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Respiratory Illness in Farmers

Dust and bioaerosols exposures in animal handling facilities

A report for the Rural Industries Research and Development Corporation

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Foreword

Occupational health and safety issues have become a major issue in Australia and all employers are required to determine whether farm environments have the potential to adversely impact on the health of their workers. The aim of this study was to review the literature to determine what is known about the potential exposure to dust and bioaerosols and the potential impact on the respiratory health of workers in animal handling facilities in an agricultural setting. The aims of the study were to identify the concentrations of dusts and bioaerosols to which people working in animal production are currently exposed and determine which animal production systems have the potential to be a risk to worker health.

The report reviews more than 250 Australian and international papers and reports on the topic. This literature acknowledged that farm workers may experience respiratory symptoms as a consequence of working in these conditions. The link between the often dusty work environment of animal husbandry workers and its adverse impact on health on is not as well defined as was expected, as very few international airborne dust and bioaerosol exposure studies have been adequately linked to epidemiological studies and none in Australia. Consequently more in-depth work on this topic needs to be undertaken in Australia.

The importance of this report is that it provides basic statistical information on the impact of dust and bioareosols on farm workers employed in the pig, poultry, cattle, sheep, horse and deer industries. It is primarily targeted at occupational health and safety and environmental health practitioners who may need to advise farm owners/managers in Australia on the potential respiratory risks for their workers from exposure to dusts and bioaerosols. Investors in these animal industries may use the report as a basis from which to make decisions about controlling dust and bioaerosols in enclosed animal housing. The report will also be useful to medical practitioners whose patients may be employed in animal handling facilities and presenting respiratory symptoms that may be a result of their work. The report will also inform policy development, and will help RIRDC as it plans its research and development priorities into the future.

The report has identified that more detailed studies on the impact of exposure to dust and bioaerosols on the health of agricultural workers need to be undertaken in Australia.

The project was undertaken by a large team contributing to the overall outcomes of the report except for Section 1.1 written by Mr Ryan Kift, Chapter 3 written by Dr Sue Reed and Chapter 4 written by Dr Maria Quartararo.

This project was funded by the RIRDC managed Joint Venture in Farm Health and Safety which is partnered by the Grains R&D Corporation, Meat and Livestock Australia, Australian Wool Innovation, Cotton R&D Corporation, Sugar R&D Corporation and the Rural Industries R&D Corporation.

This report, an addition to RIRDC's diverse range of over 1500 research publications, forms part of our Human Capital, Communication and Information Systems R&D program, which aims to enhance human capital and facilitate innovation in rural industries and communities.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O'Brien
Managing Director

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Definitions and Abbreviations

β	Beta
%	Percentage
µg	Micrograms
$\mu g/m^3$	Micrograms per cubic metre
µm	Micrometre
ACGIH	American Conference of Governmental Industrial Hygienists
ACI	Anderson Cascade Impactor
AGI	All glass impinger
AIHA	American Industrial Hygiene Association.
AIOH	Australian Institute of Occupational Hygiene
AM	Arithmetic mean
ANCOVA	Analysis of Covariance
APAIS	Australian Public Affairs Information Service
APL	Australian Pork Limited
AS	Australian Standards
BAL	Bronchoalveolar lavage
Bioaerosol	Includes a range of biologically active particles including cultural, nonculturable and dead microorganisms their fragments, toxins and particulate waste products from a variety of living organisms. This normally relates to the monitoring of fungi and bacteria (ACGIH, 2005).
BMRC	British Medical Research Centre
CA	Cellulose acetate
CAB Abstracts	Agricultural and applied life sciences database
CEN	Comité Européen de Nomalisation (European Centre for Standardisation)
CFU	Colony Forming Units
CFU/m^3	Colony Forming Units per cubic metre
CI	Confidence Interval
CO_2	Carbon dioxide
CV	Coefficient of Variation
DPI	Department of Primary Industries
Dust	Organic dusts not otherwise classified elsewhere i.e. metal dusts
EBESCO	Electronic Journal database
Endotoxin	A toxin confined within certain bacteria and released the bacterial cell dies or is broken down.
EN	European Standard
EPA(US)	Environmental Protection Agency (United States)

ES	Exposure Standards: An air concentration level that has been adopted by NOHSC to be an acceptable air concentration to which most people can be exposed without having any short term or long term health effects
EU/m^3	Endotoxin Units per cubic metre
Exposure	Contact between an agent and a target
FLD	Farmers Lung Disease
FEV_1	Forced expiratory volume in 1 second
FVC	Forced expiratory vital capacity
GF	Glass fibre
GM	Geometric mean
H_2S	Hydrogen disulfide
HP	Hypersensitivity Pneumonitis
HSE	Health and Safety Executive (UK)
Inspirable Dust	Inspirable (inhalable) dust is defined as a material that may be deposited anywhere along the respiratory tract, where the aerodynamic diameter of the dust may range from 0 to 100 µm.(ACGIH, 2005)
IOM	Institute of Occupational Medicine
ISO	International Standards Organisation
kg	Kilogram
L/min	Litre per minute
LAL	Limulus Amebocyte Lysate
LR	Logistic Regression
MAC	Maximum Air Concentration (German)
mg/m^3	Milligrams per cubic metre
mL	Millilitre
mL/min	Millilitre per minute
MMEF	Maximum midexpiratory flow
ng/m^3	Nanograms per cubic metre
NH_3	Ammonia
NIOSH	National Institute of Occupational Safety and Health (US)
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NOHSC	National Occupational Health and Safety Commission
ODTS	Organic Dust Toxicity Syndrome
OHS	Occupational Health and safety
OR	Odds ratio
OSHA	Occupational Safety and Health Administration (USA)
PM_{10}	Particles less than 10 µm aerodynamic diameter

$PM_{2.5}$	Particles less than 2.5µm aerodynamic diameter
PPE	Personal protective equipment
ppm	Parts per million
PTFE	Polytetrafluoethylene
PVC	Polyvinyl chloride
R	Regression Coefficient
RAST	Allergen-specific IgE antibody test
Respirable Dust	Respirable dust is defined as the proportion of airborne dust levels that when inhaled may penetrates to the unciliated airways of the lung. The median diameter of the dust particles is 4.25 µm. Respirable dust fraction is defined by ISO 7708 (AS2985, 2004)
SALPADIA	Swiss Study on Air Pollution and Lung Disease in Adults
SABRE	Surveillance of Australian workplace Based Respiratory Events
SE	Standard Error
Static sample	Static samples are defined by AS2985 (2004, p5) as samples collected at a fixed location. It should be noted that AS2985 that advised that static samples should not to be used to evaluate health risks unless a specific situation or circumstances indicates otherwise.
TLV's	Threshold Limit Values
TWA	Time Weighted Average

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Executive Summary

Aim

Agricultural practices have become more intensive in the past 50 years resulting in greater exposure of farmers to dust and bioaerosols, and a reported increase in respiratory illness in farm workers. As has been seen in industries like mining, dust and particulate matter can have severe negative effects on health, including development of conditions like miners lung and silicosis.

The aim of this study was to undertake a review of available research on exposure of agricultural workers to dusts and bioaerosols in animal production facilities, and the potential risks to respiratory health. This study did not investigate exposures to gases and other chemical contaminants and their impact on respiratory disease.

Background

There are two different dust fractions that can have a potential negative impact on human health, inhalable (inspirable) dust or respirable dust. Inhalable dust consists of particulates that are small enough to be inhaled (less than 100 micrometers in diameter) but may include a large proportion of particles that are not considered respirable. These larger particles may lodge in the bronchi of the lungs. Respirable dust is that portion of airborne particulates which, when inhaled, reach the lower section of the lungs, alveoli or gas exchange section of the lungs. Respirable dust particles are normally less than 7 micrometers in diameter.

Bioaerosols are defined as airborne organisms that are living or are derived from living organisms. The origins of these particles include range of biological entities, such as virus, bacteria, fungi, algae, or protozoa. The bioaerosols relevant to this study are to airborne bacteria and fungi as these have been identified to have a potential to impact to respiratory health.

There have been many methods published that measure exposures to inspirable and/or respirable dusts and bioaerosols but if airborne contaminant standards are to be developed and used for comparison of health outcomes, standard methods of collecting airborne samples need to be carefully defined and followed throughout the world. The focus of this study was farmers and workers in animal production, including animal handling activities. The review of health outcomes was limited to studies of poultry, pig and cattle farmers, whereas the worker exposure data was reviewed for a range of animal industries.

The main objectives of the study were to:

- identify the concentrations of dusts and bioaerosols to which people working in animal production are exposed that may be detrimental to respiratory health
- determine which animal production systems have the potential to be a risk to worker health
- determine current knowledge gaps on risks to humans from inhalation exposure during animal handling.

Target Audience

This report reviews the international and Australian literature on worker exposures to dusts and bioaerosols and their potential impact on the respiratory health of workers in animal handling facilities. It is targeted at occupational health and safety and environmental health practitioners who may need to advise farm owners/managers in Australia on the potential respiratory risks for their workers from exposure to dusts and bioaerosols. It will also be a resource for researchers, who are planning to undertaken further research in this field and for medical practitioners, whose patients may be employed in animal handling facilities and presenting with respiratory symptoms that may be a result of their work.

Methods

This study was limited to a review of the literature and reports from a number of organisations. The literature was restricted to publications written in English, and other reports obtained through contact with various Australian research and industry organisations. Overseas organisations, known for their research in these areas were also contacted to request reports that may not have been published.

Results

Worker Exposures

Considering the number of people world wide that work in animal housing and handling facilities, few studies have been undertaken internationally on worker exposures to dusts and bioaerosols. There have been only seven Australian studies (Rhyder 1993, Holyoake, 2002, McGarry et al 2002, Kift et al 2002b, Reed et al 2003a, Reed et al 2003b, Kift et al. 2004a and 2004b & Davidson 2004) that have measured the personal exposure of workers to dusts and bioaerosols in sites relevant to animal handling activities using sampling methods that met the relevant Australian standard. Most of these were small studies which monitored two or three people on one day. Of these, only the study by Holyoake (2002) on pig housing assessed exposure to dusts, both inspirable and respirable, and endotoxins. In particular, this study investigated the various types of building used in the pig industry and reported the exposures according to building type and bedding used. Surprisingly there has not been significantly more studies published overseas which investigated worker exposure using sampling methods that meet International standards. In Europe nine studies have been published and in North America five studies published.

Australian studies of personal exposures need to be compared to current National Occupational Health and Safety Commission (NOHSC) exposure standards, for which there is only a standard for inspirable dust (rough dust) of 10 mg/m^3. Rough dust is defined as substances, in dust form, that do not have a specific exposure standard. The respirable dust (not otherwise classified) exposure standard of 3mg/m^3 published by American Conference of Governmental Industrial Hygienists (ACGIH) is used to compare respirable dust exposures. It should be noted that these standards are not specific to agriculture, and may need to be lowered when there is a better understanding of which exposures in agriculture cause what respiratory symptoms.

The condensed findings of the Australian studies for average worker exposure to dusts and bioaerosols by industry are summarised in Table 1. None of the Australian studies reviewed adequately identified the species of fungi and/or bacteria that may be present in the environments monitored. This is important because some species of fungi and/or bacteria may have greater impacts on respiratory symptoms than others. Identification of these species and development of appropriate control measures is important for worker health.

Table 1 Summary of Worker Exposures to Dust and Bioaerosols in Animal Handling Facilities

Animal Industry	Inspirable dusts mg/m^3	Respirable dusts mg/m^3	Endotoxins EU/m^3	Fungi CFU/m^3	Bacteria CFU/m^3	Sources
Pig	10.04	0.81	841.7		2.08 x 10^5	Rhyder 1993, Holyoake 2002, Chinivasagam & Blackall 2005
Poultry	9.95	0.48				McGarry & Ivin 2002
Sheep Shearing	0.74			3.43 x 10^3	2.84 x 10^3	Kift et al 2004b
Horse feedsheds	8.49	1.08	66	1.49 x 10^3	0.86 x 10^3	Reed et 2003b & Davidson 2004
Cow feedlots	0.20	2.72		1.80 x 10^3	1.42 x 10^3	Reed et 2003a
Deer	2.74	1.64		0.91 x 10^3	2.53 x 10^3	Kift et al 2002a

Exposure and respiratory health

The majority of studies examined in this review are of European and North American farmers. In most studies the prevalence of respiratory symptoms in farmers and workers in pig, poultry and cattle production is higher than in non farming populations. From this you may conclude that farmers and farm workers have a higher risk than normal for the development of respiratory symptoms and decline in lung function as a result of their occupation. Few studies, eight in Europe and five in North America, have assessed exposure by personal and/or static monitoring and related the results to reported respiratory symptoms. However, from these studies there is some evidence that symptoms are associated with exposure of farm workers to dust and endotoxins but this is not consistent for all studies. This may have been due to methodological difficulties in measurement and the duration of measurement, rather than a true lack of an association. Importantly, endotoxin levels, which relate to gram negative bacteria, have been found to be both significant and negative predictors of lung function and lung function decline in cohort studies of pig farmers. This may also be true for poultry farmers since a negative association was found between endotoxin levels and lung function measurements in cross-sectional studies. Static or personal exposures to dusts or bioaerosols were not measured in any of the longitudinal studies of cattle farmers. However, these studies are the least relevant to Australian cattle farmers because of differences in climate and farming practices.

Key Findings

It is well accepted that animal husbandry practices are dusty and that farmers often experience respiratory symptoms as a consequence of working in these conditions. Epidemiological studies support these conclusions, although few studies have demonstrated an association between respiratory symptoms and exposure to dust and bioaerosol concentrations. The evidence is strongest for an association with endotoxin exposure. Current Australian standards used for exposure to airborne contaminants in animal handling industries need to be revisited as they are not specific to the agricultural industry let alone animal handling. For airborne exposure standards to be adopted it is important that standardised methods of measurement of dust and bioaerosols use used to collect the data that the exposure standards are developed on.

The conclusions of this report are based mainly on the findings of overseas studies, with only a few contributions from Australia. Generally, the findings of the Australian studies are consistent with the studies from North America and Europe. However, there are key differences in some areas, eg, the relatively higher asthma prevalence rates in Australian farmers and variations in methods used to measure dust and bioaerosol concentrations. Given this, and differences in animal farming practices between Australia, and North America and Europe, further Australian research is required in the areas of both exposure assessment and respiratory health outcome measurement.

No Australian respiratory health studies have been undertaken that relate directly to measured airborne contaminant exposures. Before any conclusions can be made about the potential impacts of exposures to airborne contaminates, properly designed and implemented exposure and health studies need to be undertaken in Australia

Recommendations

It is highly recommended that studies be undertaken in each of the major animal production industries in Australia such as pigs, poultry, dairy, horses and sheep, and in a range of conditions, such as different climate and seasons. The areas that further studies should focus on include:

- measuring worker exposure to a range of contaminants
- measuring changes in respiratory function before and after exposure
- recording respiratory symptoms for at least a week after exposure
- measuring both exposure and respiratory function and symptoms over time
- measuring long term changes in respiratory function and symptoms
- identifing the species of bacteria and fungi to which workers are exposed in the different animal industries, define their toxicity, and if appropriate develop appropriate approaches to exposure control.

Chapter 1: Introduction to the Problem

1.1 Overview of agriculture

Worldwide, more people are involved in agriculture than in any other work related activity (Jacobs, 1994). However, in the developed nations (including Australia), the proportion of the workforce engaged in agricultural production is now less than 2% and continues to contract as modern production techniques are adopted (Merchant and Reynolds, 2000). Technological advances and socio-economic forces have brought about dramatic changes in agriculture and agricultural working conditions. In some cases these changes have proved beneficial (reduction of some risks) while in others, exposures to potential risks have intensified. The use of livestock confinement housing for intensive animal production has led to an increase in specialisation, with workers spending more time on fewer tasks. In general, agricultural workers continue to work long hours under what is considered adverse climatic conditions. They also tend to differ from most other occupations in having a larger proportion of the workforce older than 65 years and younger than 16 years (Merchant and Reynolds, 2000).

1.1.1 Different work done on farms

Agriculture is a broad economic sector that includes multiple occupational and environmental exposures to dusts and bioaerosols associated with varying work practices (Kirkhorn and Garry, 2000). Many occupational health and safety risks are shared between different tasks and often these tasks will have their own additional risks (Fragar et al. 2001). There are many different types of work that are regularly carried out by the same agricultural worker. These tasks may include preparing feed, animal feeding, cleaning buildings, harvesting, moving animals, performing veterinary treatments, maintenance and other husbandry tasks. In contrast to an industrial worker, the work of an agricultural worker varies throughout the year depending on the nature of the crop, geographical location, and the type of handling or processing required to bring the product to market (Ferguson, 1998). Each of these activities brings with it, its own individual risk. This risk can result in a potential disease, injury or other potentially hazardous problem. Farm workers in the animal production industries have the risk of different types of injuries depending on the animal and living area of that animal. For example, slippery surfaces in confinement facilities are just one hazard (Virtanen et al. 2003).

1.1.2 Confinement housing

Confinement housing was first applied to poultry production in the early 1960s. Since that time, it has also been used extensively for swine production and in a limited fashion for dairy operations as well as beef and sheep production (Donham, 1994). Confinement houses or animal housing are a different production method, to historical outdoor farming methods, which are used in the raising of livestock. Confinement houses for livestock (usually pigs, poultry or cattle) enable the producer to raise a large number of animals under controlled conditions so that labour, time, feed and management of the environment for the animals can be used more efficiently than in the field (Gurney et al. 1991). Confinement houses are used worldwide, however the greatest use of confinement housing occurs in European and in particular, Scandinavian countries. Their use in these countries is widespread as it is often too cold and/or wet for the animals to be kept outdoors, and mostly occurs in winter. In Australia confinement houses are used mainly for swine and poultry, and to a lesser degree for medium (sheep, goats) and larger animals (cattle, horses and deer). This is because the environmental conditions found in Australia are more favourable for the raising of livestock outdoors. The winter in Australia still allows animals to be kept outside although some may be kept indoors to better manage the feed supplements being made available to them. Many people who work in confinement housing for animals are also involved in other types of farming, as many grow their own feed (Virtanen et al. 2003).

Health risks on farms with animal housing have increased as a result of labour saving technology (McDuffie et al. 1995). Various factors that contribute to these risks include:

1. building designs that minimize housing costs per animal
2. mechanised feeding to deliver feed to the animal; and
3. air exchange to optimise and maintain animal health.

The above factors can affect air quality which may result in ill health in humans.

Animal confinement can also be used to hold animals while veterinary treatments and other inspections of the animals are undertaken. This is different to raising the animals indoors. Large numbers are often held within a small area, for a short time period. People working with the animals are exposed to air-borne contaminants that are brought in on or produced by the animal. This is common in Australia and can affect people who work with large and medium size animals that are usually kept outdoors (e.g. cattle, horses and sheep). Exposure may also be substantially increased by the method of feeding or animal waste removal (Murphy, 1992). When animals are managed indoors their behaviour may also become unpredictable and potentially dangerous.

1.2 Aims and Objectives

The aim of this study is to undertake a gap analysis of the data available on exposure of workers to dusts and bioaerosols in animal production facilities, and the potential risks to health. To achieve this aim the project has the following objectives:

- identify the concentrations of dusts and bioaerosols to which people working in animal production are exposed that may be detrimental to respiratory health
- determine which animal production systems have the potential to be a risk to worker health
- determine gaps in our current knowledge on risks to humans from inhalation exposure from animal handling.

Chapter 2: Methodology

The literature review process involved examination of a number of electronic databases, contact with research and industry organisations in Australia and overseas, and personal communication with leading researchers in the field. The purpose of this multifaceted approach was to obtain a comprehensive range of publications and information to enable a current assessment of the relevant information required to address the objectives of the study.

2.1 Literature Search

Search keywords included: organic dust, inorganic dust, respirable dust, bioaerosols, endotoxin, bacteria, fungi, allergenic, mycotoxins, glucans, actinomycete, respiratory diseases, respiratory symptoms, ODTS, HP, Farmers lung, bronchitis, asthma, inflammation, fibrosis, zoonoses, animal confinement, animal handling, cattle, sheep, pigs, chickens, swine, deer, poultry, hogs, broilers, horses, exposure.

The following electronic databases were searched for relevant articles:

- Science Direct
- EBESCO
- Cambridge Journals
- Proquest
- Blackwells
- Toxnet
- Medline
- Pubmed
- APAIS
- CAB Abstracts

The Australian Libraries Network was used to search for relevant publications in the following library catalogues:

- National Occupational Health and Safety Commission
- CSIRO
- National Library
- Australian National University
- University of Sydney
- University of New South Wales
- University of Canberra

With the exception of one German paper, only journal articles written in English were reviewed.

2.1.1 Internet Searches

An Internet search was undertaken to locate relevant papers and reports relating to the same keywords as for electronic journal databases. Materials were considered acceptable if from credible, independent sources such as university websites or recognised occupational health related organisations like NIOSH or ACGIH.

2.1.2 Other

Conference proceedings from organisations that may have contained papers relevant to the study were reviewed, including AIOH, IOHA and Animal Production in Australia.

A list of people and organisations contacted directly are attached in Appendix 1. In an attempt to ensure that no research group was missed an email, requesting assistance was sent to the Australian Research Co-ordinators email list.

2.2 Sorting of information collected

Papers that were reporting on either exposure and/or health data from animal handling in facilities such as research facilities (using rats, guinea pigs etc) and small animal housing (eg dogs, cats guinea pigs etc) were excluded from the review. Papers and publications on animal related farming were separated into two groups, exposure related data and health related data. The two groups were not mutually exclusive.

2.3 Gaps in Current Knowledge

The identification of gaps in knowledge involved an examination of the evidence from the review of the published exposure data as well a review of published data relating to respiratory health effects

The findings of each review are presented separately in Chapters 3 and 4 and discussed together in Chapter 5. From this combined review a comprehensive picture of current knowledge was obtained.

Chapter 3: Exposure Data

When reviewing the literature on exposure, many papers related more to the general indoor air quality of the shed or animal housing, and did not relate directly to worker exposure. In most cases the projects were undertaken to look at animal health and how to improve the air quality for the animals in general. The studies with animal health as a focus collected the air samples using static (sometimes referred to as stationary) sampling methods as the animals are not able to appropriately wear the current air sampling equipment without undue stress. As a consequence many of the studies collected samples at only one point in a shed or facility. Worker exposures should be assessed by what is called personal sampling which involves measuring the airborne concentrations in the breathing zone of the worker, over a whole working shift (if possible), while the worker is undertaking typical activities. The breathing zone of a worker is defined as a 30cm radius from the nose. The data in many studies were collected using standard sampling methods but the samples collected were static samples not personal samples. Therefore the data collected may be inappropriate to determine worker exposure and the likely health effects of those exposures. Across these studies the data were collected using a variety of sampling methods, which in some cases were not clearly defined. This made comparative analysis between studies difficult. Furthermore, some of the studies referred to earlier papers that were difficult to access, or to standards that are not available in English.

3.1 Exposure Data Methodology

The papers that were collected for the exposure data analysis section of the study were initially divided into animal types:

- pigs/swine
- poultry
- cows/cattle
- horses
- sheep
- deer

Descriptions of the type of farming system, and activities undertaken during exposure assessments were often not clearly described. For papers to be considered to have acceptable exposure data it was important that the data was collected using an internationally accepted method. The two most important criteria when determining if the data was acceptable was sample collection device and the sampling flow rates.

In the last 10 years there has been an increase in the use of direct reading instruments for measuring concentrations of dusts, but none have been designed for measuring personal exposure to dusts and bioaerosols. These instruments are excellent at determining major sources of dust exposure and investigating peaks and troughs in airborne exposures in a building or developing a dust map of an area. As yet there are no standard methods published for using these types of equipment in the workplace to assess worker exposures, especially personal exposures. These instruments are generally called real-time dust monitors and can currently only be used to collect static samples..

The correct flow rate when using the equipment is important because these devices are designed to collect contaminants within a given size range. This is important when looking at whether the data was for inhalable/total or inspirable dust samples which should be set at a flow rate of 2 L/min. The type of sample collected is dependent on the type of sampling collection medium used although this is referred to in both Australian and International Standards for sampling of this type. Respirable samples are generally collected at a flow rate of 1.9 L/min for a common cyclone or 1.7 L/min for a MSA cyclone (commonly used in USA). When monitoring fungi and bacteria the most common apparatus used was an Anderson Impactor at a flow rate of 28.3 L/min, followed by methods using an AGI-30 impinger at a flow rate of 12.5 L/min.

The respective Australian Standards are:

- AS 2985.2004: Workplace atmospheres. Method for sampling and gravimetric determination of respirable dust (previous edition 1987)
- AS 3640.2004: Workplace atmospheres. Method for sampling and gravimetric determination of inhalable dust (previous edition 1989)

The respective International Standards are:

- ISO 7708:1995 Air quality. Particle size fraction definitions for health-related sampling.
- ISO 7168-1:1999 Air quality. Exchange of data - Part 1: General data format
- ISO 7168-2:1999 Air quality. Exchange of data - Part 2: Condensed data format
- ISO 6879:1995 Air quality. Performance characteristics and related concepts for air quality measuring methods

The respective USA Standards are:

- NIOSH 0800 Bioaerosol Sampling (Indoor Air)
- NIOSH 0500 Particulates Not Otherwise Regulated, Total
- NIOSH 0600 Particulates Not Otherwise Regulated, Respirable

The respective British and European Standards are:

- MDHS 14 (2003) General methods for sampling and gravimetric analysis of respirable and inhalable dust. Health and Safety Laboratory, UK
- BS EN 13098:2001 Workplace atmospheres. Guidelines for measurement of airborne micro-organisms and endotoxin
- BS EN 14031:2003 Workplace atmospheres. Determination of airborne endotoxins
- PD CEN/TR 15230:2005 Workplace atmospheres. Guidance for sampling of inhalable, thoracic and respirable aerosol fractions

Endotoxin sampling involves the analysis of dust samples that have been collected and weighed. Analysis of these samples varies according to method of sample collection. This impacts on recovery due to the type, preparation and storage of the filters used. All these factors can impact on either a low recovery or overestimations due to contamination of the filter sample. In the literature on airborne endotoxins in agriculture there several methods for measuring and analysing endotoxins have published but only studies that meet BS EN 14031:2003 have been included in the final review..

The only data accepted in this analysis were data collected according to the following criteria.

Dusts:	Inhalable / Inspirable / total Dust collected on a filter holder, IOM sampler, 7-hole sampler at a flow rate of 2 L/min ±10%. Respirable Dust samples collected on a filter in a cyclone apparatus at a flow rate of 1.9 L/min ±10%, unless using a clone that requires either a higher or lower flow rate of 1.7, 2.2 or 2.5 L/min such as MSA cyclone.
Endotoxins:	Dust samples were collected according to the above criteria and analysed using the LAL method. The results were reported in EU/m^3. Where data were reported as ng/m^3 a conversion using multiple of 10 has been made to allow comparison of results. Where the results have been reported as EU/g^{-1} and dust concentration reported, then a conversion has been made to EU mg/m^3. If no dust levels reported then results have not been included in the following analysis.

Bioaerosols: Samples of fungi and bacteria were collected on agar plates using a single, 2 or 6 stage cascade impactor at a flow rate of 28.3 L/min such as an Anderson Cascade Impactor. Alternatively samples can be collected in an impinger AGI-30 apparatus at a flow rate of 12.5 L/min ±10%.

In total 47 papers were considered to contain data suitable for the gap analysis. Table 3.1 summarises the sources that were considered to have valid exposure data against each animal type of dust or bioaerosol, and region. Many of the sources collected only reported results of static sampling in one location, and a number only monitored on between one to three days. Of the 47 papers summarised only 21 contained personal sampling data.

Table 3.1 Number of Papers with valid exposure data according to animal group and region

Animal	Region	Dust No. with static data (no. with personal data)		Bioaerosols No. with static data (no. with personal data)		Endotoxins No. with static data (no. with personal data)	
		Inhalable Dust	Respirable Dust	Fungi	Bacteria	Inhalable Endotoxin	Respirable Endotoxin
Pigs	Australia/Asia	4 (1)	4 (2)	2 (0)	2 (0)	3 (1)	
	Europe	9 (4)	4 (1)	2 (0)	3 (0)	7 (3)	3 (1)
	North America	4 (3)	2 (2)	2 (0)	4 (0)	3 (2)	1 (1)
Poultry	Australia/Asia	1 (1)					
	Europe	5 (3)	1 (0)	2 (0)	3 (0)	5 (2)	1 (0)
	North America				1 (0)	3 (1)	
Cattle	Australia/Asia	1 (1)	1 (1)	1 (0)	1 (0)		
	Europe	3 (1)	1 (0)		1 (0)	3 (0)	
	North America	2 (2)	2 (2)	1 (0)	2 (0)	2 (2)	1 (1)
Sheep	Australia/Asia	2 (2)	2 (2)	2 (0)	2 (0)		
	Europe	1 (1)					
	North America						
Horses	Australia/Asia	5 (2)	3 (2)	1 (0)	1 (0)	1 (1)	
	Europe						
	North America						
Deer	Australia/Asia	1 (1)	1 (1)	1 (0)	1 (0)		
	Europe						
	North America						
Total		37 (22)	21 (13)	12 (0)	18 (0)	27 (12)	6 (3)

The majority of the air exposure data that has been collected both in Australia and internationally has been aimed at animal health. The following data is a summary of what has been collected using the accepted methods of data collection. Data that has been collected for both human health and animal health has been included, as on occasion it is difficult to differentiate between the two.

3.2 Pigs

Tables 3.2 to 3.4 show the levels of airborne contaminants reported in the literature. The concentrations varied significantly depending on where the samples were collected, what was going on in the pig shed, and the aim for which the air monitoring was undertaken. One of the problems in analysing the data reported in the literature was that much of it had been collected to ascertain the general air quality levels within the pig housing, and their potential impact on pig health. Some of the studies did try to relate the measured concentrations to potential health impacts on workers, but as the methods of collecting the samples did not meet the current standard methods for assessing personal exposure, as listed in section 3.1, it is difficult to undertake this type of comparison.

Table 3.2 Average Dust and Bioaerosol Exposures Reported in Australia/Asia in Pig Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Boar Shed		9.9					Rhyder 1993
Farrowing shed		3.9					
Weaner Shed		3.7					
Finisher Shed		3.6					
Mixed areas		6.7					
Straw							Holyoake 2002
Weaner (early)	12.39	0.68			686.7		
Grower (late)	4.86	0.41			695.1		
Handling Bedding using Manitou	0.86	0.21			866.4		
Manually Handling Bedding	21.46	1.90			869.4		
Rice Hulls							
Weaner (early)	24.40	1.83			1832.5		
Weaner (late)	1.64	0.22			423.5		
Grower (early)	6.49	0.49			1029.5		
Grower (late)	2.73	0.68			330.5		
Handling Bedding using Bobcat	15.62						
Grower Sheds				1.8×10^4 – 9×10^5			Chinivasagam & Blackall 2005
Pig shed area sample: summer	1.68						Banhazi et al. 2004
winter	2.95						
Farrowing	2.044	0.188					Banhazi, et al. 2002a
Weaner	2.333	0.580					

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Grower sheds	1.68	0.24					Cargill et al. 2000
Finisher Sheds	1.67	0.31					
Straw Based Shelters	2.57	0.64					
Dry Sow Accomm	0.80	0.16					
Farrowing Accomm	1.23	0.18					
Weaner Rooms	2.66	0.27					
Swine					33.1		Banhazi et al. 2005
Swine			2.693 x 10^3	3.35 x 10^5 gram –ve 143			Chang et al. 2001a
Swine	0.15 – 0.34	0.14			36.8 – 298	14.1 – 129	Chang et al. 2001b
Swine				Total 8.4 x 10^4 Repirable 2.8 x 10^4			Predicala et al. 2002

Table 3.3 Average Dust and Bioaerosol Exposures Reported in Europe in Pig Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Pig Farmers	2.63				105		Vogelzang et al. 2000.
England The Netherlands Denmark Germany Average	1.87 2.43 2.76 1.95 2.19	0.24 0.25 0.26 0.18 0.23					Takai et al. 1998
Sows Weaners Fattening Pigs					523-1146 1574-1865 1091-1351	74-83 177-189 114-130	Seedorf et al. 1998
Piggery 1 Piggery 2	0.17 0.10	1.26 0.51					Gustafsson 1999.
Swine	5.78				66020		Simpson et al. 1999
Mixed activities	4.13	0.45			640	50	Christensen et al. 1992
Swine	3.08		3.0×10^2	3.0×10^5 gram -ve 0.88×10^5	1200		Clark et al. 1983
Personal Static	12.6 8.5						Louhelainen et al. 1987,
Mixed Pig Framing	3				1300		Preller et al. 1995
Pig farm buildings	4.01	1.31		1.073×10^5 gram -ve 0.077×10^5	1300		Heederik et al. 1991
Traditional swinery Composting swinery, sawdust: • Background • turning Composting swinery, peat: • Background • turning			7.13×10^3 5.27×10^3 11.3×10^3 1.56×10^5 4.40×10^5	4.02×10^5 2.05×10^5 5.79×10^5 1.444×10^6 3.160×10^6			Rautiala, et al. 2003

Table 3.4 Average Dust and Bioaerosol Exposures Reported in North America in Pig Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Swine					434-40 650		Reynolds et al. 2002
Hog Farmers Control Farmers	0.17 0.14	2.06 1.30					Holness et al. 1987
1st samples 2nd samples	0.23 0.26	4.55 3.45			202.67 176.12	16.95 11.86	Reynolds et al. 1996
Swine	0.76-15.8			2.9×10^5 gram -ve 2.0×10^5	2040-24100		Thorne et al. 1997
Inside Swine Shed • Site A with out Swine • Site A with Swine • Site B with Swine			3.0×10^1 8.1×10^1 9.0×10^1	7.2×10^1 7.4×10^3 2.1×10^3			Gibbs et al. 2004
Farrowing Unit Fattening Unit	1.6-1.9 3.1-8.8		10^1 - 10^2 4×10^1 – 1.5 10^2	4.92×10^5 – 5.44×10^5 1.51×10^5 – 1.83×10^5			Cormier et al. 1990
Pig housing			1.16×10^3	4.62×10^5			Butera et al 1991

3.2.1 Discussion

Cargill (2000), Chang et al. (2001), Banhazi et al. (2002b, 2005) and Chinivasagam and Blackall (2005) all looked at static monitoring, and generally only in one location within a building. Although this may be adequate to assess air quality in relation to pig health, it is not appropriate for human health. In some studies where personal worker exposure data has been collected the results are mixed in with the results from static monitoring, making interpretation difficult.

