Grain and Endotoxin Exposure Monitoring Results

British Columbia Grain Elevators
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Report to HRDC Labour Program

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1. Introduction

The Occupational Lung Diseases Research Unit, University of British Columbia, has been conducting the Medical Surveillance Program, required by Labour Canada, since 1975. As part of this program, exposure monitoring has been carried out by Labour Canada officers at 3 year intervals. The last testing was conducted during 1996.

Summary results of the health monitoring from the 1996 tests were presented in the report entitled "7th Medical Surveillance Program Report" was previously submitted to the Terminal Elevator Operators. A copy of that report is appended here.

In 1996, exposure monitoring was carried out by Labour Canada officers following a protocol developed jointly by Labour Canada and UBC. In addition to evaluating airborne dust, the samples were further analysed for the endotoxin content of the dust. This report describes the results of the dust and endotoxin sampling.

2. Background

Grain dust is a mixture of kernels, husk, and contaminants, including mites, microorganisms, silica, pesticides, and other plant and animal material. One contaminant is bacterial endotoxin, present in the outer membrane of Gram-negative bacteria commonly found in organic dusts.

In many occupational settings endotoxin exposure has been associated with acute changes in respiratory function and increased respiratory symptoms (Castellan 1987, Rylander 1985), as well as with chronic airflow limitation (Kennedy 1987, Smid 1992a, Schwartz 1995). Endotoxin has been identified in dust from grain elevators (DeLucca 1984, 1987), but studies of endotoxin levels or of health effects associated with endotoxin exposure in the Canadian grain elevator industry have not been reported.

2.1 Health effects of exposure to grain dust and endotoxin

2.1.1 Grain dust

Grain dust exposure is associated with respiratory and mucous membrane irritation, grain fever, specific asthma, hypersensitivity pneumonitis, acute and chronic impairment of airflow, and chronic bronchitis. This same constellation of syndromes has been reported in association with other organic dusts (Broder 1985, Chan-Yeung 1992, doPico 1982, Dosman 1987, James 1990, Kennedy 1994). Many of the studies in which these health effects were determined, were based on comparison of grain workers to workers from other industries not exposed to grain dust.

Exposure-response relationships have been reported for both acute and chronic changes in lung function and respiratory symptoms (Enarson 1985, Corey 1982, Smid 1992a, Huy 1991). In some studies, investigators have been able to estimate cumulative grain dust exposure and have shown greater reduction in lung function over time in workers with greater cumulative exposure (Huy 1991, Enarson 1985). In a recent comparative study, Peelen (1996) showed similarity in the slopes of exposure-response relationships for grain handlers in Canada and the Netherlands.

These lung function changes have been shown among workers who have worked in environments where dust exposure levels, on average, are considerably less than the current Canadian dust standard of 10 mg/m3.

2.1.2 Endotoxin

Integral to the composition of the outer membrane of Gram-negative bacteria are lipopolysaccharide complexes comprised of polysaccharide molecules and lipid A. These heat-stable complexes are the active components of bacterial endotoxin.

The health effects of exposure to airborne endotoxins associated with organic dusts have been reviewed recently (Olenchock 1997). Numerous studies have shown respiratory effects from this exposure (Pernis 1961, Heederik 1991, Schwartz 1995, Milton 1996) although others have not seen similar effects (Rask-Andersen 1989).

In experimental studies, with human volunteers, endotoxin exposure causes fever and acute airflow obstruction (Rylander 1985). It is hypothesized to be linked to 'grain fever' and other febrile responses experienced by workers who are exposed after a layoff period or holiday.

A small number of studies have also demonstrated chronic reductions in airflow linked more closely to endotoxin exposure level than to dust level. These studies were carried out among grain farmers and handlers (Zedja 1994, Schwartz 1995), cotton textile workers (Kennedy 1987), and animal feed workers (Smid 1992a).

However, other biologically active components of organic dust, such as tannins and glucans, have been suggested as prime candidates for inciting inflammation and airflow obstruction in workers exposed to organic dust, as not all studies show the same responses associated with endotoxin.

Although there are no regulatory exposure limits for endotoxin that we are aware of in any jurisdiction, several investigators have suggested values which may be useful in determining a 'safe' level of exposure. These recommendations range from 33 ng/m3 (Rylander 1985) to 9 ng/m3 (Castellan 1987), both derived from studies of cotton workers and 30 ng/m3 suggested by Palchak (1988) in the protein products manufacturing industry. Recently, a Dutch expert committee on occupational standards (A Committee of the Health Council of the Netherlands) proposed "a health based exposure limit for airborne endotoxins of 50 Endotoxin Units / m3 (approximately 4.5 ng/m3) based on personal inhalable dust exposure measured as eight hour time weighted average" (February 1997).

2.2 Grain dust and endotoxin exposure assessment and determinants of exposure

Although a number of studies have demonstrated associations between levels of grain dust exposure and impaired lung function, few were designed to systematically collect occupational hygiene measurements of grain dust exposure, to quantify exposure to the endotoxins found in the grain dust, or to evaluate factors which may be associated with increased exposure levels.

