

Exposure to Grain Dust in Great Britain

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Airborne grain dust is a complex mixture of fragments of organic material from grain, plus mineral matter from soil, and possible insect, fungal, or bacterial contamination or their toxic products, such as endotoxin. In the 1990s, grain workers in Britain were frequently exposed to inhalable dust $>10 \text{ mg.m}^{-3}$ (8 h), with particularly high exposures being found at terminals where grain was imported or exported and in drying operations (personal exposure typically $\sim 20 \text{ mg.m}^{-3}$). Since then, the industry has made substantial progress in improving the control of airborne dust through better-designed processes, increased automation, and an improved focus on product quality. We have used information from the published scientific literature and a small survey of industry representatives to estimate current exposure levels. These data suggest that current long-term exposure to inhalable dust for most workers is on average less than $\sim 3 \text{ mg.m}^{-3}$, with perhaps 15–20% of individual personal exposures being $>10 \text{ mg.m}^{-3}$. There are no published data from Britain on short-term exposure during cleaning and other tasks. We have estimated average levels for a range of tasks and judge that the highest levels, for example during some cleaning activities and certain process tasks such as loading and packing, are probably $\sim 10 \text{ mg.m}^{-3}$. Endotoxin levels were judged likely to be $<10^4 \text{ EU m}^{-3}$ throughout the industry provided inhalable dust levels are $<10 \text{ mg.m}^{-3}$. There are no published exposure data on mycotoxin, respirable crystalline silica, and mite contamination but these are not considered to present widespread problems in the British industry. Further research should be carried out to confirm these findings.

Keywords: endotoxin; exposure estimation; exposure modelling; grain dust; inhalable dust; inhalation exposure

INTRODUCTION

Grain dust is a complex mixture of organic and inorganic materials, mainly comprising cellulose-based seed coating and carbohydrate. Grain dust may also contain bacterial and fungal contamination, along with associated endotoxin and mycotoxin, plus mites, insects, and small amounts of crystalline silica. Exposure to grain dust may result in a range of acute and chronic respiratory symptoms and reduced lung function (DoPico *et al.*, 1982; Huy *et al.*, 1991; Becklake, 2007). These health effects may be due to the organic dust or one or more of the agents previously identified. A small proportion of those exposed may eventually suffer from asthma, either attributed to the microorganisms (Swan *et al.*, 2007), dust

mites (Armentia *et al.*, 1997), or some other components in the grain dust. Workers may also experience a non-allergic acute asthma-like response, which may be associated with exposure to endotoxin (Chan-Yeung *et al.*, 1992). However, there is no clear indication of which agent or agents in grain dust are primarily responsible for the chronic respiratory effects, which manifest as reduced lung function. There is some limited information suggesting an increased risk of laryngeal cancer among Finnish men with high cumulative exposure to plant dust, of which the majority were grain millers (Laakkonen *et al.*, 2006).

Phillips (1993) summarized the available data on occupational exposure to grain dust in the early 1990s, including the results from an extensive survey of grain dust exposures in British agriculture, grain storage plus handling, and transport in the major grain terminals. In total, almost 250 measurements

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of personal exposure to inhalable dust were made along with a small number of respirable dust measurements. These data showed that exposures were highest in grain drying and at terminals loading grain (arithmetic average $\sim 20 \text{ mg.m}^{-3}$) with lower levels in harvesting, malting, and grain storage (arithmetic average $7\text{--}9 \text{ mg.m}^{-3}$).

Grain dust is defined as a hazardous substance under the Control of Substances Hazardous to Health Regulations (COSHH) 2002 as amended and has been given a workplace exposure limit (WEL) of 10 mg.m^{-3} (first introduced in 1992). For the purpose of compliance with the WEL, grain dust is considered to be dust arising from the harvesting, drying, handling, storage, or processing of barley, wheat, oats, maize, and rye. This definition includes any contaminants or additives within the dust. Under the COSHH Regulations, control of exposure to grain dust is only considered adequate if the exposure is reduced as far below the WEL as is reasonably practicable and employers follow the principles of good practice for the control of exposure as set out in the regulations. Employers should also consider the potential for short-term peaks in exposure as well as longer term time-weighted averages. General guidance on exposure to dusts suggests that short-term exposure (15 min) should not exceed 30 mg.m^{-3} .