In Australia, only two studies have been undertaken with human health as the primary aim. A study by Rhyder (1993) only reported worker exposure to respirable dust levels. These levels were very high ranging from respirable dust concentrations of 3.6 to 9.9 mg/m^3. There is no current respirable dust exposure standard in Australia for 'dusts not otherwise' classified, but the current USA ACGIH standard is 3 mg/m^3 (previously 5 mg/m^3). The levels reported by Rhyder (1993) exceed the guidelines that would have been used for assessing exposures.

More recently Holyoake (2002) sampled two types of pig shed and reported on a broader range of air contaminants. Both worker exposure and general area samples were collected. Personal samples ranged from 0.02 to 3.57 mg/m^3 for respirable dust, 0.40 to 42.3 mg/m^3 for inspirable dust, for respirable endotoxin none detected to 1833 EU/m^3 and for inspirable endotoxin none detected to 2117 EU/m^3. There did not appear to be any correlation of exposure with the activities being undertaken by workers, although the exposures in the piggery with a concrete flooring system were overall lower. The data collected in Australia is similar to overseas to studies in that most have been undertaken in relation to pig health. In some cases personal samples were collected, but only a small number had sufficient information about the types of activities undertaken.

The monitoring of bioaerosols has not been as well described in the literature as it has for dusts. This is probably because currently there is no suitable method of monitoring personal exposures to bioaerosols. The current methods only allow for sampling for a limited time, which in many cases is less than one minute. A number of studies that have reported bioaerosol levels, especially bacteria, have been deleted from this review as the samples were not collected using one of the standard methods, and the sampling rate used could have affected interpretation of data. In the studies reviewed levels of bacteria ranged from 72 to 31.6 x 10^5 CFU/m^3 and fungi ranged from 30 to 1.44 x 10^5 CFU/m^3. The lower levels were collected using a 2 stage Anderson impactor whereas the higher levels were collected using a 6-stage Anderson impactor. The diverse span in exposure levels is due to the range of activities that may be undertaken in the pig sheds at the time of monitoring. The lower concentrations were measured when there were no pigs in the sheds, but workers may be still be exposed as they may be required to work in the shed when there are no pigs present.

Gibbs et al. (2004) identified and quantified a number of microorganisms. These microorganisms included coliforms, *Staphylococcus aureus*, *Salmonella, Candida, Chrysosporium, Mucor, Rhizopus, Alternaria, Aspergillus niger, Acremonium* and *Aspergillus fumigatus*.

The levels of endotoxins measured varied depending on how the samples were collected, the type of filters used, and how the samples were analysed. The results reported ranged from 11.9 to 189 EU/m^3 for respirable endotoxin and from 33 to 66 020 EU/m^3 for inspirable/inhalable/total endotoxin.

In addition to the sampling and analysis problems, the way in which the results were reported varied between researchers. For this report, the results have been standardised to EU /m^3 but the original papers reported them in ng/m^3, ng/mg of dust or EU/m^3**.** The standard unit is likely to become EU/m^3 as the Netherlands has published an endotoxin standard of 50 EU/m^3, at present the only country to do so (DECOS, 1998).

Donham (1995) is often quoted when discussing environmental airborne contaminant standards in relation to air monitoring in animal containment facilities. The levels he has suggested are 2.4 mg/m^3 for total dust, 0.23 mg/m^3 for respirable dust and 4.3 x 10^5 CFU/m^3. The level listed for endotoxins does not currently use the standard units for endotoxins and there is no simple conversion factor. Although these standards may be valid for the pig industry particularly in the USA they may not be valid for other animal related industries and countries where farming practices are different. This is because there are a number of factors that may impact on types and levels of airborne contaminants in different farming environments such as farming practices, types of housing, types of animal food types and breeds of animals, climate etc. Before air standards can be accepted, more exposure and health studies need to be undertaken to ascertain whether the standards proposed by Donham are appropriate for use internationally in all animal related industries.

3.3 Poultry

Tables 3.5 to 3.7 summarise the exposure data that were considered valid. Only one study was considered valid for Australia. The data collected in the study by Brown (1990a) did not report the flow rates at which the dust samples were collected or the standard method used.

Table 3.5 Average Dust and Bioaerosol Exposures Reported in Australia in Poultry Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Personal sampling Static sampling	1.9-18 0.1-16.5						McGarry et al 2000

Table 3.6 Average Dust and Bioaerosol Exposures Reported in Europe in Poultry Facilities

	Dust		Bioaerosols		Endotoxins		
Activity	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	**Source**
Coops Personal Coops Static Floor Personal Floor Static	7.2 5.0 13.0 6.0						Louhelainen et al. 1987
Loose laying/new bedding Loose laying/old bedding Cage rearing	4.8 4.1 2.4				125 96 106		Larsson et al. 1999
Layers Broilers					3389-8604 7842-7857	296-581 351-718	Seedorf et al. 1998
England The Netherlands Denmark Germany Average	3.31 4.58 4.52 2.22 3.60	0.51 0.58 0.64 0.19 0.45					Takai et al. 1998
Slaughterhouse				4.6-42 x 10^3	14-52000		Laitinen et al. 2001
Mixed activities	10.38 (8.38–13.34)				84310 (53130–133860)		Simpson et al. 1999
Slaughter house	6.3		0.5 - 4.0 x 10^3	4 x 10^6	4000		Hagmar et al 1990
Mixed activities			160-1900	(total) 42x104 (gram –ve) 4.1 x 10^4			Clark et al. 1983

Table 3.7 Average Dust and Bioaerosol Exposures Reported in North America in Poultry Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Mixed activities					1130-5720		Reynolds & Milton, 1993
Mixed activities					764-37 190		Reynolds et al. 2002
Mixed activities				3.9×10^5 gram -ve 1.1×10^5	140-4510		Thorne et al. 1997

3.3.1 Discussion

Only one study on dust and bioaerosols concentrations in Australia was located. The data was collected as part of an overall risk assessment of hazards in the poultry industry in Queensland (McGarry et al, 2000). The results of that study are limited in that only inhalable dust samples were collected. The results for personal sampling ranged from 1.9 to 18 mg/m^3 and from 0.1 to 16.5 mg/m^3 for static sampling. This study showed why personal sampling is important, as static sampling may not be able to measure the contaminants present in the breathing zone of a worker.

Data collected overseas varied both in the levels measured and methods of collection. Only one of the sources was less than five years old. The results for dust concentrations in Europe ranged from 0.19 to 0.64 mg/m^3 for respirable dust samples, and from 2.4 to 13 mg/m^3 for inspirable/inhalable dust samples. No dust data was reported for the poultry industry in North America, although a number of studies did report endotoxin analysis of dust samples, but did not report the respective dust concentrations. The fungi concentrations ranged from 160 to 4000 CFU/m^3, while total bacteria ranged from 4.6×10^3 to 4×10^6 CFU/m^3, and gram negative (-ve) bacteria ranged from 4.1×10^4 to 1.1×10^5 CFU/m^3. The respirable endotoxin results ranged from 296 to 718 EU/m^3, whilst inspirable endotoxin measured at the same time was generally much higher and ranged from 14 to 84310 EU/m^3. The endotoxin levels were difficult to interpret as none of the studies discussed either the endotoxin recovery efficiency, or how the samples were handled to ensure they did not get contaminated in the handling and analysis process.

Hagmar et al. (1990) identified some of the fungi species present in poultry facilities as *penicillium*, *scopulariopsis*, *aspergillus*, *cladosporium*, *alternaria* and *mucor* and some of the gram negative bacteria as *E.coli*, *proteus* and *acinetobacter*.

3.4 Cattle

Tables 3.8 to 3.9 summarise the few studies that were found with valid exposure for people working with cattle. For the purposes of this report, cattle refers to both dairy and beef animals that may be held in confinement buildings or on pasture.

Table 3.8 Average Dust and Bioaerosol Exposures Reported in Australia/Asia in Cattle Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Mixed activities			1.65×10^3 - 2.23×10^3				Adhikari et al. (2004)
Dairy Cows Feed Shed	0.20	2.72	1.8×10^3	1.42×10^3			Reed et al. (2003a)

Table 3.9 Average Dust and Bioaerosol Exposures Reported in Europe in Cattle Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Cows Beef Calves					74-151 118-136 487-639	6-16 10-13 63-67	Seedorf et al. (1998)
Cow Calf Stables					36-761 44-262		Zucker & Muller (1998)
Cattle house					127-5012		Zucker et al. (2000)
Cow houses			3.0×10^4 - 7.5×10^6				Pasanen et al (1989)
Mixed: Personal Mixed: Static Milking: Cold Barn Milking: Tied barn Milking: Cubicle Feeding: Cold Barn Feeding: Tied barn Cubicle	5.6 1.0 0.3 0.8 1.1 1.8 0.3 1.9		Xerophilic 4.1×10^3 – 4.0×10^4 Mesophilic 3.8×10^3 – 2.0×10^4 Thermotolerant 2.7×10^1 – 4.7×10^2				Louhelainen et al. 1997,
Mixed Farming	0.38	0.07					Takai et al. 1998
Mixed activities				10^5 - 10^7			Handela et al. 1995

Table 3.10 Average Dust and Bioaerosol Exposures Reported in North America in Cattle Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Chopping of Cattle Stall Bedding	8.6-40.9	1.6-2.5			366-27096		Olenchock et al. 1990a
Cattle Feed yards			Mesophilic 7.8×10^1 Thermophilic 2×10^0	Mesophilic 1.44×10^3 Anaerobic 7.51×10^2 Thermophilic 5.4×10^1			Purdy et al. (2004)
Dairy barn	1.78 (personal)	0.07 (area)		1.2×10^7	647	16.8	Kullman et al. (1998)

3.4.1 Discussion

The inhalable dust levels in cattle related environments appear to be considerably lower than the current NOHSC rogue dust exposure limit of 10 mg/m^3. The respirable dust levels also appear to typically be lower than the ACGIH recommended exposure level of 3 mg/m^3 for nuisance dusts, with the exception of Reed et al. (2003a) who reported exposures of 2.72 ± 2.43 mg/m^3.

Bioaerosol levels vary widely between studies. Fungi levels were lowest in dryer regions like Australia (1.8×10^3 CFU /m^3), India (1.65×10^2 - 2.225×10^3 CFU /m^3) and the United States (7.8×10^1 CFU /m^3), while European studies recorded considerably higher concentrations; Poland (1.72×10^4 CFU /m^3), Finland (7.6×10^4 CFU /m^3) and Sweden (1.51×10^7 CFU /m^3). The same pattern is also reported for bacteria concentrations in cattle related environments. (Pasanen et al 1989, Kullman et al. 1998, Reed et al. 2003a, Adhikari et al. 2004 & Purdy et al. 2004)

Bacteria genera identified in cattle feed yards include *Bacillus* spp., *Corynebacterium* spp. and *Staphylococcus* spp. (Purdy et al. 2004). Seedorf et al. (1998) identified that up to 90% of airborne microorganisms in livestock buildings consisted of *Staphylococcus* spp. and *Streptococcus* spp., while coliform members of the bacterial family Enterobacteriaceae only consisted of 1-2% of the total bacterial count. Dutkiewicz et al. (1994) identified that *Corynebacterium* spp. and *Arthrobacter* spp. were the dominant species in cow barns, racing stables and piggeries. Dominant species of fungi in livestock environments included *Aspergillus* spp., *Penicillium* spp. and *Mucor* spp., some of which can produce aflatoxins (Seedorf et al. 1998). Adhikari et al. (2004) reported that concentrations of *Cladsporium*, *Alternaria* and *Penicillium* were the highest species in a cattle shed.

As for other species reviewed, comparison of data on endotoxin exposure in cattle environments to identify typical exposure ranges is difficult because of the variety of methods used to sample (filters and dust fractions etc) and quantify endotoxin levels (extraction and analysis methods), and the use of different units for reporting exposures. However, endotoxin exposures in environments where cattle are present appear to typically exceed the Dutch Health Council's suggested exposure limit of 50 EU /m^3. The extremely high endotoxin levels of up to 500 000 EU/m^3 recorded in the study by Rask-Anderson et al. (1989) may have been influenced by LAL assay enhancement, because LAL assay interference assessments were not conducted. In general endotoxin levels appear to be commonly in the hundreds of EU mg/m^3, which is much lower than for swine and poultry sheds where levels are usually in the thousands.

Bovine epithelial antigen has also been measured in cowsheds. Virtanen et al. (1992) reported levels of 3.2-22.5 μg/m^3 using personal sampling methods, and 2.1-13.0 μg/m^3 using static methods.

3.5 Sheep

Table 3.11 reports the only exposure data that could be found relating to sheep handling facilities, whereas Table 3.12 reports the data that has been published on exposures in wool processing mills.

Table 3.11 Average Dust and Bioaerosol Exposures Reported in Australia in Sheep Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Mixed Activity 3 Farms	0.97	0.49	4.695 x 10^3	3.865 x 10^3			Kift, et al. 2004b
Mixed Activity 2 Farms	0.41	0.46	1.523 x 10^3	1.298 x 10^3			Kift et al. 2003

Table 3.12 Average Dust and Bioaerosol Exposures Reported in Europe in Sheep Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Wool Mill	3.93 (2.53-6.12)				836 (36-190)		Simpson et al. 1999

3.5.1 Discussion

There was only one paper that had been published on sheep facilities outside Australia which dealt with airborne contaminates and sheep. Simpson et al. (1999) reported on nine different occupational settings which included a wool mill where they collected 259 samples from 36 different sites. This study also included swine and poultry operations and animal feed preparation.

In the Australian studies (Kift et al. 2003, 2004a) on respiratory contaminants in NSW sheep shearing sheds the respirable dust contaminants ranged from 0.17 to 1.07 mg/m^3, and the inspirable dust concentrations from 0.35 to 1.11 mg/m^3. The bacteria levels ranged from 1.271 x 10^3 to 6.146 x 10^3 CFU/m^3 whereas the fugal concentrations ranged from 1.213 x 10^3 to 5.706 x 10^3 CFU/m^3.

3.6 Horses

Australia was the only country that had published data for handling animals. These studies are summarised in Table 3.13

Table 3.13 Average Dust and Bioaerosol Exposures Reported in Australia in Horse Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Preparing feed for horses	14.97	1.08	1.494×10^3	8.64×10^2			Reed et al. 2003b
In stall In barn Conventional stable In pasture	0.70-2.55 0.20-0.95 2.19-5.48 0.08-0.17	0.20-0.44 0.44-2.20 0.08-0.17					Cargill 1999
Stables: sawdust Straw bedding Horse Nappy	0.397 0.606 0.287						Banhazi et al. 2002a
Stables	1.13	0.35					Banhazi et al. 2002a
Stable cleaning	1.20-2.81				50-82		Davidson 2004

3.6.1 Discussion

There appears to be little published data on dust, fungi, bacteria and endotoxin levels in facilities where horses are handled or stabled. Inhalable dust levels in stables and during feed preparation appear to be lower than the current NOHSC rogue dust exposure standard of 10 mg/m^3. Dust levels were considerably higher in feed preparation areas in comparison with normal stable activities. Endotoxin levels recorded in stables all exceeded the Dutch Health Council's recommended exposure limit of 50 EU/m^3.

Dutkiewicz et al. (1994) in a general paper on farming activities identified that thermophilic fungi concentrations recorded in cattle and horse stables represented the greatest health risk to humans as previous studies indicated that they cause allergic alveolitis in humans and similar pulmonary diseases in cattle and horses.

3.7 Deer

Similar to horses and sheep the only published exposure data that relates to the handling of deer were published in Australia.

Table 3.14 Average Dust and Bioaerosol Exposures Reported in Australia in Deer Facilities

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Drafting Deer	2.27	1.64	9.05×10^2	2.529×10^3			Kift et al. 2002a

3.7.1 Discussion

There appears to be two articles that have been published that deal with airborne contaminants and deer but both papers were written using the same data set which was collected from three farms in NSW and one was aimed at the methodology of collecting the data (Kift et al. 2002b). The main differences between the farms are the type of flooring and ventilation. The average inspirable dust levels ranged from 1.90 to 2.99 mg/m^3 whereas average respirable ranged from 0.63 to 2.55 mg/m^3.

The average bacteria levels ranged from 4.56×10^2 to 7.048×10^3 CFU/m^3 depending on when the samples were collected. The percentage of gram negative bacteria (gram –ve) ranged from 11 to 28%. The average fungi concentrations range for 3.1×10^1 to 3.785×10^3 CFU/m^3. The fungi types identified were *zygomycota* (0 to 8 %), *ascomycota* (36 to 41%), *basidioycota* (13 to 26%) and *deutermycota* (36 to 40%). The farm with the concrete floor which also had the best ventilation had the lowest levels of dust (both inspirable and respirable), bacteria and fungi (Kift et al. 2004a).

3.8 Mixed Farming

There was only one study in Europe that reported on dust exposure from mixed animal farming. This is reported in Table 3.15.

Table 3.15 Average Dust and Bioaerosol Exposures Reported in Mixed Animal Farming

Activity	Dust		Bioaerosols		Endotoxins		Source
	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)	
Mixed Framing	0.84		1.2×10^6	2.5×10^6	13×10^3		Eduard et al. 2001

Eduard et al. (2001) reported on some monitoring that had been collected in farms that undertook mixed farming, including a range of animal types. They did not differentiate between the types of activity sufficiently to allocate exposure data to be attributed to a given animal type.

Chapter 4: Prevalence of respiratory symptoms and association with dust and bioaerosol exposures in animal farmers

4.1 Introduction

In this section, we examine the prevalence of respiratory symptoms in farmers involved in animal farming, and whether these symptoms are linked to dust and bioaerosol exposures. Examined are published studies of farmers or farm workers where this prevalence and link have been investigated. The papers were identified through the MEDLINE and Science Direct databases and are mostly of overseas studies. An introduction is followed by a brief outline of the methodological issues considered and then the findings of studies of swine, poultry and cattle farmers. Studies of sheep farmers are not included as only one European study was located (Radon and Winter 2003).

When assessing the findings, it is important to consider differences in farming practices between farmers in these studies and farmers in Australia. For example, several studies are from Northern European countries, where because of climate, the intensity and duration of work in confinement houses for dairy and cattle farmers is greater than in Australia. In other areas, there are many similarities between overseas and Australian practices. For example, the models of large poultry and swine confinement buildings are similar in that they have been developed for economic efficiencies rather than for reasons of climate, but the housing and farming techniques may be different.

4.1.1 Background

Occupational respiratory diseases have been linked to inhalation of dusts, and bioaerosols (Jacobs 1989, Lacey and Dutkiewicz 1994). In farmers, respiratory illness may result from the inhalation of dusts, both organic and inorganic, bioaerosols including endotoxins and gases (Rylander 1986, Gurney et al. 1991, Shenker 2000, Douwes et al. 2003). Bioaerosols may result in zoonoses causing respiratory disease such as psittacosis. Endotoxins are the likely cause of byssinosis in cotton farmers (Castellan et al. 1987, Jacobs 1989). That exposures to these hazards in excess of normal exposure can result in illness is supported by case study reports and symptoms in workers with very high levels of exposures. For example, Cormier et al. (1996) reported the case of a 58 year old man who developed Reactive Airways Dysfunction Syndrome after exposure to high levels of toxic gases, possibly hydrogen sulphide, in swine confinement units.

Non infectious respiratory illness in farmers includes well defined syndromes such as Farmers' Lung Disease or hypersensitivity pneumonitis and Organic Dust Toxic Syndrome (Rylander 1986, Gurney et al. 1991, Zejda and Dosman 1993, Kirkhorn and Garry 2000). Both have a similar history of presentation, four to eight hours following exposure. Hypersensitivity pneumonitis is due to a hypersensitivity response possibly to bacterial and fungal allergens for which antibodies can sometimes be detected. It is a progressive disease with continued exposure resulting in interstitial fibrosis and emphysema. Extrinsic allergic alveolitis is a type of hypersensitivity pneumonitis that can occur in animal farmers (Warren and Tse 1974). The cause of Organic Dust Toxic Syndrome (ODTS) is a toxic, as opposed to allergic response and it is reversible. Its true prevalence is likely to be low. Eighty farmers of an original survey of 3267 farms in Sweden were identified as having ODTS (Rask-Anderson 1989).

Farmers are reported to have a high prevalence of non specific respiratory symptoms such as cough, phlegm production and wheezing which may be chronic or associated with exposures to dusts, bioaerosols and endotoxins during farming activities, such as working in swine confinement barns (Zejda and Dosman 1993, Douwes and Heederik 1997, Rylander 1997, Iversen et al 2000, Kirkhorn and Garry 2000). Non specific symptoms are not exclusive to a particular exposure or activity, they may occur in non farmers and may indicate a number of underlying diseases or syndromes. For example, wheezing may be a symptom of asthma or ODTS. Its aetiology may be intrinsic (asthma) or extrinsic following work exposures. The focus of this review is on these non specific respiratory symptoms, how prevalent they are in farmers exposed to animals in farming practices and their association with dust and bioaerosol levels.

4.1.2 Studies of farmers and respiratory symptoms

The findings of a number of studies suggest that farmers in general, and animal farmers specifically, are at high risk of respiratory symptoms. In the European Community Respiratory Health Study, farmers were more likely to have reported asthma symptoms or medications for asthma than professional or clerical groups (Kogevinas et al. 1999). Swiss farmers have an increased prevalence of respiratory symptoms compared to non farmers and the general population (Danuser et al. 2001). Swiss farmers were 1.9 times more likely to report chronic bronchitis and 4.5 times more likely to report chronic phlegm than the general population (Danuser et al. 2001). By contrast, they were also 60% less likely to report nasal allergies. Melbostad and Eduard (2001) found a high prevalence of respiratory symptoms in a population based survey of 8482 Norwegian farmers and their spouses. The prevalence of at least one symptom, eg, red eyes, sneezing, cough or wheeze was highest for male and female farmers involved in grain handling, 54% and 44% of these, respectively. Of those involved in animal farming, swine and poultry farmers had the highest prevalence, 30% and 32% respectively. Dusty occupations and smoking were found to increase the risk for chronic symptoms and chronic bronchitis (Melbostad et al. 1997).

The findings of a population based postal questionnaire survey of New Zealand farmers also showed high rates of symptoms for those whose activities included pig or poultry farming. Farmers exposed to pigs or poultry reported the highest prevalence of work related symptoms amongst animal farmers such as breathing problems; 23% for exposure to pigs and 26.4% for those working in pig sheds. The rates for poultry shed workers and poultry farmers were 27.8% and 25% respectively (Kimbell-Dunn et al 2001)..

The prevalence of asthma does not seem to be increased in animal farmers and this is widely attributed to a healthy worker effect where farmers with asthma tend to leave this occupation because of exacerbation of their symptoms. Vogelzang et al. (1999b) found the prevalence of self reported asthma in swine farmers to be 6% and similar to that in the control group. Farmers were also significantly less likely to report common allergies or history of atopy than controls. Those with asthma were more likely to report childhood symptoms of asthma than farmers without asthma (prevalence odds ratio 4.1, $p<0.05$). The association with a family history of asthma or allergy and the low prevalence of asthma is supported by the findings of a survey of 1901 farming students in Denmark (Omland et al. 1999). The overall prevalence in male students was 11.3%, less than that for male control subjects 13.2% ($p>0.05$). The prevalence in female students was 21% but no control group was available for comparison (Omland et al. 1999).

The association between symptoms or lung function and declining exposures to dusts and bioaerosols is supported by studies of farmers, workers in animal feed production industries and challenge exposure studies of both farmers and healthy subjects. Melbostad and Eduard (2001) in their survey of Norwegian farmers and spouses found moderate correlations (0.52 – 0.72) between the prevalence of symptoms and high personal exposure levels to total dust, fungal spores and endotoxins.

The relationship between dust or endotoxin exposure and respiratory symptoms has been documented in other farm industries e.g. cotton farming. A longitudinal study in the cotton and silk industries found a significant and declining association between end point FEV_1 at 11 years and cumulative dust exposure. This association was adjusted for age for which the association was also negative ($p<0.05$), gender, for which the association was positive ($p<0.05$) and smoking ($p>0.05$) (Christiani et al. 1999).

Workers in animal feed processing factories have exposures to the same organic material contained in feed to which farmers are exposed. Animal feed production workers in Turkey have been found to have a higher prevalence of work related respiratory symptoms and lower than predicted spirometry findings, including FEV_1 and FVC than controls (Baser et al. 2003). Smid et al. (1992) found consistent negative associations between personal dust and endotoxin exposure and a range of lung function tests in workers in grain processing and animal feed industries in the Netherlands. These associations were statistically significant for FVC and FEV_1 in male animal feed production facilities when adjusted for age, height and smoking status. Further, findings from the same study suggested cross-shift declines in lung function (Smid et al. 1994) and long term declines in FEV_1 (Post et al. 1998).

Post et al. (1998) developed a model to predict long term lung function deterioration based on five years of follow-up data. Personal exposure levels at baseline were divided into low, intermediate and high levels and the predictions were adjusted for age, height and smoking status. Deterioration in FEV_1 and FVC were both higher for intermediate or high levels of exposure. There was a decreasing level of decline according to the number of years worked in the industry and those lost to follow-up were older and more likely to have had respiratory symptoms at baseline. This supports the hypothesis of a healthy worker effect. In these large facilities, workers would have a more intensive and longer exposure to organic matter and dust than farmers who would only be exposed to feed related activities for part of the day. Farmers' exposures may be less intense and more intermittent than for workers in these facilities, however, the findings do support the conclusion that exposure to feed associated dust and bioaerosols should also be considered a hazard to farmers handling animal feed.

Human challenge studies in experimental conditions with pure endotoxins, endotoxin extracts or contaminated dust support the conclusion that endotoxin exposure affects lung function with reductions, eg, in FEV_1 and is associated with both local and systemic inflammatory responses (Michel 1997). In a study of healthy subjects, Castellan et al. (1987) found a strong and statistically significant correlation between mean percentage negative change in FEV_1 following exposure and endotoxin levels($r=-0.74$, $p<0.0001$). The findings suggested a dose response relationship. The correlation between endotoxin and total dust exposure levels was however low ($r=-0.07$) and not significant (Castellan et al. 1987).

Crucial to the assessment of occupational symptoms is whether the symptoms are self-limiting or long term and whether they result in long-term respiratory incapacity. Long term declines in lung function tests are an indicator of this capacity. What is unknown is whether this incapacity results in disability or premature death. Beaumont et al. (1995) reported the findings of a historical cohort study based on Californian population datasets. They found that Californian agricultural workers who had filed respiratory disease compensation claims had significantly higher rates of mortality in the subsequent 16 to 45 years due to non malignant respiratory illness and emphysema than the population of California. The analyses were not adjusted for smoking and animal farming activities were not specifically identified. However the findings do suggest that the long term outcomes of respiratory illness in animal farm workers require further investigation. The need for longitudinal studies to assess acute and chronic symptoms in farmers leading to end stage disease has already been identified by Rylander et al. (1989).

In the following sections of this review, three animal farming groups are examined in greater detail. These are pig, poultry and dairy farming. They are common farming types in Australia, as well as overseas. Most of the epidemiological research has been carried out overseas, and for pig farmers in particular. The evidence for the prevalence of symptoms and links to farming exposure found in individual studies is examined according to basic principles of evaluation, study design, subjects, methods of data collection and analysis. These are briefly outlined with reference to the reviews, which follow.

4.2 Considerations in the methods of studies of animal farmers

There are a number of common areas and observations in the methods of the studies examined which affects the strength of the evidence provided for a link between farming exposure and respiratory symptoms. The studies discussed in detail are done so with reference to the following.

4.2.1 Study design

The majority of studies reviewed were cross-sectional studies. Cross-sectional studies provide only a snapshot in time of symptoms and exposure. They provide good evidence for the prevalence of symptoms, but are weaker than prospective studies in supporting a link between exposures and symptoms and long term health effects. Additionally, the prevalence of symptoms and the association with exposure may be over or underestimated because of movements within the workforce occurring outside the point or period in time during which data was collected. For example, ill farmers or those with severe symptoms may have ceased farming.

The lack of a control group in some studies is another weakness. Farmer subjects in these studies may have developed symptoms or illness whatever their occupation. Several cross-sectional studies have also examined a cross-sectional control group. Prospective studies are required to measure the incidence of symptoms, to examine progress or deterioration over time and to evaluate the long term impact of exposure on disability and mortality. The best evidence in this review is from longitudinal cohort studies. These are both prospective and controlled. None were available for poultry farmers. Randomised controlled trials are not feasible for this research question and none were identified.

Identification of a dose response relationship between exposure and symptoms or lung function is important in strengthening the evidence for a causal relationship. Researchers have examined this in several ways. In cross-sectional studies, a history of exposure indicated by time worked in animal farming and/or number of hours worked is the most frequent strategy. Identification of symptoms during the work shift and cross-shift changes in lung function is important in determining the acute effects of exposure, whether due to a hypersensitivity or inflammatory reaction. Longitudinal studies can confirm whether work related symptoms and decline are progressive and contribute to chronic disease.

To support the epidemiological findings, challenge studies are also referred to in the following sections. In these studies, farmers or healthy non farmer subjects are exposed to either conditions similar to farmers or extracts of dusts and bioaerosols to test the hypothesis that exposure causes change in lung function or an immunological reaction. No attempt has been made to be comprehensive in the identification of challenge studies and two reviews of such studies have been referred to in the preceding section (Jacobs 1989, Michel 1997).

The study design provides a framework for the research. The details of the methods of the study are also important contributors to the value of evidence. The choice of subjects can affect the applicability of findings to farmers outside the group studied. Population based selection of farmers or their controls provides greater confidence in interpretation of findings, since the authors have attempted to include subjects representative of all farmers from the potential group of farmers for that study. For example, several studies have used registered lists of farmers to identify all possible subjects. The choice of a population based control group indicates that the researchers have tried to also assemble a control group similar to the farmers in all characteristics, including lifestyle that may affect the outcome of respiratory symptoms. An example of a population based control group would be residents of the same areas as farmers and matched for age and gender.

Participation is voluntary. Even if choice of subjects is population based, participants may still differ from non participants in characteristics which affect the findings, eg, those who volunteer to participate may tend to have better (or worse) health than those who do not. Few studies compared the characteristics of participants with those of non participants to determine if this was the case.

4.2.2 Measurements

The validity of the information collected and its reliability are crucial to the value of the evidence and in most studies symptoms and diagnoses were self reported. For example, Vogelzang et al. (1999a) in their study of 239 farmers and 311 control subjects measured the prevalence of ODTS according to self-reported symptoms suggestive of ODTS. To support the validity and reliability of self reported symptoms and diagnoses, several authors used or modified previously developed questionnaires. Frequent sources are the European Community Respiratory Health Survey, the British Medical Council Respiratory Symptoms Questionnaire and the American Thoracic Society Respiratory Questionnaire. Most studies have differentiated between chronic symptoms and work related symptoms since their long term outcome and prevention may differ.

A history of asthma or chronic bronchitis was either measured by asking subjects to report medically confirmed diagnoses or constructed by the authors. For example, Wilhelmsson et al. (1989) defined chronic bronchitis as a ‘yes’ response to three or more respiratory symptom questions. Zuskin et al. (1992) used the definition of chronic bronchitis as ‘*cough and phlegm for a minimum of three months a year and for not less than two successive years*’. An almost equivalent definition was used by Zedja et al. (1993 and 1994); ‘*cough and phlegm on most days lasting at least 3 months per year for at least 2 years*’. While symptoms and diagnoses were self reported, it was not always stated whether the questionnaires were interviewer assisted or self-completed.

Lung function measured by spirometry provides more objective measures of impairment. When these are associated with respiratory symptoms they are suggestive of underlying impairment whether short or long term. Spirometry findings are usually accepted at face value but even these may vary across studies. Most studies describe the equipment used, any criteria for adjustment, eg, weight and height, the guidelines and standards followed, eg, those of the American Thoracic Society as in Donham et al. (1990) or Zedja et al. (1994) and the normal values with which comparisons were made, eg, the Australian Normal Values for Spirometry (Driesen 2003).

A reasonable approach to reviewing the papers in this section is to accept the validity and reliability of the methods unless the authors suggested that this may not have been the case. Vogelzang et al. (1998) used two spirometers in their study. All subjects used a dry rolling sealed machine at baseline. They noted that those measured with a dry rolling sealed machine at follow-up showed a greater drop in FEV_1 than those measured with a water sealed unit. On both occasions, the European Respiratory Society guidelines were used. The direction of the change was that expected and suggests accuracy rather than reliability problems.

In this review, spirometry findings are accepted at face value with the assumption that if the same methods are used in each study than any variations between studies would be a matter of accuracy rather than reliability; findings within studies could be accepted in their direction, if not their magnitude. For example, Quinn et al. (1995) used a mini Wright flow meter to assess peak flow in swine farmers with respiratory symptoms and two control groups matched for age, sex and smoking status; swine farmers without symptoms and neighbouring non swine farm controls. Peak flow measures taken several times throughout the day were consistently lower in symptomatic swine farmers.

A range of lung function measures were reported in the studies, FEV_1, FVC, FEF_{25-75}, FEV_1/FVC and so forth. Only FVC and FEV_1 were noted in the studies of farmers identified for this review since these are consistently reported throughout the studies.

Most studies defined subjects according to farm size or time spent in confinement buildings as a strategy to obtain subjects where exposures to dust and bioaerosols could be considered equivalent. The measurement of prior exposure is still problematic in cross-sectional studies and in most cases this was done by recording the number of years worked in farming.

Measurements of actual dust and endotoxin exposure are reviewed in Chapter 3. Their detail was variably described. Like spirometry findings, comparability across studies may not be feasible. However directions and associations identified within studies are accepted as reliable if the authors had used the same methods throughout, whether by statement or assumed if this detail was omitted. Other measurements included work history, time spent in various work activities and smoking history. All of these were self reported rather than observed and findings are accepted at face value.

4.2.3 Confounding factors

An important consideration was how the authors dealt with other factors that may have accounted for the same symptoms, such as smoking which also results in endotoxin exposure (Larsson et al. 2004) or a history of asthma or atopy.

Methodologically, it is also difficult to link illness to a single hazard given that exposure is usually to a pool of potential hazards including, dusts, fertilisers and bioaerosols. Coble et al. (2002) demonstrated this in their baseline report on 52,127 subjects in the Agricultural Health Study. Subjects were certified pesticide applicators, 88% of whom also worked on farms. In addition to exposure to pesticides, they reported a wide range of activities including use of solvents, grinding animal feed and work in poultry or pig confinement units. The solution is for studies to make these links by measuring all work activities, exposure levels and length of exposure and use stratified analyses and multiple regression modelling to support conclusions for the individual contribution of different exposures to symptoms. Sample sizes inadequate for modelling may have accounted for non significant findings in a number of studies which have used these approaches.

One approach to deal with the multiplicity of exposure is to study a group of farmers as homogenous as possible, eg, farmers primarily involved in pig or poultry farming. Most of the studies in this section have also defined inclusion criteria based on farm size or time spent in confinement buildings as a strategy to obtain subjects where exposures to dust and bioaerosols could be considered equivalent. For example, Zedja et al. (1994) only included farmers who worked at least two hours in confinement buildings and on farms with at least 200 pigs and Holness et al. (1987) only farms with more than 500 pigs.

