as one week, flu?) Yes ____ No ____

If "Yes": Did you bring (more) phlegm than usual in any of these illnesses? Yes ____ No ____

If "Yes": During the past three years have you had:

Only one such illness with increased phlegm Yes ____ No ____

More than one such illness Yes ____ No ____

4. Tightness

Does your chest ever feel tight or your breathing become difficult? Yes ____ No ____

Is your chest tight or your breathing difficult on any particular day of the week? (after a week or 10 days away from the mill) Yes ____ No ____

If "Yes" Monday:

At what time on Monday does your chest feel tight or your breathing difficult?

Before entering the mill ____
After entering the mill ____

Ask only if NO to Question:

In the past, has your chest ever been tight or your breathing difficult on any particular day of the week? Yes ____ No ____

If "Yes": Which day?

Mon. Tues. Wed. Thur. Fri. Sat. Sun.

(1) Sometimes (2) Always

5. Breathlessness

Are you ever troubled by shortness of breath when hurrying on the level or walking up a slight hill? Yes _____ No _____

If "No", grade is 1. If "Yes", proceed to next question.

Do you get short of breath walking with other people at an ordinary pace on the level? Yes _____ No _____

If "No", grade is 2. If "Yes" proceed to next question.

Do you have to stop for breath when walking at your own pace on the level? Yes _____ No _____

If "No", grade is 3. If "Yes", proceed to next question.

Are you short of breath on washing or dressing? Yes _____ No _____

If "No", grade is 4. If "Yes", grade is 5.

6. Tobacco use

Do you smoke? Yes _____ No _____
Record "Yes" if regular smoker up to one month ago. (Cigarettes, cigar or pipe)

If "No":

Have you ever smoked? (Cigarettes, cigars, pipe. Record "No" if subject has never smoked as much as one cigarette a day, or 1 oz. of tobacco a month, for as long as one year) Yes _____ No _____

If cigarettes, how many packs per day? ______________________________
(Write in number of cigarettes)

Number of pack years:

If an ex-smoker (cigarettes, cigar or pipe), how long since you stopped? (Write in number of years)
0-1 year _____
1-4 years _____
5-9 years _____
10+ years _____

Do you wear a respirator on your job? ______________________
Type ____________ How much of your work day is a respirator worn? ______________________

Have you had breathing problems at work in the past year that you attribute to work? (Explain) ______________________
____

Employee Signature ______________ Interviewer ________

APPENDIX

C

Elevator ID: ____________
Recorder: ______________
Date: __________________

WORKER EXPOSURE TO DUST
IN THE GRAIN INDUSTRY

National Grain and Feed Association
Washington, DC

Facility Name: ____
Address: ____
____
____
Contact: ____
Title: ____
Telephone: ____

Health & Hygiene, Inc.
Greensboro, North Carolina

ELEVATOR ID: ____________________
RECORDER: ____________________
DATE: ____________________

Health & Hygiene, Inc.

ENVIRONMENTAL MONITORING
SAMPLE LOG

DATE	SAMPLE NO.	EMPLOYEE OR SAMPLE LOCATION	PUMP NO.	FLOW RATE L/min	TIME			CONTAMINANT	RESULT · UNITS
					On	Off	Min		

WORK ACTIVITY: ____________________

COMMENTS: ____________________

LOCATION: ____________________

SAMPLED BY: ____________________

ELEVATOR ID: ____________
RECORDER: ____________
DATE: ____________

Health & Hygiene, Inc.

CALIBRATION LOG

CLIENT ____________

SAMPLING ELEMENT ____________

PUMP ____________

NO.: ____________

Soln/Amt: ____________

Config: ____________

VOLUME INDICATOR ____________

TEMP ____________

PRESSURE ____________

PUMP NO.	FLOW SET	CALIB VOL	TIME or COUNT				FLOW RATE
			1	2	3	Avg	

By ____________

Date ____________

Elevator ID: ____________
Recorder: ____________
Date: ____________

ELEVATOR QUESTIONNAIRE

Facility Information

Type elevator? Country ______ Terminal ______ Export ______

Region? Central_____ SE_____ NE_____ SW_____ NW_____

Date elevator built?________________ Additions?________________

What is elevator capacity?________________ Throughout?________

Number of bins?________________ Type bins?________________

How many months/year is elevator operated? ________________

What types of grain are handled? Barley______ Corn______
Flax______ Milo______ Oats______ Rice______
Soybeans______ Sunflowers______ Wheat______
Other ________________________________

What grain conveying equipment is used? Belts_____ Drags______
Serew conveyors_____ Elevators_____ Others________________

Facility Operations

What types of unloading done? Truck______ Rail______

What types of loading done? Truck______ Rail______
Barge_______ Ship_______

Is cleaning done?___________ Drying?________________

Dust Controls

What engineering techniques are used for dust control?__________
____
____

What type of dust collection is used? Cyclone_______
Baghouse________ Other________________________

Are working areas open or enclosed?____________________________
____

Is an oil additive used for dust control?______________________
Which one?____________________ At what rate?__________________

Do employees typically use respirators?________________________
What type?____
Is there a wrtten program?____________________________________

What clean up procedures are used?____________________________

Current Operations

What grain(s) are being handled today? Barley______ Corn______
Flax______ Milo______ Oats______ Rice______
Soybeans______ Sunflowers______ Wheat______.
Other________________________________

What is the moisture content of the grains being handled?______
____
____

Are current conditions typical or normal?______________________
If no, explain.____
____

Comments
____
____
____
____
____
____

Facility ID: ______________
Recorder: ______________
Date: ______________

OBSERVATIONS

1. Schematic layout of elevator area

Indicated loading/unloading sites, dust control equipment, pulmonary tests site, area sampling locations

2. Employee activities and work practices

3. Engineering/Administrative controls

4. Respiratory Protection