Over the past 30 years, a wide range of grain dust exposures among workers handling a diversity of grains has been reported (Huy 1991). Recently, an occupational hygiene survey of grain elevators in Colorado found mean concentrations of 27 mg/m^3 and 1 mg/m^3 for total and respirable dusts, respectively (Beard 1996). Mean inhalable grain dust concentrations ranging from 1.1 mg/m^3 to 14.3 mg/m^3 were measured in a flour mill in eastern France (Massin 1995). A study of seasonal grainhandlers in Western Australia measured low (<10 mg/m^3) and high (>20 mg/m^3) inhalable dust concentrations, but found nothing in the 10-20 mg/m^3 range (James 1990). Although exposure to endotoxin in organic dust has been measured in a variety of industries, few measurements are available for the grain industry. Endotoxin concentrations of grain dust have been reported in only two studies, both conducted by the same investigators at grain terminals on the lower Mississippi River, and ranged from non-detectable to 7.4 ng/m^3 in one (DeLucca 1984) and from 0.28-5.28 ng/m^3 in the other (DeLucca 1987).

Determinants of exposure to grain dust have been measured in several studies. Beard and colleagues (1996) examined seasonal effects and found lower dust levels in the winter compared to the summer. James (1990), Smid (1992b) and Massin (1995) all found grain dust exposure levels varied with different job categories and tasks being performed. In two studies of grain elevators along the Mississippi River, DeLucca evaluated differences in endotoxin content of settled vs. airborne grain dust, as well as the effect of seasonal variation. He found higher concentrations of endotoxin in the settled dust as compared to the airborne dust (DeLucca 1984) and that endotoxin concentrations in both settled and respirable dusts varied according to time of year the samples were collected, with the lowest observed in January and the highest in March (DeLucca 1987).

Exposure to endotoxin has been better characterized for other industries than for the grain industry. Studies in two of those industries are noteworthy because of the comprehensive evaluation of determinants of exposure to endotoxin (Milton 1996, Preller 1996). A detailed exposure assessment of worker exposure to endotoxin in a fibreglass insulation manufacturing plant found that concentration varied by: process area, job title within area for fixed location workers, and job title for mobile workers (Milton 1996). In a study of Dutch pig farmers, also conducted with a very detailed exposure assessment strategy, endotoxin exposure was found to vary depending on farm characteristics (eg. type of flooring, method of feeding), and activities performed every 10 minutes (eg. feeding, controlling, repenning, cleaning, iron injection, castrating, teeth cutting, or ear tagging) (Preller 1996). We are not aware of any studies reporting of determinants of exposure to endotoxin in grain elevators.

3. Methods

3.1 Sampling strategy

Dust samples for this survey were collected by occupational hygiene officers of Labour Canada, as was done in previous surveys. Prior to sampling, the UBC research team met Labour Canada to develop a standardized sampling protocol and sampling questionnaire which Labour Canada agreed to administer. A copy of the sampling data collection form is included as Appendix 1. The sampling objective was to collect 2 - 3 samples for each job title sampled in each elevator. The jobs targeted for sampling were determined from previous tests, and included jobs found previously to have high or low average exposures. Area samples were collected to supplement the personal samples, for areas which Labour Canada inspectors had some prior concern about possible high exposure levels.

The entire sampling protocol was repeated twice, once in the winter period and once in the summer / fall period.

3.2 Equipment and procedures for measurement of dust level

Sampling procedures and equipment were selected to allow subsequent analysis of endotoxin content. This involved using 37 mm open faced cassettes, with heat depyrogenated (180^{o}C for 4 hr) glass fibre filters (Type A/E, Gelman Sciences, Ann Arbor, Michigan), equilibrated and weighed in our laboratory. Samples were collected for 6-7 hours using a flow rate of 1.7 litres per minute. After desiccation for 48 hr, filters were reweighed, for determination of dust level, and the filters transferred to sterile 50 ml centrifuge tubes (Corning, Cambridge, MA). Samples were stored dry at 4^{o}C until extraction. Douwes (1995) has shown that storage at refrigerator temperatures for a period of a year had no effect on endotoxin levels.

3.3 Determination of endotoxin content of grain dust on stored filters

Endotoxin content of stored grain filters was analysed using a recent improvement to the standard endotoxin assay, in which the reaction is measured by turbidimetric measurements in a kinetic assay (Milton 1990).

All glassware used in the assay was depyrogenated at 180^{o}C for 4 hr prior to use. Filters were extracted in 5 ml 0.05 M potassium phosphate-0.01% triethylamine (pH 7.5) buffer (Walters 1994) by sonicating for 60 min., shaking on a platform shaker for 60 min. and centrifuging at 100 x g for 10 min. The *Limulus* amebocyte lysate (LAL) reagent used, Pyrogent 5000 (BioWhittaker, Walkersville, MD), was chosen because it has been shown to be the least reactive to contaminating b-D-glucans (Berzofsky 1989). Samples were serially diluted in LAL reagent water. Aliquots of 100 µl sample or control *E. coli* 055:B5 endotoxin were dispensed in sterile 96 well tissue culture grade microtitre plates (Corning, Cambridge, MA). Plates were preincubated for 15 min. at 37^{o}C. Immediately before use, LAL reagent was reconstituted in reagent buffer (supplied by BioWhittaker) and 100 µl LAL reagent added to sample and control wells. The plate was read in a Thermomax microplate reader (Molecular Devices, Sunnyvale, CA) at 340nm wavelength, 37^{o}C incubation using time of onset (O.D. onset 0.05, O.D. max 0.03) data reduction parameters. Log-log standard curves were constructed from the control endotoxin included in each plate. Final results are expressed as nanograms endotoxin per cubic meter of air sampled.