4.2.4 Statistical evidence

Generally the direction of the findings in the following studies is in favour of a conclusion that dust and endotoxin exposure is a risk factor for respiratory symptoms and decline in lung function. However the association was not always statistically significant. Lack of statistical significance may be due to lack of power in the sample size for some symptoms which may be less prevalent than others. For the purposes of this review, the level of statistical significance was set at $p<0.05$. The terms ‘significance’ and ‘statistical significance’ are both used to indicate statistical significance at $p<0.05$.

4.2.5 Scope of review

Reports and papers examined were limited to those published in English following a search back to 1965 and available at the time of writing. A study may have been missed which would have resulted in a major change to the conclusions of this literature review. However, this is unlikely as it could be expected that such a study would be indicated in at least one of the research studies or in the more recent literature reviews. The methods and findings for individual studies are summarised for individual studies in Tables 4.1-4.9.

4.3 Studies where principal activity is pig farming

Studies of pig farmers include studies using population based samples (Donham et a. 1984, Choudat et al. 1994, Wilhelmsson et al. 1989, Donham et al. 1995 and Schwartz et al. 1995). Choudat et al. (1994) had a relatively high participation rate, greater than 80%, possibly a result of visits to each potential subject. Comparisons with non respondents were done in more recent studies. Senthilselvan et al. (1997) compared the baseline characteristics of subjects followed and those lost to follow-up and reported no significant differences. Iversen and Dahl (2000) found that non respondents had a higher risk of respiratory symptoms as they were more likely to be smokers. Given this, the significantly higher annual decline in FEV_1 observed for pig farmers compared with dairy farmers, 52.8 mL, is likely to be an underestimate of the expected decline in swine farmers in general (Iversen and Dahl 2000).

In general, self-reported respiratory symptoms and health status were measured with standardised questionnaires based on previously developed questionnaires, eg, from the Medical Research Council of Great Britain (Wilhelmsson et al. 1989, Heederik et al. 1991, Choudat et al. 1994), or the American Thoracic Society (Donham et al. 1984, Donham et al. 1989). Methodological considerations are summarised in Tables 4.1-4.4 for studies of pig farmers and swine confinement workers where the prevalence of symptoms is reported.

4.3.1 Prevalence of respiratory symptoms

When compared with other types of farming, pig farmers have a comparatively high prevalence of respiratory symptoms (Tables 4.1, 4.2 and 4.3) (Donham et al. 1989, Radon et al. 2001a). Radon et al. (2001a) found that the prevalence of cough without phlegm was 20% in pig farmers compared to 15.2% in poultry farmers and 9.2% in sheep farmers. Zejda et al. (1993) reported a prevalence of 15.7% of chronic bronchitis in swine farmers compared to 7.2% in grain farmers. Wilhelmsson et al. (1989) found a prevalence of 34% for three or more symptoms in a population based survey which included both current and ex pig farmers. As expected, when compared with non farmers, pig farmers have a higher prevalence of symptoms. Dosman et al. (1988) found that the prevalence of each chronic bronchitis, phlegm and wheeze was significantly higher in swine confinement farmers than in non farmers.

Table 4.1 Cross-sectional studies of pig farmers according to country
Prevalence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Findings and Significance	Adjustment for confounding
Driesen 2003 Australia Victoria	Symptoms questionnaire Lung function (79 had winter follow-up lung function tests)	Pig farmers 107 males Ave age 46.5 yrs 35 females Ave age 50.6 yrs Population based†	Except for wheeze, prevalence of symptoms > 10% FVC similar to expected FEV_1 lower than expected ($p<0.05$ for FEV_1). Multiple regression - age, gender, height and smoking were significant predictors of FEV_1 FEV_1/FVC lower than expected ($p<0.05$) and associated with years working in piggery ($p<0.05$) FEV_1 and FVC slightly higher in summer ($p<0.05$)	Multiple regression models for FEV_1 and FVC Exploratory variables included farm characteristics, length of exposure and protection
Zedja et al. 1994 Canada	Symptoms questionnaire* Lung function Static sampling	54 male pig farmers Ave age 36.3 yrs	Prevalence of work related cough and phlegm > 60% and chronic symptoms > 20% (bar chart only published) Regression of chronic cough and bronchitis significantly predicted by endotoxin levels but not NH_3 ($p=0.05$) or total dust ($p>0.05$). Significant interaction between endotoxin levels and number of hours worked per day FVC correlated with endotoxin level and FCV and FEV_1 with interaction term	Multivariate analysis prediction of symptoms adjusted for smoking status Small sample size may have accounted for non significant findings
Heederik et al. 1991 Netherlands	Symptoms Questionnaire* Lung function Static exposures	183 male swine farmers Ave age 36.8 yrs	40% had at least one respiratory symptom and 52% had symptoms during or shortly after work. Prevalence of most symptoms was between 10% and 20% Some symptoms had a higher prevalence during or after the work shift eg, cough, 15.8% vs. 19.7% during or after the shift.	Odds ratios for symptoms according to exposures adjusted for smoking status and age. Multiple regression analyses for lung function results on static measures, height, age and smoking habits. ($P>0.05$) Although negative in direction for a number of associations eg,

	Measurements	Subjects	Findings and Significance	Adjustment for confounding
			Geometric means of static exposures were; total dust 4.01 mg/m^3, ammonia 4.41 mg/m^3, endotoxin 130 mg/m^3. Dose response relationship for symptoms and exposure to three categories of endotoxin levels. ORs $p<0.05$ for at least one and most individual symptoms during or at the end of work, and exposure to gram negative bacteria (shortness of breath, sputum, shivering, perspiration and clogged nose $p<0.05$)	FVC and endotoxin levels, the ∃ coefficient for endotoxin level and FEV_1 was found to be statistically significant only in one model where bacterial levels were also included.
Bongers et al. 1987 The Netherlands	Symptoms questionnaire Lung function Lung function results compared European Commission for Steel and Coal (ECSC) reference values	132 male pig farmers 3 types of pig farming Fattening (47%) breeding (32%) confinement farming (21%) Ave 41.1 yrs (54% also cattle and 7% also poultry farmers) 28%	FEV_1 < ECSC standard (residual 0.09 and $p<0.05$) FVC > ECSC standard (residual 0.16, $p<0.05$) No difference in lung function between confinement and other types of pig farming Association between lung function and proportion of pigs with lung disease ($p<0.05$ for FEV_1)	Multivariate analysis for lung function reported for 62 farmers involved in pig fattening and adjusted for age, height smoking and exposure to irritating chemicals (not identified). FEV_1 was significant and positively predicted by feeding by hand and mechanical ventilation and negatively by use of a mask.

* based on a previously developed questionnaire eg, the American Thoracic Society Questionnaire, the American Thoracic Society - Epidemiology Standardized Project, the British Medical Research Council Questionnaire

†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

Table 4.2 Cross-sectional controlled studies of pig farmers according to country
Prevalence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Zedja et al. 1993 Canada	Symptoms questionnaire* Lung function	249 male swine producers Ave age 37.7 yrs 86% also grain farmers Population based	2 groups 251 male grain farmers Ave age 44.7 yrs Population based 263 non farmers Ave age 40.7 yrs Population based from selected professions	Prevalence of chronic bronchitis 15.3% compared with grain farmers, 7.2% and non farmers, 5.7%. Swine farmers had lower FEV_1 and than grain farmers and lower FEV1/FVC ($p<0.05$) No. of hours worked was inversely associated with FEV_1 ($p>0.05$) and FVC ($p<0.05$)	Spirometry comparisons controlled for age, height and smoking status. Correlation between hours worked and spirometry values adjust for age height, smoking and dust mask usage
Dosman et al. 1988 Canada	Interviewer administered Symptoms questionnaire* Lung function	183 male swine producers from a larger study of male farmers in Saskatchewan Ave age 42.2 yrs Population based	193 male non farmers (town residents) Ave age 39.7 yrs Population based (non matched)	Farmers older, taller and heavier than controls ($p<0.05$). Smoking status similar. Higher prevalence of symptoms in farmers, eg, phlegm (17.1% vs8.7%), wheeze (29.2% vs. 10.3%), chronic bronchitis (13.3% vs. 7.6%) and shortness of breath (32.1% vs. 19.4%) (all $p<0.05$) FVC, FEV_1, FEV_1/FVC lower than expected and lower than for controls ($p<0.05$)	Lung function reported as % expected for height, weight and age.
Radon et al. 2001a Denmark, Germany, Switzerland, Spain	7496 farmers 83%, male Ave age 48.2 yrs Respiratory symptoms self reported by mailed questionnaires* or phone or visits.	885 swine farmers Population based	107 poultry farmers 2776 cattle farmers 95 sheep farmers 4233 mixed animal farmers	Prevalence of asthma lower and phlegm higher in farmers aged between 20-44 years than similarly aged respondents in European Community Health Survey ($p<0.05$). Pig farmers had the highest prevalence rates of all work related respiratory symptoms. Prevalence of cough without phlegm 20% vs. 15.2 for poultry farmers, 9.7 for sheep farmers	Logistic regression analysis. Odds ratios for work related respiratory symptoms were adjusted for study centre, age, gender, smoking status and full time or part-time working. Odds ratios for length of exposure adjusted for country, age, sex and

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
			Population based	and 16.2 for mixed animal farming. Adjusted prevalence ORs, (reference cattle farmers) were highest for pig farmers except for wheezing which was second highest to that of sheep farmers. Eg, pig farmers were 15.2 times more likely to report work related shortness of breath than cattle farmers. ($p<0.05$) The prevalence ORs stratified according to number of hours worked inside pig houses suggested a dose response relationship with shortness of breath, cough without phlegm and flu like illness symptoms. Findings were suggestive of a dose response relationship for hours worked in poultry houses for shortness of breath; cough with or without phlegm and wheezing.	smoking status
Radon et al. 2001b Europe	Symptom questionnaire* Lung function Static exposures	40 Danish pig farmers Ave age 39 yrs Male 90% Population based	36 Swiss poultry farmers Ave age 41 yrs Male 67% Population based	No significant reduction across shift for either group Spirometry values significantly higher for pig farmers FEV_1 and FVC overall higher than expected Cross-shift declines greatest overall for asymptomatic farmers, for FEV_1 $p<0.05$. Pig farmers -absence of a humidity sensor associated with lower FEV_1 and FVC Higher T° associated with symptoms Poultry farmers –absence of a porous air inlet associated with lower FVC	Univariate analysis Authors note that all results were confirmed when adjusted for pack years of smoking (no figures provided) No difference between the groups in age and smoking status ($p>0.05$) however there were ore male pig farmers ($p<0.05$) and this may account for higher spirometry values
Vogelzang et al. 1997	Classification as symptomatic or asymptomatic based on previous postal survey of 2433	94 symptomatic male pig farmers mean age	100 non symptomatic male farmers	Subjects and controls different in age, duration of farming and smoking ($p<0.05$) in favour of the asymptomatic group.	Logistic regression models adjusted for age and smoking status.

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	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Netherlands	male pig farmers (62% response rate). 200 of each group randomly selected for medical examination and further interview. 115 of symptomatic farmers classified as COPD or asthma and 98 followed by medical examinations and interviews Measurements in this study Histamine provocation test Lung function Walk through surveys of farm characteristics (winter) 7 day activity diaries (summer and winter) personal sampling (summer and winter)	Ave. age 41.2 years Population based	Ave age 37.3 years Population Based	Bronchial responsiveness was greatest for symptomatic farmers and associated with years worked as a pig farmer (p <0.05). Adjusted for age, smoking and baseline FEV_1, increased bronchial responsiveness was associated with individual symptoms of chronic cough, shortness of breath, history of wheeze, chest tightness and more than one symptom (p<0.05) In LR models of bronchial responsiveness, significant associations were found for use of quaternary ammonium compounds as disinfectants (OR 6.7) use of wood shavings for bedding (OR 13.3), use of pellets for feeding (OR 4.8) and pit or rook location of air exhaust (compared with side of building OR 2.7).	
Choudat et al. 1994 France	Symptoms questionnaire* Lung function Static sampling	102 male pig farmers Ave 39.7 yrs Population based	51 male dairy farmers Ave age 40.1 yrs 81 male dairy workers Ave 38.5 yrs Population based	Chronic symptoms highest in farmers, eg, morning cough (13.3% & 10.4% vs. 3.8%), Work related symptoms generally highest in pig farmers, eg, fits of coughing (24.5%vs 8.3% and 4.1%, p<0.05) and sneezing (21.4% vs. 10.4% and 9%, p<0.05). Low prevalence of asthma in all groups, 4% in pig farmers. Spirometry findings were not significantly different in the three groups and reported as normal according to European reference values. On methacholine challenge, FEV_1 fell by more than 10% in 35.6% of dairy farmers, 17.9% of	Analyses were univariate and reported to have been adjusted for smoking (discrete outcomes) and age, height and smoking (continuous outcomes). The methods of this adjustment were not described.

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
				pig farmers and 6.7% of dairy workers.	
Iversen& Pedersen 1990 Denmark	Interview questionnaire for respiratory symptoms Lung function Bronchial hyperreactivity on histamine challenge	124 pig farmers Ave age 42.8 yrs Population based	57 male dairy farmers Ave age 43.4 yrs Population based	Subjects and controls similar in age, smoking status, bronchitis, FEV_1, FVC and response to histamine challenge ($p>0.05$) Prevalence of work related symptom, wheeze, cough and shortness of breath or at least one of these higher in pig farmers ($p<0.05$). Eg, prevalence of cough was 32% in pig farmers compared with 4% of dairy farmers. Current smoking associated with at least one work related symptom, (OR 2.2, 95% CI 1.1-4.4) and bronchial hyperreactivity ($p<0.05$). Significant negative predictors of FEV_1 in multiple regression analysis were pig farming, age and smoking pack years. Height was a positive predictor	Stratified analyses Multiple regression analysis
Wilhelmsson et al. 1989 Sweden	Postal survey including symptoms questions** Response between 58% (retired producers) and 89% (large livestock farms)	307 current and ex swine farmers Ave age 53 yrs Population based	125 welders < 60 yrs Not population based	34%t of active farmers and 17% of the controls had three or more respiratory symptoms In active farmers. OR for smokers was compared with that of smoking welders. OR of 3 or more symptoms, 5.25 (CI, 1.9-14.8). For smokers. OR for non smokers of 3 or more symptoms, 2.08 ($p>0.05$). Smoking and estimated yearly accumulated exposure in confinement buildings were significant predictors of number of symptoms. Positive interaction between smoking and accumulated exposure ($p<0.05$).	Comparisons between smokers and non smokers were stratified for age (Mantel-Haenszel odds ratio) Multiple regression analysis excluded ex smokers, and was adjusted for age, smoking, number of years in farming, estimated yearly exposure to swine confinement buildings and allergic predisposition. ANCOVA for interaction effect

* based on previously developed questionnaire such as the American Thoracic Society Questionnaire, the American Thoracic Society - Epidemiology Standardised Project or the British Medical Research Council Questionnaire
†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

Table 4.3 Cross-sectional controlled studies of swine confinement farmers according to country
Prevalence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Mackiewicz 1998 Poland	Clinical examination Lung function Symptoms questionnaire* Skin prick allergen tests Static samples	53 swine confinement workers from 3 villages Ave age 38.9 yrs Males 34%	53 workers in machinery industry from one city Ave age 40 yrs Males 36%	24% subjects compared with 3.8% of controls had symptoms of chronic bronchitis ($p<0.05$). Work related also symptoms higher in confinement workers, eg, dry cough, 80.6% Positive skin prick tests to 5 allergens common in swine buildings higher in subjects vs. controls ($p<0.05$). Eg, 20.7% to swine serum protein compared with 3.8%. Positive test for *Corynebacterium xerosis* only associated with symptoms ($p<0.05$). Auscultation, dry rales in 7.5% of subjects. No comparisons of static sample concentrations and symptoms made No difference in FEV_1 and FVC between subjects and controls.	Symptoms may have been overestimated in farmers, 66% of whom compared with 40% of controls.
Zuskin et al. 1992 Yugoslavia	Self-reported symptoms**	Swine confinement workers 41 male Ave 32 yrs 18 females Ave 38 yrs	Workers in fruit juice bottling factory 31 male Ave 36 yrs 15 female Ave 35 yrs	Chronic symptoms more prevalent in swine confinement workers. Eg. For men, the prevalence of chronic cough was 41.5% compared to 19.5% in controls ($p<0.05$). In women the prevalence of chronic cough was 50% compared with 6.7% ($p<0.05$). Not all comparisons were statistically significant. Asthma similar in all groups High prevalence rates of work shift symptoms eg, cough 70.7% in men and 72.2% in women and eye irritation, 46.3% in men and 77.8% in women.	Separate analyses were carried out for men and women Stratified analyses according to smoking status for men only. Prevalence higher in smokers for cough with or without phlegm ($p<0.05$) Cross-shift declines in FEV_1 and FVC for smokers and non smokers ($p<0.05$)

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
				Cross shift declines were observed in all lung function tests and statistically significant in both men and women.	
Donham et al. 1990 USA	Interview based self reported symptoms*	207 Confinement swine farmers Ave age 36 yrs Males 87.8% Population based	158 Neighbourhood control farmers race, age, sex matched Ave age 38.8 yrs Males 88.6% Population based 150 Second control group (postal workers, light industry Ave age 42.1 yrs Males 58%	Confinement farmers had highest prevalence of chronic and work related symptoms. Eg, chronic cough 15% versus 9.5% in non confinement controls and 8% in non farm controls ($p<0.05$). Symptoms suggestive of ODTS high in both farmer groups 34% for subjects & 42% for control farmers but only 7% of non farm controls ($p<0.05$)	Chronic symptoms stratified according to smoking status. Reported to be highest for smokers, no figures included in paper
Donham et al. 1984 USA	Administered symptoms questionnaire* Lung function	24 male swine confinement workers Ave age 44.5 yrs Randomly selected from an original sample who volunteered for further study from a population based postal survey of swine farmers in Iowa No difference between swine confinement respondents and non respondents on symptoms	24 male non confinement swine workers Matched for age, residence	91% of confinement workers reported work related symptoms and 33% delayed symptoms (figures not reported for controls) Chronic symptoms more prevalent in confinement workers eg, chronic phlegm 58% vs. 21% ($p<0.05$). No difference in lung function tests	Stratification according to smoking status but reported to be inconclusive due to small sample size
Holness et al. 1987 Canada	Symptoms questionnaire* Lung function	53 hog confinement farmers (farms with >500 pigs) Ave age 40.2 yrs	43 neighbourhood farmers of other animals	Pig farmers had higher symptoms prevalence, eg, cough 57% compared with 21% ($p<0.05$). Pig farmers exposed to higher total and	

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
	Static and personal sampling	Population based Respondents reported to be similar to non respondents in demographic characteristics (no figures)	Ave age 40.3 yrs Population based and similar to subjects in height, weight, age and smoking	respirable dusts ($p<0.05$) Low prevalence of asthma in both groups, 2% and 5% ($p>0.05$) No difference in lung function	
Donham et al. 1989 Sweden	Interviews included symptoms questionnaire* (Swedish translation). Lung function (subjects only) Antibodies for fungal and mould antigens Static & Personal exposure sampling	57 swine confinement workers from large commercial farms Demographic characteristics of subjects not reported	55 non swine farmers matched for age, sex and smoking history	Prevalence of respiratory symptoms higher for confinement workers. Only significant for cough and history of chest colds. For cough 68% compared with 24%. ($p<0.05$). Both symptoms were significantly higher for smokers but not for non smokers. Decrease in workshift FEV_1 commenced at endotoxin levels of 0.18 µg/ml ($p>0.05$) In multiple regression, significant predictors of work shift reductions in FEV_1 were smoking static endotoxin levels and baseline FEV_1. No difference in antibody/antigen test findings	Analyses stratified for smoking status Multiple regression analysis Analyses for smokers and multivariate analyses were limited by the small sample size.

* based on previously developed questionnaire such as the American Thoracic Society Questionnaire, the American Thoracic Society - Epidemiology Standardised Project or the British Medical Research Council Questionnaire
†population based – the authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

Health risks of workers in swine confinement buildings are of current concern as the trend is for more intensive, large scale and housed operations (Cole et al. 2000). Working in confinement buildings poses exposures to higher concentrations of dusts and bioaerosols than open air activities (Gustaffson 1997). Studies of swine confinement farmers are summarised in Table 4.3 and Table 4.4.

Donham et al. compared confinement farmers with non confinement swine farmers and found the former had reported significantly higher prevalence rates of both acute and chronic symptoms (Donham et al. 1984). For example 58% of confinement farmers reported chronic phlegm compared with 21% of the control farmers. Although a small study, the findings do suggest confinement activities pose a higher risk to farmers' health.

Donham et al. (1989) found that workers in confinement buildings had a significantly higher prevalence of cough and history of colds than control farmers who were not involved in swine farming; in the case of cough, 39% compared with 13%. However, swine confinement farmers in Iowa reported similar levels of symptoms suggestive of ODTS than a non confinement farming control group, 34% compared with 42%, although both groups were much higher than the 7% reported in the non farm control group (Donham et al. (1990).

There is a suggestion of gender differences in the occurrence of symptoms although the direction of this difference is inconsistent. Driesen (2003) found that female farmers reported a higher rate of some symptoms than male farmers. For example, cough was reported by 35% of 32 female farmers and 17.1% of 105 male farmers. However, a similar proportion of males and females reported cough in Zuskin et al (1992). In this study women were more likely to report symptoms of eye irritation (Zuskin et al. 1992).

Gender differences may be intrinsic or due to external factors such as a lower prevalence of smoking in females. Some studies have dealt with this by restriction, i.e., reporting findings on male farmers only (Choudat et al. 1994, Heederik et al. 1991, Iversen and Dahl 2000). This reduces the problem of confounding but also limits the generalisability or relevance of the findings to male farmers only.

Where reported, swine farmers generally had a low prevalence of asthma, eg, 4% (Choudat et al. 1994) or 2% (Holness et al. 1987). Radon et al. (2001b) found a significantly lower prevalence of asthma (1.3%) in farmers aged between 20 years and 44 years compared with similarly aged respondents in a previous European health survey. This may simply reflect the healthy farmer effect. In the Choudat et al. (1994) study the average duration in swine farming was 15 years and enough time for symptomatic farmers to have left the workforce.

No difference in the prevalence of asthma was found in controlled studies where this was examined, for example, Zuskin et al. (1992). Vogelzang et al. (1999a) carried out a telephone survey of 239 male pig farmers in the Netherlands and a non farm control group of males resident in the same villages. The prevalence of self-reported symptoms suggestive of ODTS were much higher in swine confinement farmers than in non farm rural control subjects, 6.4% compared with 2.6%. Pig farmers also had a significantly higher prevalence of self reported chronic bronchitis and symptoms suggestive of chronic bronchitis, eg, chronic cough but not asthma or symptoms suggestive of asthma. The prevalence of self reported asthma was about 6% in both groups (Vogelzang et al. 1999b). Pig farmers were also significantly less likely to report common allergies or history of atopy than controls. Farmers with asthma were also more likely to report childhood symptoms of asthma than farmers without asthma (prevalence odds ratio 4.1, $p<0.05$). There was also a significant association with the use of disinfectants, in particular quaternary ammonium compounds.

The one conflicting study for asthma prevalence was carried out in Australia. Driesen (2003) in a cross-sectional survey of pig farmers did find a high prevalence of asthma, 31.3% in females and 21% in males.

Table 4.4 Longitudinal and cohort studies of pig farmers according to country

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Kirychuk *et al* 1998 Canada 5 year follow of subjects in Zedja *et al* 1993 (Table 4.2)	Methods for Respiratory symptoms questionnaire, spirometry and environmental measures same at baseline and follow up	42 male swine confinement workers Ave 37.5 years		Annual decline in both FEV_1 (53.9 mL/year) and FVC (48.9 mL/year). Low to moderate correlations with baseline negative shift declines in each ($p<0.05$), $r=0.34$ between baseline shift decline in FEV_1 and annual rate of decline in FEV_1. Baseline percentage shift changes were statistically significant predictors in regression modelling for these outcomes and adjust for age, smoking status, height and work hours. Only endotoxin exposure levels were significant predictors of annual decline for both FVC and FEV_1	Multiple regression. Sample size may have been inadequate for multiple regression modelling.
Senthiselvan *et al* 1997 Canada 5 year follow-up of same subjects as Zedja *et al* 1993 and 1994 (Tables 4.1 and 4.2)	Same as baseline Symptoms questionnaire* Lung function Baseline measures similar for subjects lost to follow-up	327 male swine farmers from large operations Population based†	217 grain farmers 261 non farming controls \	Swine farmers were significantly younger than subjects in the two control groups. Prevalence of asthma 5.5% in swine farmers and 8.8% in non farm controls Swine farmers had an additional decline in FEV_1 of 26.1 mL/yr and 33.5 mL/yr in FVC above non farm control subjects ($p<0.05$). Grain farmers experienced average additional declines of 16.5 mL/yr in FEV_1 and 26.7 mL/yr in FVC when compared to the non farm group.	Stratification by age categories and adjustment for age, height, baseline pulmonary function and smoking status in multivariate analyses.
Schwartz *et al* 1995 USA 2 year follow-up study	Symptoms questionnaire* Lung function Exposure history Personal sampling	168 swine confinement farmers Ave 37.6 yrs Males 89.3% †Population based	127 neighbourhood farmer Ave 39.4 yrs Males 88.2% Selection not described	Subjects had higher exposures to total dust and endotoxin concentrations than controls % decrease in FEV_1 and FVC over 5 years higher for the control group (-0.84 compared with -1.15 for FEV_1.) In regression modelling, FEV_1 predicted by % of cross-shift decline & negatively predicted by endotoxin level & working in swine confinement ($p<0.05$)	Multiple regression modelling adjusted for age, height, smoking, smoking pack years and years follow.
Iversen M & Dahl R. 2000 Denmark	Detailed methods Baseline findings in Iversen and Pedersen 1990	94 male swine confinement farmers from medium to large farms.	38 male dairy farmers	Follow-up non participants had higher respiratory risk more smokers and work related respiratory symptoms, lower FVC ($p<0.05$), and FEV_1 ($p<0.05$).	Stratified and multivariate analyses Decline in FEV_1 adjusted for height, age and pack years of

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
7 year follow-up study	(Table 4.2) Lung function histamine challenge test were repeated.	Ave age 43 yrs		Decline in FEV_1, was higher in swine farmers, 53.8mL versus 41.8 in dairy farmers ($p<0.05$). No difference for FVC. Swine farmers with respiratory symptoms were more likely than asymptomatic swine farmers to be smokers, to have airways obstruction (lower FEV_1/FVC ratios) and larger annual declines in FEV_1 (All $p>0.05$).	cigarettes smoked
Vogelzang *et al* 1998 Netherlands 3 year follow-up study of farmers described in Vogelzang *et* al. 1997 (Table 4.2)	Baseline measurements were those reported in 1997. Follow-up Lung function Two different spirometry units were used at follow-up. Average long-term exposure to dust and endotoxin algorithm based on individual exposure and the findings of the farm surveys (baseline), activity diaries (baseline).	171 male swine confinement farmers Ave age 39.6 years		The mean decline in FEV_1 was 73ml/year and 55ml/year for FVC. The decline in FEV_1 was greater than that which would be expected. Analyses according to the different spirometry units, showed a reduction in FEV_1 in both cases but less for the water sealed unit than for the dry rolling sealed unit. Multivariate regression analysis for exposure and FEV_1 showed a statistically significant and positive association for endotoxin concentrations.	The analyses was adjusted for age, baseline $FEV_{1,}$ FVC and smoking. The findings of this study are difficult to interpret given different findings between spirometry units

* based on the American Thoracic Society Questionnaire
†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

4.3.2 Work related symptoms and lung function in pig farmers

Pig farmers report a high prevalence of work related symptoms. Work related symptoms were 11% in Iversen and Dahl's (2000) study. In the case of work related coughing, Heederik et al. (1991) found a prevalence of 19.7% and Choudat et al. (1994) 24.5%. Work related symptoms may also occur at higher rates than chronic symptoms.

In a previous review of studies of swine confinement workers, the occurrence of acute respiratory symptoms (cough, phlegm and wheeze) was between 1.5-2 times higher than that of chronic symptom (Donham 1990). The studies examined here are consistent with this conclusion. Zuskin et al. (1992) found that 41.5% of 41 male confinement workers reported chronic cough and 70.7% reported coughing during the work shift. Nasal and eye irritation was also high but the same, 46.3% for chronic and work shift symptoms (Zuskin et al. 1992). Cross-shift declines in lung function measures such as FEV_1 have been identified by a number of studies (Donham et al. 1995, Schwartz et al. 1995). Small, but statistically seasonal declines in these measures were noted by Driesen (2003) between summer and winter.

4.3.3 Association between symptoms, lung function and exposures

Holness et al. (1987) found total respirable dust to be significantly higher for hog confinement farmers than for a control group of farmers of other animals and that they also had a higher prevalence of symptoms such as cough, 57% compared with 21% and chronic bronchitis, 26% compared with 7%. Zedja et al. (1994) found that endotoxin, and not total dust or NH_3 levels were significant predictors of chronic cough or phlegm. Zejda et al. (1993) found an inverse correlation between number of hours worked per day and FVC ($p<0.05$) and FEV_1 ($p>0.05$). Radon et al. (2001b) found that the prevalence odds ratios for symptoms according to hours spent in pig houses were suggestive of a dose response relation for some symptoms. Significant cross-shift declines in lung function measures were found by Zuskin et al. (1992) in confinement workers, eg, between 3.6% and 4.5% for FEV_1 in separate analyses for male, females, male smokers and male non smokers.

Long term effects on lung function are suggested by cross-sectional findings of a reduced FEV_1/FVC which were negatively associated with years worked in a piggery. This is suggestive of obstructive airways disease (Heederik et al. 1991). Heederik et al. (1991) used multiple regression modelling to assess the association between various spirometry results and static exposure levels. Several associations were in the expected negative direction but not statistically significant. The βcoefficient for endotoxin level and FEV_1 was found to be statistically significant in only one model where bacterial levels were also included.

Lung function declines have been confirmed by longitudinal studies (Table 4.4). The findings of Iversen and Dahl (2000) and Senthiselvan et al. (1997) support a conclusion that continued exposure of swine farming results in deterioration in lung function over time and at a greater rate in swine farmers than in non farming or other controls. Iversen and Dahl (2000) found that pig farmers experienced greater declines in FEV_1 over seven years and only pig farmers reported work related symptoms.

Vogelzang et al. (1998) reported the findings of a three year longitudinal study, and found that the average reduction in FEV_1 per year was significantly associated with endotoxin exposure. Decline in FVC was significantly associated with both estimated total dust exposure and endotoxin. However, the findings of this study should be examined with caution. Reasons for this include the wide variation in personal exposure used to derive estimates of exposure. In addition, two different spirometry units were used for the follow up assessment and the fall in FEV_1 was less in those who were measured with a water sealed unit compared with subjects measured with a dry rolling seal unit (Vogelzang et al. 1998).

Schwartz et al. (1995) found that swine confinement workers had significantly higher exposures to total dust and endotoxin concentrations than neighbourhood control farmers who did not work in confinement buildings. Over five years, the control group experienced slightly higher percent decreases in both FEV_1 and FVC. For FEV_1, the percent decreases were -0.84 for swine confinement workers and 1.15 for the controls. However, cross-shift declines were highest for swine confinement workers at any time during the study. In multiple regression modelling for FEV_1 at follow-up, percentage cross-shift decline was a statistically significant predictor, and total endotoxin level and working in swine confinement were both significant negative predictors when adjusted for age, height, smoking, smoking pack years and years. Only percentage of cross-shift decline was a significant predictor in modelling for FVC.

The predictive model explored by Schwartz et al. (1995) suggested that level of cross-shift decline in lung function may determine and predict long term incapacity. This was confirmed in similar modelling by Kirychuk et al. (1998). Kirychuk et al. (1998) noted an annual decline in both FEV_1 (53.9 mL/year) and FVC (48.9 mL/year) over five years for 42 swine confinement workers. Negative shift declines observed at baseline were significant predictors in regression modelling for these outcomes when adjusted for age, smoking status, height and work hours. Of exposures only endotoxin levels were significant predictors of annual decline for both FVC and FEV_1.

4.3.4 The effect of smoking and other factors on symptoms and lung function

Smoking may be an independent risk factor and effect moderator for respiratory symptoms and lung function decline in pig farmers. Studies where the effect of smoking was examined in univariate analyses include Donham et al. (1989) who stratified their findings according to smoking status. There was no longer a significant difference in cough and history of colds between smoking confinement workers and smoking control farmers. A significant increase in prevalence of these symptoms was still reported in non smoking confinement workers compared with controls. Heederik et al. (1991) adjusted the ORs between symptoms and static exposure levels for smoking status and age. Only the ORs for at least one symptom (shortness of breath, sputum or clogged nose) and concentration of gram negative bacteria were statistically significant ($p<0.05$).

Wilhelmsson et al. (1989) modelled the number of symptoms on age, smoking, years worked, allergic predisposition and accumulated yearly exposure time in swine confinement buildings. Smoking and accumulated exposure were statistically significant predictors. Further analysis by ANCOVA suggested a positive interaction effect between smoking and accumulated one year exposure ($p<0.05$). Donham et al. (1995) found that cross-shift declines in FEV_1 were greater for smokers than non smokers.

These findings indicate that smoking may have an independent effect on the occurrence of symptoms and lung function measures as well as moderating effect which require further study. Given this, analyses which have included smoking in models predicting long term outcomes (Schwartz et al. 1995, Kirychuk et al. 1998) are better evidence in assessing the association between symptoms or lung function and workplace exposures than those which have not.

4.3.5 Allergy and challenge exposure studies

How exposure results in non specific respiratory symptoms is not completely understood. Allergies and components of an inflammatory response have been examined in several studies.

The evidence for allergy to components of swine confinement dusts is mixed but does suggest that, if present, farmers are at greater risk of respiratory symptoms. Larsson et al. (1992) found increased serum antibodies to swine dander in 14 of 20 pig confinement workers, as well as a significant increase in total cell count and specifically neutrophils in bronchoalveolar lavage fluid. Iversen and

Dahl (1994) tested 247 farmers for allergy to pig epithelium by RAST test. Only six subjects had positive tests and five of these were asthmatics (Iversen and Dahl 1994). Mackiewicz (1998) found a higher proportion of farmers than controls tested positive to skin prick tests to a range of common allergens found in pig barns. A positive test to *Corynebacterium xerosis* was significantly associated with symptoms of chronic bronchitis (Mackiewicz 1998). By contrast, Zuskin et al. (1991) found a similar prevalence of reactions to antigens present in pig confinement buildings such as swine hair, between farmers and controls. However, the 14 farmers with positive tests, reported a higher prevalence of symptoms than the 18 farmers with negative tests, eg, 50% compared with 33.3% for chronic bronchitis, although none were statistically significantly.