Since the early 1990s, there have been considerable developments in the grain industry, both in the technology used and in the way that the work is organized. These changes will almost certainly have had an impact on the number of people exposed to grain dust and the level of exposure they experience.

AIMS

The aims of this paper were to briefly summarize the technology and work practices in the British grain industry in relation to potential dust exposure, to review the published literature on exposure to grain dust in Britain since the 1990s, to use this information to provide an estimate of the likely current exposure in the industry, and to identify exposure-significant tasks in the grain industry.

METHODS

A literature review sought to identify exposure data for the grain industry published over about the last 15 years. The search strategy focused on studies investigating grain dust exposure levels and control measures. Information from outside Britain was reviewed but is not reported here.

We also undertook a series of telephone interviews and visits to industry stakeholders to collect information about current work practices and changes since the early 1990s. The industry sectors identified for investigation were farms, flour mills, malting houses (including malt millers), animal feed manufacture plus grain merchants (commercial storage), and importers. Recruitment of representatives was undertaken using lists of possible informants provided by trade organizations. Each person was first contacted by email and this was followed-up by telephone; we aimed to have 30 people for telephone interviews and 12 follow-up visits. We tried to ensure an even balance of participants across industry sectors.

The telephone interviews were guided by a checklist of topics for discussion (Spankie and Cherrie, 2010). Questions covered the type of grain processed, tasks undertaken, and turnover or throughput. In addition, we asked about the operators' work pattern (duration and frequency of task), subjective views about airborne dust released, other hazardous substances added or produced during the task, dust generating opportunities within tasks, and control measures for each task. We also asked interviewees to disclose summarized exposure measurement data, but most were reluctant to do so. During the site visits, information was collected by observation plus informal discussion with operators and/or health and safety managers. Photographs of key plant and equipment were obtained.

Exposure-significant tasks were considered to be those activities where exposure could exceed the exposure limit for grain dust or where elevated exposure to some component in the grain dust could give rise to adverse health effects. The first criterion broadly corresponds to a geometric mean exposure level of 1 mg.m^{-3} for a task, assuming a geometric standard deviation of 4.5 (Meijster *et al.*, 2007) and that the task could last for most of the day.

Using the available information and our scientific judgment, we attempted to estimate the approximate arithmetic average inhalable dust levels in work tasks and the proportion of time typically spent in these tasks by industry sector. These data were then used to estimate the long-term average inhalable dust levels in each sector by calculating the time-weighted average level. To estimate the 90th percentile of the exposure distribution, we assumed that the data were log-normally distributed with a geometric standard deviation of 4.5 (Meijster *et al.*, 2007).

We used evidence from studies of temporal trends in exposure data to extrapolate exposure levels from the early 1990s to estimate current long-term average

inhalable dust exposures by sector. Creely *et al.* (2007) reviewed the literature on temporal trends and identified 38 datasets that were informative for aerosols. They analysed the temporal trends on the log scale assuming an exponential decline in exposure level over time. For 58% of these situations, there was a statistically significant reduction in exposure, generally between ~5 and 10% per year. Only one dataset (3%) showed a significant increase in average exposure over time. We selected an appropriate annual percentage reduction in exposure level based on the described changes in operations.

During the literature review, we attempted to identify associations between the measured concentrations of different constituents of the dust, e.g. correlation between the inhalable dust and endotoxin levels. Finally, we considered evidence for the possible effectiveness of control measures and respiratory protective equipment (RPE) in reducing exposures.

RESULTS

Data from Phillips study

The highest average exposure levels reported by Phillips (1993) were in grain terminals, where the main tasks contributing to these elevated exposures were cleaning (Table 1). The next highest average exposures were found in grain drying on farms. Cleaning in malting and distilling also showed elevated exposure levels.

There were clearly different levels of exposure for harvesting with and without air-conditioned cabs on combine harvesters: with cabs, the average exposure level was 1.2 mg.m^{-3} and without 29 mg.m^{-3} . Phillips noted that during many tasks, there were high airborne dust concentrations close to the sources but that operators tended to stand back from these points and consequently had relatively low personal exposures, e.g. in

animal feed milling on farms. About 50% of exposure measurements in the grain terminals exceeded 10 mg.m^{-3} . In all the other sectors combined, ~25% of measurements were $>10 \text{ mg.m}^{-3}$.

