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Total Dust, Respirable Dust, and Microflora Toxin Concentrations in Colorado Corn Storage Facilities

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To aid in the process of characterizing corn dust exposures on farms and in elevators in northeastern Colorado, several parameters were examined. Total dust and respirable dust samples were collected and evaluated. Potentially dangerous dust components evaluated were respirable silica, endotoxin, and mycotoxin levels. Many of the total dust samples (58%) would have exceeded 8-hour time-weighted average (TWA) had sampling been conducted for 8 hours; on farms the operation takes between two and four hours. The same statement may be made for respirable dust samples collected for this project. Nearly 33 percent of the respirable dust samples collected would have exceeded the Occupational Safety and Health Administration (OSHA) TWA had sampling been conducted over an 8-hour period. Respirable silica standards were exceeded at 25 percent of the sampling locations. Presence of mycotoxins at all sites was confirmed by the use of ELISA kits. The most significant finding of this study was high levels of endotoxin at several of the sampling sites. Eighty-five percent of the sampling locations had endotoxin levels above 500 EU/m³. One location, Farm 4, had endotoxin levels of above 1.7 million EU/m³.

Keywords Agricultural Dust Exposures, Endotoxins, Respirable Grain Dust Exposures

Grain dust exposure is common to those employed in agriculture. Exposures to dust on farms and in elevators have been associated with several respiratory effects. Sneezing, coughing, eye irritation, phlegm production, and decreased lung function are common symptoms of exposure.⁽¹⁾ Chronic bronchitis, asthma, and possibly pneumoconiosis may result from long-term exposures to dusts in an agricultural setting.^(2,3) Research has shown that Colorado farm and grain elevator workers are exposed to dust concentrations that exceed existing exposure limits.^(4,5) Personal protective equipment, in the form of respirators, are not commonly used by agricultural workers. Research in California

demonstrated that time spent performing dusty tasks did not correspond with increased respirator usage.⁽⁶⁾

Particle size, as determined by respirable dust samples, is important in determining deposition regions in the respiratory system. Since grain dusts are a complex and highly variable mixture of components, contaminants in the dust are also of concern. Endotoxin exposures have been linked to acute respiratory impairment and may lead to chronic obstructive pulmonary disease (COPD).⁽⁷⁾ Respirable silica exposures, although not common, do occur, especially in sandy soils of the western United States.⁽³⁾

Mycotoxins, in general, are known to produce effects in livestock, and aflatoxin is listed as a suspected human carcinogen.⁽⁸⁾ These mycotoxin effects are noted for oral intake. The effects of inhalation exposures to these contaminants are not currently known. Corn dust characterization is a specific area that has not been extensively studied. Given the research on other grain dusts and the potential for acute or chronic illness in exposed workers, this study is warranted.

MATERIALS AND METHODS

Seven grain elevators and five farms in northeastern Colorado were surveyed between June and August of 1998. Most of the elevators were operating in conjunction with an on-site feed mill. The five participating farms were all larger than 1,000 acres, and corn was the primary crop produced in terms of acres planted. All the grain bins in the survey had been filled in late October or early November. The length of time corn was stored at the elevators in the study was very different, ranging from nine months to three weeks. Farms and elevators were all located in the three largest corn producing counties in Colorado.

Samples were collected during the performance of routine elevator operations, some of which included bin clean-out tasks, and bin clean-out activities on the farm. All farm samples were collected inside the grain bins. Both personal and area sampling were conducted at all sites. All samples collected for endotoxin or mycotoxin analysis were area samples. Area sampling for total dust, respirable dust, and respirable silica were collected from

heights that were approximately breathing-zone level of workers in the occupational environment. Sampling times ranged from two hours to seven and one half-hours.

To characterize the exposure hazard, a variety of samples were collected. All samples were collected using MSA and SKC sampling pumps. Total dust samples were collected using 37-mm, 5 μm pore size polyvinyl chloride filters with a calibrated pump flow rate of 2.0 liters per minute. Respirable dust and respirable silica samples were collected using 10-mm Bendix nylon cyclones calibrated to a flow rate of 1.7 liters per minute. Total dust and respirable dust filters were desiccated for 24 hours and were then preweighed. After sampling, the filters were once again desiccated for 24 hours and postweighed. Gravimetric analysis was accomplished using a Mettler H54AR mechanical analytical balance accurate to ± 0.01 mg. Respirable silica analysis was coordinated through NIOSH. Sample analysis included both gravimetric analysis and X-ray diffraction.