Bronchoalveolar inflammation, independent of smoking, has been demonstrated in pig farmers. Pedersen et al. (1996) compared healthy non smoking pig farmers and healthy non smoking controls. They found statistically significantly higher concentrations of neutrophils and lymphocytes in the bronchoalveolar lavage fluid of farmers as well as increased visual median scores for macroscopic signs of inflammation in swine farmers on bronchoscopy.

Inflammatory responses have also been demonstrated in healthy non farming subjects exposed to the same conditions as pig farmers. Healthy subjects have been found to have increased bronchial responsiveness on methacholine challenge and the onset of respiratory symptoms (Wang et al. 1997, Wang et al. 1998, Sunblad et al. 2002) as have reductions in FEV_1 and FVC (Cormier et al. 2000). This hyper-responsiveness does not seem to be affected by the route of breathing, oral or nasal (Cormier et al. 1998). This response is accompanied by significant increases in cell counts in bronchoalveolar lavage (Larsson et al. 1994) and may only be partially prevented by protective devices. Larsson et al. *(*2002) in a trial involving 16 healthy non farm subjects found that bronchial responsiveness increased in both subjects wearing a mask and those without a mask, although significantly more in those without a mask ($p<0.05$).

In comparative challenge studies, farmers may be more hyper-responsive than control subjects. Zhou et al. (1991) compared responses to methacholine challenge and spirometry in 20 male pig confinement workers and 20 control subjects who were matched for age and smoking status. In addition to reporting a higher prevalence of symptoms, farmers had significantly lower FEV_1 and FVC at baseline and required significantly lower methacholine concentrations to produce both a 10% and 20% reduction in FEV_1. By contrast Larsson et al. (1992) did not find increased responsiveness to methacholine challenge in 20 non smoking confinement workers when compared with 20 non smoking office workers.

There is some evidence to suggest that existing symptoms and continued exposure result in increased responsiveness. Vogelzang et al. (2000) reported the findings of histamine provocation tests at baseline and after 3 years in 171 swine farmers in the Netherlands. They found an increase in responsiveness over time for both a 10% and 20% fall in $FEV_{1.}$ In analyses adjusted for age and smoking status, dust exposure estimated from baseline measures were significantly associated with the 10% test and ammonia concentrations with the 20% test. Farmers with respiratory symptoms at baseline had greater increases than those without symptoms. However a different nebuliser was used for the follow-up tests and the authors suggested that care should be taken in interpreting these results. A sub study comparing the findings of the equipment used at baseline and at follow-up found that the follow-up findings may have been overestimated.

The findings of Bessette et al. (1993), however, confirm the conclusions of Vogelzang et al. (2000). Workers in pig confinement buildings with respiratory symptoms and FEV/FVC ratios less than 95% of predicted were found to be more responsive to methacholine provocation than other workers with better symptom and spirometry profiles (Bessette et al. 1993). Iversen and Dahl (2000) noted a significant but small decrease in bronchial reactivity response to histamine at follow-up in both pig and dairy farmers. However, subjects examined at the seven year follow-up were also more likely ($p<0.05$) than non participants to have higher FEV_1/FVC ratios at baseline (Iversen and Dahl 2000).

Studies assessing hyper-responsiveness, with the exception of Vogelzang et al. (2000) and Iversen and Dahl (2000) were cross-sectional and used a small number of subjects. This is probably unavoidable given the nature of the intervention and cost of the procedure. Sputum assessment following hypertonic saline inhalation and measurement of expired nitric oxide may be more acceptable to subjects and allow future evaluations in larger samples. Von Essan et al. (1998) used these methods to compare 24 swine confinement workers with 14 control subjects. They found that the farmers had increased sputum cell numbers, in particular macrophages ($p<0.05$) and consistent with studies of histamine and methacholine challenge.

4.3.6 Safe working conditions

The findings of studies also measuring exposure could contribute to the identification of safe working concentrations of dusts and bioaerosols. Some cross-sectional studies have reported the findings of personal and static sampling in addition to symptoms. For example, Choudat et al. (1994) found generally higher prevalence of both chronic and work related symptoms in pig farmers compared to dairy farmers. At the same time the static concentrations were 2.41mg/m^3 for average total dust,, 8.5 mg/m^3 for ammonia and carbon dioxide was found to range between 1000 ppm to 5000 ppm in swine confinement buildings. In a small analysis involving 17 non smoking farmers, Christensen et al. (1992) compared farmers above the median total dust concentration of 3.3 mg/m^3 with those below. Eight subjects with higher concentrations reported coughing whereas only one subject below this threshold level did so.

Exposure threshold levels could be explored in the findings of studies such as Heederik et al. (1991) and Donham et al. (1995) where dose response relationships between symptoms or lung function and levels of exposure have been examined. Donham et al. (1989) identified a threshold endotoxin level for a decrease in FEV_1 over the work shift as 0.18µg/ml.

Studies focussing on the physical environment and modifications to reduce exposures are more recent and exploratory, eg, dust suppression with canola oil (Senthinselvan et al. 1997). The use of canola oil to control dust and endotoxin exposures has been demonstrated to result in a reduction in decline in FEV_1 and FVC during exposure in normal subjects (Zhang et al. 1998).

Working in swine confinement buildings poses particular hazards since toxic gases are likely to be in greater concentration in addition to dust and bioaerosols, than outdoors. In a trial of 22 healthy subjects, Dosman et al. (2000) found that bronchial hyper responsiveness on methacholine challenge increased whether or not a disposable respirator was used, although the response was attenuated in the latter. This suggests that exposure to gases, in addition to dusts, affects respiratory function in swine confinement workers.

Vogelzang et al. *(*1997) attempted to identify which of the hazards in pig farming are most likely to cause respiratory symptoms. In logistic regression analysis, bronchial responsiveness on histamine challenge was significantly predicted by the use of quaternary ammonium compounds as disinfectants (OR 6.7 95% CI, 1.4-32.8), wood shavings for bedding (OR 13.3, 95% CI 1.3-136.7), pellet feeding (OR 4.8, 95% CI 1.1 –21.1) and air exhausts located on the roof or pit as opposed to the side of the building OR 2.7, 95% CI 1.2-6.3). The authors reported no association between personal dust exposures and bronchial hyper-responsiveness. However these measurements were only performed twice during the study. The wide confidence intervals also suggest a need for further study in this area.

4.3.7 Conclusion

The prevalence of a range of non specific respiratory symptoms in pig farmers is high, although the magnitude of the prevalence differs in different studies. The direction of the findings is generally that swine farmers have increased respiratory symptoms, both chronic and work related, and poorer lung function than non farmers. The findings are not explained by farmers' smoking habits, although farmers who smoke are more likely to have symptoms. The high prevalence of asthma in the only Australian study conflicts with overseas studies and requires further investigation.

There is evidence for a dose response relationship, in that, symptoms and lung function declines are associated with continued exposure and with the number of hours worked. Farmers working in pig confinement buildings may be at particular risk given the duration of exposure.

Longitudinal studies support the conclusion that long term lung function impairment will result from continued work place exposure. Cross-shift declines in lung function are important predictors of long term decline in lung function. Given this, cross-shift declines may not be fully reversible. Whether this impairment results in premature mortality or even severe functional incapacity requires further study. These studies suggest that exposure standards and protective strategies against dust, gases and bioaerosols have been inadequate and that further research in these areas is required.

4.4 Studies where principal activity is poultry farming

The studies examined covered a range of poultry farming activities including chicken, turkey and egg farming. Most studies are from the USA and Europe and include intensive and relatively high density barn operations, whether cage based or floor based. Large commercial operations in Australia will function on a similar basis. The conclusions from these studies may not apply to small operations or free range farmers. Studies reporting the prevalence of respiratory symptoms are summarised in Tables 4.5 and 4.6.

All studies of poultry farmers reviewed are cross-sectional. They include studies which have selected subjects from population based registers, which will strengthen the external validity of the findings at least to those original populations (Brown et al. 1990a, Radon et al. 2001b). None compared characteristics of respondents to those of non respondents to assess how well the subjects represented the source population. Most studies have measured self-reported respiratory symptoms health status using standardised questionnaires based on previously developed questionnaires, eg, from the Medical Research Council of Great Britain (Morris et al. 1991, Zuskin et al. 1995, Simpson et al. 1998, Radon et al. 2001b), American Thoracic Society Respiratory Questionnaire (Brown 1990a, Reynolds et al 1993, Donham et al. 2000, Kirychuk et al. 2003,), or European Community-Respiratory Health Survey (Danuser et al. 2001).

Table 4.5 Cross-sectional studies of poultry farmers according to country
Prevalence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Findings and Significance	Adjustment for confounding
Brown 1990a Australia (Victoria)	Symptoms questionnaire* Lung function	372 poultry farmers Mean age 44.3 years Males 74.7% Population based	Self-reported prevalence of symptoms (34.9% cough/sputum, 38.4% wheeze) FEV_1 and FVC overall higher than expected. Lower for symptomatic farmers (<0.05). Trend for increasing symptoms with time in farming inconsistent. p<0.05 for chronic bronchitis and wheeze only	Stratified analysis. All symptoms more likely in smokers than non smokers
Brown 1990b Australia (NSW)	Symptoms questionnaire*	280 poultry farmers (working in sheds) Males 61.8% Age reported in categories 66.5% males and 80.4% aged 31-60 years Population based Response rate 87% of 141 farms (farms contracted to a particular processing plant)	66.5% of males and 55.1% of females had one or more respiratory symptoms (cough, sputum, wheeze or shortness of breath). A higher proportion of symptomatic farmers were smokers. For females 18.6% of those with symptoms were smokers compared with 2.1% of asymptomatic subjects. The prevalence of chronic bronchitis and asthma were respectively 16.2% and 11% in males, 10.3% and 12.1% females.	For males and females, separate logistic regression analyse for outcomes of any symptoms, chronic bronchitis, asthma and wheeze. Explanatory variables age, smoking, family history or atopy, estimate of cumulative shed year exposure and use of respiratory protection None were significant predictors in any of the models
Brown 1992 Australia	As in Brown 1990a and 1990b	Subjects from Brown 1990a	Chronic bronchitis, asthma and eye irritation similar between areas and males and females. Eg, between	Prevalence reported separately for male and females

	Measurements	Subjects	Findings and Significance	Adjustment for confounding
(Conference paper)	Further analyses	and 1990b	48.7%-71.6% for eye irritation and between 9.7%-13.8% for asthma. Current smoking and family history of atopy associated with increased risk for all three symptoms. ORs for each ($p<0.05$)	Logistic regression modelling of each symptom with explanatory variables: age, smoking, family history of atopy and exposure (shed years).
Reynolds *et al* 1993 USA	Symptoms questionnaire* Lung function Static sampling Two phase cross-sectional (winter and summer)	95 turkey farmers Ave age 37 yrs 90% males 40 subjects measured for cross-shift decline	Symptoms of cough, phlegm, and allergies increased in winter compared to summer. ($p<0.05$). Eg, prevalence of cough, 39.7% in winter, 22.2% in summer. Seasonal differences most marked in smokers. Eg, prevalence of cough in smokers in winter was 57.7% and 22.7% in summer. Prevalence of cough for never smokers, 31.3% in winter and 27.3% in summer. FEV_1 and FVC were both lower than predicted in all seasons, ($p<0.05$ for both). Statistically significant cross-shift declines, average of -2.7% for FEV_1 and - 2.5% for FVC. FEV_1 and FVC were moderately and negatively correlated with years worked in the industry ($p<0.05$).	Data were stratified according to spirometry findings and smoking status, spirometry and years of work in the industry. These findings were inconclusive possibly due to small numbers in each cell.
Morris *et al* 1991 USA	Symptoms questionnaire* Lung function	59 chicken catchers	Comparison with NIOSH ref. group. Prevalence of symptoms greater than expected ($p<0.05$) Reduced FEV_1 across shift ($p<0.05$). Trend for increased prevalence with length of exposure >5 years compared with less than 5 years	

* based on previously developed questionnaire such as the American Thoracic Society Questionnaire, the American Thoracic Society - Epidemiology Standardised Project or the British Medical Research Council Questionnaire
†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

Table 4.6 Cross-sectional controlled studies of poultry farmers according to country
Prevalence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Donham *et al* 2000 USA	Symptoms questionnaire* Lung function personal sampling, .	257 poultry farm workers Ave age 38.8 yrs Males 77% Population based†	150 non farm blue collar workers Ave age 42.1 yrs Males 58%	3% decline in FEV_1 across shift noted in 30% of poultry workers. Declines correlated with personal exposure measures in univariate analyses. FEV_1 weakly and significantly ($p<0.05$) correlated with total dust (!=0.265), respirable dust (!=0.155), total endotoxin (!=0.193) and respirable endotoxin (!=0.157) exposures but not with ammonia (!=0.081, $p>0.05$). Threshold levels for exposure were suggested on the basis of LR results predicting 3% or greater cross-shift declines in FEV_1: 2.4 mg/m^3 for total dust, 0.162 mg/m^3 for respirable dust, 614 EU/m^3 for total endotoxin, 7.15 EU/m^3 for respirable endotoxins and 12 ppm for ammonia.	Logistic regression (LR) modelling adjusted for age, years worked, gender, smoking status and level of education. LR showed significant trend in increasing ORs for a decline in FEV1 with increasing quartiles of total endotoxin and dust exposure.
Kirychuk *et al* 2003 Canada	Symptoms Questionnaire*	303 poultry workers 2 groups Floor based Ave age 42 yrs Males 5.6% Cage based operations Ave age 44. yrs Males 85.2 yrs Population based	241 grain farmers Ave age 46.4 yrs Male 87.6% 206 non farm workers Ave age 43.4 yrs Male 76.7% Population based age/sex matched	Analyses separate for cage based and floor based workers. Both groups had higher prevalence of chronic cough (15.5%, 18.9% versus 1.7%) and chronic phlegm (17.1%, 19.8% versus 8.7%) compared with non farmers workers ($p<0.05$). Caged based workers had higher levels of symptoms of current cough and wheeze than floor based workers. FEV_1 lower in caged based poultry workers ($p<0.05$).	Grain farmers to control for confounding effects of grain farming on respiratory outcomes in the study group. ANCOVA to adjust for age, sex height and smoking
Radon *et al* 2001b	Symptom questionnaire*	36 Swiss poultry	40 Danish pig farmers	No significant reduction across shift for either group	Univariate analysis Authors note that all results were

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Europe	Lung function Static exposures	farmers Ave age 41 yrs Male 67% Population based	Ave age 39 yrs Male 90% Population based	Spirometry values significantly higher for pig farmers FEV_1 and FVC overall higher than expected Cross-shift declines greatest overall for asymptomatic farmers, for FEV_1 $p<0.05$. Poultry farmers –absence of a porous air inlet associated with lower FVC	confirmed when adjusted for pack years of smoking (no figures provided) No difference between the groups in age and smoking status ($p>0.05$) however there were ore male pig farmers ($p<0.05$) and this may account for higher spirometry values
Zuskin *et al* 1995 Croatia	Symptoms questionnaire* Lung function	343 poultry workers 64% males Mean age 37 years	200 food packing workers Reported to be similar study group in age, employment duration and smoking status (figures not published)	Prevalence higher in poultry workers than in controls and significant ($p<0.05$). Eg, chronic cough (males 33.7%, females 19.8%), Other symptoms: as well as chronic phlegm, chronic bronchitis, chest tightness Symptoms higher in subjects who had worked for greater than 10 years compared with subjects who had worked for 10 years or less ($p<0.05$). Association with both smoking status and employment duration ($p<0.05$ in males). Eg, the prevalence of chronic cough was 37% for work duration of 10 years or less and 60% for those who had worked longer than 10 years. There were no significant differences for asthma or dyspnea in any of these comparisons. High prevalence of acute symptoms during the work shift. Eg, eye irritation (males 55.2%, females 67.0%) For both male and females FEV_1 and FVC were lower than predicted.	Stratified analyses for respiratory outcomes separately for males and females, smoking status, work duration.

* based on a previously developed questionnaire eg, the American Thoracic Society Questionnaire, the American Thoracic Society - Epidemiology Standardized Project, the British Medical Research Council Questionnaire

†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

4.4.1 Prevalence of respiratory symptoms

The prevalence of respiratory symptoms in poultry workers is high (Donham et al. 2000, Hoppin et al. 2003), but, similar to studies of pig farmers, although the magnitude of the prevalence may vary across studies and according to gender. In an Australian survey of Victorian poultry farmers, 34.9% reported symptoms of cough or sputum and 38.4% reported wheezing (Brown 1990a). In Canada 15.5% of workers in cage-based housing systems and 19% of those in floor based systems reported symptoms of chronic cough. (Kirychuk et al. 2003). There may also be a gender difference. Zuskin et al. (1995) reported a prevalence of chronic cough of 33.7% in male and 19.8% in female poultry farmers. A seasonal trend is likely with higher prevalence of symptoms during the winter months (Reynolds et al. 1993). The occurrence of asthma appears to be low in poultry farmers, possibly a result of the healthy worker effect. Zuskin et al. *(*1995) found the prevalence to be only 1.2% in male poultry farmers. Brown (1990a, 1990b, 1992) found relatively higher prevalence rates for asthma in Australian poultry workers, 9.7% and 11.0% for males and 13.8% and 12.1% for females.

Comparative studies show a higher prevalence of respiratory symptoms in poultry farmers than in non farm populations or farmers of other animals. This is the case with different reference comparison groups (Morris et al. 1991, Zuskin et al. 1995, Simpson et al. 1998). Morris et al. (1991) compared the symptoms experienced by their sample with a previously assessed NIOSH reference population of blue collar workers. The odds of chronic cough were 5 times higher in poultry farmers than in the reference population. Simpson et al. (1998) found a higher prevalence of respiratory tract symptoms in poultry workers compared to workers on pig farms and in other industries such as textile manufacturing.

Danuser et al. (2001) compared symptoms in Swiss poultry farmers both with the general Swiss population and between different farming groups. In logistic regression modelling adjusted for age and smoking status for different symptom outcomes, the highest odds ratios, 2.68 and 2.87, for wheeze and asthma respectively, were for poultry farmers but not statistically significant ($p>0.05$). The only odds ratio for poultry farming that was statistically significant was for nasal irritation at work, 5.33.

4.4.2 Work related symptoms and lung function in poultry farmers

Poultry farmers experience a high prevalence of acute symptoms during the workday. Zuskin et al. (1995) found that workers in intensive conditions in confinement buildings reported a high incidence of eye irritation (males 55.2%, females 67.0%) and cough (males 51.9%, females 54.9%). The findings of studies measuring cross-shift declines in lung function are consistent in demonstrating a negative decline although of differing magnitudes (Thelin et al. 1984, Morris et al. 1991, Reynolds et al. 1993, Donham et al. 2000). Donham et al. (2000) found that 30% of poultry farmers experienced a decline in FEV_1 of 3% at the end of the working day. Reynolds et al. (1993) found statistically significant cross-shift reductions of 2.7% for FEV_1. A similar decline was not observed in the control group of blue collar workers.

4.4.3 Association between symptoms, lung function and exposures

Exposure to dusts and bioaerosols are the likely cause of respiratory symptoms in poultry farmers. As for pig farmers, increased bronchial hyper responsiveness has been demonstrated in healthy non farmers exposed to poultry farming conditions. A five fold increase in bronchial reactivity has been demonstrated by Larsson et al. (1999) in naive subjects exposed for three hours to three different housing systems for poultry.

The length of exposure appears to be related to the occurrence of symptoms. Brown (1990a) found a statistically significant association with length of time spent in the industry (mean shed years) for chronic bronchitis and wheeze sometimes, but not for other symptoms. Zuskin et al. (1995) found that workers who had worked for greater than 10 years had a higher prevalence of symptoms than those who had worked for less than 10 years ($p<0.05$). Reynolds et al. (2003) found a moderate correlation between years of work in the industry and symptoms ($p<0.05$). The presence of symptoms is also associated with reduced FEV_1 and FVC and exposure levels. Brown (1990a) found statistically significant higher FEV_1 and FVC measures in farmers without symptoms than in farmers with symptoms.

Reynolds et al. (1993) found that cross-shift declines in FEV_1 were weakly and significantly correlated with total dust ($r=0.265$), respirable dust ($r=0.155$), total endotoxin ($r=0.193$) and respirable endotoxin ($r=0.157$) levels, but not with ammonia ($r=0.081$, $p>0.05$) exposures. However, the findings of logistic regression modelling adjusted for age, years worked in poultry industry, gender, smoking status and education support the conclusion that a dose response relationship exists between exposure and symptoms. A significant trend in increasing ORs for a decline for FEV_1 was observed with increasing quartiles of total dust and total endotoxin concentrations (Reynolds et al. 1993).

4.4.4 The effect of smoking and other factors on symptoms and lung function

Respiratory symptoms in poultry farmers may also result from smoking. Included in Table 4.5 and Table 4.6 are studies which have carried out stratified analyses according to smoking status or adjusted for this characteristic in multiple regression. Overall, the findings are inconclusive. Zuskin et al. (1995) found that male smokers had a higher prevalence of cough, phlegm and chronic bronchitis than non smokers. Brown (1992) found current smoking status was a significant predictor for chronic bronchitis symptoms in logistic regression analysis. Thelin et al. (1993), however, found no difference in cross-shift reductions in lung function in stratified analyses for smokers and non smokers.

4.4.5 Workers in related industries

This review is focussed on farmers and excludes workers in poultry abattoirs or slaughtering industries. However, workers in these industries are also exposed to endotoxins and dusts found in the farming of poultry. Their findings support a role for exposures in the development of symptoms and lung function decline. Hagmar et al. (1990) found significant post shift declines in FVC and FEV_1 in 24 poultry slaughterhouse workers of 3.1% and 4.1%, although no significant association was found with dust and endotoxin levels. Netto and Johnson (2003) carried out a retrospective cohort study of 7700 Missouri workers in poultry slaughtering plants using union records of occupation, and population datasets of mortality and motor accidents, as well as personal interviews. Over a 21 year period, from 1969, males but not females, had a higher proportionate mortality rate than the US general population for deaths due to non malignant respiratory diseases, 1.8 for all males and 1.9 for white males ($p<0.05$).

4.4.6 Safe working conditions

Studies in which exposure, symptoms and/or lung function were measured may provide a starting point for determining exposure standards. Donham et al. (2000) suggested threshold levels for exposure based on LR results predicting 3% or greater cross-shift declines in $FEV_{1.}$ These were 2.4 mg/m^3 for total dust, 0.162 mg/m^3 for respirable dust, 614 EU/m^3 for total endotoxin, 7.15 EU/m^3 for respirable endotoxins and 12 ppm for ammonia. The fivefold increase in bronchial reactivity in non farmers studied by Larsson et al. (1999) was associated with inhalable dust levels of $4mg/m^3$ in cage rearing houses and 2 mg/m^3 in floor based systems. Endotoxin concentration was 100 mm/m^3 in both.

Physical characteristics of the working environment also need to be considered to ensure a safe workplace. The type of housing in which poultry are raised or managed may affect the amount and type of exposure. Kirychuk et al. (2003) found that workers in cage based poultry farming had a higher prevalence of allergies (22.1% versus 16.0%), and significantly higher prevalence rates of work related cough and wheeze than workers in floor based poultry housing. They also had significantly lower FEV_1. An explanation may be the expected higher concentration of feathers, dust and so forth when chickens are kept in a confined space. These findings contradict those of an experiment on urban adults exposed for three hours in the two different housing types (Larsson et al. 1999). Subjects in floor based poultry houses (with fresh bedding) had a small statistically significant reduction in FEV_1 at the end of the period, but those in cage based housing or floor based housing with old bedding did not. Possible reasons for this difference between the two studies may have been environmental factors, such as the amount of fresh or old bedding material on the cage free floors.

4.4.7 Conclusion

The conclusions are similar to those of the preceding section on pig farmers, but are weaker in the absence of longitudinal studies. There are also fewer studies to draw results from. Poultry farmers experience a high prevalence of respiratory symptoms. Their risk is higher than that of non farmers and other animal farmers, with the possible exception of pig farmers. Poultry farmers experience both work shift and chronic symptoms. There appear to be associations between symptoms and reduced spirometry measures, work duration, smoking, dust and bioaerosol exposure. The presence of symptoms may not necessarily mean long term lung disease or lung function impairment. These need to be confirmed in longitudinal studies. Further studies are required to explore the independent effects on symptoms of smoking, gender and farm characteristics. The findings of the two Australian studies are consistent with those of overseas studies. However, like the Australian study of pig farmers in the preceding section, relatively higher rates of asthma were reported for Australian farmers.

4.5 Studies where principal activity is cattle or dairy farming

All studies in this section are overseas studies from cold climate areas in Europe, mainly France. The duration of barn exposure and mechanical characteristics of barns such as heating will differ from dairy or cattle farming in Australia. This may affect both the prevalence of symptoms and exposures. Several of the studies in France are from the Doubs where the health cover provided by the Mutualite Sociale Agricole has been used to identify and monitor farmers for population based longitudinal studies. Several papers have been reported from the same cohorts of subjects; eg, baseline findings and then follow-up findings, both examining the same question, the association between exposure and symptoms. Where this is the case, the longitudinal findings are preferred since these will provided better evidence for the occurrence of symptoms and their association with exposures. Given the small number of studies, those for cattle and dairy farming are examined together in this section (Tables 4.7, 4.8 and 4.9).

Table 4.7 Cross-sectional studies of cattle and dairy farmers according to country
Prevalence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Findings and Significance	Adjustment for confounding
Radon et al. 1999 Germany	Interviews Symptom questionnaire Farm characteristics	Participation by 1735 cattle farmers (66.9% of 1247 farms) Ave age 45 yrs Males 63.3% 1468 also cattle farmers †Population based	All farmers, prevalence of one or more work related symptoms was 40.3%. Prevalence of cough without phlegm 17.4%. Analyses for cattle farmers according to farm characteristics. Significant predictors of one or more symptoms were barn heating (OR 9.66) and living inland (1.40). Significant protective predictors included plant crop activities (0.71 – not adjusted for smoking), median barn size, per log m^3 area (OR 0.59), wall air outlet location (OR 0.66), daily feeding (OR 0.47).	Comparisons of one or more work related symptoms according to farm characteristics were adjusted for age, gender, smoking status and response rate for each municipality.

†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

Table 4.8 Cross-sectional controlled and case control studies of cattle and dairy farmers according to country Prevalence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Dalphin et al. 1998a France Dairy farmers Cross-sectional	Postal symptoms questionnaire* returned on day of examination Skin prick tests and IgE levels to common exposures Sub sample of non respondents in each group similar in sex age and smoking status.	265 dairy farmers Ave age 45.9 yrs Males 57.7% Population based†	149 agricultural branch workers, Ave age 37.4 yrs Males 47.7%	Controls were younger, had a lower proportion of males and a higher proportion of smokers (all $p<0.05$). Prevalence of asthma and atopy similar. FEV_1 and FVC similar in both groups. Percent predicted FEV_1/ FVC lower in farmers ($p<0.05$). Prevalence of morning cough, phlegm, wheezing and chronic bronchitis higher in farmers when adjusted for age, gender and smoking status ($p<0.05$). Eg, OR for morning phlegm was 11.3 (95% CI, 3.1-40.5). Smoking was a significant predictor of both FEV_1 and FVC. Non specific respiratory symptoms not related to allergy tests.	Adjusting of prevalence ORs by logistic regression analysis. Multiple regression analysis for predictors of FEV_1 and FVC.
Dalphin et al. 1993 France Dairy Farmers Case control	Posted symptoms questionnaire* prior to routine medical examination 2720 farmers, 84% of potential farmers (Mutualite Sociale Agricole) Occupational history questionnaire. Lung function	197 dairy male farmers with chronic bronchitis Population based	163 male dairy farmers without chronic bronchitis matched for age and smoking status	No difference in prior history of plant exposure between the groups. Similar exposures to activities such as barn threshing. Previous FLD associated with chronic bronchitis. RSBT (Acute Respiratory Syndrome during Barn Threshing) (cough/dyspnea < 1 hr after exposure) more frequent in cases 28.9% vs. 16%. 16% of cases vs. 1.2% of controls had a history of Semi Delayed Respiratory Symptoms (4 -8 hours after exposure). RSBT and SDRS both preceded chronic bronchitis in all cases. Over 80% preceded chronic bronchitis. No association between acute symptoms and chronic bronchitis.	
Dalphin et al. 1989 France	Mailed symptoms questionnaire* Lung function	250 dairy farmers Age 20-60 yrs	250 administrative employees matched for age, gender, height and smoking status	Prevalence of chronic bronchitis 12% in dairy farmers compared with 6% in controls ($p<0.05$). Chronic bronchitis associated with non smoking status ($p<0.05$). No difference in dyspnea. FEV_1 in farmers lower than controls. For women, the prevalence of dyspnea was 48.3% compared with 30.8% in female controls ($p<0.05$).	Stratified analyses for males and females

* * based on a previously developed questionnaire eg, the American Thoracic Society Questionnaire, the American Thoracic Society - Epidemiology Standardized Project, the British Medical Research Council Questionnaire
†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

4.5.1 Prevalence of respiratory symptoms in cattle and dairy farmers

The prevalence (7.6%) and three year incidence (2047/100,000) of chronic bronchitis were similar in Finnish cattle farmers and Finnish farmers in general (Tehro et al. 1987a). A higher risk was evident for both atopic and smoker subjects and stratified analyses suggested an interaction between these two characteristics; atopic farmers who were smokers were more likely to report chronic bronchitis than atopic farmers who did not smoke. The incidence of FLD or at least self reported symptoms suggestive of FLD in this study was 540/100, 000 (Tehro et al. 1987a).

Dairy farmers in France have been found to have a higher prevalence of respiratory symptoms such as cough and chronic bronchitis than non farming controls (Dalphin et al. 1989, Dalphin et al. 1998a). Control subjects were younger, had a lower proportion of males and a higher proportion of smokers (all $p<0.05$). Odds ratios were still statistically significant when adjusted for sex, age and smoking status. For example, dairy farmers were 11.8 times more likely to report chronic bronchitis than non farmers (95% CI, 1.4-97.1).

4.5.2 Association between symptoms, lung function and exposures

In a five year follow-up study, Chaudemanche et al. (2003) found dairy farmers to have significantly higher prevalence of cough (15.9% vs. 8.2%) and chronic bronchitis (7.5% vs. 1.8%) than non farming controls. Lung function findings were similar in both groups, although the FEV_1/FVC ratio was slightly lower than for controls, 98.2% vs. 100% ($p<0.05$) suggesting obstructive disease. There were no differences in atopy or asthma. For all subjects in this study, the mean annual declines in FEV_1 and FEV_1/FVC were 13.4 ml and 0.30% respectively. In regression analyses, baseline lung function was a significant predictor of annual change in the same measures and adjusted for a number of variables including age and smoking. Dairy farming was a significant predictor in a model for decline in FEV_1/FVC.

These findings are consistent with those of an earlier longitudinal study of dairy farmers in France (Dalphin et al. 1998b). The prevalence of chronic bronchitis, acute bronchitis and dyspnea were all higher in dairy farmers than non farming controls ($p<0.05$). Annual decline in FVC was significantly predicted by age, height, pack years smoked, baseline FVC and being a dairy farmer. Annual decline in FEV_1 was significantly predicted by baseline FEV_1, age, geographical location (tableland as opposed to plains) and being a dairy farmer.

Long term health sequelae are suggested by the findings of a case control study in France. Dairy farmers with chronic bronchitis, more frequently reported a history of symptoms shortly after barn threshing (husking) or delayed up to eight hours after exposure to mouldy or dusty hay than dairy farmers without chronic bronchitis. In all cases these episodes preceded symptoms of chronic bronchitis. This was also the case for FLD confirmed by radiological and clinical examination (Dalphin et al. 1993)

Mould and bacteria in damp hay have been suggested as causes of lung function decline in dairy farmers. Mauny et al. (1997) did not find that method of drying fodder had a significant association with lung function tests. Westeel et al (2000) examined the findings of immunological tests for the same subjects in Mauny et al. (1997). Ig (G) response to *Aspergillus fumigatus* was negatively correlated to FVC, FEV_1 and FEV_1/FVC at follow-up and a significant predictor of mean annual declines in FEV_1 and FVC. However, Finish dairy farmers did not differ from a control group of teachers in reactions to a skin prick test for *Aspergillus fumigatus* (Terho et al. 1987b).

4.5.3 Safe working conditions

Radon et al. (1999) explored farm characteristics associated with one or more symptoms in cattle farmers in Northern Germany. These factors included barn heating which was associated with a ten fold increase in risk (OR 9.66, 95% CI, 1.21-77.85). Protective factors included a decrease in risk of 41% per log m^3 area of barn (OR 0.59, 95% CI 0.38-0.92) and a 34% decrease if the outlet was located in a wall (OR 0.66, 95% CI 0.51-0.86). The method of drying fodder may affect the level of exposure to mould and bacteria, particularly in cold climates. Mauny et al. (1997) have explored this in a longitudinal study but did not find the method of drying fodder for dairy cattle to be a significant factor in annual decline in lung function.

4.5.4 Conclusion

Cattle and dairy farmers appear to be at higher risk for respiratory symptoms than non farming controls, although perhaps not to the extent that pig and poultry farmers are at risk. For farmers exposed to hay, exposure to moulds and bacteria may play an important part in the development of symptoms. There is longitudinal evidence to suggest that Farmers' Lung Disease and symptoms experienced following exposure precedes symptoms of chronic bronchitis. Long term declines in FEV_1 and FVC have been demonstrated, which is consistent with the findings in pig and poultry farming.

Studies of cold climate farming are perhaps least relevant to Australian conditions. None of these studies compared symptoms or lung function with static or personal sampling. The importance of longitudinal studies is illustrated by the findings of Mauny et al. (1997) who were not able to confirm in the longitudinal analysis the hypothesis suggested in the baseline findings that the method of barn drying of fodder was associated with declines in lung function.