Description of the industry and changes since Phillips

We obtained information from interviews and/or visits to 32 grain industry sites throughout Britain. All but four of the study participants (from farms, flour mills, malting houses including malt milling, animal feed millers, pest controllers, grain merchants, and importers/exporters) were recruited via the relevant trade organizations. These organizations then generated a list of candidates from their membership who might be approached. These potential candidates were then contacted directly and invited to participate in the survey and if they agreed, arrangements were made for the conducting the telephone interviews. Companies were asked during the telephone interviews if they would be willing to participate in subsequent site visits. No companies interviewed refused to host a site visit.

Site visits were made to 17 premises, 11 of which belonged to companies participating in the telephone surveys. Farms and grain merchants (import/export and commercial storage) generally preferred to be visited rather than interviewed by telephone. One farm was interviewed by telephone, while the other five farms were visited only. Three commercial grain importers/exporters and storage operations (two large stores and one small port operation, which formed part of one of the store companies) were visited and one was interviewed by telephone. One pest control company and one malt milling company were interviewed only by telephone. One animal feed production company was interviewed by telephone for information on a site in a different location

Table 1. Inhalable dust levels measured in the British grain industry in the early 1990s—long-term (8 h) average data

Process or task	Number of samples	Mean and range of inhalable dust levels (mg.m^{-3})
Harvesting	40	6.8 (0.2–41)
Grain loading/unloading ^a	31 ^b	22 (1–119)
Grain drying	11	19 (4.1–56)
Grain storage	56	7.1 (1.3–29)
Malting	44 ^c	9.2 (0.4–57)
Animal feed manufacture	33	1.8 (0.1–11)
Milling and mixing animal feed	24	3.1 (0.1–21)

^aBased on measurements made at a grain terminal.

^bExcludes three measurements during loading barges with mean exposure of 150 mg.m^{-3} (range 69–267).

^cExcludes one measurement on the dust plant of 317 mg.m^{-3} .

to the one that was actually visited. Three flour mills were visited and these three companies were included in the six companies interviewed by telephone. Of the nine malting companies interviewed, two were visited only, three were telephoned and visited, and four were interviewed by telephone.

None of the flour millers, maltsters, animal feed millers, grain merchants, or importers/exporters could truly be thought of as a small business. They may employ only a few operators per location but each site was part of a larger organization operating in the UK and abroad. Farmers could be considered as independent small businesses but they often had close ties with a grain merchant or a co-operative who will store and sell on their product.

Over the last 20 years, the industry has moved to 24 h a day, 7 days a week, and 365 days a year production for mills and malting houses. The processes are now generally automated with aspiration of the plant, in-line vacuum cleaning systems, and remote process control. There is compulsory use of a dust sock (i.e. cloth tube) for the discharge of grain from trucks. These changes have resulted in a worker typically now undertaking several tasks where in the past, there would have been a number of people undertaking individual tasks. With automation, workers spend more time in control rooms supplied with filtered air. Overall, there are fewer operators involved with processes and less opportunities for exposure to airborne dust.

Major tasks such as grain and silo spraying, silo cleaning, and cleaning premises are now generally outsourced to specialist companies. Greater enclosure of the process has reduced the need for routine cleaning and there have been moves to encourage vacuum cleaning of premises and plant and consequently, there is less use of sweeping. Use of compressed air to blow dust off high areas and of inaccessible dead spaces is generally prohibited.

From our stakeholder consultation, we identified increased awareness of respiratory diseases caused by exposure to grain dust among people employed in the industry and a greater focus on minimizing contamination of grain by microorganisms. There was generally ready access to disposable half-mask respirators from dispensing boxes located around the factory. In mills, all incoming grain is tested for contamination with mites, insects, and mycotoxin and the product is rejected if found to be unsatisfactory. Farms also have to test their grain crop before it leaves the farmyard for mycotoxins and endotoxins, and records of these test results must be kept. The exact nature of the microorganisms tested depends on the area of the country where the grain was grown.