Endotoxin and mycotoxin samples were collected using 0.45- μm pore size polycarbonate filter in a 37-mm filter cassette. The flow rate was calibrated to 1.0 liter per minute. These samples were frozen on return from the field and sent to NIOSH for analysis using the Limulus amoebocyte lysate test. Aflatoxin, vomitoxin, and zearalenone were the three mycotoxins of interest. The mycotoxin samples were analyzed using an enzyme linked immunoassay (ELISA) obtained from Diagnostix Inc., Mississauga, Ontario, Canada. This assay determines the concentration (ng/ml, or ppb) of a specific mycotoxin from dust samples collected at all 12 sites. In this assay an antibody specific for one of the mycotoxins had been coated to the wells of a 96-well microtiter plate. After adding controls, standards, and sample extracts, absorbance was measured at a wavelength of 450 nanometers (nm) on a Molecular Dynamics MTP reader (model Bio-Tek Elx 800). The absorbance was directly proportional to the amount of a specific mycotoxin in the sample. The absorbance was converted to parts per million or billion, depending on the mycotoxin, by using a standard curve prepared on the same day of sample analysis.

This study was designed to characterize potential exposure parameters at farms and elevators. Therefore, the data were analyzed in a descriptive nature. Ranges, means, percentages, standard deviations, and histograms are examples of the descriptive statistical methods used to present the data. The t-test for independent samples was used to determine if the sample means for the farms and elevators were statistically different. Microsoft Excel 97 SR-1 was used for performing statistical functions. The Student Edition of Minitab 8 was used to perform the t-test analysis.

RESULTS

Total Dust

The total dust concentrations measured at the five farms yielded a range of 0.71 to 335 mg/m^3 . Farm 4 had the highest

mean total dust concentration of all the farm sites sampled, at 225 mg/m^3 . Farm 3 had the lowest total dust concentration and highest level of corn still in the grain bin. The bin was 75 to 80 percent full during sampling. There was very little visible dust in the air at this location. Farm 3 was also the only farm location at which the grain bin could not be accessed from a ground level entry point; access into the bin was from the roof. Farm 4 was tremendously dusty inside the grain bin. The mean total dust concentration for this location was over 225 mg/m^3 . Total dust concentrations at this location ranged from 153 to 335 mg/m^3 . Farm 4 was the only site where three workers used dust masks.

All farms except for Farm 3 had total dust concentrations that would have exceeded legally enforceable or recognized exposure standards had sampling been conducted over an 8-hour sampling period. The relevant exposure standards for this project were the Occupational Safety and Health Administration's Permissible Exposure Limit (OSHA PEL) and the American Conference of Governmental Industrial Hygienists (ACGIH[®]) Threshold Limit Value (TLV[®]) for particulates not otherwise classified (PNOC).⁽⁹⁾ The PNOC TLVs have been established at 10.0 mg/m^3 and 3.0 mg/m^3 , respectively, for total dust and respirable dust. The OSHA PELs are set at 15.0 mg/m^3 for total dust and 5.0 mg/m^3 for respirable dust PNOC.⁽⁹⁾

Elevators participating in the study had a mean total dust concentration of 74.1 mg/m^3 , while individual site concentrations ranged from 2.2 mg/m^3 to 255 mg/m^3 . Three of the participating elevators, sites 1, 2, and 6, had mean dust concentrations below the OSHA PEL and the ACGIH TLV for PNOC.⁽⁹⁾ Elevators 3 and 5 had mean total dust concentrations of 22.9 and 29.2 mg/m^3 , respectively, while Elevator 4 had a mean concentration of 60.6 mg/m^3 . Elevator 7 had the highest mean total dust concentration at nearly 255 mg/m^3 .

Total dust concentrations calculated for all of the sampling locations demonstrated the potential for worker overexposure during bin clean-out activities on farms and in elevators. Fifty-eight percent of the samples collected would have exceeded the OSHA PNOC exposure restrictions had the samples been collected over an 8-hour sampling period. Often, hired workers on farms or the newest employees at elevators are given the dustiest jobs. These activities, such as grain bin clean out, are often performed without use of a respirator or any type of exhaust ventilation. Table I contains total dust concentration data collected during this project.