3.4 Analysis of results

Data were reviewed for completeness and accuracy and coded for computer entry. Review and analysis of keyed data files was carried out using SAS-PC statistical analysis software (SAS Institute, Cary NC). Prior to analyses, data files were checked again for valid responses, missing values, and logically consistent responses.

The detection limit for each analytic method was determined as twice the standard deviation of the values from the laboratory blanks. A total of 25% of the samples fell below the detection limit for dust and 13% below the detection limit for endotoxin. For these samples, a value of the detection limit divided by the square root of two was substituted in the data file and used for analyses.

As the area samples were not collected using a consistent sampling strategy, statistical analyses of the results were confined to the personal samples.

4. Results

4.1 Number of samples, job titles, and areas sampled

A total of 376 personal samples and 77 area samples were collected during the two sampling periods. The distribution of samples across elevators is shown in Table 1.

Table 1: Number and type of samples collected per sampling period

Elevator	Jan - Mar 1996			Aug - Oct 1996		
	Personal	Area	Blank	Personal	Area	Blank
1	32	3	2	29	9	2
2	31	8	4	36	9	3
3	33	11	6	34	12	6
4	30	8	4	30	6	3
5	26	3	3	27	2	3
6	35	3	3	33	3	3
Total	187	36	22	189	41	20

The objective was to sample each selected job (or group of jobs in the case of distributors, bintops, annex, and galley jobs) at each elevator on three days during each sampling period. As shown in Table 2, below, this objective was not completely met, although for most jobs (or groups) 3 samples were collected from each elevator. Of the 17 job titles sampled, 9 had 30 or more samples, 4 had 10-20 samples, and 4 had fewer than 10 samples taken.

Table 2: Number of personal samples per job, elevator, and sampling period

Jobtitle	total n	Jan - Mar 1996 Elevator						Aug - Oct 1996 Elevator					
		1	2	3	4	5	6	1	2	3	4	5	6
Panel Control Operator	30	3	0	3	3	3	0	3	3	3	3	3	3
Cleanerman	33	3	3	3	3	3	3	3	3	1	2	3	3
Sweeper/Labour	40	3	4	4	3	3	3	0	5	4	5	3	3
Pitman/Trackshedman	35	3	3	3	3	2	3	3	3	3	3	3	3
Pellet Plant Operator	32	3	2	2	2	3	3	3	3	3	2	3	3
Supervisor/Foreman/ Chargehand (in-plant)	37	3	5	3	2	3	3	3	3	3	3	3	3
Electrician	34	3	3	2	3	3	3	2	3	3	3	3	3
Sheetmetal Worker	35	2	3	3	3	3	3	3	3	3	3	3	3
Millwright	35	3	3	3	2	3	3	3	3	3	3	3	3
Basementman	15	0	1	2	3	0	3	0	0	3	0	0	3
Annexman	12	3	0	3	1	0	0	0	0	2	3	0	0
Bintopman	14	0	3	2	2	0	2	0	2	0	0	0	3
Distributor	10	0	0	0	0	0	0	3	4	3	0	0	0
Galleryman	6	3	0	0	0	0	0	3	0	0	0	0	0
Peco Operator	3	0	0	0	0	0	3	0	0	0	0	0	0
Inspector/Timekeeper	3	0	0	0	0	0	3	0	0	0	0	0	0
Spare	2	0	1	0	0	0	0	0	1	0	0	0	0

Area samples were planned only for selected areas of specific concern. Therefore, the number of areas sampled was small and not consistent across elevators.

Table 3: Number of area samples collected per elevator per sampling period

Work Area	Jan - Mar 1996						Aug - Oct 1996					
	Elevator						Elevator					
	1	2	3	4	5	6	1	2	3	4	5	6
distributor floor	0	0	3	0	3	0	0	0	3	0	2	0
cleaner floor	0	3	0	0	0	0	3	3	0	0	0	0
bin tops/annex	0	2	0	3	0	3	0	3	0	3	0	3
gallery	3	0	4	0	0	0	3	1	3	0	0	0
trackshed/pit	0	0	2	0	0	0	0	0	3	0	0	0
basement	0	3	2	5	0	0	3	2	3	3	0	0

4.2 Dust concentrations

Tables 4 and 5 display the dust concentration levels from the personal and area samples according to elevator and sampling period. Statistical analyses to investigate possible differences among elevators indicated no significant difference in dust concentrations (based on personal samples) across elevators.

As shown in Table 4, average dust levels were slightly higher in the Jan-March sampling period than in the August - September sampling period. This is most evident when looking at the arithmetic average (due to higher extreme values in the winter period). This difference was statistically significant ($p=0.05$) for both the arithmetic average comparison and for the comparison of geometric mean values.