Compared to the 1990s, there is a reported increased use of RPE for cleaning, maintenance, and some process-related tasks (typically P3 disposable filtering facepiece respirators) through a 'help-yourself/self regulating' approach. Companies are becoming aware of the need to 'fit-test' those wearing RPE, with the responsibility for this being given to the in-house staff, the respirator supplier, or an external consultant. Not all companies currently carried out RPE fit testing, although almost all were reportedly arranging these tests. Areas of the premises where RPE should be worn were generally identified with appropriate signs. Larger companies carry out routine monitoring of personal exposure to inhalable and respirable dust.

Review of published literature from exposure studies in Britain

There are very few published exposure studies from the British grain handling industries during about the last 15 years. Swan and Crook (1998) describe measurements of airborne viable bacteria and fungi in farming and during grain handling at terminals. There were $>10^4$ bacteria and fungi per cubic metre of air in all areas with levels $\sim 10^7 \text{ m}^{-3}$ outside the vehicle cab while harvesting and while unloading grain. These authors showed the potential importance of Gram-negative bacteria and the consequent exposure to endotoxin, although they did not measure this directly.

Simpson *et al.* (1999) published a comparative study of personal exposure to inhalable dust and endotoxin in nine different work environments, including handling of grain in docks and storage and milling tasks in a flourmill. The geometric mean inhalable dust level in these grain processes was 4.4 mg.m^{-3} ($<1\text{--}72 \text{ mg.m}^{-3}$). The highest levels were associated with silo cleaning (median 25 mg.m^{-3}). The geometric mean endotoxin level was $\sim 1150 \text{ EU.m}^{-3}$ (individual measurements ranging from $30\text{--}2.2 \times 10^4 \text{ EU.m}^{-3}$). The highest median endotoxin levels were associated with silo cleaning (6500 EU.m^{-3}). There was a statistically significant correlation between endotoxin and inhalable dust levels ($r = 0.71$) in the grain sector, although the authors noted that endotoxin levels might be expected to vary in different parts of an industry due to processing of the materials.

Swan *et al.* (2007) reported on two successive studies of exposure during harvesting (13 farms), storage tasks (four farms), loading/unloading, grain transfer, and control room tasks at two ports. Measurements were made before and after the introduction of an occupational exposure limit of 10 mg.m^{-3} . They found that before the introduction of the limit,

for dock workers, the inhalable dust exposures exceeded the limit on >40% of occasions and after the introduction on 23% of the samples. On farms prior to the limit being introduced, there were 28% of samples >10 mg.m⁻³ and afterwards only 17.5% above the limit. There was no statistically significant correlation between measurements of endotoxin and inhalable dust on farms ($r = 0.23$) but a highly significant association was found at the docks ($r = 0.98$). These data are shown in Fig. 1.

There are no other published studies of exposure to grain dust in Britain during the last 15 years. Studies of exposure to grain dust have been reported outside Britain, but it is difficult to be sure of their relevance to exposures to British workers because of differences in agricultural practices, handling procedures, climate, and other factors. We summarize these data elsewhere (Spankie and Cherrie, 2010).

Estimates of current exposures in Britain

There were no published data on exposure to mycotoxin, insects, mites, or crystalline silica in the grain industry and so we have not estimated these quantitatively, but there is equally no evidence to suggest that there are significant exposures to these agents in Britain.

Table 2 lists the range of tasks carried out in handling or processing grain, and we have assigned an approximate arithmetic average inhalable dust level to each of these based on the reviewed literature. A more detailed breakdown of the tasks and the control measures in place are shown in the Appendix 1. The estimated inhalable dust concentrations ranged from 0.1 mg.m⁻³ for work inside control rooms with filtered air to 200 mg.m⁻³ during the use of compressed air to clean settled dust. For each of the six sectors in the grain industry, we estimated the aver-

age percentage of time workers spend in these tasks. For example, it can be seen that operators in milling spend the largest proportion of their time in control rooms (56%) and farmers the least time (2%). The sector median exposure estimates range from 0.9 mg.m⁻³ for animal feed manufacture to 3.2 mg.m⁻³ for farming, with the corresponding 90th percentiles ranging from 6.3–19 mg.m⁻³.