Table 4.9 Longitudinal and cohort studies of cattle and dairy farmers according to country
Incidence of symptoms and association with exposure and other risk factors

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
Terho et al. 1987a Finland 3 year follow-up	Postal surveys 1979 & 1982 Symptoms questionnaire*	3467 cattle farmers 'healthy' at baseline survey Males and females included Population based data from the Farmer's Occupational Health Programme		Cattle farmers had similar 3 year incidence of chronic bronchitis, 7.6% as all farmers (9483 farmers). Prevalence and incidence of symptoms of Farmer's Lung Disease, 1.7% and 540/100,000 respectively. Significant association between prevalence and incidence of chronic bronchitis and atopy (OR 2.03) adjusted for age sex and smoking status and smoking (OR 1.23) adjusted for age, sex and atopy. Interaction between atopy and smoking status suggested in the stratification tables.	Stratification for gender, age category, atopy and smoking.
Chaudemanche et al. 2003 France 5 year follow-up of subjects in Dalphin et al 1998a (Table 4.8)	Symptoms questionnaire* Lung function Blood O_2 saturation Follow-up 81.9% of baseline subjects. Baseline characteristics similar between follow-up participants and non participants.	215 dairy farmers Ave age 51.7 yrs Males 56.3% 81.1% from baseline	110 non farming controls Ave age 43.9% Males 46.4% 73.8% from baseline	Prevalence of asthma and atopy were similar at follow-up. Dairy farmers had a higher occurrence of cough (15.9 vs. 8.2%) and chronic bronchitis (7.5% vs. 1.8%) significantly higher. No difference also in FEV_1 and FVC although FEV_1/FVC ratio slightly lower than for controls, 98.2% vs. 100% ($p<0.05$) Blood O_2 saturation slightly lower in farmers ($p<0.05$) For all subjects, mean annual declines in FEV_1 and FEV_1/FVC were 13.4 ml and 0.30% respectively. Predictors of FEV_1/FVC decline ($p<0.05$) were dairy farming, age and smoking pack-years and baseline FEV_1/FVC. For FEV_1 and FVC, in separate analyses, height, age, male gender and baseline FEV_1 were significant predictors of decline. Follow-up controls younger than dairy farmers and had a higher proportion of smokers ($p<0.05$).	Multiple linear regression for decline in FEV_1 and FEV_1/FVC. Explanatory variables included gender, age, height, smoking, log (IgE), farming/control status, altitude, baseline lung function.
Dalphin et al. 1998b	Same as in baseline study	194 dairy farmers 77.6% of baseline	155 agricultural administrative employees	At follow-up, prevalence of chronic bronchitis, acute bronchitis and dyspnea higher in dairy farmers ($p<0.05$). Eg, OR for chronic bronchitis 3.29, 95% CI:	Multiple regression modelling for annual decline in FEV_1 and FVC. Explanatory variables were initial

	Measurements	Subjects	Control	Findings and Significance	Adjustment for confounding
France Dairy farmers 6 year follow-up of subjects in Dalphin et al. 1989 (Table 4.8)	Postal questionnaires collected during medical check up Symptoms questionnaire* Lung function	Non respondents similar to respondents age, sex, smoking status and symptoms	62% of baseline Matched at baseline age, sex, height and smoking habits Non respondents similar to respondents age, sex, smoking status and symptoms Non respondents more likely to be heavier smokers	1.38-7.84. % predicted FEV_1 but not FVC was significantly lower in dairy farmers (adjusted for smoking habits and geography). Annual decline in FVC significantly predicted by age, height, pack years smoked, baseline FVC and being a dairy farmer. Annual decline in FEV_1 was significantly predicted by baseline FEV_1, age, geographical location (tableland as opposed to plains) and being a dairy farmer.	FEV_1 or FVC, age, sex height, pack years smoked, smoking status at baseline, smoking status at follow-up, geographic location, and group status.
Mauny et al. 1997 France Dairy farmers 5 year follow-up Baseline findings suggested a protective effect of barn drying	Same as baseline Symptoms questionnaire* Lung function Immunological tests published in Westeel et al. (2000)	113 male dairy farmers Barn drying of fodder Ave age 48.6 yrs Population based	231 dairy farmers traditional drying Ave age 47.9 yrs Population based	Follow-up groups similar in demographic characteristics. Prevalence of symptoms similar in both groups, except chronic bronchitis where the OR suggested a protective effect for barn drying (0.32, (5% CI 0.11, 0.95). FEV_1 lower than predicted in both groups but more for traditional drying farm groups ($p<0.05$) although no significant difference in annual decline in any lung function measures. Annual decline in FEV_1 negatively predicted age and tableland location of farms ($p<0.05$) Decline in FVC negatively predicted by tableland location ($p<0.05$).	Multiple regression analyses for annual declines in lung function measures. Explanatory variables were age, smoking habits, geography and exposures variables

* based on a previously developed questionnaire eg, the American Thoracic Society Questionnaire, the American Thoracic Society - Epidemiology Standardized Project, the British Medical Research Council Questionnaire
†Population based – The authors have attempted to obtain a representative sample of all farmers, by eg, use of national or occupational registers

Chapter 5: Gap Analysis

5.1 What has this study shown

A broad range of papers on exposures and exposure measurements to dusts and bioaerosol and respiratory symptoms in farmers have been examined in detail. The following is a précis of the discussion in Chapters 3 and 4 detailing what is known about workers' exposures and the potential impact on respiratory health of workers in animal handling facilities.

5.1.1 Exposure data

There are relatively few studies that have been undertaken in Australia and internationally considering the number of people that may be exposed to dusts and bioaerosols in animal housing and handling facilities. In Australia, there have been only four studies that have looked directly at exposure of workers to dusts and bioaerosols in a number of sites relevant to particular animal species. Of the 4 studies, only the study by Holyoake (2002) on pig housing measured worker exposure to dusts and bioaerosols. In particular this study investigated whether bedding type had an effect on exposure levels. In addition to the levels of dusts and endotoxins measured, bacterial contamination was also measured but not using the correct sampling method for the type of equipment according to one of the published standards listed in Section 3.1. Another study nearing completion (Kift et al. 2003, 2004b), is investigating the exposure of sheep shearers to dusts and bioaerosols in shearing sheds in NSW.

A number of other studies have been undertaken in Australia in relation to dusts and bioaerosols in animal housing that relate mainly to animal health, and in most cases only one sample of each type of contaminant was collected in the animal shed at a time. This data is not considered relevant to human exposure as the samples were generally not collected in areas where and when people were working.

Table 5.1 summarises the exposures that have been measured both in Australia and internationally. This data has been collated as an average of the data presented in Chapter 3 and in some cases may represent only one exposure result.

Table 5.1 Summary of Exposure Data Reported in the Literature

		Dust		Bioaerosols		Endotoxins	
Animal	**Region**	Inhalable Dust (mg/m^3)	Respirable Dust (mg/m^3)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Inhalable Endotoxin (EU/m^3)	Respirable Endotoxin (EU/m^3)
Pigs	Australia/ Asia	5.73	1.75	2.67×10^3	3.35×10^5		
	Europe	3.68	0.52	1.03×10^0	8.85×10^5		
	North America	3.93	0.02	6.40×10^1	7.49×10^4	8498	14.4
Poultry	Australia/ Asia	9.95					
	Europe	5.53	0.47	1.64×10^3	1.48×10^6	16061	486.5
	North America				3.9×10^5	8242.3	
Cattle	Australia/ Asia	0.2	2.72	1.80×10^3	1.42×10^3	1195	
	Europe	1.46	0.07		5.5×10^5	653.9	29.1
	North America	24.75	2.05	8.0×10^1	6×10^6	7189	16.8
Sheep	Australia/ Asia	0.74	0.48	3.43×10^3	2.84×10^3		
	Europe	3.93				836	
	North America						
Horses	Australia/ Asia	2.56	0.62	1.49×10^3	8.64×10^2	66	
	Europe						
	North America						
Deer	Australia/ Asia	2.27	1.64	9.05×10^2	2.53×10^3		
	Europe						
	North America						

5.1.2 Respiratory health and exposure

Farmers involved in pig, poultry or cattle farming have a higher prevalence of a range of work related and chronic respiratory symptoms compared with non farmers. Symptoms may include non specific respiratory symptoms or specific syndromes such as ODTS. These findings are consistent across all studies. The findings are not explained by farmers' smoking habits, although farmers who smoke are more likely to have symptoms. Further studies are required to explore the independent effects on symptoms of smoking, gender and farm characteristics. The relatively high prevalence of asthma in Australian pig and poultry farmers compared with overseas farmers requires further investigation.

Longitudinal controlled studies of pig and cattle farmers provide evidence that continued work exposure is associated with symptoms and lung function decline. An important indicator of long term decline in lung function is cross-shift decline in the same lung function measurement. Work-related symptoms and cross-shift declines in FEV_1 and FVC may be useful in identifying farmers at risk of long term lung function impairment.

There is some evidence that symptoms are associated with exposure to dust and endotoxins but this is not consistent for all studies. This may have been due to methodological difficulties in measurement of dust and endotoxins and the duration of measurements rather than a true lack of an association with respiratory symptoms Importantly, endotoxin levels, which relate to gram negative bacteria, have been found to be significant and negative predictors of lung function and lung function decline in cohort studies of pig farmers. This may also be true for poultry farmers since a negative association was found between endotoxin levels and lung function measurements in cross-sectional studies. Longitudinal studies of poultry farming are required to confirm this association. Static or personal exposures to dusts or bioaerosols were not measured in any of the longitudinal studies of cattle farmers. However, these studies are the least relevant to the Australian farmers because of differences in climate and farming conditions.

Farmers face a number of hazards as a result of their occupation including accidents, respiratory and communicable diseases. In the case of accidents and communicable diseases, the association with farming activities is easier to monitor and identify than is the case with respiratory disease. Surveillance systems and responses to investigate outbreaks already exist in the general health system to which these events can be reported. For example, in NSW a provisional diagnosis of psittacosis is notifiable under the Public Health Act of 1991. An outbreak of *chlamydia psittici* infection can be quickly identified and managed. Surveillance based on reporting from respiratory and occupational health physicians has recently been introduced in Victoria and Tasmania (SABRE[1]). Although a validation study for a diagnosis of occupational asthma in SABRE was disappointing (Elder et al 2004), such a system will, in the long term, contribute to a better understanding of respiratory illness in farmer in the identification of syndromes, patterns of occurrence, and incidence as opposed to prevalence.

The studies reviewed in Chapter 4 were limited to those published in the English language and therefore may not have been as comprehensive as ideally required for a literature review. Although farming conditions may not be similar to those in Australia, the overseas studies are most likely to be of farmers with similar general health and lifestyles as Australian farmers. Overall, there is a need for further study of Australian farmers and the associations between symptoms, lung function and dust and bioaerosol exposure. Equally important, is the need for a better understanding of respiratory illness in farmers. The non specific respiratory syndromes may represent work related syndromes, which are not yet identified or defined.

[1] Surveillance of Australian workplace Based Respiratory Events

5.2 Gaps in Knowledge

It is clear from this review that we are not able to adequately inform farmers about the potential risks from their work practices. There are a number of areas that require further exploration and evaluation. These are in the areas or exposures, exposure measurements and respiratory health impacts. Particularly for Australia there are major gaps in our knowledge since most of the studies are from overseas.

5.2.1 Exposure Data in Australia

Generally there is insufficient human exposure data in relation to working with animals in agriculture in Australia. At best there has been one exposure study undertaken in workers in pig confinement houses. Several small studies have reported on dusts and bioaerosols exposures of workers who work with pigs, poultry, cattle/cows, horses and deer.

Currently there is one larger exposure study being undertaken in assessing exposure of sheep shearers to dusts and bioaerosols. This is due for completion at the end of 2005.

The other study about to commence is in relation to exposure of poultry workers and this is part of a larger study that is being undertaken looking at the poultry industry and environmental issues, which is due for completion in 2008.

5.2.2 Health Studies in Australia

Apart from the single study of pig farmers and two studies of poultry farmers, all papers examined were from overseas. These studies were all cross-sectional and uncontrolled. None compared symptoms with concurrent static or personal exposure levels. The relatively high rates of asthma reported in these studies suggest that there are differences in the health experiences of Australian farmers. The SABRE study has the potential to help us to better define and understand the respiratory illness and syndromes for which Australian farmers are at risk. Clearly, given the differences in farming practices in Australia we cannot rely sole on the findings of overseas studies. Further epidemiological studies are required in Australia for different animal handling situations and where exposures are measured in addition to respiratory symptoms. The feasibility of controlled and longitudinal studies should be considered.

5.3 Recommendations for further Studies

It is recommended that studies be undertaken in each of the major Australian animal production industries including pigs, poultry, dairy, horses and sheep, and in a range of conditions, such as climate and seasons. The objectives of these studies would be to:

- measure worker exposure to a range of contaminants
- measure changes in respiratory function before and after exposure
- record respiratory symptoms for at least a week after exposure
- measure both exposure and respiratory function and symptoms over time
- measure long term changes in respiratory function and symptoms
- identify the species of bacteria and fungi to which workers are exposed in the different animal industries, define their toxicity, and if appropriate develop appropriate approaches to occupational hygiene

It is important that any worker exposure studies undertaken be closely linked to a health outcomes study and similarly any health outcome study be closely linked to an worker exposure measurement study.

Chapter 6: Research Currently Being Undertaken in Australia

6.1 Exposure Related Studies

The studies that are either currently being undertaken or proposed to be undertaken which may be collecting exposure related data are:

For pigs:

- Intensive livestock environmental management air quality research: Queensland Department of Primary Industries and Fisheries (http://www.dpi.qld.gov.au/environment/1450.html accessed 29/3/05)
- Determination of dust composition from a beef cattle feedlot on the Darling Downs: Queensland Department of Primary Industries and Fisheries (http://www.dpi.qld.gov.au/environment/13805.html accessed 29/3/05)
- Development of odour performance criteria for the feedlot industry: provision of odour sampling and olfactometry services: Queensland Department of Primary Industries and Fisheries (http://www.dpi.qld.gov.au/environment/14036.html accessed 29/3/05)
- Statistical Modelling of Airborne bacteria and Endotoxins Concentrations in Australian Piggery Buildings: SARDI (personal email with Thomas Banhazi, 2005)

For poultry:

- Australian Poultry CRC SUB-PROGRAM 3B: The Impact of Poultry Production on the Environment. The objective of the project is to quantify odours and dust emissions from broiler and layer sheds in Queensland and Victoria. It aims to:

  - develop an emissions model for odour and dust emissions from broiler sheds
  - develop an odour and dust emission database
  - develop cost effective, novel instrumentation and data management techniques to measure dust, odour and other production factors on commercial poultry farms
  - quantify and evaluate specific poultry shed odourants

  The project is being undertaken by a group of researchers from:

  - Queensland Department of Primary Industry
  - Queensland University of Technology
  - Victorian Department of Primary Industry
  - University of New South Wales

For cattle:
None reported

For sheep:
Currently a PhD project assessing workers inhalation exposure while working with sheep and wool is being completed at University of Western Sydney

For horses:
None reported

6.2 Health Related Studies

The studies currently being undertaken looking at the impact of the working environment on the health of workers that may relate to agricultural industries are:

- Australian Pork Ltd follow-up study on the respiratory health of a small group of pig farmers in Victoria
- SABRE: respiratory surveillance being undertaken by Monash University on respiratory health and the impact of workplaces.

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Appendices

Appendix 1	Organisations Contacted for Research Reports and Appropriate Data
Appendix 2	Annotated Bibliography

Appendix 1:

Organisations Contacted for Research Reports and Appropriate Data

ACTU

Agriculture Western Australia Finish Institute of Occupational Health

And Health Association Presidents

Angus Society of Australia

Australian Beef Industry Foundation

Australian Centre for Agricultural Health and Safety

Australian Pork Limited

Australian Wool Innovation

Cargill Beef Australia

Certified Australian Angus Beef Pty Ltd

Congress of Occupational Safety

Cotton R&D Corporation

CSIRO Atmospheric Research

CSIRO Health Sciences and Nutrition's Clinical Research Program.

CSIRO Livestock Industries: Queensland Bioscience Precinct

CSIRO Health Flagship Program

Dairy R&D Corporation

Department of Epidemiology and Preventive Medicine,

Faculty of Medicine, Nursing and Health Sciences

Farmsafe Australia

FarmSafe NSW

Farmsafe Western WA

Grains R&D Corporation

Horticulture Australia

Institute Livestock Systems Alliance

Meat & Livestock Australia

National Farm Injury Data Centre

National Farmers Federation

NSW Department of Health

NT WorkSafe

Queensland Department of Primary Industries

Queensland University of Technology

RIRDC Committee Chairs and Research Project Managers

Roseworthy Campus, University of Adelaide

SARDI Livestock Roseworthy

South Australian Primary Industries Research and Development (SAPIRD)

South Australian Research and Development

Sugar R&D Corporation

University of Sydney

Australian Wool Innovation

WorkCover NSW

Appendix 2

RIRDC Summary of Annotated Bibliography on Exposures

Adhikari A, Sen MM, Gupta-Bhattacharya S & Chandra S 2004, 'Volumetric assessment of airborne fungi in two sections of a rural indoor dairy cattle shed', *Environment International*, vol. 29, pp. 1071-1078.

This paper investigates the fungal aerosol exposure levels in an Indian dairy cattle shed over a 2 year period. 31 spore types and 35 types of viable colony forming units were identified. The average concentration range for total fungal spores was 233-2985 per /m^3, and the concentration of viable fungi was between 165-2225 CFU /m^3. The most prevalent fungi type at a site varied depending on the type of sampler used (Burkard or Andersen).

This article does a volumetric assessment of culturable and non -culturable airborne fungal spores. The study was performed in an animal shed in India that housed both buffalo and cows. Both sections of the shed differed widely in their environmental aspects (ventilation, drainage, sanitary and ventilation systems). The buffalo section had wet floor, inadequate sanitary conditions while the cows had better sanitary & ventilation conditions. Samples were collected over a 2 yr. period using a Burkard Personal Slide sampler (to measure total airborne fungi) and an Anderson Two stage Viable (to measure airborne culturable fungi). The Burkard sampler detected higher numbers of *Aspergillus, Cladosporium* and *Alternaria* sp. fungi. The Anderson sampler detected a prevalence *of Aspergillus niger*, A. *flavus* and *Cladosporium cladosporioides* fungi. Total number of spores detected with the Burkard sampler was 233- 2985 spores/m^3, while viable fungal colony forming units (CFU) detected with the Anderson sampler were 165- 2225 CFU/m^3. Temperature/Relative Humidity was also measured and the local rainfall obtained. Both sections of the animal shed had 50% of the total fungal spores belonged to the fungal genera of *Aspergillus*, *Penicillium*, *Cladosporium* and *Nigrospora* spp. They suggest that this may be useful for doing skin prick testing of dairy farmers to test for mould allergy against these fungi.

The authors conclude that this study is useful in dealing with occupational problems such as respiratory allergy and pulmonary impairment in workers in dairy and cow sheds. They state there have been few reports on fungal numbers in sheds in the US, organic dusts and fungi in Canadian dairy barns and airborne fungi in Danish calf houses. They state that few studies have tested viable and non- viable fungi over such a long time period as their study. The authors note that their study did not measure fungal numbers in the outside ambient air that may possibly influence numbers in indoor environments. The authors suggest that to improve the environment, chlorine cleaning should be done, relative humidity is reduced by improving ventilation and using dried straw feed fresh uncontaminated feed.

Agranovski V, Ristovski Z, Blackall P & Morawska, L 2000, 'Real-time detection of Bioaerosols at a Piggery', *Journal of Aerosol Science*, vol. 3, no.1, pp. 5739-5740.

An Australian conference paper, this report uses an Ultraviolet Aerodynamic Particle Sizer (UV-APS) Spectrometer to measure size distribution and concentration of both biological and total particles inside several outdoor swine houses. This report also demonstrated the capability of the UV-APS to detect bioaerosols.

Results where high levels of biological and dust particles, up to 10^6 bacteria per m^3. A dramatic decrease in total bacteria concentrations occurred from inside the facility to immediately outside. A distance of 1m dropped the bioaerosol count 2 orders of magnitude.

Attwood P, 1985, '*Quantification of Airborne Organic Dust and its Biologically Active Constituents in the Working Environment'*, Wageningen, Agricultural University, The Netherlands.

This is a thesis from the Netherlands, with some Australia funding. An Andersen impaction sampler was used for bioaerosol collection. Swine confinement building was the area that was studied. Actual numbers of concentrations found are not available at this time. However, it is suggested that the current MAC is too high for dust and should be reduced to 3.9 mg/m^3.

Attwood P, Brouwer R, Ruigewaard P, Versloot P, De Wit R, Heederik D & Boleif J 1987, 'A study of the relationship between airborne contaminants and environmental factors in Dutch swine confinement buildings', *Annals Industrial Hygiene Association*, vol. 48, no.8, pp. 745-751.

A report studying the concentrations of airborne total and D50< 8.5 μm dust fractions, total and gram-negative bacteria, bacterial endotoxin and NH^3. These results are statistically correlated to environmental factors such as feeding practices, number of animals and ventilation.

Methods included dust sampling, microbiological sampling, endotoxin analysis, gas sampling and environmental factors. Dust sampling was undertaken at 23.5 L/min onto glass fibre filters, which were later analysed for endotoxins using the LAL method. Microbial sampling at 1 L/min using midget impingers.

Airborne dust, endotoxins, bacteria and NH^3 are commonly in high concentrations in swine confinements.

	Total Bacteria/m^3 ($x10^6$)	**Gram-negative Bacteria/m^3 ($x10^6$)**
Farrow and nursery (geometric mean)	0.90	0.11
Fattening buildings (GM)	0.86	0.07

While ventilation is an important criteria for airborne contaminants, there are a number of farming practices that significantly contribute to the levels of airborne contaminants. The instances that involved humans indicate that there are important criteria that an industrial hygienist should measure when faced with similar problems.

Attwood P, Verslot P, Hedderik D, De Wit R & Boleij J 1986, 'Assessment of dust and endotoxin levels in the working environment of Dutch pig farmers: A preliminary study'. *Annals of Occupational Hygiene,* vol. 30, no.2, pp. 201-208.

This report looks at levels of airborne dust and endotoxins present in pig confinements. Dust separated into 3 size fractions, using cyclone pre-separators and a modified cassette holder for total dust.

Total dust sampled were taken using glass micro-fibre filters GF/A. Endotoxin determination was through filters being collected from cyclones, placed in test tubes, extracted with water and refrigerated overnight. Then rocked for 60 min and centrifuged at 1000g for 10 min.

There is a large day to day variation in total dust determined in a single confinement building and that the smallest fraction =< 3.5μm varies from building to building but not in a single building. For endotoxins, it was found that there is a significant enrichment of endotoxin in the size fraction 3.5-8.5μm.

Endotoxin levels in airborne dust fractions in swine confinements as ng/m^3:

Size fraction	Geometric mean
D50 <= 3.5um	4.4
D <= 8.5um	24.8
100% < 51.2um	62.7

Endotoxin levels per gram of airborne dust for each of the size fractions in four swine confinements.

Size fraction	GM
D50 <= 3.5um	39.3
D <= 8.5um	64.3
100% < 51.2um	45.9

Assessment of potential risk to the farmer from endotoxin must be assessed using a biologically relevant criterion based on particle penetration in the thoracic region of the exposed farmers lung.

Banhazi T, 2002, *Reduction of dust emissions from broiler and caged layer sheds*, Progress Report, SAR-33J, RIRDC, (Available on line at: http://www.rirdc.gov.au/comp03/cm1.html#_Toc48366032; last accessed on 17/3/05)

This is the progress report of the project that was assessing the potential levels of airborne bacteria, inhalable and respirable dust in 26 poultry facilities in South Australia. The final report that would contain the dust levels has not yet been published and results form the study cannot be reviewed.

Banhazi T & Cargill C 1997, 'The Distribution of airborne particles in Pig Sheds', Manipulating Pig Production VI, p 295, *6th Biennial Conference of the Australasian Pig Science Association*, Canberra, ACT.

This is a summary of a conference presentation on air monitoring that had been undertaken in 4 points within pig sheds. This paper compares the results achieved in the 4 monitoring locations and advocated that for assessing air quality in pig shed at only one measurement point is needed.

The total dust samples were collected at a flow rate of 2 L/min using an IOM sampler and at 1.9 L/min using a cyclone for respirable dust samples.

The results reported are:

	Total dust mg /m^3	**Respirable dust** mg /m^3
Centre of Room B air inlet	3.00 ± 0.62	0.28 ± 0.03
End of Room near air exhaust	3.38 ± 0.73	0.24 ± 0.07
Over a solid Floor	1.93 ± 0.51	0.31 ± 0.05
Over a Slatted Floor	1.35 ± 0.83	0.29 ± 0.06

Banhazi T & Cargill C 1997, 'The Effect of General Hygiene on Air Quality in Mechanically – ventilated Weaner Rooms', Manipulating Pig Production vol. 1, p 296, *6th Biennial Conference of the Australasian Pig Science Association*, Canberra, ACT.

This paper compared air monitoring results between clean and dirty weaner rooms. The total dust samples were collected at a flow rate of 2 L/min using an IOM sampler and at 1.9 L/min using a cyclone for respirable dust samples. The Bacteria samples were collected using an Anderson Impact with horse blood agar plates at a flow rate of 2 L/min. The results reported are:

	Clean Room	**Dirty Room**
Total dust mg/m^3	4.289	4.188
Respirable dust mg/m^3	0.398	0.706
Vaiable bacteria CFU/m^3	87000	194000

Banhazi T & Cargill C 1999, *Improving shed environment in grower and finisher facilities*, Australian Association of Pig Veterinarians, Hobart.

The aim of this paper is to determine airborne concentration in different types of pig shed and to look at association between air concentrations and difference types of pig sheds.

The paper documents the methods used in collecting the air samples are follows:

- Bacteria samples were collected using a Anderson Impact with horse blood agar plates at a flow rate of 2 L/min;
- Total dust samples were collected at a flow rate of 2 L/min using a IOM sampler; and
- Respirable dust samples using a cyclone at a flow rate of 1.9 L/min

The results reported are:

	Respirable dust (mg /m^3)	**Total dust** (mg /m^3)	**Bacteria Levels** (CFU /m^3)
Grower Sheds	0.222	1.884	112,014
Finisher Sheds	0.245	1.635	94,753
Straw based shelters	0.625	2.442	
Average	0.266	1.846	

The outcome of this paper is that shed management is the main factor in dust and bacteria concentrations. Suggestions have been made on how to reduce airborne contaminants.

Banhazi T & Cargill C 1999, *Survey of Pig Sheds in Australia – Preliminary Results*, Dust Control in Animal Production Facilities, Aarhus, Denmark, pp. 76-82.

This paper reports the preliminary findings on a study being undertaken in Australia. In addition to air sampling for dust concentrations, using a IOM sampler at a flow rate 2 L/min for total dusts and a cyclone at a flow rate of 1.9L/min for respirable dust samples, a questionnaire was completed looking at the management practices of the farm in respect to housing features cleaning, pig maintenance, feeding and manure handling.

The following dust concentrations were reported:

	Respirable dust (mg /m^3)	**Total dust** (mg /m^3)
Grower Sheds	0.227	1.884
Finisher Sheds	0.242	1.635
Straw based shelters	0.675	2.442
Dry sow accommodation	0.196	0.815
Farrowing accommodation	0.178	1.162
Weaner rooms	0.298	2.890
Average	0.266	1.846

Banhazi T, Hillyard K, & Kloppers M, 2002, 'The Short Term Suppression of Dust In Piggery Buildings', *Animal Production Australia*, vol. 24, p. 374.

This paper investigates the potential to reduce dust exposure by applying oil to the floor of an intensive pig farming pen. The methods of monitoring have previously been published in Banhazi and Cargill (1997). The results measures are:

Treatment	**Respirable dust** (mg/m^3)	**Inhalable dust** (mg/m^3)	**Viable bacteria** (CFU/ m^3)
Control (farrowing)	0.188a	2.044a	60,288a
Treatment (farrowing)	0.109b	0.721b	14,828b
Control (weaner)	0.580a	2.333a	36,341a
Treatment (weaner)	0.259a	0.5171b	13,736b

Table 1: Concentrations of respirable and total airborne dust and viable bacteria in the control and treatment rooms.

Values in the same column with different superscripts differ significantly ($P<0.02$)

Banhazi T, Hillyard K, Murphy T, & Tivey D 2002, 'Ozone treatment of air in pig sheds'. *Ageng 2002 Conference*, Charles Stuart University, Wagga Wagga, Australia.

This Australian study looked at the possibility and benefits of using low concentrations of ozone to reduce pollution emission in piggeries. It was found that ozone could reduce airborne bacteria and concentrators of inhalable particles, but did not decrease the concentration of respirable particles. Without ozone the bacteria concentration was approx. 50000 CFU/m^3, and with ozone treatment 25000 CFU/m^3. Without treatment inhalable particles were 1.6 mg/m^3 and with treatment 0.8 mg/m^3. Respirable particles were approx 0.24 mg/m^3 with or without treatment. This article provides concentrations for swine buildings in Australia.

Banhazi T, Murphy, T & Cargill C 2002, 'Evaluating Oil Inclusion Rates For Bedding Materials', *Animal Production Australia*, vol. 24, p. 378.

This paper compared the effect of both sawdust and rice hulls as air quality. The evaluation undertaken in an experimental set-up to assess which type of bedding may produce the most dust. The effect of the spraying of canola oil on the dust suppression was also assessed. The results achieved are as follows:

Inclusion rate (%)	**Sawdust** resp	**Sawdust** inh	**Rice hull** resp	**Rice hull** inh
0 0	0.150a	4.275a	31.568a	224.651a
3 0	0.075b	0.124b	0.383b	0.611b
6 0	0.060c	0.085c	0.150c	0.246c
9 0	0.100a	0.046d	0.137c	0.228d

Table 2: Concentrations of respirable (resp.) and inhalable (inh.) airborne particles in mg/m^3 at different oil inclusion rate (%).

Ab values in the same column with different superscripts differ significantly (P<0.05).
The study showed that inclusion of oil did have an impact on the dust levels especially in relation to rice hulls.

Banhazi T, Murphy T, Kloppers M & Cargill C, 2002, 'The Effects Of Oil Spraying On Air Quality In Piggery Buildings – Preliminary Results', *Animal Production Australia*, vol. 24, p. 377.

This paper reports on the monitoring of air quality in pig housing for 32 days and the effects of spraying the flooring with canola oil and water.

Treatment	Respirable dust (mg/m^3)	Inhalable dust (mg/m^3)	Viable bacteria (CFU/ m3)
Control	0.208a	4.023a	
Treatment	0.150b	2.278b	
Reduction %	28	44	

Table 3: Concentrations of respirable and total airborne particles, viable bacteria and carbon dioxide for the control and treatment periods.

Ab Values in the same column with different superscripts differ significantly (P<0.05). Unfortunately no viable bacteria levels were reported in the abstract

Banhazi T, Seedor J, Rutley DL, & Berckmans D, 2004, 'Instrumentation Kit for Measuring Airborne Pollutants in Livestock Buildings', *International Society for Animal Hygiene Conference Proceedings*, Saint-Malo, France, pp. 215-217.

This paper describes the methods that were used to collect the air sampling data presented in a number of other papers. The methods include:
Airborne particle: Respirable dust using a cyclone at a flow rate of 1.9 L/min. This met previous Australian Standards (which was in place during the data collection period of this study) but the flow rate was recommended to be increased recently to 2.3 L/min. The inhalable samples were collected using a 7-hole sampler at 2 L/min.

Endotoxin estimation was made of the air samples collected using a LAL test. Insufficient information was given about sample handling and all equipment needing to be made pyrogen-free. Also there were no comments on storage and transport of samples.

Bacteria samples were collected using a 6-stage Anderson Cascade Impactor (ACI) on horse-blood-Agar plates at a flow rate of 1.9 L/min. This is in conflict with the manufacturer's instruction on the cascade impactor and the NIOSH Method 0800 for Bioaerosol sampling that samples should be collected at 28.3 L/min. Therefore the data collected under this regime could be used in comparative studies, but the concentrations reported might not be reliable. It has to be mentioned that the reduced flow rate has been used in previous studies, which was published in reputable journals (Seedorf et al., 1998; Wathes et al., 1998).

Banhazi TM, Seedorf J, Rutley DL & Pitchford WS 2005, 'Statistical modelling of airborne bacteria and endotoxins concentrations in Australian piggery buildings.' In RR Stowell (Ed) *'International Livestock Environment Symposium'*. Bejing, China. In press (ASAE).

This paper looked at a number of building parameters that may affect airborne dust concentrations. The methods to collect the airborne particles are described in a paper by Banhazi, Seedorf, Rutley and Breckmans (2004). The main difference in inhalable dust concentration was between summer (1.68 mg/m^3) and winter (2.95 mg/m^3). The other major factor was number of sows, building type, size, management and airflow. Whereas seasons did not seem to have the same effect on respirable dust concentration but building type, number of sows, humidity, airflow temperature and management may have an effect.

Banhazi T, Seedorf J, Rutley DL & Pitchford WS 2004, 'Factors Affecting the Concentrations of Airborne Bacteria and Endotoxins in Australian Piggery Buildings', *International Society for Animal Hygiene Conference Proceedings*, Saint-Malo, France, pp. 197-198.

This paper looked at a number of building parameters that may affect airborne bacteria and endotoxins concentrations. The methods to collect the samples are described in a paper by Banhazi, Seedorf, Rutley and Breckmans (2004). The 2 main parameters identified are for airborne bacteria are building type and level of hygiene. Building type and humidity were the significant parameters for endotoxin concentrations. The highest concentration for air borne bacteria and respirable endotoxin were found in deep-bedded buildings. The levels measures are 2.17 x 10^5 CFU /m^3 and 76.3 EU /m^3 respectively.

Banhazi TM, Seedorf J, Rutley DL & Pitchford, WS 2005, 'Statistical modelling of airborne bacteria and endotoxins concentrations in Australian piggery buildings.' In R R Stowell (Ed), *'International Livestock Environment Symposium'*. Beijing, China. In press. (ASAE)

160 piggeries in 4 states of Australia were tested for total bacterial and endotoxin levels. This was to identify key factors affecting these concentrations and to help reduce internal concentrations and potential emissions from the piggeries. Results showed mean airborne bacterial levels of 1.17 x 10^5 CFU/m^3 and mean internal respirable endotoxin concentrations of 33.1 EU/m^3.

A general linear model (GLM) statistical procedure was used to predict housing effects and management factors relating to airborne pollutant levels. Humidity affected the endotoxin levels, while bacterial levels were related to building classification and pen hygiene.

Factors affecting airborne bacteria and endotoxin levels are stated and many researchers have found a circadian pattern - i.e. concentrations are higher during day than night.

Current recommendations for airborne bacteria in livestock sheds (in Australia) is 1 x 10^5 CFU/ml. For respirable endotoxins 50 EU/m^3 is acceptable. This study showed piggeries in Australia had levels near or below these recommendations. Piggeries here have lower or comparable respiratory endotoxin levels to European published results. This study showed 18% of all raw endotoxin and 41% of raw airborne bacteria were above recommended levels. When these levels were calculated according to the conditions/other effects, high levels mainly occurred in deep-bedded shelters and in sub optimal hygiene buildings. Our climate (high temps and low humidity) explains why relatively low levels of bacteria and endotoxins were found.

Banhazi, T, Wegiel, J & Cargill, C 2002, 'Ozone Treatment of Air in Weaner Accommodation', *Animal Production Australia*, vol. 24, p. 379.