Respirable Dust

The mean respirable dust exposure at the farms surveyed was 3.1 mg/m^3 with a range from 0.2–8.2 mg/m^3 . The mean respirable dust concentration for each farm was below enforceable or legal limits, but Farms 4 and 5 exceeded recommended limits. The OSHA PEL for respirable dust classified as a particulate not otherwise classified (PNOC) is 5.0 mg/m^3 , while the ACGIH TLV for respirable nuisance dust is 3.0 mg/m^3 .⁽⁹⁾ Farm 3 had the lowest mean respirable dust concentration. The grain bin used at this location was around 80 percent full of corn and also had the

TABLE I

Total dust concentration data from farms and elevators in northeastern Colorado, January 1999

Location	Averaged total dust concentration (mg/m ³)	Mean total dust concentration by farm or elevator	Range	Standard deviation	t-test p-value ^A
Farm 1	22.1 (N = 2)	81.4 mg/m ³ (N = 13)	0.7 to 335 mg/m ³	94	.73
Farm 2	12.9 (N = 3)				
Farm 3	0.8 (N = 2)				
Farm 4	225 (N = 3)				
Farm 5	99.3 (N = 3)				
Elevator 1	2.2 (N = 2)	74.0 mg/m ³ (N = 20)	1.6 to 644 mg/m ³	90.8	.73
Elevator 2	6.5 (N = 2)				
Elevator 3	22.9 (N = 3)				
Elevator 4	60.1 (N = 2)				
Elevator 5	29.2 (N = 3)				
Elevator 6	4.2 (N = 4)				
Elevator 7	255 (N = 4)				

^AP-value for comparison of mean concentrations of total dust measured at farms and elevators.

lowest total dust concentration of any farm. Farms 1, 4, and 5 contained the least amounts of corn in the bin. Farm 1 had the second lowest respirable dust mean. Farms 4 and 5 had mean respirable dust concentrations of 4.3 and 4.6 mg/m³, respectively. These two farms also had the highest mean total dust concentrations. All respirable dust samples were collected inside the grain bin.

The mean respirable dust concentration for all elevators was 5.1 mg/m³, with a standard deviation of 12.8 mg/m³ and a range from 0.1 to 68.8 mg/m³. Excluding Farm 7, the mean respirable dust concentrations would have been 0.4 mg/m³, with a standard deviation of 0.17 and a range of 0.1 to 0.5 mg/m³. Elevators that were part of a feed mill operation generally had some form of

dust control device or had a transfer system with small cracks from which dust would escape. Elevator 4 actually had a cyclone separator that was supposedly designed to remove dust from corn before it enters the milling process. One-third of all the respirable dust samples collected exceeded the ACGIH TLV for PNO of 3.0 mg/m³.⁽⁹⁾ Since none of the workers observed wore an approved respirator, they were inhaling small dust particles capable of penetrating deep into the respiratory system. Data for respirable dust concentrations are shown in Table II.

Respirable Silica

Most of the respirable silica samples collected at the 12 locations were below the analyzing laboratory's detection limit

TABLE II

Respirable dust concentrations calculated from data collected at 12 sites in northeastern Colorado, December 1998

Location	Mean respirable dust concentrations (mg/m ³)	Farm or elevator mean (mg/m ³)	Standard deviation (mg/m ³)	Sample range (mg/m ³)	t-test p-value ^A
Farm 1	1.8 (N = 2)	3.1 (N = 16) (TLV = 3.0)	1.7	0.2-8.2	.50
Farm 2	2.3 (N = 4)				
Farm 3	0.5 (N = 2)				
Farm 4	4.3 (N = 4)				
Farm 5	4.6 (N = 4)				
Elevator 1	0.4 (N = 4)	5.1 (N = 28) (TLV = 3.0)	12.8	0.1-68.8	.50
Elevator 2	0.3 (N = 5)				
Elevator 3	0.3 (N = 3)				
Elevator 4	0.6 (N = 4)				
Elevator 5	0.7 (N = 5)				
Elevator 6	0.4 (N = 3)				
Elevator 7	33.2 (N = 4)				

^AP-value for comparison of mean concentrations of respirable dust measured at farms and elevators.