Exposure-significant tasks that could result in exposures >10 mg.m⁻³ if carried out for a whole day are

- Store work;
- Blending additives;
- Packing;
- Clearing blockages;
- Ship loading;
- Cleaning—dry sweeping;
- Other cleaning—malting;
- Loading—shovel and
- Cleaning—using compressed air.

However, only store work and ship loading are typically carried out for more than a quarter of a working day.

Assuming a 5% decline per annum in exposure levels, the mean and upper measured value for each sector from Phillips study were extrapolated to estimate the likely exposure levels in 2010. These data are shown in Fig. 2, along with the original Phillips data and the 2010 task-based estimates of exposure, described above. There is reasonably good agreement between the estimates of current exposures using the two approaches. In five of the six processes, the mean was within ~0.5 mg.m⁻³ or less. Only in the case of grain import/export, was there an important discrepancy (8 mg.m⁻³ for the extrapolation from the Phillips data and 2.2 mg.m⁻³ using the task data). The main reason for the difference is probably the dramatic reduction in recent years in the amount of cleaning undertaken. Phillips notes that in the 1990s, there were teams of cleaners 'employed to pile the deposited dust back on the fast moving conveyors' with exposures during this work being as high as 100 mg.m⁻³ and seldom <20 mg.m⁻³, whereas today terminal operators spend only ~3 or 4% of their time cleaning, using cleaning methods where less airborne dust is generated. If the task-based estimates are correct, then for all six sectors between ~5 and 20% of daily average inhalable grain dust exposures are >10 mg.m⁻³.

The data from Simpson *et al.* (1999) and Swan *et al.* (2007) suggest that in some situations, there is a good correlation between inhalable dust and endotoxin but

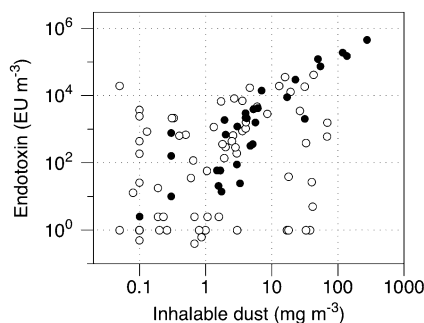


Fig. 1. Comparison of inhalable dust and endotoxin levels on farms and at docks [from Phase II of the study by Swan *et al.* (2007)] Legend: solid points are from dock work and open points from farm work.

Table 2. Percentage time on each task by sector in the grain industry and estimated inhalable dust levels

Task	Estimated inhalable dust exposure levels during task (mg.m^{-3})	Farming	Import/export	Commercial storage	Malting	Milling	Animal feed
Control room with filtered air	0.1	2%	25%	25%	15%	56%	20%
Loading—bulk	0.5	—	10%	5%	15%	2%	5%
Intake	0.5	5%	14%	10%	10%	10%	10%
Routine inspection of plant	0.5	—	10%	10%	24%	5%	10%
Harvesting—inside cab with air filtration	1	30%	—	—	—	—	—
Drying—local controls	1	1%	—	10%	5%	—	—
Other cleaning—non-malting	1	9.50%	2.5%	2%	—	1%	10%
Pelletizing	1	—	—	—	—	—	41%
Store work	5	50%	10%	22%	14%	—	1%
Blending additives	5	—	—	—	—	1%	1%
Packing	5	—	—	—	—	23%	—
Clearing blockages	5	0.50%	0.50%	0.50%	1%	1%	1%
Ship loading	5	—	27%	—	—	—	—
Cleaning—dry sweeping	10	1%	1%	0.5%	1%	1%	1%
Other cleaning—malting	10	—	—	—	15%	—	—
Loading—shovel	10	1%	—	15%	—	—	—
Cleaning—using compressed air	200	—	—	—	—	—	—
Estimated industry long-term (8-h average) exposure level (mg.m^{-3})		3.2	2.2	2.9	2.7	1.5	0.9
90th percentile long-term (8-h average) exposure level (mg.m^{-3})		19.0	14.0	18.0	17	10.0	6.3

in other situations such as farming, there was no relationship between these measures (Swan *et al.*, 2007). However, these data suggest that in Britain, for inhalable dust levels $<10 \text{ mg.m}^{-3}$, the endotoxin level would not be expected to exceed 10^4 EU.m^{-3} .