This paper looked at the impact of ozone in a pig housing in relation to potential inhalation of contaminates. The concentration of ozone is 0.05 ppm which is the exposure standard for people undertaking hard work. For light work the exposure standard is 0.1 ppm. The results reported in the paper are:

Treatment	**Respirable dust** (mg/m^3)	**Inhalable dust** (mg/m^3)	**Viable bacteria** (CFU/m^3)	**Ammonia** (ppm)	**Carbon dioxide** (ppm)
Control	0.272a	1.69a	98,000a	3.4a	960a
Ozone	0.262a	1.70a	73,000b	3.5a	974a
Reduction %	3.7	-0.59	25	-2.94	-1.46

Table 4: Concentrations of respirable and total particles, viable bacteria, ammonia and carbon dioxide for the control and experimental periods.

Ab Values in the same column with different superscripts differ significantly (P<0.05).

The ozone treatment did not make a noticeable improvement in the air quality parameters measured.

Banhazi T, Woodward R, Cargill C & Hynd P 2002, 'Comparison Of Air Quality In Horse Stables', *Animal Production Australia*, vol. 24, p. 376.

This paper studied methods of improving air quality in horse stables by trailing 3 different methods.

Treatment	**Temperature** (^{o} C)	**Inhalable dust** (mg/m^3)	**Carbon dioxide** (ppm)
Control (saw dust)	22.2a	0.397a	499a
Straw bedding	22.5a	0.606b	488a
Horse-nappy	22.2a	0.287c	508a
Oil-impregnated saw dust	22.3a	0.298c	504a

Table 5: Temperature and the concentrations of inhalable airborne particles and carbon dioxide for the control and treatment boxes

ab Values in the same column with different superscripts differ significantly (P<0.05).

The paper shows that by using alternative control methods, inhalable dust levels can be reduced.

Banhazi T, Woodward R & Hynd P 2002, ‘Improving Air Quality In Bedded Systems’, *Animal Production Australia*, vol. 24, pp. 375.

This paper reported the effects of reducing dust exposure in horse stables by the use of canola oil. The results reported are:

Treatment	**Respirable dust** (mg/m^3)	**Inhalable dust** (mg/m^3)	**Carbon dioxide** (ppm)
Control	0.35a	1.13a	553a
Treatment	0.19b	0.47b	551a

Table 6: Concentrations of respirable and inhalable airborne particles for the control and treatment boxes

ab Values in the same column with different superscripts differ significantly ($P<0.05$).

Baruah HK 1961, ‘The Air Spora of a Cowshed.’ *Journal General Microbiology*, vol. 25, pp. 483-491.

An Indian study that looked at the concentration of fungal spores found in a cowshed. The range found was between 95,000 and 16,000, 000 spores/m^3. The results were collected using a Hirst Automatic Volumetric Spore Trap.

Bascom R 1996, ‘Environmental factors and respiratory hypersensitivity: the Americas’, *Toxicology Letters*, vol. 85, pp. 115-130.

This article focuses on environmental (e.g. humidity, ozone, bioaerosols) and respiratory hypersensitisation (asthma) in the Americas. It concludes that environmental factors influence allergenic responses and the severity of respiratory diseases. These conclusions have been made by a meta-analysis of a large longitudinal study of people in contact with ambient particles (PM10) < 10 um and associated respiratory symptoms. The author writes into detail about:

- allergic sensitisation/respiratory disease- allergy exposure, environmental determinants, skin tests
- non allergenic environmental factors -exposure patterns, ambient air quality standards, ozone, nitrogen, acid sulphates
- indoor non allergenic pollutant exposure- chemical- human response to ambient irritants, tobacco smoke, formaldehyde, VOCs

Black, JL 2003, *‘Effect of air quality on pig performance and health of piggery workers’*, A review commissioned by Australian Pork Ltd, Canberra.

This report is a review of many sources of information including Australian Pork Ltd Research Reports. The majority of the review relates to pig health. The exposure standards relate mainly to pig health but the Human exposure standards are specified in OSHA (USA) legislation which is generally considered outdate. Australian data could have been compared for human standards.

Brown AM, 1990, 'The respiratory health of Victorian broiler growers', *The Medical Journal of Australia*, vol. 152, pp.521-524.

In this descriptive study, Brown measured the self-reported prevalence of respiratory symptoms in poultry farmers in Victoria. The interview survey was of members of the Chicken Meat Group of the Victorian Farmers Federation, which represented at that time 90% of poultry farmers in Victoria. Three hundred and seventy-two farmers from 224 farms were interviewed. The average age was 44.3 years and 74.7 of subjects were male. Seventy-seven percent reported respiratory symptoms. Most frequently, farmers reported cough and/or sputum (34.9%) and wheezing sometimes (38.4). FEV1 and FVC measurements were adjusted for body temperature and pressure saturation. Overall, both measures were slightly higher than the predicted levels. However stratified analysis according to symptoms found a reduction in those with chronic bronchitis (91.8% for FEV1, 97.8% for FVC) and those who reported wheezing for most days and nights (85.55% for FEV1, 94.79% for FVC). All these measures were statistically significant when compared with those for farmers who reported no symptoms. For chronic bronchitis or those who reported wheezing sometimes, there was a statistically significant ($p<0.05$) association with length of exposure. However, this was not consistent; for example, the association was not significant for those with persistent wheeze.

Stratified analysis of odds ratios for potential confounding factors found increased and statistically significant odds ratios for smokers in the four categories of symptoms: cough and/or sputum production (2.8), chronic bronchitis (5.5), wheeze sometimes (2.9) and wheeze most days and nights (5.4). Except for the wheeze most days and nights, the odds were also statistically significantly higher in farmers with a family history of atopy than in those without. The study did not demonstrate a trend between exposure and symptoms, although those with the equivalent of at least one and a half years of exposure of 12 hours had significantly high odds compared with those with the equivalent of half a year of exposure in the categories chronic bronchitis and wheeze sometimes. The trend was not consistent in the remaining categories.

Brown AM, 1990, *Respiratory Health of Chicken Farming*, Report to the Chicken Meat Research Council, University of Newcastle.

The objective of this report was to identify the prevalence of respiratory disease in chicken farmers in the Hunter region, NSW and to determine potential exposures.

The health related data has been reported in Brown, A M 1990, 'The respiratory health of Victorian broiler growers', *The Medical Journal of Australia*, vol. 152, pp.521-524.

The dust exposures were assessed using a 7-hole sampler for inspirable dust and a cyclone for respirable dust levels. Both static and personal samples were collected. Seven farms were sampled and 2 farms were sampled weekly during the sampling period. The results were not presented against personal and static. Only respirable levels from 1.92 mg/m^3 (0.1 to 13.6 mg/m^3) and inspirable results of 14.37 mg/m^3 (4 to 20 mg/m^3) were reported.
The microbiological samples were collected using a midget impinger. The results achieved are:

- Bacteria gram +ve: 467 to 3280 x 10^4 CFU mg/m^3
- Bacteria gram –ve: 0 to 2090 x 10^4 CFU mg/m^3
- Aspergillus: 0 to 610 x 10^4 CFU mg/m^3
- Other Fungi: 0 to 590 x 10^4 CFU mg/m^3

As with many papers of this time period neither the sampling flow rates nor the time periods monitored have been reported.

Brown AM, 1992, *Some Occupational Health Aspects of Work in Broiler Sheds*, Australian Poultry Science Symposium, vol. 4.

This paper reported on the outcomes of the research report Brown, AM, 1990, Respiratory Health of Chicken Farming, Report to the Chicken Meat Research Council, University of Newcastle.

Brown, D & Donaldson, K 1996, 'Wool and grain dusts stimulate TNF secretion by alveolar macrophages in vitro', *Occupational and Environmental Medicine*, vol. 53, pp. 387-393.

This study reports that exposure of rat alveolar macrophages to endotoxin and other unidentified leachable substances from grain and wool (lesser extent) dusts triggered the production of tumour necrosis factor (TNF).

Buchan RM, Rajal P, Sandfort D, & Keefe T 2002, 'Evaluation of Airborne Dust and Endotoxin in Corn Storage and Processing Facilities in Colorado.' *International Journal of Occupational Medicine and Environmental Health*, vol. 15, no. 1, pp. 57-64.

A different study found the concentration range for endotoxins between 499 EU/m^3 and 54 653 EU/m^3 as measured by total dust sampling.

Butera M, Smith JH, Morrison WD, Hacker RR, Kains FA & Ogilvie JR 1991, 'Concentration of respirable dust and bioaerosols and identification of certain microbial types in a hog-growing facility', *Canadian Journal of Animal Science*, vol. 71, pp. 271-277.

This study was aimed at investigating the impact of various environmental variables such as ventilation rate, temperature and relative humidity on the levels of airborne bioaerosols in a pig building.

The dust sampling was undertaken using 0.8μm, 37 mm Nuclepore filters sampled at a flow rate of 2 L/min. The microbial samples were collected using a 6 stage Andersen Impactor at a flow rate of 28.3 L/min for:

- Total bioaerosols the samples were collected for 10 seconds on Trypticase Soy Agar.
- Fungal bioaerosols the samples were collected for 20 seconds on Potato Dextrose Agar

The results of the study showed that the Total bacteria varied from 1.48×10^5 to 9.20×10^5 CFU/m^3 whereas fungi levels varied from 0.14×10^3 to 6.44×10^3 CFU/m^3. The dust concentrations were not reported.

Cargill C, 1999, *Reducing Dust in Horse Stables and Transporters*, A report for the Rural Industries Research and Development Corporation, RIRDC Project No SAR-14A.

This report highlights the issues of dusts and bioaerosols in the horse industry. It is mainly aimed at the impact of dusts and bioaerosols on horses. The levels reported in the report have been taken form the literature and relate to activities. Insufficient information is given on how the data was collected.

The reported values are:

Activity	Total Dust Concentrations mg/m^3	Respirable Dust Concentrations mg/m^3
In stall	0.70 – 2.55	0.20 – 0.44
In horse's breathing zone	0.52 – 17.51	0.30 – 9.28
In barn	0.20 – 0.95	
In stall	0.55 – 3.63	
Conventional stable	2.19 – 5.48	0.44 – 2.20
'Low dust' stable	0.29 – 2.78	0.15 – 0.29
In pasture	0.08 – 0.17	0.08 – 0.17

Cargill CF & Banhazi T, 1996, The importance of limiting population size and density for providing optimal air quality in pig shed, *13th International Clean Air Conference*, CASANZ, Adelaide, Australia, pp. 375-379.

This is a conference paper that reported on air monitoring that was being undertaken in South Australia. The sampling method used was:

- Inspirable dust was collected on a filter in an IOM sample head using a flow rate of 2 L/min.
- Respirable dust was collected on a filter is a cyclone at a flow rate of 1.9 L/min.
- Total viable bacteria was collected on horse blood agar plates (bacteria) and Sabouraud agar (fungi) at a flow rate of 1.9 L/min using a Anderson Impactor

The mean values reported are:

- Inspirable dust: 1.68 ± 1.47 mmg/m^3
- Respirable dust: 0.18 ± 0.12 mg/m^3
- Air Borne bacteria: 1.43 x10^5 ± 0.65 x10^5 CFU /m^3
- Fungal particles: 1.36 x10^4 ± 1.32 x10^4 CFU /m^3

Cargill C, Banhazi T & Pisaniello D 2000, *'The effect of shed environment on occupational health in the pig industry'*, Adelaide, WorkCover Corporation.

This project was undertaken to ascertain what major OHS issues in the pig industry are. Data for this study was collected as area samples as follows:

- Inspirable dust was collected on a filter in an IOM sample head using a flow rate of 2 L/min.
- Respirable dust was collected on a filter is a cyclone at a flow rate of 1.9 L/min.
- Total viable bacteria were collected on horse blood agar plates at a flow rate of 1.9 L/min.
- Ammonia and CO_2 levels were also measured.

The study looked at a range of issues including type of sheds, levels of hygiene, numbers of pigs, ventilation and different types of management of sheds. The average dust concentration of the 159 sheds surveyed was 0.26 (±0.02) mg/m^3 for respirable dust and 1.74 (±0.13) mg mg/m^3 for inspirable dusts. The average results for the total viable bacteria were 117 x 10^3 CFU mg/m^3.

The air concentrations against type of sheds are as follows:

Type of Shed	Dust Levels mg/m^3			Total Viable Bacteria x 10^3 CFU/m^3	
	N	Respirable	Inspirable	N	Mean
Grower sheds	37	0.24 ± 0.03	1.68 ± 0.20	28	134 ± 17.01
Finisher Sheds	27	0.31 ± 0.05	1.67 ± 0.18	26	96 ± 11.37
Straw Based Shelters	11	0.64 ± 0.19	2.57 ± 0.62	10	327 ± 58.82
Dry Sow Accommodation	22	0.16 ± 0.02	0.80 ± 0.20	15	76 ± 12.39
Farrowing Accommodation	29	0.18 ± 0.02	1.23 ± 0.25	19	68 ± 7.34
Weaner Rooms	33	0.27 ± 0.04	2.66 ± 0.44	24	94 ± 13.68

The authors in this report that Donham's 1995 recommendations for air pollutants should be adopted. They are 0.23 mg/m^3 for respirable dust, 2.4 mg/m^3 for total dust, 10^5 CFU /m^3 for total viable bacteria and 0.15 ng /m^3 for endotoxins.
NOTE: To date none of these standards have been accepted even for consideration by any of the exposure standards bodies such as ACGIH, NIOSH, HSE or NOHSC.

Cargill C, Murphy T & Banhazi T, 2002, 'Hygiene And Air Quality In Intensive Housing Facilities In Australia', *Animal Production Australia*, vol. 24, pp. 387-393.

This paper looks at the major sources of poor air quality in animal housing facilities in Australia. They have reported that pollutants of concern are: ammonia, carbon dioxide, organic and inorganic bioaerosols.

The authors reported that that in pig sheds the highest exposures to respirable pollutants was to animals and people in finisher sheds (18%), farrowing houses (15%) and growing housing (14%) but they did not elaborate on what the pollutants were or how these figures were obtained. They did highlight the major sources of pollutants are: animal excretions, feed and bedding. In relation to airborne bacteria, gram positive was the most common.

They did report of some recommended exposures levels for viable airborne bacteria of 100,000 colony forming units (CFU's)/m^3 but did not report who have set this recommendation which is much higher that the European of 23 to 85 EU/m^3 standards for respirable endotoxin and total endotoxin is 600 EU/m^3 in pig sheds.

Carty CC, Gehring U, Cyrys J, Bischof W & Heinrich J 2003, 'Seasonal variability of endotoxin in ambient fine particulate matter', *Journal of Environmental Monitoring*, vol. 5, pp. 953-958.

This article describes the methods used to determine seasonal variation of outdoor endotoxin levels at 40 sites (158 samples) in Germany. They determined levels in fine particulate matter with a 50% cut off diameter value of 2.5 µm (PM2.5). An Anderson sampler with teflon membrane (2 µm pore size) and a Harvard impactor (collecting 50% aerodynamic cut off diameter of 2.5 µm (PM2.5). They used the Limulus Amebocyte Lysate (LAL) test. Their study showed higher temperatures yielded higher endotoxin levels- i.e. higher levels in spring/summer than autumn/winter months but this may be because increases in temperature increase bacterial growth and plants during the warmer months. In addition, it was found a decrease in RH caused an increase in endotoxin levels. They also state that other outdoor factors such as humidity, wind and rain may affect endotoxin levels.

The authors propose guidelines for endotoxin levels to give a no-effect level to airways inflammation inhalation exposure should not be greater than 10 ng/m^3.

Cathomas RL, Bruesch H, Febr R, Reinhart WH & Kuhn M 2002, ‘Organic dust exposure in dairy farmers in an alpine region’, *Swiss Medical Weekly*, vol. 132, pp. 174-178.

This study monitored the exposure of alpine region dairy farmers in Switzerland to organic dust. Six farms of varying size and infrastructure were monitored during late winter, summer and early winter in 2000. Static area sampling was conducted for 3-5 working days (total of 14-30 hours) using a cascade impactor (8 stage) that collected particles between 0.5 and 20 µm. The sampling flow rate was 22-23 L/min.

Building Number	**Season**	**Organic Dust Exposure** (µg/m^3)	
		PM$_{10}$	**PM $_{2.5}$**
1	Early winter	638	35
	Late winter	1535	110
	Summer	2803	192
2	Early winter	1295	90
	Late winter	2207	196
	Summer	4862	385
3	Early winter	1275	97
	Late winter	1460	88
	Summer	1511	76
4	Early winter	270	9
	Late winter	247	10
	Summer	-	-
5	Early winter	154	8
	Late winter	109	0
	Summer	76	0
6	Early winter	200	13
	Late winter	136	48
	Summer	329	0

PM$_{10}$ concentrations ranged from 109-2207 µg/m^3 for daily barn activities in winter, and 76-4862 µg/m^3 for hay storage in summer. PM$_{2.5}$ ranged from 8-90 µg/m^3 in early winter to 0-385 µg/m^3 in the summer. Season and farm infrastructure (farm size and ventilation systems etc) influenced exposures. The authors suggest that organic dust exposure in dairy farming over many years may be a major risk factor in the development of chronic obstructive pulmonary disease due to the moderate to high exposures measured in this study, in conjunction with epidemiological data already collected. The authors also call for determination of threshold values for indoor organic dust exposure.

Chang CW, Chung H, Huang CF & Su HJJ 2001a**,** 'Exposure of workers to airborne microorganisms in open-air swine houses', *Applied and Environmental Microbiology*, vol. 67, 155-161.

This investigated the levels of fungi and bacteria in 6 farms in Taiwan. The samples were collected simultaneously using a number of sampling techniques:

- Single stage Andersen impactor at 28.3 L/min
- Glass impinger, AGI30, at 12.5 L/min, and
- 0.4 nm Nuclepore filter in a 37 mm diameter 3 stage cassette at 2 L/min

An interesting result from this study is that although the samples were collected simultaneously there was large differences in the results obtained between the sampling methods. The number of cultural bacteria able to be measured was highest for the samples collected using the AGI 30. The factor was 12 times the number for the Nuclepore filter and 17.8 times the number on the Andersen impactor. The Andersen impactor as overloaded even with very short sampling times. Similar results occurred for Gram –ve bacteria but it was 3.4 times for Nuclepore filter and 7 times for Andersen impactor.

The results for the cultural fungi were not as pronounced, in that the Nuclepore filter measured the highest average concentrations and the AGI30 just behind. The Nuclepore filter was 2.1 times the results of the Andersen Impactor.

The average concentration for culturable bacteria in the swine houses was 3.3 x 10^5 CFU/m^3 for, ranging from 1.0 x 10^5 to 7.5 x 10^5 CFU/m^3 and for gram –ve bacteria the concentrations ranged from 42 to 452 CFU/m^3. The concentration of culturable fungi were much lower ranging form 2.2 x 10^3 to 3.6 x 10^3 CFU/m^3.

Chang CW, Chung H, Huang CF & Su HJ 2001b, 'Exposure assessment to airborne endotoxin, dust, ammonia, hydrogen sulphide and carbon dioxide in open style swine houses', *Annals of Occupational Hygiene*, vol. 45 no. 6, pp. 457-465.

This report looks at exposure levels of airborne hazardous substances in swine buildings that are not completely closed. 'Open-style' swine houses were studied.

Endotoxin, dust, ammonia, hydrogen sulphide and carbon dioxide were measured. Airborne dusts were quantified respectively by using Drager diffusion tubes and a filter-weighing method. Endotoxin was analysed by the Limulus amoebocyte lysate assay.

Average concentration of airborne total endotoxin among piggeries was between 36.8 and 298 EU/m^3, while that for respirable endotoxin was 14.1–129 EU/m^3.

Mean concentration of total dust was between 0.15 and 0.34 mg/m^3, with average level of respirable dust of 0.14 mg/m^3. The respective concentrations of NH^3, CO2 and H2S were less than 5 ppm, 600–895 ppm and less than 0.2 ppm.

The levels were much lower in open-style than past reported enclosed buildings.

Chinivasagam HN & Blackall PJ 2005, 'Investigation and application of methods for enumerating heterotrophs and Escherichia coli in the air within piggery sheds.' *Journal of Applied Microbiology,* vol.98, pp1137-45

This paper describes methods of identifying particular bacteria in air within a piggery. Two methods were used to collect samples, AGI-30 impinger at a flow rate of 12.5 L/min for 20 minutes and 6-stage Anderson Impactor at a flow rate of 28.3 L/min for 40 to 45 seconds. The average results reported in one comparison trial were for the AGI-30 ranged from 8.4x10^4 to 2.3x10^5 CFU/m^3 whereas the Anderson impactor count was 2.8x10^4 CFU/m^3. In another comparison trail the results ranged from 2 to 9 x10^5 CFU/m^3 for the AGI-30 and 1.8 to 4.1 x10^4 CFU/m^3 for the Anderson Impactor. This paper also compared different agars in comparison of air concentrations.

Choudat D, Goehen M, Korobaeff M, Boulet A, Dewitte JD & Martin MH 1994, 'Respiratory symptoms and bronchial reactivity among pig and dairy farmers', *Scandinavian Journal of Work Environment and Health*, vol. 20, pp. 48-54.

In this cross-sectional study, all pig farmers in two districts of western France with more than 50 sows or 800 pigs were approached. The number of animals was chosen so that at least one worker was likely to have exposure for at least 50% of the time. Farmers were identified from the Rural National Health Service Register. All farmers were visited and this may account for the high participation rate of 84.1% (138 farmers). The findings in this paper are for the 102 male farmers in this group. Two control groups were selected similarly from the same register matched for age and country of residence; 51 dairy farmers and 81 workers in the dairy industry not exposed to air contaminants. The definition of non exposure for the latter was not described. The response rate in the control groups was also above 80% and women were excluded. The last group had a significantly higher proportion of smokers (44%) than the pig (28.4%) or dairy farmers (27.4%) groups.

Self-completed questionnaires included respiratory symptoms based on questionnaires of British Medical Research Council and the International Union against Tuberculosis and Lung Disease. All three groups had a low prevalence of asthma, only 4% in pig farmers. Respiratory symptoms were generally higher in both the pig and diary farmers than in the dairy workers group, for example, morning cough (13.3% and 10.4% vs. 3.8%) and phlegm (10.2%, 6.7% vs 7.7%). Work related symptoms were generally highest in pig farmers, eg, fits of coughing (24.5%vs 8.3% and 4.1%, $p<0.05$) and sneezing (21.4% vs 10.4% and 9%, $p<0.05$). Although of lower prevalence there was no significant difference in work related symptoms of rhinitis, wheezing and shortness of breath.

Other measurements included spirometry and methacholine challenge, personal sampling (average inspirable dust 3.63 mg/m^3 and ammonia 3.23 mg/m^3 based on 4 samples only) and airborne dust (average total dust 2.41mg/m^3), ammonia (average 8.5 mg/m^3 and carbon dioxide (range 1000 ppm to 5000ppm) concentrations in swine confinement buildings. Spirometry findings were not significantly different in the three groups and reported to be normal according to European reference values. On methacholine challenge, FEV1 fell by more than 10% in all 35.6% of dairy farmers, 17.9% of pig farmers and 6.7% of the non exposed dairy workers. Analyses were univariate and reported to have been adjusted for smoking (discrete outcomes) and age, height and smoking (continuous variables). The methods of this adjustment were not described.

Christensen H, Vinzents P, Nielsen BH, Finsen L, Pedersen MB & Sjogaard G 1992, 'Occupational exposures & health among Danish farmers working in swine confinement buildings', *International Journal of Industrial Ergonomics*, vol. 10, pp. 265-273.

This article reports on a cross sectional study of 27 workers from 11 large pig farms in Denmark. Simultaneous work exposures to dust (total and respirable), endotoxins, manual work rates and loads (heart and respiratory rates) and ergonomics were measured.
Farmers were observed for working postures for burdens weighing greater than 1kg. Personal dust sampling was performed using 25 mm 8 *u*m filters in closed face millipore cassettes at 1.9 L/min (v= 1.25m/s). Respirable dust was measured using BMRC guidelines. Endotoxins were measured using Limulus amoebocyte lysate test.

A questionnaire was also issued regarding musculoskeletal and respiratory symptoms amongst 25 workers.

Total working time per day was 5 hr 55 minutes. Mean concentration of total dust for 22 workers was 4.13 mg/m^3. Respirable dust was 11% of total dust concentration.

Mean concentrations of endotoxins sampled as total dust was 64 ng/m^3 which was equal to 15 ng/mg in total dust. 3 workers showed endotoxin levels above 100 ng/m^3. The concentration of endotoxins sampled as respirable dust was 5 ng/m^3 corresponding to 12 ng/mg endotoxins in respirable dust.

Respiratory symptoms: cough was present in 58% (no. 15) of workers with 9 reporting worse coughing during work hrs. 27% (7) reported sneezing, with 4 workers reporting worse sneezing at work.

Dust exposure levels ranged from 1.2 to 6.8 mg/ m^3 – median value was 3.9 mg/m^3. Of the 11 workers exposed to dust above 3.9/m^3, 9 workers reported coughing often compared to 4 among the 11 workers who were exposed to dust below 3.9 mg/m^3.

22% of the workers in this study were exposed to levels of dust above the OEL set for Denmark (i.e. 5 mg/m^3 for organic and 1 mg/m^3 for inorganic dust). The respirable dust concentration was 11% of the total dust, which means most of the dust is deposited in the upper airways tract. This explains high degree of upper airways respiratory symptoms in this study. The frequency of respiratory symptoms found here are similar to those reported by other researchers such as Donham.

Chun DTW, Harrison RE & Chew V 1999, 'Organic Dusts.' *Journal of Cotton Science*, vol. 3 pp. 177-182.

This study relates to cotton dust and outlines the process that was used to collected samples so that they could be used in other studies. It also found that 5µ filters collected more sample then 8µm filters.

Clark S, Rylander R & Larsson L 1983, 'Airborne Bacteria, Endotoxin and Fungi in Dust in Poultry and Swine Confinement Buildings', *American Industrial Hygiene Association Journal,* vol. 44, no. 7, pp. 537-541.

This report analysed airborne dust in both swine and poultry. Total and gram-negative bacteria, total fungi, *Aspergillus fumigatus* and endotoxins. Bacteria were collected with 6 stage Andersen Samplers. The number of airborne viable bacteria was determined using an Agar impacter sampler.

	Dust (mg/m^3)	**Total Bacteria** CFU/m^3	**Gram-negative** CFU/m^3	**Fungi** CFU/m^3	**Aspergillus** CFU/m^3	**Endotoxin** (µg/m^3)
swine confinement buildings	3.08	300,000	88,000	300	30	0.12
poultry confinement buildings	2.34	420,000	41,000	500	0	0.31

The concentrations of total and gram-negative bacteria were high, and may cause health effects to the workers.

Cleave J, Ingram L, Barber E & Willson P 2002, *'Sask Pork Final Report: Airborne Dust, Endotoxin and DNA Downwind from Swine Barns'*, Saskatoon; University of Saskatchewan.

This study monitored total dust, endotoxin and total DNA exposures inside, upwind and downwind of two rural swine confinement facilities during spring and summer 2001-2002.

Total dust concentrations 600m downwind of the facility (0.06 mg/m^3) were not significantly different to those 2400m upwind of the facility (0.08 mg/m^3). However, the total dust concentration at the outlet (0.4 mg/m^3) was significantly higher in comparison to upwind and downwind locations. Season did not have a significant impact on total dust concentrations.

There was no significant difference between endotoxin concentrations 600m downwind (67.5 EU/m^3) and 2400m upwind of the facilities (67.5 EU /m^3). However, the outlet endotoxin concentration (1589.5 EU /m^3) was significantly higher in comparison to upwind and downwind levels.

Coble J, Hoppin JA, Engel L, Elci OC, Dosemeci M, Lynch CF & Alavanja M 2002, 'Prevalence of exposure to solvents, metals, grain dust, and other hazards among farmers in the Agricultural Health Study,' *Journal of Exposure Analysis and Environmental Epidemiology,* vol.12, pp. 418-426.

This study looks at the prevalence of exposure to many different potential hazards from a farm environment including grain dust. This study was carried out in America (North Carolina and Iowa), but was concentrated on pesticide users and handlers. So the relationship to dust is from the use of pesticide, not from other means.

Collins R 2003, 'Culturable Air Sampling for Fungal Contaminants.' *The Synergist,* January pp. 27-29.

This is a very basic article that describes different fungal (and related constituents) collection methods. It is related to office and housing buildings, not animal handling buildings.

Cooper GS, Miller FW & Germolec DR 2002, 'Occupational exposures and autoimmune diseases,' *International Immunopharmacology,* vol. 2 pp. 303-313.

This American study is focused on autoimmune diseases and the possible risk of this disease from occupational exposure. It does not concentrate on farming (there is in fact no mention of farming, but a mention of possible farming activities, such as pesticide and silica). It does not provide a definitive answer on if occupational exposure is an important risk factor for this disease, but suggests it could be.

Cormeir Y, Coll B, Laviolette M & Boulet LP 1996, 'Reactive airways dysfunction syndrome (RADS) following exposure to toxic gases of swine confinement building', *European Respiratory Journal,* vol. 9, pp. 1090-1091.

This article is a case report of a 58 year old man, without prior symptoms, who developed RADS after exposure to high levels of toxic gases in swine confinement units. The man was hospitalised following acute symptoms of dizziness, chest tightness, cough and shortness of breath. He still complained of shortness of breath after one month. Spirometry suggested obstructive disease (FEV1 2.76L and 88% of predicted, FEV1/FVC 0.66) and methocholine broncho-provocation test was positive. No baseline tests were available for comparison. The authors attribute hydrogen sulphide as a causative agent following the failure of the ventilation above manure at the time the worker was starting the pit pump. Two sows also died as a result of exposure.

Cormeir Y, Israël-Assayag E, Racine C & Duchaine C 2000, ‘Farming practices and the respiratory health risks of swine confinement buildings’, *European Respiratory Journal*, vol. 15, pp. 560-565.

Total dust samples were collect on a closed face cassette at a flow rate of 1.5 L/min. Airborne bacteria samples were collected in a glass impinger at a flow rate of 12.5 L/min. These samples were later analysed for endotoxin levels using the LAL test method. Airborne moulds were collect on a 6-stage Anderson Cascade impactor are a flow rate 28.3 L/min.

There appears to be no relationship between the size of the sheds, number of pigs and contaminant levels. The average report exposures for the static samples are:

- Inhalable dust are 3.40 mg/m^3
- Bacteria are 443375 CFU/m^3 (~0.44 x10^6 CFU/m^3)
- Endotoxins are 404 EU/m^3
- Moulds are 883 CFU/m^3 (~0.0009 x10^6 CFU/m^3)

This study did not find any significant relationship between inhalable exposure and airway responsiveness.

Cormier Y, Tremblay G, Meriaux A, Brochu G & Lavoie J 1990, ‘Airborne microbial contents in two types of swine confinement buildings in Quebec’, *American Industrial Hygiene Association Journal*, vol. 51, pp. 304-309.

The samples were collected using a 6 stage Andersen impactor for both bacteria and fungi and the sampling time was determined to be 4 minutes for total organisms whereas sampling only for the respirable fraction could be undertaken for 20 minutes. The samplers were run at 28.3 L/min at a height of 1 metre above the ground. Total dust samples were collected on 37mm PVC membrane filters at the flow rate of 2L/min for 1 hour. The study was undertaken in 4 swine building, 2 farrowing and 2 fatting units over 4 months.

The results for the total organisms ranged from 112 x 10^3 to 1248 x 10^3 CFU/m^3 bacteria, 0 to 4593 CFU/m^3 gram –ve bacteria and 0 to 557 CFU/m^3 mould (fungi). The results for the respirable organisms are 51 x 10^3 to 497 x 10^3 CFU/m^3 bacteria, 0 to 122 CFU/m^3 gram –ve bacteria and 5 to 62 CFU/m^3 mould (fungi). The mean total dust concentrations range from 1.6 8.8 mg/m^3.

Covello VT & Merkhofer MW 1993, *‘Risk Assessment Methods, Approaches for assessing health and environmental risks’*. New York, Plenum Press.

The Authors draw on their background, in conducting risk assessments for the National Science Foundation (NSF), to compile a book on all of the different topics that go into conducting a risk assessment. It includes information gained from epidemiologists, toxicologists, engineers and statisticians. The book gives overviews of all of the different types of assessments that can go into making a risk assessment, this includes release assessment (looking at amounts and types of pollutants released), exposure assessment (looking at the amount that a person or area is exposed to something), and, consequence assessment (looking at the possible and probable health effects of an exposed person or area). They found that all of the different steps are necessary to making a sound risk assessment. The book outlines and provides examples of all of these steps. Risk assessments are relevant to the project, as a primary risk assessment will need to be conducted to see if there is a risk to workers from handling livestock. This is a very good book for an overview of risk assessments; it however, doesn’t have a great deal of information about agriculture.

Crook B, Robertson JF, Glass SA, Botheroyd EM, Lacey J & Topping MD 1991, 'Airborne dust, ammonia, microorganisms, and antigens in pig confinement houses and the respiratory health of exposed farm workers', *American Industrial Hygiene Association Journal,* vol. 52, pp. 271-279.

This paper reports on exposure assessments, for dust, ammonia, aeroallergens and microorgansisms, and respiratory health outcomes of workers who work in pig housing facilities.

Exposure assessments undertaken in 12 sheds include:

- dust measurements using static samplers that collected the dust sample on 25mm glassfibre filters contained in total dust sampling heads at a flow rate of 2L/min. The samples were collected for a whole working shift every 4 weeks for 6 months.
- Two types of microbial sampling were undertaken simultaneously for 40 minutes in 6 buildings,
  - multistage liquid impingers (3 stages) at a flow rate of 55 L/min, and
  - filtration using 0.8μm pore polycarbonate filters housed in 37 mm open face filter holders at a flow rate 4 L/min

  Different types of micro-organisms were assessed by the use of different agars. The micro-organism concentrations assessed were total bacteria, gram +ve bacteria, gram +ve cocci, gram -ve bacteria, Thermophilic bacteria and actinomycetes and total fungi
- Endotoxin samples were collected on 37 mm nuclearpore filters at a flow rate of 70 L/min. Following weighing the filers were assayed using a LAL assay.

The results varied from shed to shed with the mean airborne results ranging from 1.66 to 21.04 mg/m^3. The total bacteria results ranged from 2 x 10^3 to 8 x 10^6 CFU/m^3 depending on the temperature of incubation. The lower incubation temperatures resulted in higher bacteria concentrations. The major types of the bacteria present was gram +ve identified as *Staphylococcus lentus, Aerococcus viridans, Staphylococcus hominis, Micrococcus lylae* and *Bacillus* spp.