Similar patterns were seen in the area samples (Table 5), although there was no consistent relationship between area and personal samples by elevator and season (ie. in some elevators, area samples tended to be higher than personal samples, and in other areas the reverse was true).

Table 4: Personal dust concentrations by elevator and sampling period

Elevator	Dust Concentration (mg/m³)						
Jan - Mar 1996	N	Ave.	SD	Min	Max	GM	GSD
1	32	3.25	8.32	0.09	46.66	1.00	4.10
2	31	1.43	1.84	0.07	7.87	0.79	3.00
3	33	1.31	2.24	0.06	10.90	0.47	4.32
4	30	2.27	7.25	0.07	39.99	0.68	3.42
5	26	4.46	12.92	0.06	63.67	0.65	6.05
6	35	3.39	9.84	0.07	54.55	0.57	5.79
Aug - Oct 1996	N	Ave.	SD	Min	Max	GM	GSD
1	29	1.28	1.64	0.14	6.49	0.61	3.59
2	36	0.95	1.05	0.15	4.22	0.59	2.64
3	34	0.76	0.88	0.14	4.15	0.47	2.59
4	30	2.00	3.43	0.14	13.35	0.71	4.01
5	27	3.00	6.71	0.14	27.56	0.71	4.95
6	33	0.96	1.24	0.15	4.80	0.50	3.07

Table 5: Area dust concentrations by elevator and sampling period

Elevator	Dust Concentration (mg/m³)						
Jan - Mar 1996	N	Ave.	SD	Min	Max	GM	GSD
1	3	3.61	5.39	0.36	9.84	1.31	5.87
2	8	0.94	0.52	0.32	1.79	0.81	1.79
3	11	1.57	1.51	0.07	5.14	0.97	3.27
4	8	5.40	10.69	0.07	31.56	1.44	5.96
5	3	1.00	0.46	0.66	1.53	0.94	1.54
6	3	0.45	0.53	0.08	1.06	0.25	3.79
Aug - Oct 1996	N	Ave.	SD	Min	Max	GM	GSD
1	9	4.80	5.15	0.16	13.66	1.89	5.61
2	9	1.83	1.70	0.15	5.40	1.15	3.12
3	12	0.51	0.36	0.16	1.29	0.40	2.14
4	6	3.63	5.42	0.75	14.59	1.90	3.05
5	2	1.22	1.52	0.15	2.30	0.58	7.05
6	3	0.27	0.19	0.15	0.48	0.23	1.92

Notes regarding Tables 4 and 5:

N number of personal samples collected
Ave average dust or endotoxin concentration of the personal samples
SD standard deviation of the personal samples
Min lowest dust or endotoxin concentration measured (personal samples)
Max highest dust or endotoxin concentration measured (personal samples)
GM geometric mean concentration of dust or endotoxin of the personal samples
GSD geometric standard deviation of the personal samples

Results by job title and area location are shown in Tables 6 and 7. For personal samples, the difference among job titles were statistically significant ($p<.05$). The cleanerman, sweeper / labourer, and sheetmetal jobs tended to have consistently higher values and panel control operators had consistently lower values, compared to other jobs. Similarly, area samples tended to be highest on the cleaner floor and in the basement areas.

Figures 1,2 and 3 show results for each job title, not divided by elevator or sampling period. Since there were no significant differences among elevators, and since the sampling period differences were small, these results can be used to help target prevention efforts.

In comparing the results to regulatory limits, it is necessary to take into consideration both the number of samples collected for each job and the overall variability in the samples collected. We used the approach described by Hewett (1997) to estimate the average personal dust level for each job title (taking into account the fact that the distribution of samples does not follow a normal curve), and the 95% confidence interval for the average. This is shown in figure 1 on page 11. The 95% confidence interval indicates that the true average exposure level is expected to fall within this interval 95% of the time. In figures 2 and 3 on page 11, we display the estimates of the percent of samples for each job title which are likely to exceed 4 mg/m3 (the ACGIH recommended exposure limit) and 10 mg/m3 (the current ‘nuisance dust’ standard for Canada). As seen in all of these figures, among the jobs sampled in this survey, annexmen, cleanermen, sheetmetal workers, and sweepers could be targeted for particular attention to reduce dust exposures as the upper 95% confidence limit for average exposure in these jobs exceeds 4 mg/m3 and the upper 95% confidence limit for the percent of samples expected to exceed 10 mg/m3 was over 10%.