DISCUSSION

The inhalable dust levels in the British grain industry were high in the 1990s, with many workers in all sectors being frequently exposed to 8-h average inhalable dust levels $>10 \text{ mg.m}^{-3}$ (Phillips, 1993). Key high-exposure tasks were associated with cleaning and maintenance. Since this investigation, there have been considerable changes in the technology and work practices in the industry. In general, there is more automation and fewer workers employed in grain handling processes. In addition, there appears to be a greater focus on minimizing the release of dust into the work environment, both from process-related activities and from cleaning and

more consistent use of RPE. Finally, there is a greater focus on the quality of the finished products and this should contribute to lower emissions into the workplace and less bacterial and fungal contamination in grain. All these changes will have tended to reduce exposures compared to the past, both to inhalable grain dust and to toxic components such as endotoxin or mycotoxin.

Our best estimate is that the average level of exposure to inhalable dust associated with all tasks in the British grain industry are generally $<10 \text{ mg.m}^{-3}$ (Table 2) and that taking account of the pattern of work for operators in the key industry sectors the average 8-h personal exposure levels are probably less than $\sim 3 \text{ mg.m}^{-3}$, although perhaps 5–20% of individual personal exposures in the industry are still $>10 \text{ mg.m}^{-3}$.

There is uncertainty in the data available to construct the task–exposure matrix (Table 2). The time budgets for each sector are based on a limited survey of stakeholders, and we cannot be certain about the

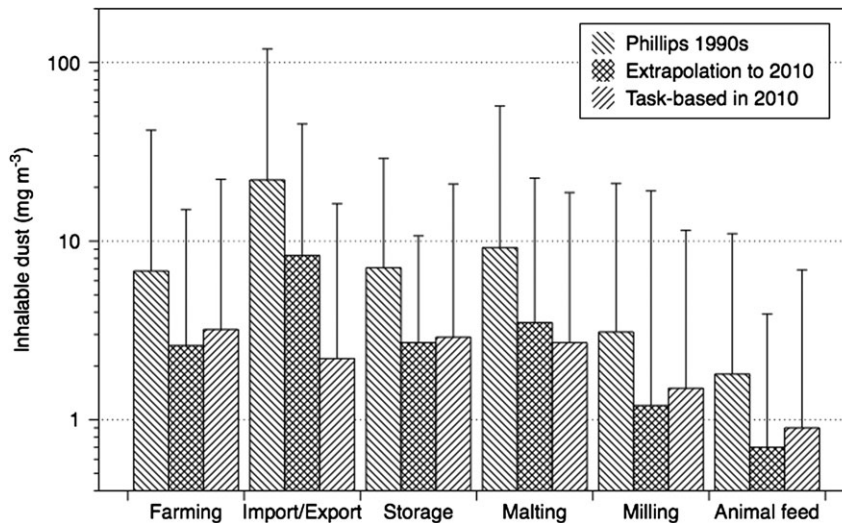


Fig. 2. Inhalable dust levels measured in the British grain industry in the early 1990s and estimated levels in 2010—long-term (8 h) average data. Note: The bars represent the upper measured value (Phillips), the upper extrapolated measurement from Phillips, or the estimated 90th percentile from the task-based assessments, assuming $GSD = 4.5$. Phillips data excludes one measurement in maltings of 317 mg.m^{-3} and three measurements in a terminal during loading barges with mean exposure of 150 mg.m^{-3} (range 69–267).

work practices of all individuals or organizations. For example, we do not know whether the contractors carrying out silo cleaning do this work for a few hours or a whole day, i.e. they may work at more than one site on the same day. In addition, there are uncertainties about the level of exposure for some tasks such as shovel loading on farms or at merchants, during dry sweeping, ship loading, and in pedigree animal feed production because of the limited data available to us (see Appendix 1, for identified uncertainties in exposure levels). Also, we are less certain about practices in smaller companies involved in the grain sector. For the extrapolation from the 1990s exposure data, we used the data from a general review to identify a likely annual percentage reduction in exposure in advance of developing the task–exposure matrix, but we have no direct quantitative information to substantiate the chosen value for the British grain industry. However, the fact that these two independent approaches to assess current exposure give broadly similar estimates increases the likelihood that these levels reflect current conditions.