Airborne fungi concentrations ranged from 3 x 10^2 to 10^5 CFU/m^3. The most commonly isolated fungi were *Scopulariopsis brevicaulis* and *Cladosporium* spp.

The airborne endotoxin concentrations were measured for 5 of the sheds and ranged from 25 – 30 ng/m^3.

The health assessments were undertaken on 29 workers on the 12 farms assessed and 48 controls who lived in a urban area. The assessments included:

- Completing a questionnaire on occupational history and clinical history;
- Respiratory assessment involved using a dry wedge bellows spirometer measuring FEV_1 and FVC.
- Immunological Investigations to measure Specific IgE and Specific IgA.

The results of the questionnaire should that 23 of the 29 workers report a range of respiratory symptoms the most common being nasal and eye irritation. 3 of the 29 should impaired FEV_1 and FVC of which two reported typical symptoms of a obstructive ventilatory defect and on a restrictive defect.

8 of the 24 workers had specific IgE to pig meal whereas as 15 workers has IgG to pig skin and/or pig urine but only 8 to the pig food. There was no relationship between IgG and reported respiratory symptoms or airborne concentrations.

Crook B & Sherwood-Higham JL 1997, 'Sampling and assay of bioaerosols in the work environment.' *Journal of Aerosol Science,* vol. 28 pp. 417-426.

This paper compares various methods of sampling for bioaerosols and discusses the pros and cons of each method.

Danuser B, Weber C, Kunzli N, Schindler C & Nowak D 2001, 'Respiratory symptoms in Swiss Farmers: An epidemiological study of risk factors', *American Journal of Industrial Medicine*, vol. 39, pp. 410-418.

This cross-sectional study comprised of a sample of German speaking farmers chosen, every 150th on an alphabetical basis, from a national registry. Of 1542 farmers, 940 male farmers who returned questionnaires. Respondents were divided into seven groups based on farming type and duration of farming; eg, pig farming was working for more than one hour each day inclosed buildings with pigs. Five of these categories are of relevance here; pig farming, pig and cattle farming, cattle farming, poultry farming and mixed farming. The average age of farmers was 48 years. Self reported respiratory symptoms were derived from the European Community Respiratory Health Survey. Trends of symptoms across age categories in univariate analyses were inconsistent. For example, the prevalence of wheezing ($p>0.05$), chronic bronchitis ($p<0.05$), breathlessness at work ($p<0.05$), phlegm ($p<0.05$) and cough with phlegm at work ($p<0.05$) increased with age. A decreasing trend was the case for nasal allergy ($p>0.05$) and nasal irritation at work ($p<0.05$), perhaps suggesting a health worker effect.

Separate LR analyses for association with farming type and the outcomes of wheezing, chronic bronchitis, phlegm, asthma and nasal irritation at work were adjusted for age, smoking status and the amount of time spent in confinement buildings. For wheeze and asthma, farmers in all farming types had odds ratios greater than 1 (compared with small farms) but none were statistically significant. The highest odds ratios, 2.68 and 2.87 (wheeze and asthma respectively) were for poultry farmers. Few explanatory factors reached statistical significance in any of the models. The only odds ratios for farming type that were statistically significant were for pig and cattle (3.37) and poultry farming (5.33) for nasal irritation at work where the referent group was small farms. Independent of type of farm, farmers older than 60 were significantly more likely to have chronic bronchitis (2.40), phlegm (1.87) compared with farmers aged 21 years to 40 years. Being a current or former smoker was significantly associated with symptoms of wheezing, chronic bronchitis, phlegm and asthma. All odds ratios for this comparison were statistically significant except for current smoking and chronic bronchitis. The findings for time spent in confinement suggested a dose response relationship for wheezing, chronic bronchitis and asthma independent of the type of farming and age.

The responses were compared with findings of the SALPADIA study, a population survey of respiratory symptoms in the Swiss adult population. The odds ratios were age adjusted since the SALPADIA subjects were younger than the formers in this study. Farmers had significantly higher odds ratios for phlegm (4.98) and chronic bronchitis (2.07 – for non smokers) only. The latter suggests a risk independent of smoking.

Demmers TGM, Wathes CM & Frost AR 2002, 'Interactions between housed livestock and their environment', *Animal Production Australia,* vol. 24 pp. 394-405.

This paper reports on data that has been generated in Europe of the measurements air pollutants in pig hosing. For UK occupational exposure limit in 2001 for human health is 10 mg/m^3 for total inhalable dust and 4 mg $/m^3$ for the respirable fraction of dust. This is above the level recommended by Donham et al. (1995) who recommended 2.5 mg $/m^3$ for inhalable and 0.23 mg/m^3 for respirable, on grounds of human health.

	Inhalable dust (mg /m^3)	**Respirable dust** (mg /m^3)	**Inhalable endotoxin** (ng/m^3)	**Respirable endotoxin** (ng /m^3)	**Ammonia** (ppm)
Sows on litter, n=16	1.14	0.14	302.35	27.30	8.80
Sows on slats, n=32	1.67	0.20	32.65	3.45	11.93
Weaners on slats, n=32	3.74	0.30	150.15	16.25	5.55
Finishers on litter, n=16	1.30	0.13	156.00	15.45	6.70
Finishers on slats, n=34	2.42	0.22	101.73	9.88	14.88

Demmers T, Wathes C, Richards P, Teer N, Taylor L, Bland V, et al. 2003, 'A Facility for Controlled Exposure of Pigs to Airborne Dusts and Gases', *Biosystems Engineering*, vol. 84, issue 2, pp. 217-230.

This report exposed pigs to airborne dust (nominally 0, 2.5, 5 or 10 mg/m^3 inhalable fraction) and ammonia (nominally 0, 10, 20 or 40 parts per million, ppm) and the effects on production and respiratory disease measured.

The dust concentration was monitored with a tribo-electric sensor, which was calibrated against an aerodynamic particle sizer and gravimetric samplers. Ammonia was measured continuously with a NO chemiluminescence gas analyser after catalytic conversion of NH^3 to NO at 7508C.

Donham K 1990, 'Health Effects from Work in Swine Confinement Buildings', *American Journal of Industrial Medicine*, vol. 17, pp. 17-25.

This paper has review of 14 epidemiological studies undertaken in swine workers in USA, Canada, Sweden and Netherlands. The types of health effects described and the percentage of reporting are reported as:

- cough is seen between 10-55% of cases;
- phlegm is seen between 5-40% of cases;
- wheeze is seen between 10-25% of cases;
- tightness of chest (TOC) is seen between 0-10% of cases;
- shortness of breath (SOB) is seen between 5-30% of cases; and
- organic dust toxic syndrome (ODTS) is seen between 10-30% of cases.

Donham K J 1994, '*Swine Confinement Buildings. Organic Dusts*'. R. Rylander, and Donham, K. J. Boca Raton, Lewis Publishers.

A 6-year follow-up study revealed about 15% of farmers had dropped out of framing because of respiratory disease.

Donham K J 1995, 'Health Hazards of Pork Producers in Livestock Confinement Buildings: From Recognition to Control', Chapter 1.9 In: *Practical Applications of Agricultural Health and Safety*. Lewis Publishers

> Chapter 1.9 discussed generally the types of hazards that maybe present in the pig industry. The author has recommended the levels of exposures that should be adopted as limits both for human health and animal. For human health he has recommended the following levels: 0.23 mg/m^3 for respirable dust, 2.4 mg/m^3 for total dust, 4.3 $x10^5$ CFU /m^3 for total microbes and 0.08 mg/m^3 for endotoxins.

Donham KJ, Cumro D, Reynolds S J & Merchant JA 2000, 'Dose-response relationships between occupational aerosol exposures and cross-shift declines of lung function in poultry workers: recommendations for exposure limits'. *Journal of Occupational & Environmental Medicine*, vol. 42, no.3, pp. 260-269.

> Cross-sectional data for 92 poultry workers are compared with that of 111 non farm blue collar workers. The sample was originally derived from the Iowa membership roster of poultry producers. Assessments included personal sampling, spirometry and modified American Thoracic questionnaires. In addition to univariate analyses, several LR models explored including prediction of cross-shift declines in FEV1 and FEF25-75 of 3%, 5% and 10% and adjusted for age, years worked, gender, smoking status and level of education. Thirty percent of workers demonstrated a 3% decline in FEV1. These declines were correlated with personal exposure measures in univariate analyses. FEV1 was weakly and significantly ($p<0.05$) correlated with total dust (!=0.265), respirable dust (!=0.155), total endotoxin (!=0.193) and respirable endotoxin (!=0.157) but not with ammonia (!=0.081, $p>0.05$). FEF25-27 was significantly associated only with total dust (!=0.275) and total endotoxin (!=0.205) levels.
>
> Total dust and total endotoxin concentrations were divided into quartiles for LR analysis. A significant trend in increasing odds ratios for a decline for both FEV1 and FEF25-27 with increasing quartiles was found in models which were adjusted for age, years worked in poultry industry, gender smoking status and education. Threshold levels for exposure were suggested on the basis of LR results predicting 3% or greater cross-shift declines in FEV1; 2.4 mg/m^3 for total dust, 0.162 mg/m^3 for respirable dust, 614 EU/m^3 for total endotoxin, 7.15 EU/m^3 for respirable endotoxins and 12 ppm for ammonia.
> The methods used to collect the dust and endotoxin levels have not been adequately specified in that NIOSH method 0500 (last revised 1994) was quoted that allows a flow rate between 1 to 2 L/min. For Australian data a rate of 2 L/min is required. Respirable dust levels (NIOSH 0600) at a flow rate of 1.5 to 1.8 L/min. This is below the recommended flow rate of 1.7 L/min for the type of cyclone used.

Donham K, Haglind P, Peterson Y, Rylander R & Belin L 1989, 'Environmental and health studies of farm workers in Swedish swine confinement buildings', British *Journal of Industrial Medicine*, vol. 46, pp. 31-37.

> The finding reported in this paper from a cross-sectional study of workers in confinement buildings in large commercial swine farms. The farms were selected from members of Farmers Safety and Preventive Association of the Bjuv district in Sweden, which represents 35% of farmers in the area. Fifty-seven farm workers participated in the study together with 55 control farmers who were matched for age, gender and smoking status. The control farmers were not swine farmers. Occupational and symptom history was measured by interview questionnaire, which included questions on symptoms developed by the American Thoracic Society (Swedish translation). Spirometry was performed twice but only in the swine farmers, at the beginning and at the end of the work shift. Blood samples were tested for fungal and mould antigens. Personal and environmental samples were examined in the analyses for dust, microbial and gas concentrations (ammonia, carbon dioxide and hydrogen sulphide).

The prevalence of chronic cough and history of colds was significantly higher for swine farmers (39% vs 13% and 53% vs 20% respectively), however on stratified analysis the comparison was statistically significant only for non smokers (29% vs 7% and 59% vs 20%). Spirometry results were not reported but their assessment against predicted values were and only for swine farmers. Forced expiratory flow at both 50 and 75 seconds were significantly lower than predicted, 84% and 60%. FEV1 was reported to be within 95% of predicted. A non significant decrease in FEV1 was noted over the work shift. Multiple comparisons and associations are presented in between symptoms and exposure. Analyses were stratified for smoking status and. The findings suggested length of exposure associated with symptoms such as chronic bronchitis. In multiple regressions analysis significant predictors of work shift reductions in FEV1 were smoking status endotoxin levels and baseline FEV1. A decrease in work shift FEV1 commenced at endotoxin levels of 0.18 µg/ml ($p>0.05$). The multivariate analyses were limited by the small sample size, eg, there were insufficient number of smokers for this last analysis.

Donham JK, Reynolds SJ, Whitten P, Merchant JA, Burmeister L & Popendorf WJ 1995, 'Respiratory dysfunction in swine production facility workers: Dose response relationships of environmental exposures and pulmonary function', *American Journal of Industrial Medicine*, vol. 27, pp. 405-418.

This paper reports further findings of a previous comparative study but only for swine farmer subjects (Donham et al. 1990, Schwartz et al. 1995)). Two hundred and seven farmers were randomly selected from the population of Eastern Iowa farm. Controls were local farmers not involved in confinement production matched for smoking status, age and sex. Measures included interviewed assisted questionnaires for respiratory symptoms, lung function tests before and after 2-6 hours of work, personal and environmental dust, endotoxin and gas assessments. The environmental measures were weakly correlated with lung function tests, FEV_1 (r=0.13) and all remaining analyses were done on personal exposures. Cross-shift declines in FEV_1 were negatively correlated with age and positively correlated with total dust, endotoxin and ammonia levels as well as two interaction terms, total dust*age and years (of work)*total dust. Cross-shift declines in FEV_1 were greater for smokers than for non smokers. Cross-shift declines in lung function tests were examined stratified according to number of years worked and correlations were ranged from week to moderate with some statistically significant. Multiple regression modelling was carried out to predict change in FEV_1 (0%. 3%, 10%) and for four groups according to number of years worked (0-6, 7-9, 10-13, 14+). The number of subjects in each of these four groups ranged from 43 to 54 and may account for the finding that some of these models had no significant predictors. On the basis of these analyses the authors suggested threshold levels of 2.8 mg/m^3 for total dust and 7.5 ppm for ammonia.

Dosman JA & Cockcroft DW 1989, '*Principles of Health and Safety in Agriculture*', CRC Press Inc.

Both authors are professors of medicine at the University of Saskatchewan, Canada. The papers in this book were based on work presented at the International Symposium on Health and Safety in Agriculture. The papers in this book can be divided into two categories, one including information with regard to health and safety risks to the respiratory system as a result of airborne particulate and gaseous contamination in the workplace. The other category deals with health and safety risks as a result of chemicals, cancer, skin problems, accidents and injuries, as well as stress and psychiatric problems in rural areas. According to the authors these papers confirm the idea that farmers, as a group, are exposed to respiratory dysfunction, and give credibility to results of epidemiologic investigations indicating that farmers are at risk of developing lung dysfunction. This is very important for the project as the findings are proving a link between exposure and disease. The book is quite old now, but the claims are still found to be correct, supported by recently Adel Hameed and Khodr (2001).

Dosman JA & Cotton DJ 1980, *'Occupational Pulmonary Disease, Focus on Grain Dust and Health'*. New York, Academic Press.

At the time of writing both authors were staff at the University of Saskatchewan, Respiratory Diseases Clinic, Department of Medicine, Canada. They draw on their experiences dealing with farmers and grain workers in a clinical setting to write this book. While this book is mostly about grain workers and farmers, it also pertains to general farm workers. This can include people who generally are livestock handlers. Livestock handlers are often also exposed to grain dust and other contaminants on a farm not just to the potential dust or contamination that comes from the animals. The book provides information on the different methods that can be used in the diagnosis of occupational pulmonary disease. It also provides in depth information about the causes, treatments and general information about pulmonary disease. The book provides evidence of a link between negative pulmonary health impacts and dust generated from working with grain. It is an old book that had some findings that were not as well known then as they are now. This is simular to information provided by Dutkiewicz (1997), but the information in this book is much older.

Dosman JA, Graham BL, Hall D, Van Loon P, Bhasin P & Froh F 1987, 'Respiratory symptoms and pulmonary function in farmers', *Journal of Occupational Medicine*, vol. 29, no. 1, pp. 38-43.

This paper, written in 1987 (bit dated) collected data (by questionnaire) on 1,824 Saskatchewan farm workers and 556 control subjects, in order to assess respiratory health and pulmonary function in farmers. Each subject questioned also underwent pulmonary function assessment (i.e. measurement of forced vital capacity (FVC), forced expired volume in 1 sec (FEV_1) and maximum midexpiratory flow rate (MMFR)). Symptoms such as morning phlegm, wheeze, shortness of breath (SOB) and bronchitis were clearly defined and recorded.

More than 90% of farmers tested grew grain or other field crops, 65.4% had beef cattle and much less had other types of animals.

Results (Table 8 below) showed farmers in this area had more striking respiratory symptoms and lower values for FVC and FEV_1 than do a group from non farming town dwelling men (control group). 14.5% of farmers (9.2% in control non farmer group) had morning phlegm, wheeze in 27.4% (99% control group), SOB 33.3% farmers (18.2% control group)

Table 8: Pulmonary function test results

Variables	**Age 20-34 yo** (mean)	**35-49 yo** (mean)	**50-70 yo** (mean)	**Total mean**
FVC Farmers	95	98	100	98
Control gp	104	107	110	106
FEV_1 Farmers	95	97	96	96
Control gp	102	105	103	103
MMFR				
Farmers	94	92	78	87
Control gp	96	93	78	90
FEV_1/FVX x 100				
Farmers	100	99	96	98
Control gp	98	98	94	97

Douwes J, Pearce N & Heederik D 2002, 'Does environmental endotoxin exposure prevent asthma?' *Thorax*, vol. 57, no. 1, pp. 86-90.

This is a review article from The Netherlands; focused on the ideas that exposure to low levels of endotoxin may prevent the onset of asthma. After reviewing many of the issues involved in this issue, the article concludes that the idea may be 'plausible' but that there is no direct evidence, at this stage.

Douwes J, Thorne P, Pearce N & Heederik D 2003, 'Bioaerosol Health Effects and Exposure Assessment: Progress and Prospects', *Annals of Occupational Hygiene*, vol. 47, no 3, pp. 187-200.

This is a review of the health effects of bioaerosols and methods of assessment of toxins and allergens. In most situations exposures are complex mixture resulting in an infectious disease, respiratory disease or cancer.

Infectious diseases include tuberculous, Q-fever, swine influenza, legionnaires disease and Pontiac fever. Respiratory disease includes irritation induced asthma, chronic obstructive pulmonary disease (COPD), allergic asthma, allergic rhinitis, hypersensitivity pneumonitis and farmers lung. Cancer; in particular aflatoxins resulting in liver cancer. Farmers have also shown an increase risk of a range of others cancers but precise causes have not been adequately documented

Methods of assessment were discussed as being either culture based or non-culture based.

Culture based methods include the collection of the bioaerosols directly on either a media plate using an impactor, in a liquid using a impinger or on a filter. The liquid and filter collected need to be transferred to a media for culturing and then counting. These methods are not good for undertaking personal samples and sample time is usually short.

Non-culture based methods use samples that have been collected either in a liquid or on a filter. The organisms can then be stained and counted under a microscope. More commonly today samples are assessed by the use of flow cytometry. These methods are better for personal sampling and sample time can be longer

For estimating microbial exposure it is better to measure the toxic components such as myotoxins and endotoxins. A range of analytical methods was discussed. No suitable biomarkers have been identified.

The setting of exposure standards is varied throughout the world. No country has adequately addressed the levels of bioaerosols. Endotoxin standards levels have been set in Netherlands of 50 EU/m^3 although 20 EU/m^3 is now being considered. For dusts that may also be biologically active such as wood or grain dusts and a range of levels have been set in different countries.

A number of research needs have been identified including:

- Exposure method development especially in non-culture techniques
- Current methods need validation and for the development if they are to be used in epidemiological studies of a significant size.
- More rapid analysis methods especially for identification.
- Others looking at the behaviour of specific bioaerosols and the potential health hazard.

Downs SH, Marks GB, Mitakakis TZ, Leuppi JD, Car NG & Peat JK 2001, 'Having lived on a farm and protection against allergic diseases in Australia, *Clinical and Experimental Allergy*, vol. 31, pp. 570-575.

This paper reports on a cross sectional study of 1500 children aged 7-12 yrs. The study was undertaken to determine if living on a farm as a child in Australia is associated with a lower risk of allergic diseases. Two areas were chosen; Wagga Wagga (mostly livestock and mixed farming area) and Moree (mostly crop grain farming area).

Results showed that living on a Wagga Wagga farm, children had a 66% reduction in the risk of being atopic, but children in Moree showed no such reduction in the risk. Wagga Wagga children showed similar results to children in northern Europe.

The authors suggest that non animal farming confers no such protection as gained by exposure to animal livestock farming (eg touching, feeding animals- exposure to orofaecal route/food borne microbes can prevent development of atopy). Crop farming such as in Moree (i.e. harvesting) may expose people to high levels of aeroallergens such as fungal spores (12 x increase).

They conclude this study shows similar results to northern Europe where exposure to farm life can ‘be associated with reduction in the prevalence of atopy.’ This protective affect is not found in all farming areas. Wagga Wagga findings - consistent with European studies. There may also be ‘ecological fallacies’- i.e. other ‘unidentifiable factors that explain the differences associated with exposure to farming between towns.’

They suggest that further work is needed to identify possible protective measures that may be related to farm animals or to determine of this protection is explained by other related exposures.

Drennan R 1986, ‘Prevention of Dusts Exposure.’ *American Journal of Industrial Medicine,* vol. 10 pp. 229-243.

This article outlines different ways that farmers and people working on farms can reduce the concentrations of dust that they are exposure to while working. Most of the suggestions are related to outdoor work or indoor work with grain. This does not mean that some of the ideas such as education are not relevant to animal handling. All of the ideas fall into the broad categories of control measured outlines in the Australian Standards (Elimination, Substitution, Engineering, Administration, PPE).

Drennan R, Friend JAR, Legge J & Bruce CE 1986, ‘The Causes, Detection, and Control of Respiratory Dust Diseases of Farm Workers in Northern Scotland’, *American Journal of Industrial Medicine*, vol. 10 pp. 331-335.

Farm workers in Scotland, who had a chest infection, were visited by investigators to find out what the source of the agent was, and ways to reduce the exposure. Species of bacteria and fungi were not identified in this study, and no concentrations were found.

Duchaine C, Thorne P, Meriaux A, Grimard Y, Whitten P & Cormier Y 2001, ‘Comparison of endotoxin exposure assessment by bioaerosol impinger and filter-sampling methods’, *Applied and Environmental Microbiology*, vol. 67, no. 6, pp. 2775-2780.

This study compared the use of air sampling filters versus impingers for monitoring endotoxin levels in 7 swine barns during 1997 (June-August), and 17 sawmills between May and November in 1996 and 1997.

Table 9: Comparison of Endotoxin Concentrations for Aerosols Collected with Filters and Impingers in Sawmills and Swine Barns

Location and Sample Type	Endotoxin Concentration (EU /m^3)	
	Mean	Range
Sawmill (impinger)	740	208-485
Sawmill (filter)	188	6.2-252
Swine Barn (impinger)	4385	2026-4480
Swine Barn (filter)	3927	729-4976

Dutkiewicz J 1978, ‘Exposure to Dust-Borne Bacteria in Agriculture. I. Environmental Studies.’ *Archives of Environmental Health* September/October, pp. 250-259

This is a Polish study that measures concentrations of bioaerosols in a grain handling plant, in a chicken growing area (100 samples taken) and cow barn (468 samples). A battery-operated Boudillon slit-sampler was used to collect the samples. In the cow barn the average concentration of total viable particles in air was 177.4 thous/m^3 in the chicken areas the average was approximately 200 thous/m^3, depending on the activity in the area at the time of sampling.

Dutkiewicz J 1992, ‘Bacteria and their Products as Occupational Allergens.’ *Pneumonologia I Alergologia Polska,* vol. 60, no. 2 (suppl.), pp. 14-21.

This is a review article that looks at the possible causes and microorganisms involved in the development of allergic alveolitis. It also looks at ways to prevent exposure.

Dutkiewicz, J 1997, ‘Bacteria and fungi in organic dust as potential health hazard.’ *Annals of Agricultural Environmental Medicine,* vol.4, pp. 11-16.

This is a review article that looks at all of the different exposures and health effects that can come from the exposure to different microorganisms. A small amount of information is also included on the possible changing of the exposure standards for dust and establishing exposure limits for microorganisms.

Eduard W 1997, ‘Exposure to non-infectious microorganisms and endotoxins in agriculture,’ *Annals of Agricultural Environmental Medicine*, vol. 4, pp.179-186.

This is a literature review of studies on determinants of exposure to microorganisms in agriculture. Most studies have analysed tasks, processes and/or production. Little information exists in the literature on other determinants.

Concentrations of bacteria are generally large in animal houses, up to 10^8CFU (Colony Forming Units) /m^3 and 10^9 total cells/m^3. This was found with viable culture methods and concentrations of culturable microorganisms were about an order of magnitude less than concentrations determined with non-viable culture methods.

The literature showed that exposure to *fungi* is high during handling grain, hay, bedding material (especially when mouldy) and when handling cattle. *Bacterial* exposure was high during handling grain, hay, bedding material and in animal houses. *Endotoxin* exposure was high during chopping of bedding material and in animal houses (except in cowsheds). Exposures varied widely between measurements taken of the same tasks, even in some of the same studies.

This article discusses:

Measurement methods: culture of viable microorganisms is possible, but non culturable microorganisms that can still elicit a health response cannot be measured. Culturing methods grossly underestimate the number of organisms present (e.g. 1 in 1000 may only be cultured). Also it is not possible to do personal sampling, as sampling instruments are unsuitable. It is possible to sample more hardy organism such as fungi and actinomycetes using personal sampling. Filter samples can be analysed by non-culture methods- using microscopy. Bioassays (e.g. LAL) can measure metabolites of microorganisms.

Exposure assessment: Exposure assessment methods must be based on methods that use personal sampling. Short and long term exposures would enable exposure –response relationships to be assessed. Due to the variable nature of farm tasks, a large number of measurements need to be undertaken.

Eduard W, Douwes J, Mehl R, Heederik D & Melbostad E 2001, 'Short term exposure to airborne microbial agents during farm work: exposure-response relations with eye and respiratory symptoms', *Journal of Occupational Environmental Medicine*, vol. 58, pp 113-118.

This study was based on results obtained from 127 farms in Norway. The method on aerosols sampling gives the types of filters used and analysis methods but the flow rates at which the samples were collected. Also the method used to collect and analysis for fungal and bacteria spores are different to other studies. The results obtained are:

		Personal Total Exposures		
	n	**AM**	**GM**	**GSD**
Dust (mg /m^3)	106	0.84	0.31	4.2
Endotoxin (x10^3 EU /m^3)	105	13	1.2	14
Bacteria (x10^6 CFU /m^3)	104	2.5	0.56	7.7
Fungal spores (x10^6 CFU /m^3)	106	1.2	0.099	16

Eduard W & Heederik D 1998, 'Methods of quantitative assessment of airborne levels of noninfectious microorganisms in highly contaminated work environments,' *American Industrial Hygiene Association Journal*, vol. 59, pp. 113-127.

This article gives a very comprehensive account of methods used for sampling microorganisms. Culture and non culture methods are discussed for estimating microorganisms in a heavily contaminated work area (i.e. impaction, filtration and impingement methods). This article reviews sources of errors and validation studies used when evaluating quantitative methods for measuring airborne levels of non infectious microorganisms. They state culture based methods of analysis may not be accurate because non viable (i.e. non culturable) particles are still able to cause health effects. Also not all culture media can grow all organisms, so some will be missed. Culture based methods are have poor precision but do enable specific organism to be identified by culture. Filter sampling is preferred for personal exposure monitoring because they can be later analysed.

There is no biological occupational exposure limits available, making interpretation of data difficult.

Methods discussed: Sampling of microorganisms:

1. Sampling efficiency (using suction) - depends on aspiration, collection and for culture based methods, the culturability of microorganisms present. Aerosol sampling instruments should have same sampling efficiency as human respiratory system. Health related size criteria adopted by ISO and CEN.
Results may be affected also by unsuitable transport and storage means of collected samples. Also use of unsuitable equipment- wrong velocity rate, pore size filters etc.

2. Filtration – porous filters with a pore size of 5 *u*m collect 0l.3 *u*m particles with an efficiency of 95% or better. Capillary pore membrane filters less efficient and need a pore size of -.6 *u*m to match efficiency of 5 *u*m filters.

3.Impaction and other methods– Discusses Andersen sampler (6 stage impactor) and AGI glass impinger as well as the Reuter Centrifugal Air sampler.

Analysis – Culture, light microscopy, fluorescence microscopy, scanning EM, flow cytometry discussed also.

This article also discusses estimation of bioaerosol components such as endotoxins, glucans, antigens, allergens and chemical markers.

Validity of results – i.e. lack of systematic measurement error. Discussed here are particle sampling efficiency, comparative lab and field studies. Also precision of results, assessment of microorganisms and interpretation of measurement data are discussed.

Elliott LF, McCalla TM & Deshazer JA 1976, 'Bacteria in the air of housed swine units', *Applied and Environmental Microbiology*, vol. 32, pp. 270-273.

The paper is aimed at investigating the levels of airborne bacteria present in a swine shed that may impact on a pig's health. The samples were collected in a 50 ml of sterile 0.2% peptone-water in AGI at 2 L/min at approximately 30 and 122 cm in height on either side of the pig pen.

The results reported for total bacteria ranged from 1.3 x 10^5 to 3.1 x 10^5 CFU/m^3. Whereas as the Fecal coliforms ranged from 1.9 x 10^3 to 2.4 x 10^4 CFU/m^3, depending on the height of the sample.

enHealth Council 2004, ‘Application of health impact assessment to the intensive livestock industry’, *Consultation Draft*, available on line at http://enhealth.nphp.gov.au/council/pubs/pdf/ili_consul_draft_oct_04.pdf (last accessed 9/2/05)

This report is aimed at local governments in handling issues relating intensive livestock industry. Air quality issues have been covered in a general way. Exposures for workers have been mentioned in relation to studies that have also been reviewed. The majority of the report relates to chickens.

Ferguson TJ 1998, ‘Respiratory risk associated with agriculture, emphasis on organic dusts’ *1998 Proceedings Beltwide Cotton Conferences*. N. C. C. o. America, Memphis, National Cotton Council of America.

This is a review article that presented at a conference held by the National Cotton Council in America. This article reviews the different methods (processes and techniques) used for assessing the incidence of lung disease. The article focus is on cotton farming but does include some information about rice farmers; there is however no information about animal farming.

Feron VJ, Arts JHE, Kuper CF, Slootweg PJ & Woutersen RA 2001, ‘Health risks associated with inhaled nasal toxicants.’ *Critical Reviews in Toxicology,* vol. 31, no. 3, pp. 313-338.

This is a review article that outlines what the nose does and the role of the upper-respiratory system in dealing with potential hazards that may be inhaled. The article focuses on chemical and the affects of these chemicals.

Gibbs SG, Green CF, Tarwater PM & Scarpino PV 2004, ‘Airborne Antibiotic Resistant and Nonresistant Bacteria and Fungi Recovered from Two Swine Herd Confined Animal Feeding Operations’, *Journal of Occupational and Environmental Hygiene*, vol.1, pp. 699–706.

This paper investigated the impact on antibiotic resistant bacteria on bacteria and fungi levels inside, upwind and downwind of a swinnery. The samples were collected using a 2 stage Anderson impactor. The bacteria was collected an a tryptic soy agar (TSA) plate and the fungi were collected a malt extract agar plate at a flow rate of 28.3 L/min for between 0.5 and 15 minutes depending on the placement of the sampler. The genera results are:

Location	Respirable Bacteria (CFU/m^3)	Non-respirable Bacteria (CFU mg/m^3)	Respirable Fungi (CFUm^3)	Non-respirable Fungi (CFU/m^3)
Site A Without Swine				
Inside	72 ± 8.3	94 ± 16	30 ± 2.7	30 ± 2.2
Upwind	10 ± 1.2	24 ± 0.39	12 ± 2.1	7 ± 0.55
Downwind	17 ± 1.1	9 ± 0.8	29 ± 3.2	9 ± 1.5
Site A With Swine				
Inside	7400 ± 1470	31,000 ± 2680	81 ± 6.2	640 ± 320
Upwind	59 ± 0.68	13 ± 2.3	23 ±9	6.9 ± 0.75
Downwind	1100 ± 210	2800 ± 340	60 ± 4.0	30 ±5
Site B With Swine				
Inside	2100 ± 180	8300 ± 550	90 ± 8.6	160 ± 29
Upwind	36 ± 4.2	40 ± 3.2	18 ± 2.3	4 ± 1.2
Downwind	1300 ± 200	1500 ± 250	40 ± 2.3	20 ± 5.5

The paper also identified a number of organisms that were present.

Gordon T, Galdanes K & Brosseau L 1992, 'Comparison of sampling media for endotoxin-contaminated aerosols,' *Applied Occupational and Environmental Hygiene*, vol. 7 no.7, pp. 472-477.

This is a study on the influence of collection media and sampling method on endotoxin extraction for a variety of aerosols examined. 8 different filter media were tested i.e. glass fiber (GF), cellulose acetate (CA), PVC, polysulfone, polytetrafluoethylene (PTFE), polycarbonate, silver and nylon). On a saline endotoxin solution, GF and CA were equivalent and showed significantly higher amounts of extractable endotoxin than other filters. Polysulfone, PVC, PTFE extracted 2/3rd the amount of GF and CA filters. Polycarbonate, nylon and silver extracted 1/10th the amount of GF and CA. These results varied according to the extract being analysed e.g. when testing machining oil samples, CA extracted much higher amounts of endotoxin than PVC or GF filters. This article stresses the need for optimization and standardization of the LAL assay in order to maximize results. The choice of filter will be dependent on the type of aerosol being tested.

Grandin T 2000, *Livestock handling and transport*, CABI publishing, London.

The author's background is in animal sciences, and he currently works in the department of Animal Sciences at Colorado State University. This book gives information into the latest scientific research about the handling and storage of animals. All aspects of animal handling and transport are covered in this book, including handling for veterinary and husbandry procedures, restraint methods, transport systems, corral and stockyard design, handling at slaughter plants and welfare. Principals of animal behaviour and how behaviour patterns related to handling are covered for cattle, sheep, pigs, horses, deer and poultry. There is not much in this book on the health impacts that animals can have on people, but this book still outlines the correct way that livestock should be handled and transported, to have the least impact on the animals. This book is simular to a book by Wathes, C. M. and Charles, D. R. titled Livestock Housing (1994), published by CAB International. The books are so similar that only one book has been revived for this bibliography. The book by Grandin was chosen as it is a newer book and hence has more up to date information.

Groves WA, Hahne RMA, Levine SP & Schork MA 1994, 'A Field Comparison of Respirable Dust Samplers.' *American Industrial Hygiene Association Journal,* vol. 55, no. 8, pp. 748-755.

Three different cyclone respirable dust collectors were field tested against each other in an American study. The BMRC-type sampler collected the highest average concentrations, followed by the proposed ACGIH and previous ACGIH- type. These cyclone samplers were also compared to a cascade impactor and the results were not significantly different.

Guernsey JR, Morgan DP, Marx JJ, Horvath EP, Pierce WE & Merchant J 1989, 'Respiratory disease risk relative to farmer's lung disease antibody status', *Principles of health and safety in agriculture.* J. Dosman, A. and Cockcroft, D, W. Boca Raton, CRC Press Inc.

This is a book section that acts as a review of current (for 1989) information about Farmer's Lung Disease. It focuses on everybody in the farming industry and does not break out exposure of task competed. It looks at the way that antibodies that are found in a person can be related to their exposure and risk of Farmers Lung.