Table 6: Mean dust concentrations by job title and sampling period

Jobtitle	Jan - Mar 1996 Dust Concentration (mg/m³)							Aug - Oct 1996 Dust Concentration (mg/m³)						
	N	Ave	SD	Min	Max	GM	GSD	N	Ave	SD	Min	Max	GM	GSD
Panel Control Operator	12	0.17	0.12	0.06	0.46	0.14	1.86	18	0.19	0.08	0.14	0.42	0.18	1.36
Cleanerman	18	4.22	5.11	0.41	21.39	2.44	2.96	15	2.60	1.71	0.64	5.47	2.10	1.99
Distributor	—	—	—	—	—	—	—	10	0.70	0.51	0.15	1.80	0.56	2.03
Sweeper/Labour	20	4.40	10.25	0.06	46.66	1.10	5.82	20	3.31	3.27	0.43	13.35	2.39	2.25
Pitman/Trackshedman	17	2.84	9.59	0.06	39.99	0.44	4.44	18	0.54	1.35	0.14	5.91	0.24	2.53
Basementman	9	1.51	1.90	0.08	5.08	0.69	4.14	6	0.45	0.26	0.16	0.80	0.39	1.84
Pellet Plant Operator	15	0.57	0.49	0.07	1.64	0.40	2.53	17	3.97	8.32	0.14	27.56	0.67	6.28
Spare	1	0.62	—	—	—	0.62	—	1	0.16	—	—	—	0.16	—
Inspector/Timekeeper	3	0.11	0.06	0.07	0.17	0.10	1.86	—	—	—	—	—	—	—
Bintopman	9	2.07	1.98	0.68	6.53	1.53	2.15	5	0.64	0.43	0.21	1.36	0.54	1.95
Supervisor/Foreman/ Chargehand (in-plant)	19	0.24	0.17	0.06	0.64	0.19	2.82	18	0.56	0.55	0.14	2.40	0.40	2.25
Annexman	7	2.45	4.37	0.07	12.18	0.76	5.27	5	0.77	0.22	0.51	1.07	0.74	1.34
Galleryman	3	1.39	0.43	0.94	1.80	1.35	1.39	3	1.87	1.48	0.89	3.57	1.53	2.10
Peco Operator	3	0.16	0.08	0.07	0.23	0.14	1.78	—	—	—	—	—	—	—
Electrician	17	0.67	0.54	0.08	2.61	0.54	2.02	17	0.86	2.25	0.14	9.59	0.35	2.59
Sheetmetal Worker	17	9.86	19.44	0.20	63.67	2.08	5.69	18	0.87	0.51	0.16	2.07	0.69	2.18
Millwright	17	1.95	2.57	0.30	10.90	1.17	2.68	18	1.17	1.53	0.15	5.55	0.63	3.15

Note: — indicates no samples collected

Table 7: Mean dust concentrations by location and sampling period

Work Area	Jan - Mar 1996 Dust Concentration (mg/m³)							Aug - Oct 1996 Dust Concentration (mg/m³)						
	N	Ave	SD	Min	Max	GM	GSD	N	Ave	SD	Min	Max	GM	GSD
distributor floor	6	0.95	0.38	0.46	1.53	0.88	1.54	5	0.75	0.90	0.15	2.30	0.43	3.17
cleaner floor	3	1.44	0.46	0.92	1.79	1.38	1.43	6	4.72	5.46	0.72	13.66	2.56	3.31
bin tops/annex	8	0.70	0.54	0.08	1.71	0.49	2.76	9	0.77	0.61	0.15	2.06	0.56	2.46
gallery	7	2.21	3.50	0.07	9.84	0.80	5.00	7	2.52	4.02	0.15	10.12	0.60	6.34
trackshed/pit	2	0.92	0.21	0.77	1.07	0.91	1.26	3	0.49	0.08	0.43	0.58	0.48	1.18
basement	10	5.03	9.51	0.07	31.56	1.59	5.31	11	2.98	4.16	0.16	14.59	1.41	3.93

Figure 1 - Personal Samples, Average Dust Levels (± 95% conf. interval for the mean)

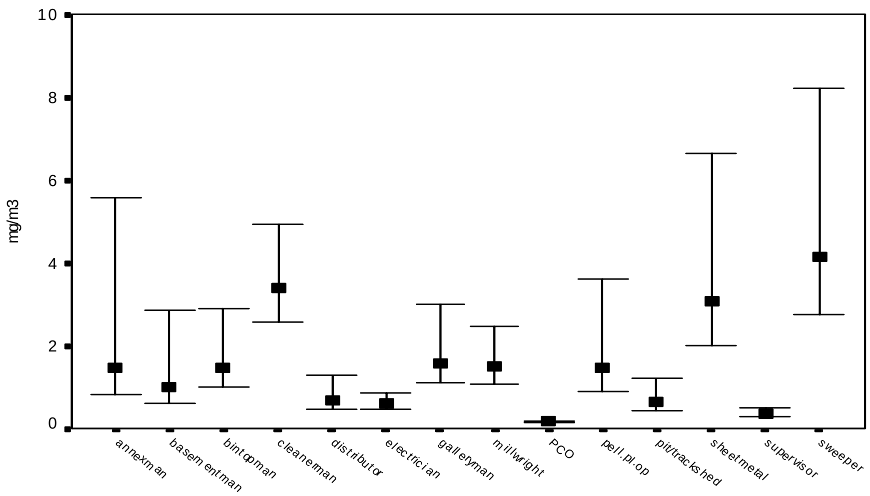


Figure 2 - Personal Samples, Percent likely to exceed 4 mg/m3 (estimate ± 95% conf. interval)