There is much less information available to predict endotoxin exposure levels, although we consider they are likely to be $<10^4 \text{ EU.m}^{-3}$ provided inhalable dust levels are $<10 \text{ mg.m}^{-3}$, which is comparable to other industries where endotoxin is found but higher than may be associated with adverse health effects (Douwes *et al.*, 2003). Exposure

to both dust and endotoxin should be controlled to as low a level as is reasonably practicable. The Dutch Expert Committee on Occupational Safety has published health-based exposure limits for both endotoxins and grain dust. They recommend a short- and long-term exposure limit of 90 EU.m^{-3} for endotoxin (DECOS, 2010) and a long-term limit of 1.5 mg.m^{-3} for inhalable grain dust (DECOS, 2011). These limits further emphasize the need to keep exposure to both dust and endotoxin controlled to as low a level as is reasonably practicable. Because of the poor correlation between inhalable dust and endotoxin levels $<10 \text{ mg.m}^{-3}$, it will be necessary to monitor both measures to assess the degree of control in any situation.

Cleaning and some maintenance tasks are probably still associated with higher exposures, although this work is also less common than in the past and is generally done while the operator is wearing RPE. It is likely that respirators would reduce the dust concentration inhaled during the task by about a factor of ≥ 20 (HSE, 2008), but the impact on 8-h average exposure would not be substantial because such tasks are generally a small part of the operator's working day. Further work is needed to improve the quality and consistency of the RPE programmes delivered within the industry. The industry has made substantial progress in introducing exposure controls on plant and equipment over the last 15 years and further progress in this respect should be encouraged.

The actual grain dust exposure levels should be verified in an industry-wide exposure survey to measure inhalable endotoxin, mycotoxin, and mite allergen along with inhalable dust concentrations.

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APPENDIX 1

Typical control measures and exposure rating for tasks in the grain industry

[Exposure codes—insignificant exposure (I), significant exposure (S), or unknown exposure (U)].

Task	Industry sector	Task elements	Typical control measures	Exposure
Control room operations	Farming	Grinding and measuring the grain moisture	Segregation	I
	Import/export		General ventilation and segregation	I
	Commercial storage	Monitor the grain quality (including moisture) remotely via sensors	General ventilation (air-conditioned room) and segregation	I
	Milling			
	Malting	Grind and analyse sample—laboratory bench work	General ventilation (air-conditioned room) LEV not routinely applied (occasionally performed in fume cupboard)	I
	Import/export			
	Commercial storage	Transferring grain (into and out of drier) by operating overhead conveyors and elevators	General ventilation (air-conditioned room) and segregation	I
	Milling			
	Malting	Transferring grain through processing plant beyond the drier by operating overhead conveyors and elevators	General ventilation (air-conditioned room) and segregation	I
	Animal feed			
Bulk outloading	Import/export	Process control operations (setting operational parameters, initiating/terminating, and running processes)	General ventilation (air-conditioned room) and segregation	I
	Commercial storage			
	Milling	Lower the delivery spout on the bin and the mobile local extract ventilation hood into the tanker 'hull' and fill tanker. During filling, the tanker is parked in the loading bay but operators do not need to stay in this yard or building.	LEV and segregation During filling, tanker driver spends time in weigh bridge office, vehicle cab, or dust-free area of yard Outloading operator initiates/terminates the tanker filling from weigh bridge office	I
	Malting			
	Animal feed			