TABLE III
Endotoxin data collected from 12 sampling locations in northeastern Colorado, Summer, 1998

Location	Mean endotoxin levels (EU/m ³)	Farm or elevator average (EU/m ³)	Standard deviation	t-test p-value ^A
Farm 1	2.1×10^3 (N = 2)	3.7×10^5	5.7×10^5	.56
Farm 2	4.8×10^3 (N = 2)			
Farm 3	8.5×10^4 (N = 2)			
Farm 4	1.73×10^6 (N = 1)			
Farm 5	3.9×10^3 (N = 2)			
Elevator 1	2.6×10^2 (N = 2)	9.4×10^4	1.7×10^5	.56
Elevator 2	2.3×10^5 (N = 2)			
Elevator 3	5.1×10^2 (N = 2)			
Elevator 4	3.9×10^4 (N = 2)			
Elevator 5	5.2×10^2 (N = 2)			
Elevator 6	2.7×10^2 (N = 2)			
Elevator 7	3.9×10^5 (N = 2)			

^AP-value for comparison of mean concentrations of endotoxin measured at farms and elevators.

for respirable silica of 0.01 mg. Farm 5 and Elevators 4 and 7 were above the ACGIH TLV for respirable silica of 0.1 mg/m³.⁽⁹⁾ Elevators 4 and 7 had concentrations of 0.33 mg/m³ and 0.26 mg/m³, respectively. Farm 5 had the highest mean respirable silica concentration at 0.60 mg/m³.

Endotoxins

There is currently no TLV or PEL for endotoxin, but different thresholds of effect that have been cited in the literature as producing certain effects: ODTs (10,000 EU/m³), acute bronchoconstriction (1000 EU/m³), and mucous membrane irritation (200 EU/m³).⁽⁴⁾ Only two of the mean endotoxin values were less than the lower threshold levels cited in the literature of 200 EU/m³. Elevators 1 and 6 were the only sampling locations under this threshold. The highest endotoxin levels were found at Farm 4. Samples from this farm had endotoxin levels of 1.7 million EU/m³. At Farms 2 and 3 endotoxin levels were taken both inside and outside the grain bin. At Farm 4, endotoxin samples were restricted to a sample from outside the bin. Farms 1 and 5 had all samples taken from inside the grain bin. Samples collected outside had higher endotoxin levels than those collected inside the bin, but was there was variability among those samples collected inside the bin. Elevators 2, 4, and 7 had high endotoxin levels that ranged from nearly 40,000 to almost 400,000 EU/m³. The t-test p-value indicates that there is no significant difference between the mean farm and mean elevator endotoxin levels. All endotoxin samples were analyzed by a NIOSH laboratory. The endotoxin data are summarized in Table III.

Mycotoxins

Three mycotoxins, aflatoxin, vomitoxin, and zearalenone, were measured by an ELISA testing procedure. The assay identified traces of all of the three mycotoxins from all of the locations. The implications of these results are currently unknown. There

are established guidelines for mycotoxin concentrations in animal feeds and milk, but very little research has been performed to determine the significance of respirable mycotoxin exposures.

CONCLUSIONS

Farm and elevator workers are potentially exposed to high levels of corn dust while performing job-related tasks. These tasks include bin clean-out activities, which are a combination of manual and machine labor that generate large quantities of dust. There are contaminants in the dust such as silica, endotoxins, and mycotoxins that may be capable of increasing the hazard associated with dust exposure. During this project very few people were observed wearing any type of respiratory protection. There is a lack of education on the potential health effects of grain dust exposure in general. However, many of the participants would ask questions about respiratory illnesses. Two methods of decreasing worker exposure are listed below:

- To protect workers in the dust-filled grain bin, it is strongly recommended that some form of local exhaust ventilation be used when the last third of the grain bin is being emptied. Above this point little dust is generated in the bin and no manual labor is required. Below this level, dust-generating activities such as shoveling and sweeping grain greatly increase dust concentrations.
- NIOSH-approved respirators should be required equipment when working in grain bins due to the dust concentration, particle size distribution supported by the respirable dust concentrations, and potential contaminants of dust found as part of this study.

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