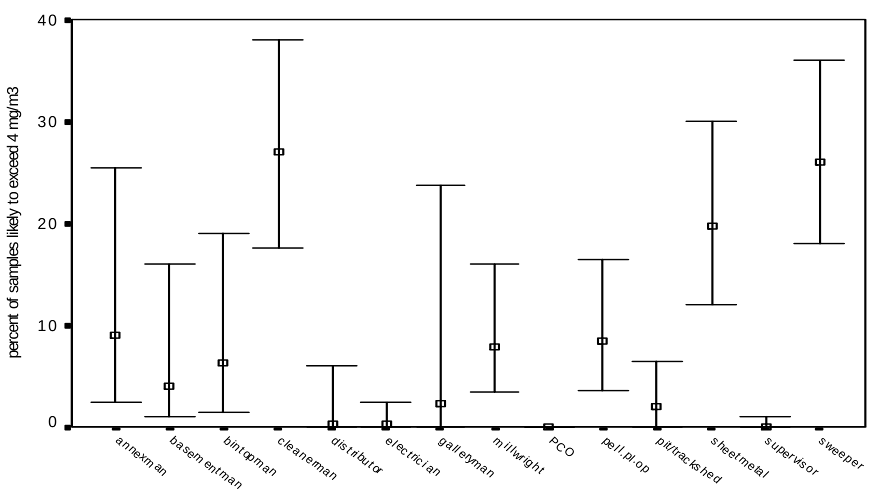
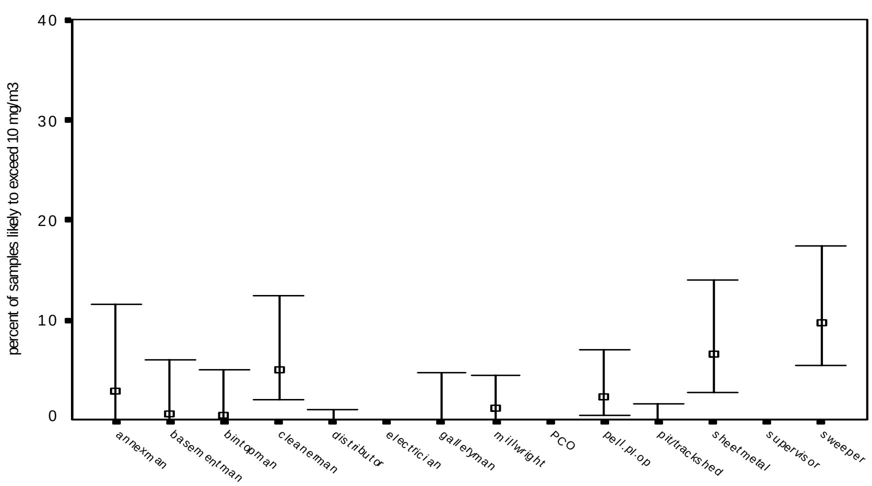


Figure 3 - Personal Samples, Percent likely to exceed 10 mg/m3 (estimate ± 95% conf. interval)



4.3 Endotoxin concentrations

In contrast to dust levels which tended to show high maximum values during the Jan-March period, endotoxin levels were consistently higher in the August - October sampling period, both for arithmetic and geometric mean values (Tables 8 and 9) ($p<.001$). The seasonal difference is consistent with increased growth of micro-organisms during the warmer months of the year. The endotoxin levels were not significantly different among elevators.
Endotoxin levels according to job title and location are shown in tables 10 and 11. The differences seen for different job titles tend to mirror those seen for dust levels.

Table 8: Personal endotoxin concentrations by elevator and sampling period

Elevator	Endotoxin Concentration (ng endotoxin/m³ of air)						
Jan - Mar 1996	**N**	**Ave.**	**SD**	**Min**	**Max**	**GM**	**GSD**
1	32	125.37	217.10	0.25	845.09	16.38	11.31
2	31	67.51	150.45	0.28	661.73	4.44	11.90
3	28	118.78	220.24	0.25	949.15	9.07	16.14
4	30	60.53	123.28	0.25	526.86	9.32	9.48
5	26	98.58	257.30	0.24	1098.27	5.76	13.54
6	35	59.09	109.60	0.26	447.75	5.95	12.19
Aug - Oct 1996	**N**	**Ave.**	**SD**	**Min**	**Max**	**GM**	**GSD**
1	29	561.94	1145.62	0.26	4669.35	24.05	28.19
2	36	273.22	760.03	0.24	4350.49	17.41	16.39
3	34	1187.87	3753.55	0.26	15652.61	13.93	24.79
4	30	1007.44	3326.80	0.32	17653.43	17.13	33.85
5	27	313.30	810.47	0.25	4128.84	14.13	26.36
6	33	548.76	1632.27	0.27	8102.08	14.27	18.89

Table 9: Area endotoxin concentrations by elevator and sampling period

Elevator	Endotoxin Concentration (ng endotoxin/m³ of air)						
Jan - Mar 1996	**N**	**Ave.**	**SD**	**Min**	**Max**	**GM**	**GSD**
1	3	49.22	66.92	3.29	126.00	19.67	6.20
2	8	16.02	13.63	0.25	33.50	5.91	7.87
3	10	50.93	65.14	0.65	183.77	18.23	6.36
4	8	390.63	772.53	0.27	2189.87	33.60	17.92
5	3	22.51	25.02	1.61	50.23	10.83	5.75
6	3	6.12	5.13	0.30	9.96	2.89	7.16
Aug - Oct 1996	**N**	**Ave.**	**SD**	**Min**	**Max**	**GM**	**GSD**
1	9	8261.53	12916.14	0.73	35245.79	563.01	52.02
2	9	1234.47	2121.44	0.27	5757.70	124.76	26.13
3	12	88.43	132.09	0.29	333.91	11.96	11.62
4	6	4520.78	10312.39	8.08	25565.28	358.95	13.83
5	2	773.72	1093.84	0.26	1547.17	19.88	472.50
6	3	38.16	61.54	2.06	109.22	8.96	8.82