Exposure to grain dust in GB

9 of 12

Appendix 1. *Continued*

Task	Industry sector	Task elements	Typical control measures	Exposure
Intake	Import/export	Fit/remove dust sock onto/off hatch before/after tipping	None	I
	Commercial storage	Scrape of residual grain from inside the lorry after tipping grain	RPE (FFP3)	U
	Milling	Initiate/terminate tipping of grain from cab of lorry	Segregation During tipping, spend time in weigh bridge office, vehicle cab, or dust-free area of yard	I
	Malting			
Routine inspection of plant operations	Animal feed			
	Import/export	Walking though the plant and premises to carry out a visual monitoring/observation of automated processes initiated in the control room	None	I
	Commercial storage			
	Milling			
Harvesting	Malting			
	Animal feed			
Drying grain	Farming	Combine harvesting the field crop and tipping from the cart into the yard	General ventilation and segregation (air-conditioned and filtered cabin enclosing driver)	I
	Import/export	Manual operation of drier from consul beside drier.	None	I
Other cleaning—non-malting	Commercial storage			
	Most malting			
	Farm	Vacuum cleaning drier at the end of harvest	RPE (FFP3)	I
	Import/export			
	Commercial storage			
	MillerMaltings	Vacuum cleaning premises and plant using in-house vacuum line on a regular basis (continuous cleaning of premises; dedicating one shift a week to cleaning plant and premises or cleaning work area every shift)	RPE (FFP3)	I
	Maltings	Wet cleaning shed floor with road sweeper vehicle	Segregation (cabs on vehicle enclosing driver)	I
	Farms	Manual pressure washing premises and vehicles	RPE/sometimes noRPE	U
	Commercial storage			
	Maltings			
	Animal feed			

Appendix 1. *Continued*

Task	Industry sector	Task elements	Typical control measures	Exposure
Pelletizing	Milling Maltsters	Organic waste from flour production (fines, dust from LEV systems, bran, etc.) is mixed with water and sometimes a binding agent and pressed into animal feed product	Segregation (housed in a dedicated room in mill)	I
	Animal feed	Commercial and pedigree animal feed made by pressing feed grain and animal feed from mills	None	U*
Storage operations	Farms	Install pedestal ventilation pipes or augers in shed	None	I
	Import/export	Inspect automated shed operations	None	I
	Commercial storage	Unblock obstructions in transfer systems, e.g. elevators	RPE (FFP3)	S
	Maltings	Sweep edges (of grain piles) with brush	None	S
	Animal feed	Transfer grain around yard and into and around sheds by vehicle	Segregation (air-conditioned and filtered cabin enclosing driver)	I
Blending additives	Milling Animal feed	Flour is mixed with nutrients removed during the milling operation and additives using a manually operated batch process	RPE(FFP3)/LEV/limit frequency of operation	S
Packing	Milling	Operation of a manual bagging unit to fill bulk containers	LEV and may be enclosed by pulling the 'spout' on bulk container over the mouth of the flour dispenser pipe and securing it on the pipe	I
		Operation of an mechanized/automated filling station to fill 25–75 kg bags	LEV and bleeper (alarm summons in event of interruption to operation or breakdown)	I
Clearing blockages	All sectors	Unblock obstructions in transfer systems, e.g. elevators or processing plant, e.g. screens	RPE (FFP3)	S
Ship loading	Import/export	Sweeping up spills from lorries tipping and clam shell grab on crane	Segregation of crane operator (air-conditioned and filtered cabin enclosing driver) and RPE (FFP3) for outside operators	U
Cleaning—dry sweeping	All sectors	Sweep shed floor between grain piles and emptied sheds with mechanized sweeper	RPE (FFP3)	U
		Sweeping up spills from leaks or opened plant with brush or scissors mop	RPE (FFP3)	U

Exposure to grain dust in GB

11 of 12

Appendix 1. *Continued*

Task	Industry sector	Task elements	Typical control measures	Exposure
Other cleaning malting	Malting	Sweeping dry waste and culms out from underneath/inside the kiln	RPE (powered full-face respirator—TM2 or 3)	S
		Hosing/power washing inside steepers and germinators and underneath germinators and kilns	Oil skins and visor	I
Silo cleaning	Malting	Scraping and sweeping inside empty silo	RPE (FFP3)	S
Loading with a shovel	Farms Merchants	Loading open-topped lorry with shovel loader	Segregation (air conditioned and filtered cabin enclosing driver)	U
Cleaning using compressed air	All sectors	Blowing out settled dust from high level surfaces and ledges in premises and inaccessible spaces in plant and vehicles	RPE (FFP3)	S

^aNote exposure during commercial feed pelletising is judged insignificant (I)

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