Table 10: Mean endotoxin concentrations by job title and sampling period

Jobtitle	Jan - Mar 1996 Endotoxin Concentration (ng/m³)							Aug - Oct 1996 Endotoxin Concentration (ng/m³)						
	N	Ave	SD	Min	Max	GM	GSD	N	Ave	SD	Min	Max	GM	GSD
Panel Control Operator	12	0.75	0.95	0.25	3.59	0.50	2.29	18	1.01	1.79	0.25	7.85	0.52	2.70
Cleanerman	18	190.16	209.59	1.80	764.21	78.08	5.74	15	2570.10	4178.90	4.20	15354.30	736.81	7.15
Distributor	—	—	—	—	—	—	—	10	193.42	394.25	0.93	1186.50	13.50	12.50
Sweeper/Labour	19	156.58	227.97	0.24	845.09	17.38	18.09	20	2271.22	3624.57	2.09	15652.61	691.84	7.13
Pitman/Trackshedman	17	47.41	135.08	0.25	526.86	2.71	9.08	18	994.08	4157.81	0.25	17653.43	2.94	17.06
Basementman	9	83.74	117.48	1.58	307.45	20.59	7.64	6	34.09	47.92	2.75	99.51	9.89	5.82
Pellet Plant Operator	14	7.40	12.97	0.30	48.62	2.61	4.43	17	574.03	1294.98	0.28	4669.35	12.35	29.38
Spare	1	0.28	—	—	—	0.28	—	1	1.72	—	—	—	1.72	—
Inspector/Timekeeper	3	0.46	0.31	0.26	0.82	0.40	1.86	—	—	—	—	—	—	—
Bintopman	9	144.79	233.36	2.77	661.73	33.98	6.99	5	72.48	109.70	0.24	254.07	10.43	16.07
Supervisor/Foreman/ Chargehand (in-plant)	18	1.37	1.99	0.25	7.98	0.68	3.08	18	42.54	97.28	0.29	386.96	3.35	10.22
Annexman	7	107.17	259.23	0.49	694.74	8.92	11.01	5	144.25	146.06	3.78	387.84	70.18	5.75
Galleryman	3	58.59	54.03	3.39	111.36	32.48	6.47	3	537.76	402.42	278.16	1001.32	453.03	2.00
Peco Operator	3	1.39	1.88	0.30	3.56	0.69	4.16	—	—	—	—	—	—	—
Electrician	16	12.43	24.89	0.70	99.30	4.37	3.87	17	105.02	396.89	0.29	1643.24	3.04	9.08
Sheetmetal Worker	17	197.93	331.65	0.78	109.27	38.72	9.17	18	107.10	139.38	0.85	473.66	32.26	7.47
Millwright	16	124.63	155.94	0.25	491.83	41.30	7.56	18	130.47	190.19	0.26	740.76	20.03	12.46

Note: — indicates no samples collected

Table 11: Mean endotoxin concentrations by location and sampling period

Work Area	Jan - Mar 1996 Endotoxin Concentration (ng/m³)							Aug - Oct 1996 Endotoxin Concentration (ng/m³)						
	N	Ave	SD	Min	Max	GM	GSD	N	Ave	SD	Min	Max	GM	GSD
distributor floor	5	17.48	20.09	0.65	50.23	6.93	6.21	5	370.71	669.95	0.26	1547.17	18.32	34.40
cleaner floor	3	25.22	5.31	20.50	30.97	24.85	1.23	6	7360.76	13888.41	114.06	35245.79	1147.80	9.72
bin tops/annex	8	11.71	11.66	0.30	33.50	4.75	6.36	9	137.49	177.75	1.91	535.38	31.97	9.75
gallery	7	35.06	44.18	1.28	126.00	14.72	5.03	7	4315.66	9387.41	0.27	25235.04	18.82	145.15
trackshed/pit	2	25.88	13.90	16.06	35.71	23.95	1.76	3	50.05	77.77	2.97	139.81	14.51	7.49
basement	10	344.21	688.90	0.25	2189.87	29.01	22.87	11	3426.96	7852.24	1.38	25565.28	268.19	21.67

4.3.1 Endotoxin levels compared to other studies

Recommendations for occupational exposure limits for endotoxin have ranged from a low of 4.5 ng/m3 to 33 ng/m3, although none of these recommendations have been translated into regulatory limits in any jurisdiction as yet. The highest 'no effect' level reported in the literature was 170 ng/m3 for non-smokers and 80 ng/m3 for smokers (or a mean of 125 ng/m3), in a study of 13 volunteers exposed to washed cotton. For comparison purposes, tables 16 and 17 show the endotoxin results divided into the proportion greater than 4.5 ng/m3, greater than 33 ng/m3, and greater than 125 ng/m3.

Table 12: Personal endotoxin concentrations, proportion > 4.5 ng/m3, > 33 ng/m3, and > 125 ng/m3

Jan - Mar 1996	N	% > 4.5 ng/m3	% > 33 ng/m3	% > 125 ng/m3
1	32	62	37	25
2	31	42	26	16
3	28	50	36	21
4	30	57	37	13
5	26	46	23	15
6	35	46	34	14
Aug - Oct 1996	**N**	**% > 4.5 ng/m3**	**% > 33 ng/m3**	**% > 125 ng/m3**
1	29	52	48	45
2	36	53	47	33
3	34	41	38	29
4	30	47	47	37
5	27	56	52	26
6	33	51	36	27

Table 13: Area endotoxin concentrations, proportion > 4.5 ng/m3; > 33 ng/m3, > 125 ng/m3

Jan - Mar 1996	N	% > 4.5 ng/m3	% > 33 ng/m3	% > 125 ng/m3
1	3	67	33	33
2	8	62	12	0
3	10	80	50	20
4	8	75	50	25
5	3	67	33	0
6	3	67	67	0
Aug - Oct 1996	**N**	**% > 4.5 ng/m3**	**% > 33 ng/m3**	**% > 125 ng/m3**
1	9	78	78	78
2	9	78	78	67
3	12	58	33	33
4	6	100	83	67
5	2	50	50	50
6	3	33	33	0

These results show that well over 1/4, and in some cases as many as half of the samples taken indicated endotoxin levels present in the elevators which are at concentration which have been shown to be associated with acute respiratory and febrile symptoms in other studies. Daily exposure to endotoxin at these levels may result in tolerance such that acute symptoms may be no longer experienced on a regular basis, except after return to work from a period away from exposure. Although chronic health effects have been associated with endotoxin exposure in several studies, there is insufficient information to determine a safe level at this point in time.

The results shown in Table 14 for endotoxin concentrations over these "no effect" values, for each job title indicate cleanermen, distributors, gallerymen, sheetmetal workers, millwrights, and sweepers as the jobs to be targeted for exposure reduction efforts.

Table 14 - % of personal endotoxin concentrations over 4.5, 33, 125 ng/m3 according to job title

Jobtitle	N	% > 4.5 ng/m3	% > 33 ng/m3	% > 125 ng/m3
Panel Control Operator	30	33	0	0
Cleanerman	33	91	88	64
Distributor	10	40	30	30
Sweeper/Labour	39	79	72	59
Pitman/Trackshedman	35	29	14	11
Basementman	15	60	33	20
Pellet Plant Operator	31	35	22	19
Spare	2	0	0	0
Inspector/Timekeeper	3	0	0	0
Bintopman	14	71	43	21
Supervisor/Foreman/ Chargehand (in-plant)	36	19	11	6
Annexman	12	67	42	25
Galleryman	6	83	83	50
Peco Operator	3	30	0	0
Electrician	33	15	15	3
Sheetmetal Worker	35	77	60	29
Millwright	34	67	59	35

5. Recommendations and Future analyses

The results from the 1996 exposure monitoring conducted at the 6 BC grain elevators indicates that dust concentrations, on average, continue at levels below 4 mg/m3, although individual excursions considerably above this level were seen for several jobs. We recommend that efforts be directed at these specific jobs for exposure reduction.

It has been hypothesized that endotoxin present in grain dust may be responsible, at least in part, for the adverse effect of grain dust on respiratory health. The endotoxin levels seen in this study are consistent with levels known to be associated with acute and chronic health impairment in other studies. Until further is known about specific strategies for reducing endotoxin levels, we recommend that efforts to reduce dust levels be continued, especially for those jobs with high dust or high endotoxin concentrations. This jobs include: annexmen, cleanermen, distributors, gallerymen, sweepers, millwrights, and sheetmetal workers.

We are continuing to analyse the data from this sampling study to determine whether or not increased dust and/or endotoxin levels are associated with particular grain types, tasks, and weather conditions. These results will be reported separately, when completed.

6. Summary

6.1 A total of 376 personal samples and 77 area samples were collected during 2 sampling periods, Jan-Mar and Aug-Oct 1996, and analysed for total dust and endotoxin levels.

6.2 Based on the jobs sampled in these surveys, no significant differences were seen across elevators for either dust or endotoxin levels. Significant differences were seen for both exposures for different job titles.

6.3 Dust concentrations were slightly higher ($p=0.05$) in the Jan-March sampling period. In contrast, endotoxin levels were significantly higher ($p<.001$) in the August-October sampling period.

6.4 Average dust levels were generally below 4 mg/m3. Based on the samples taken, exceedances above 4 mg/m3 would be expected more than 5% of the time for about 1/2 of the jobs sampled. Exceedances above 10 mg/m3 would be expected for at least 3 jobs (cleanerman, sheetmetal, sweeper).

6.5 Over 1/4 of the endotoxin samples exceeded levels believed to be associated with acute symptoms in other settings. The significance of these results are not yet known in the grain elevator industry and will be the subject of further analyses in this study.

6.6 Based on this survey, jobs with high endotoxin levels included cleanermen, distributors, sweepers, gallerymen, sheetmetal workers, and millwrights.

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