Guingand N & Salaun Y 2004, 'Air Quality inside Pig Buildings in Relation to Physiological Stages and Season', *International Society for Animal Hygiene Conference Proceedings*, Saint-Malo, France pp. 203-204.

This paper discussed dust levels measured inside pig housing and compared them based on type of pig activity and temperature based on season. Unfortunately there are insufficient details on how the samples were collected and what type they are except that they were static samples at 1 metre above ground. The average dust concentrations reported are:

	Summer	**Winter**
Farrowing Rooms	1.8±1.1 mg/m^3	2.5±1.2 mg/m^3
Post-weaning Rooms	4.1±2.0 mg/m^3	6.3±3.3 mg/m^3
Growing-finishing Rooms	2.4±1.3 mg/m^3	3.6±1.8 mg/m^3

Gustafsson G 1999, 'Factors affecting the release and concentration of dust in pig houses', *Journal of Agricultural Engineering Research*, vol. 74, pp. 379-390.

This report acknowledges the health impacts of dust for both animal and human in swine confinements and hence measures these levels. Total dust samples were collected as area samples at a flow rate of 1.9 L/min

Results of total and respirable dust concentration

	Piggery 1	Piggery 2
Total Dust mg/m^3	1.26	0.51
Respiratory Dust mg/m^3	0.17	0.10

Dust levels are affected by activity, number and weight of pigs. Spraying of small water droplets as well as an oil mixture significantly reduced dust concentration. Ventilation systems as well as type of housing system influence generation of dust.

Haglind P & Rylander R 1984, 'Exposure to cotton dust in an experimental cardroom', *British Journal of Industrial Medicine*, vol. 41, pp. 340-345.

This paper reports that dose related reductions in FEV1 was more pronounced in smoking workers exposed to cotton dust. No FEV1 reaction was observed in students exposed to dust levels of 0.58 mg/m^3, and endotoxin levels of 0.17 $\mu g/m^3$. Smoking workers displayed no FEV1 reaction for dust levels of 0.43 mg/m^3 and 0.08 $\mu g/m^3$ for endotoxin. A better correlation was observed between endotoxin concentrations and decreased FEV1, than for dust levels.

Endotoxin results for this study may be unreliable because the authors do not identify if LAL assay interference tests were carried to check for possible enhancement or inhibition of the assay.

Haglind P, Bake B & Rylander R, 'Effects of endotoxin inhalation challenges in humans', in *Proceedings from the Beltwide Cotton Conferences*, vol. 1, pp.105-106.

This paper reports that exposure of humans to pure lipopolysaccharide caused a decrease in the forced expiratory volume in one second (FEV_1), in comparison to subjects exposed to sodium chloride. The decrease in FEV_1 was visible for up to 4 hours after the final exposure.

Hagmar L, Schutz A, Hallberg T & Sjoholm A 1990, 'Health effects of exposure to endotoxins and organic dust in poultry slaughter-house workers', *International archives of occupational and environmental health*, vol. 62, pp. 59-64.

This report assesses the health of workers in a poultry slaughterhouse.
23 dust-exposed workers were tested before and after work. Tests included interview, pulmonary function tests (VC and FEV1) and blood sampling. The breathing zones were also monitored. Spot samples of airborne bacteria were collected.

	Total dust	Endotoxins	Airborne bacteria	fungi
mean	6.3 mg/m^3	0.4 $\mu g/m^3$	4 x 1000000 CFU/m^3	500-4000 CFU/m^3

Workers had an over-shift increase in respiratory symptoms but no extrinsic allergic alveolitis or Organic dust toxic syndrome. Also mean over-shift decreases of VC and FEV1.

There was no association between over-shift decreases and the individual time weighted average breathing zone levels of total dust or endotoxin.

Hameed A, & Khodr M I 2001, 'Suspended particulates & bioaerosols emitted from an agricultural non-point source', *Journal of Environmental Monitoring* (JME), vol.3, pp. 206-209.

In Egypt, suspended particulate and bioaerosol levels were measured downwind of a non-point source during wheat harvesting. Viable bacterial counts were found between 10^4 and 10^6CFU mg/m^3. Gram negative concentrations were between 10^3 and 10^5 cfm /m^3. Fungi levels were between 10^5 and 10^6 CFU/m^3. *Cladosporium* and *Alternaria* were the predominant species of fungi. *Pseudomonas, Acinetobacter* and *Enterobacteriaceae* were the dominant Gram –ve bacteria. This article is about wheat, but it makes reference to these bioaerosol concentrators being found outside of the place where they are generated, which is important, with many animal handling buildings using natural ventilation.

Hanhela R, Iivonen E, Leskinen L, Kalliokoski P & Husman K 2002, 'The effect of working conditions on development of occupational asthma in Finnish dairy farms, *Iioha 2000 Conference*, Cairns, Australia, July 2000

This paper is has been printed as a abstract in the proceedings reports looks at the self reporting of asthma on a questionnaire and the condition in they the participants work and live. The majority reporting asthma had work with diary cattle. Those who still worked in the field use air purifying respirators. This paper reports that the main cause was identified as statistically significant was microbes but dusts and carbon dioxide was also high but not statistically significant. Types of work were considered and the brushing of the cows along with the methods of preparing the food was considered to be the main factor.

Hanhela R, Louhelainen K, & Pasanen AL 1995, 'Prevalence of microfungi in Finnish cow barns and some aspects of the occurrence of Wallenia sebi and Fusaria.' *Scandinavian Journal of Work Environmental Health*, vol.21, pp. 223-228.

This study consisted of 32 farms of various ages. The number of milking cows on each farm varied from 6 to 24 samples were collected both on a filter at 2 L/min and then extracted and using a 6 stage Anderson Cascade Impactor at 28.3 L/min. Total fungal spores ranged from 10^5 to 10^7 CFU/m^3. This paper also identified a number of spores present including *aspergillus*, *penicillin, wallemia sebi*, *absidia,* yeasts and sterile mycelia.

Heederik D, Brouwer R, Biersteker K & Boleij JSM 1991, 'Relationship of airborne endotoxin and bacteria levels in pig farms with the lung function and respiratory symptoms of farmers', *International Achieves of Occupational and Environmental Health*, vol. 62, pp. 595-601.

This study was undertaken to investigate the relationship between symptoms, lung function, endotoxin, ammonia and dust levels in piggeries. 183 farmers from 136 farms in Netherlands were tested. Farms were identified by a national organising body for pig farmers. To ensure a high and similar level of exposure amongst farmers, farms were selected on the basis that pig farming contributed to 60% or more of the farm income and at least 80% of the animals were housed under similar conditions. Of 500 farms approached, 273 agreed to participate. From the latter, farms were randomly selected to participate. This paper presents the findings for 183 male farmers from 136 farms (average age 36.8 years). Respiratory questions based on previously developed questionnaires including by the British Medical Research Council. Forty percent reported at least one respiratory symptom and 52% reported symptoms during or shortly after work. The prevalence of most symptoms was between 10% and 20%, some with a higher prevalence during or after the work shift eg, cough, 15.8% vs 19.7% during or after the shift. Environmental measurements were carried out in over 167 buildings. The geometric means were; total dust 4.01 mg/m^3, ammonia 4.41 mg/m^3, endotoxin 130 mg/m^3. Total (geometric mean 1.073 CFU/m^3) and gram negative (geometric mean 0.077 CFU/m^3) bacterial levels were from a smaller number of buildings (62).

Multiple regression analyses were carried out with various lung function tests (FVC, FEV_1, MMEF, $MEF_{75\%}$, $MEF_{50\%}$ and $MEF_{25\%}$) as the independent variable and environmental measures as the dependent variables and adjusted for height, age and smoking habits. In the case of the large datasets (excluding bacterial count findings), the findings were not statistically significant, although negative in direction for a number of associations eg, FVC and endotoxin levels. The ∃ coefficient for endotoxin level and FEV_1 was found to be statistically significant only in one model where bacterial levels were also included.

Odds ratios for symptoms according to exposures were adjusted for smoking status and age. These were statistically significant for at least one and most individual symptoms during or at the end of work, and exposure to gram negative bacteria (shortness of breath, sputum, shivering, perspiration and clogged nose $p<0.05$). A dose response relationship was evident for symptoms and exposure to three categories of endotoxin levels. The difference between each category was statistically significant (<0.05) for at least one symptom.

The methods of collecting exposure data followed the method outlined by Attwood et al. 1987, a study of the relationship between airborne contaminants and environmental factors in Dutch swine confinement buildings. *American Industrial Hygiene Association Journal,* vol. 48, no. 8, pp. 745-751.

The results of the static sampling are geometric means of 4.01 mg /m^3 for total dust, 1.31 mg/m^3 for Thoracic dust, 130 ng/m^3 for endotoxin, 1.073 x10^5 CFU/m^3 for total bacteria and 0.077x x10^5 CFU/m^3 for gram negative bacteria.

Heederik D, Douwes J, Wouters I & Doekes G 2000, ‘Organic dusts: beyond endotoxin’, *Inhalation Toxicology*, vol. 12 (supp 3), pp. 27-33.

The review article identifies that other organic dust constituents with similar immunological and inflammatory properties to endotoxin include β- (1-3)-glucans, peptidoglycan. The article states that these substances are currently being researched, and that they may serve as markers for exposure to fungi (β- (1-3)-glucans) or gram-positive bacteria (peptidoglycan) in occupational environments.

Hinz T & Linke S 1998, ‘A Comprehensive Experimental Study of Aerial Pollutants in and Emissions from Livestock Buildings. Part 2: Results’, *Journal of Agriculture and Engineering Research*, vol. 70, pp. 119-129.

This paper outlines the results of the above study. Ventilation rate was highest in seasons that had higher temperatures. The average inhalable dust concentration was between 1 and 5 mg/m^3. During daytime period the concentration was found to be higher. The average concentration of ammonia was between 10 and 35 ppm.

Hinz T, & Linke S 1998, ‘A comprehensive experimental study of Aerial Pollutants in and Emissions from Livestock Buildings. Part 1: Methods’, *Journal of Agricultural Engineering research*, vol. 70, pp. 111-118.

This study is a comprehensive experimental study in both force-ventilated fattening piggery and a naturally ventilated broiler house to verify past measurements regarding the influence of livestock species and management strategies on pollutant emissions.

Force ventilation was measured directly using fan-wheel anemometers and by the C02 balance method. Inhalable dust concentration was measured with a gravimetric procedure, a micro-balance using a mass-sensitive oscillator measured dust concentration. Concentrations of gaseous components CO2 and NH^3 were detected with photo-acoustic multi-gas monitor. For NH^3, absorption tube and wet chemical analysis was used. Results were reported in a second paper.

Hoffmann HJ, Iversen M, Brandslund I, Sigsgaard T, Omland O, Oxvig C et al. 2003, 'Plasma C3d levels of young farmers correlate with respirable dust exposure levels during normal work in swine confinement buildings' *Annals of Agricultural and Environmental Medicine*, vol. 10, no. 1, pp. 53-60.

This paper reports on inflammatory response and its association with increased levels of acute phase proteins.
Compared inflammatory response of a control group of young former farmer workers with age-matched former farm workers who had developed the lower airways symptoms of wheeze, cough, tightness of the chest during work in swine buildings and had ceased work due to these symptoms.

Groups were subjected to an experimental exposure in a swine confinement building for 3 hours. Complement activation and acute phase proteins were measured in blood samples, and broncho-alvecular lavage.

Plasma C3d levels correlated with respirable dust, significantly so for individual cases and for the whole group.

Plasma C3, fibrinogen and a1-acid glycoprotein peaked 1 and 6h after exposure start, mannam-binding lectin, C-reactive protein and a-antitrypsin peaked after 2 hrs.

Surfactant protein D (SP-D) and a2-macroglobulin were down-regulated.

In lavage, only SP-D, a1-macroglobulin and fibronectin were detected. FEV1, FVC, TLC and FEV25-75 did not vary during exposure.

Assessed by collecting inhalable dust with person-borne collectors, and analysing the dust for LPS content by the LAL method. (BioWhittaker, Walkersville USA). And particle size distribution.

Location	**Respirable dusts** (mg /m^3)	**Inhalable dusts** (mg /m^3)	**Respirable Endotoxin** (EU /m^3)	**Inhalable Endotoxin** (EU /m^3)
Workers	0.14±0.10	4.10±1.13	2.45±3.39	37.7±61.2
Controls	0.14±0.05	4.51±1.42	8.18±15.28	111.2±183.7

Holglund S 1986, 'Prevention of Respiratory Problems in Agriculture', *American Journal of Industrial Medicine*, vol. 10, pp. 245-247.

This is a very short article outlining different prevention methods, to reduce respiratory problems. It covers, primary prevention (laws), Secondary prevention (education), and the role of the health care system.

Holglund S 1994, *Agricultural Preventive Occupational Health Care Systems. Organic Dusts*, R. Rylander, and Jacobs, R. R. Boca Raton, Lewis Publishers.

This is a book section and outlines the current health care system that is in place for agricultural workers through out the world, with particular emphasis on Scandinavian countries. It includes some good information on increasing involvement in prevention strategies.

Hollander A, Heederik D, Verslooy P & Douwes J 1993, ‘Inhibition and Enhancement in the analysis of airborne endotoxin levels in various occupational environments,’ *American Industrial Hygiene Association Journal*, vol. 54, pp.647-653.

This is a study on the enhancement and inhibition effects on the LAL assay in endotoxin samples collected from various occupational environments. It showed that large differences could exist depending on the dilution at which the sample is analysed. QC techniques need to be included to standardize methodology.

Samples came from animal feed industry, potato starch processing, swine buildings, synthetic textile and composting industry. Samples were diluted into 10-2 serial dilutions and 100 *u*l analysed in a microtitre well. The optical density was read automatically.

Holness DL, O’Blenis EL, Sass-Kortsak A, Pilger C & Nethercott JR 1987, ‘Respiratory effects and dust exposures in hog confinement farming’, *American Journal of Industrial Medicine*, vol. 11, no. 5, pp. 571-80.

This report addresses the health of farmers in swine confinements.

Pulmonary function, total and respirable personal dust levels and responses to a health questionnaire were obtained.

The pig farmers total and respirable dust totals were significantly higher than the retrospective levels of the control farmers. Higher levels of dust were associated with floor work (eg scatter feeding), indoor feed grinding and the use of high moisture corn feed.
Dust levels in piggery

	Geometric mean
Total dust (mg/m^3)	2.06
Respirable dust (mg/m^3)	0.17

Pig farmers report respiratory symptoms significantly more often than controls. Lung function did not differ between the two groups of farmers, nor could the dust exposure levels be related to lung function.

Holyoake T 2002, ‘*Developing a Safe Environment for People Working in Pig Production Systems*’, Report No 1618, Prepared for Australian Pork Ltd, Canberra.

This is a report on a project to ascertain the exposure of workers in the pig industry to a number of air pollutants including dusts, endotoxins, ammonia and carbon dioxide. The report also looks at some methods that may reduce exposure.

Samples were collected using techniques specified in AS AS 3640–*Workplace atmospheres—Method for sampling and gravimetric determination of inspirable dust*, for inspirable dusts. For respirable dusts they used the techniques now specified in AS 2985–2004 *Workplace atmospheres—Method for sampling and gravimetric determination of respirable dust*. The filters were analysed for endotoxin using the QCL 1000 endpoint method of amebocyte lysate assay, which is one of the more common methods for endotoxin analysis.

Both personal and static samples were collected. In addition bacterial samples were collected using a 6-stage Anderson Cascade Impactor but no flow rate was reported. In the study the types of bedding was compared. 17 worker personal exposures were report but are summarised below depending on the type of pig activity and bedding. The results have been grouped in relation to the type of activity and bedding that would be expected to have similar exposures.

Table 10: Personal Exposures based on bedding type

Housing	Bedding Type	Dust Levels (mg /m^3)		Endotoxin (EU /m^3)	
		Respirable	Total	Respirable	Inhalable
Weaner (early)	straw/hulls	0.68	12.39	686.7	1004.7
	rice hulls	1.83	24.40	1832.5	2117.1
Weaner (late)	rice hulls	0.22	1.64	423.5	452.3
Grower (early)	rice hulls	0.49	6.49	1029.5	1231.4
Grower (late)	straw/hulls	0.41	4.86	695.1	1707.1
	rice hulls	0.68	2.73	330.5	1099.1
Handling Bedding using Manitou	straw	0.21	0.86	866.4	983.2
Manually Handling Bedding	straw	1.90	21.46	869.4	1104.7
Handling Bedding using Open bobcat:	rice hulls		15.62		

Table 11: Static sampling based on bedding type

Pig Age	Bedding Type	Dust Levels (mg /m^3)		Endotoxin (EU/m^3)		Bacteria (CFU/m^3)
		Respirable	Total	Respirable	Inhalable	
Weaners (early):	old straw	0.68	5.08	843.9	757.1	1.87×10^6
	new straw					0.82×10^6
	rice hulls	0.87	7.6	533.3	674.9	2.18×10^6
Weaners (late)	rice hulls	0.99	2.63	858	1192.5	0.71×10^6
Growers (early:	adding straw	0.38	2.43	831.5	935	0.021×10^6
	adding hulls					0.295×10^6
Growers (late)	rice hulls	0.08	0.52	633	487	0.15×10^6
	straw/hulls tattooing	0.14	1.66	433.9	633.6	0.33×10^6
	removing straw	0.14	0.11	637.9	394.9	0.007×10^6
	removing hulls					0.07×10^6

Exposures have also been monitored in sheds with concrete floors and stage of pig development.

Table 12: Personal Exposures in Sheds with Concrete Floor

Pig Stage	Activity	Dust Levels (mg/m^3)		Endotoxin (EU/m^3)	
		Respirable	Total	Respirable	Inhalable
Farrowing	entire	0.15	2.10	480.3	624.6
	treatments	0.09	1.17	1197.8	990.3
Dry sow	loadout	0.31	3.47	783.2	939.7
Dry sow	entire	0.12	4.18	1105.5	ND
Gilt	gilt selection	0.42	5.05	969.5	332.3
Weaners	moving in, fixing silo		2.57		1153.8
Weaners	moving out	0.48	6.57	505.1	973.6
W/G/F	treatments	0.56	2.7	770.9	892.2
Grow/Fin	entire	0.12	0.4	1010.8	991.2

Table 13: Static Results in Sheds with Concrete Floor

Pig Age	Dust Levels (mg/m^3)		Endotoxin (EU/m^3)		Bacteria (CFU/m^3)
	Respirable	Total	Respirable	Inhalable	
Farrowing	0.49	2.46	776.1	1132.3	0.14×10^6
Dry sow/load out	0.07	1.53	193.9	271.2	0.17×10^6
Dry sow	0.71	0.89	440.2	1317.3	0.21×10^6
Gilt selection	0.15	4.23	722.3	229.9	0.08×10^6
Weaner-moving in	0.26	1.72	1011.3	13.6	0.04×10^6
Weaner-moving out	0.39	3.19	1028.1	1145.2	0.09×10^6
Grow/finish	ND	1.91	ND	398.9	0.24×10^6

The strength of this report is the personal data collected on workers exposures.

Hoppin JA, Umbach DM, London SJ, Alavanja MCR & Sandler DP 2003, 'Animal production and wheeze' in the *Agricultural Health Study: interactions with atopy, asthma, and smoking.*

This paper reports on a cross-sectional study of baseline data from the cohort of Iowa and North Carolina farmers enrolled in the Agricultural Health Study. All farmers were registered pesticide users. The findings are of data from two baseline questionnaires completed by 39% (20,468 farmers) of the original cohort. The respondents were not significantly different from non respondents in farming demographic characteristics, farming practices and medical history.

Data on symptoms of wheeze in the previous 12 months (19% of respondents) were analysed according to different farming groups and the confounding and interactive effects of smoking, atopy and asthma were statistically assessed by logistic regression modelling. The ORs reported were adjusted for age (subjects ranged in age from 16 to 88), state (Iowa or North Carolina), smoking status (past or current) and two interaction terms (atopy*asthma status, asthma*current status. The highest ORs were found in farmers involved in poultry and egg farming activities. The estimates for these were 1.36 (95% CI 1.13, 1.62) and 1.70 (95%CI 1.28, 2.26) respectively.

To control for the effects of different types of farming, the authors included all types of animals in their models. They found that ORs were attenuated but remained statistically significant for dairy, cattle swine and eggs. The figures were not reported.

Statistically significant trends were found for increasing symptoms of wheeze according to the number of animals for poultry and livestock farmers and frequency of activities for milking and veterinary procedures, measured for the preceding 12 months. For poultry, eggs and beef cattle, atopy was associated with a higher likelihood of wheeze than that of asthma alone or the presence of both. Whereas in dairy cow and milk production, the presence of both was associated with the highest odds ratios.

A confusing finding was the effect of smoking status. Current smokers had the lowest ORs, and past smokers the highest for dairy, poultry and egg farming as well as those involved in the butchering activities. People who never smoked were intermediate. The authors attribute this to a self selection effect of farmers. This was supported by the finding that past smokers also had the largest OR associated with egg production (2.88: 95%CI 1.81, 4.59).

International Journal of Occupational and Environmental Health 1997, '*Endotoxins in the environment: A criteria document*', vol. 3, S1-S48.

This article presents the available scientific about endotoxins in the environment, exposure effects (epidemiological and human experimentation) and safety guidelines for endotoxin exposure. This is an informative article divided into 8 sections. Although published in 1997 it is a very comprehensive article.

Summary of each section:

Section 1 - Endotoxins in the environment. Endotoxins are found in many working environments with pulmonary symptoms to those affected being very similar clinically. Areas where plant or animal products are handled or where materials become bacterially contaminated (with gram-negative bacteria- i.e. that produce endotoxins) may expose humans to aerosols containing endotoxins. Common environments are; agricultural (grain feed, animal breeding, dairy farming, animal confinement, livestock transport etc.), industrial (biotechnology, fermentation, pharmaceutical, wood processing, animal food production etc.), waste processing (composting, sewage), buildings (mould, humidifiers). Examples of endotoxin exposures in these environments are given- in the agricultural field the highest levels were found in swine and poultry facilities. In industry, highest endotoxin levels were found in potato processing, cotton, biotechnology and breweries. Much lower levels were found in waste processing and in buildings.

Section 2 - Endotoxin structure.

Section 3 - Biochemistry and Cell biology of endotoxins. Very complex description, for background information for clinicians, biologists and chemists.

Section 4 - Human challenge studies with endotoxins. This summarises various experimental challenges (inhalation, intravenous and skin tests) to endotoxins. The methods used and responses obtained are described in detail. Inhalation challenges are designed to define a no-effect threshold value - determined by dose-response relationship and evaluation of the intrasubject reproducibility of responses.

Section 5 - Epidemiologic investigations of endotoxins. This discusses large investigative studies of groups exposed to different levels of endotoxins from different environments. Under the heading 'Acute over-shift effects' one study of cotton workers in 1992 (i.e. relating respiratory disorders and dust and endotoxin exposures) measured baseline and cross shift lung function, symptoms as well as personal respirable dust levels. Mean 7 hr exposures to respirable dust showed levels of 0.17 to 0.58 mg/m^3 and 9 to 126 mg/m^3 for respirable endotoxin. Another study of fibreglass workers in 1996 showed endotoxin levels as slow as 4-15 ng/m^3 caused acute lung effects. This industry has no organic dust exposure.

Under the heading 'Chronic Effects' in the general population, in one study, endotoxin levels between 0,12 to 20 $ng/\ m^3$ were detected in homes. There was no correlation between house dust mite concentrations and endotoxin levels. Subject exposed to high level endotoxins showed respiratory symptoms, whereas no difference was found between high and low levels of exposure based on dust and house dust mite concentrations.

In occupational settings, numerous studies are discussed.

- Most importantly in this section 5, several epidemiologic studies have shown a dose-response relationship being found between endotoxin levels (i.e. chest tightness etc.) but not for respirable dust. Field studies have shown similar health effects to challenge (experimental) studies using pure endotoxins. This article states that endotoxins play an important etiological role in acute and chronic lung diseases in working environments where organic dust and bioaerosols are prevalent.

Section 6 - Evaluation of the risks of endotoxin exposures.

It is suggested here that a dust standard may not be sufficient to prevent workers from getting acute and chronic respiratory health effects. Organic dusts containing endotoxins should not be regarded as 'nuisance dusts'. Organic dusts also contain many other components (mycotoxins, bacterial enzymes, other biological active agents) as well as endotoxins (i.e. known as causing human ill effects). Endotoxins could be a 'marker' for some or several of these other biological agents found in organic dust.

This section also discusses exposure levels, exposure effects (toxic pneumonitis, airway inflammation, chronic bronchitis, HP, asthma, systemic effects) and guidelines. Guidelines suggested by several studies show no effect endotoxin levels of 200 ng/m^3 (for toxic pneumonitis), 10 ng/m^3 (for airways inflammation) and 100 ng/m^3 (for systemic effects). It is also mentioned that a standard assay test for endotoxin detection is needed.

Section 7 - Environmental monitoring of endotoxins. Need to consider; area vs. personal sampling, particle size selection, sampling time and filter type, pore size and diameter.

Area vs. personal sampling- personal samples suggested (not high volume samples)

Particle size- smaller dust fractions contain greater amounts of endotoxin/ unit weight of dust. As endotoxin biological activity is not limited to the gas-exchange areas of the lung, sampling should represent the endotoxin burden throughout the whole respiratory tract. Based on endotoxin- dose response data, the author suggests endotoxin analysis be collected with either thoracic or total dust samplers and aseptic technique should always be used. Sampling time - when dust levels are low, longer sampling times (e.g. up to 8 hrs) are not a problem as the endotoxin can be diluted out. But if dust levels are too high and sampling time too long, the filters become too loaded and samples may be lost during transport. Filter size, pore size/diameter- the authors recommend glass fibre filters.

This section also discusses sample analysis extraction, sample storage, and bulk sampling collection. They recommend- personal samplers (glass fibre filters), sampling time (depends on dust levels), sample storage (aseptic, store in dark enclosed containers at room temp), extract endotoxin sample using pyrogen free water, extract stored (>24 hrs) at –80C, 4C (if <24 hrs).

Section 8 - Analysis of endotoxins. This describes some methods in great detail and their limitations- e.g. the limulus amebocyte lysate assay (LAL) gel-clot test commonly described- has problems in being only semi quantitative, is prone to false negatives, has high assay variability, not good correlation between test performed by different labs.

Iowa State University, 1992, '*Livestock confinement dusts and gases'*, The national dairy database.

A fairly introductory paper, this report looks at the impact of hazardous dust in livestock housing.

Defines and explains:

-Confinement housing and its hazards
-Dusts and gases and their implications for human health.
-Who is exposed to dust and when
-How common is exposure
-Respiratory effects of inhaling confinement house dust and gases
-Prevention.

Iversen M & Dahl R 1994, 'Specific antigens in dust from swine confinement buildings', *American Journal of Industrial Medicine'*, vol. 25, pp. 49-51.

This report is the conclusion of a 7 year follow up of 180 swine farmers. It assessed FEV1, forced vital capacity, bronchial reactivity and respiratory symptoms. Farmers who worked exclusively with pigs in the follow up had an accelerated decline in FEV1, but not in FVC compared with dairy workers, where the decline in FEV1 was close to the expected.

Working in swine confinement units causes an accelerated decline in forced expiratory volume in one second but not in forced vital capacity. The mean decline is 0.5L during a working life and some farmers will develop clinically significant airway obstruction due to work in swine confinements.

Iversen M & Dahl R 2000, 'Working in swine-confinement buildings causes an accelerated decline in FEV_1: a 7-yr follow-up of Danish farmers'. *European Journal of Respiratory Disease,* vol. 16, pp. 404-408.

The method of subject selection in this longitudinal cohort study is referred to in a previous paper referring to baseline findings. The original cohort was comprised of 181 farmers from medium to large farms. The follow-up findings for 132 are reported; 94 pig farmers and 38 dairy farmers. The same symptom and exposure history questionnaires were used at follow-up. Spirometry and a histamine challenge test were repeated at follow-up. Again the authors stated that the same methods were used at baseline. Participants and non participants did not differ significantly in height, age or hours worked in a confinement building. However non participants were at significantly higher respiratory risk with significantly more smokers and lower FC and FEV1 and work related respiratory symptoms and baseline. Given this the findings probably underestimate the change in lung function in swine farmers over time. Stratified and multivariate analyses were used to deal with confounding and interactions. There was no significant difference between the two groups of farmers in the histamine challenge findings. Only swine farmers reported asthma like work related symptoms at 11%. The annual decline in FEV1, adjusted for height, age and pack years of cigarettes smoked was significantly higher in swine farmers, 53.8mL versus 41.8 in dairy farmers. No significant difference was found for FVC. Baseline findings from a histamine provocation test were not significant predictors of decline in FEV1. Swine farmers with respiratory symptoms were more likely than asymptomatic swine farmers to be smokers, to have airways obstruction (lower FEV1/FVC ratios) and larger annual declines in FEV1. However, none of these comparisons were statistically significant.

Iversen M & Pederson B 1990, ‘Relation between respiratory symptoms, type of farming, lung function disorders in farmers’, *Thorax*, vol. 45, pp. 919-923.

A random sample of 124 pig and 57 dairy farmers (aver age 43 yo) was taken to determine lung function and respiratory symptoms. Farmers worked in large farms (minimum 30 cows and 300 pigs). Detailed questionnaire/interviews were undertaken, lung function tests undertaken (also using histamine (PC_{20}) hyperreactivity testing. PC_{20} values less than 32mg/ml defined bronchial hyperreactivity - arbitrary value). Results were analysed using X^2 and odds ratio.

The table below shows a significant difference between SOB, wheezing and dry cough at work between the pig and dairy farmers.

These results agree with several previous studies showing the prevalence of work related, respiratory symptoms in pig farmers. The reason for pig farmers being more prone is not known (as of 1990 when this article published- a bit dated) but dust is stated as the probable cause.

Authors conclude that work in pig rearing units is to be considered a pulmonary hazard and some farmers will develop obstructive airways problems. Symptoms such as SOB, wheezing require further medical assessment.

Table 14: Characteristics of 181 farmers

	Pig farmers (n 124)	**Dairy farmers** (n 37)	**p**
Mean age	42.8	43.4	0.75
% work related symptoms			
SOB	30	6	<0.01
Wheezing	21	2	<0.01
Dry cough	32	4	<0.01
Any symptom	39	5	<0.01
% with aggravation of resp symptoms by:			
Physical exercise	18	7	0.08
Cold air	13	0	0.01
Tobacco smoke	19	4	0.01
Coryza (URT symptoms)	22	11	0.08
% current smokers	20	33	0.19

Iverson M, Dahl R, Korsgaard J, Hallas T & Jensen EK 1988, ‘Respiratory symptoms in Danish farmers: an epidemiological study of risk factors’, *Thorax*, vol. 43, pp. 872-877.

This paper is the report of an epidemiological study with a self administered questionnaire sample of 1175 Danish farmers. The prevalence of symptoms; wheezing at work, asthma, chronic bronchitis was reported and possible risk factors for respiratory illness were determined. Farms were mainly dairy farming, pig farming and mixture of these. Farms were similar to national average for Denmark (i.e. small to med size- < 50 hectares). Results in table 3- related to type of farming. Statistical analysis was made by using a 2 dimensional contingency table, logistic regression (multivariate analysis).

Table 15. Relation of type of farming to age, smoking, symptoms (%)

	Type of farming			
	No. of animals (n =287)	Dairy (n=20 3)	Dairy & pig (n=316)	Pig (n=369)
* Age > 50 yo	53.8	43.1	65.8	54.5
* Full time employment	37.8	88.5	77.8	81.4
+ Hay fever	8.1	7.6	9.6	13.3
+ Asthma	7.5	5.5	6.4	10.9
+ Treatment for asthma	2.2	1.5	3.6	5.3
* Cough/daily phlegm production	18.6	17.5	28.4	32
* Shortness of breath	14.4	12.5	19	23.1
+ Wheezing	16	13.5	27.1	26.2
* Dry cough	22.8	20.6	28.2	37.2
+ Smoking	35.1	41.9	37.1	35.7
* Symptoms during work hrs	-	7.4	11.6	28.3

Where * P (X2) <0.01 + P (X2) = NS

Results showed: Asthma prevalence of 7.7%, chronic bronchitis 23.6%. Logistic regression showed correction for age and smoking, pig farming had a risk factor for asthma (with an Odds ratio of 2.03), chronic bronchitis (OR 1.53) and wheezing (OR 3.33). Pig farmers had twice as high a frequency of hay fever, asthma, and respiratory symptoms compared to dairy farmers (see Table 3). The OR for respiratory symptoms and work in animal houses and pig farming was significant with a value of 3.41.

Risk factors determined from this study:

- age and pig farming risk factors for self reported asthma (in the literature pig farming has been reported as increasing risk of chronic wheezing, cough- but not a risk factor for self reported asthma as in this study). Author suggests further studies needed to determine whether this is causally related to high loads of respirable dust or toxic gases in piggeries
- Smoking and pig rearing- risk factors for SOB, wheezing, cough (w/o phlegm production)

This is a dated article 1988, so the point above (re piggeries and self reported asthma may no longer be a valid comment).

Jacobs RR 1989, ‘Airborne Endotoxins: An Association with Occupational Lung Disease’, *Applied Industrial Hygiene*, vol. 4, pp. 50-55.

Jacobs discusses physiochemical features, biological activities and clinical symptoms related to endotoxin exposure. The measurement of endotoxin is discussed (methods used include; respirable dust sampling, extraction and LAL assay, total dust sampling etc.). Jacobs suggests that a TLV for endotoxin needs to be established. He suggests that perhaps the measurement of endotoxin levels is a more accurate predictor of respiratory health effect (i.e. for acute changes in pulmonary function) than measuring gravimetric dust.

The author mentions previous studies show endotoxin levels of greater than 50 ng/m^3 have been detected in swine buildings, grain storage, poultry houses, cotton and flax mills. Also high levels in wood chipping facilities saw mills, animal handling areas and grain handling. One study of cotton workers showed endotoxin levels less than 10 ng/m^3 had a no-group response that showed no difference from groups not exposed. However, in groups exposed to greater than 50 ng/m^3 the group responses were significantly different to the non- exposed.

Jejda J, Barber E, Dosman J et al. 1994, ‘Respiratory Health status in swine producers relates to endotoxin exposure in the presence of low dust levels’, *Journal of Occupational Medicine,* vol. 36, pp. 49-56.

This report surveyed 54 male swine farmers to find the average working conditions. The average age for a swine farmer was 36.3, and had worked in the industry for an average of 10.7 years. They spent 4.7 hours per day in the swine farm.

Carbon dioxide	2632 ppm
Ammonia	11.3 ppm
Total dust	2.93 mg/m^3
Respirable dust	0.13 mg/m^3
Endotoxin	11332 µg/m^3

Respiratory symptoms and lung function studies did not relate to categories of low, medium and high exposure to respirable dust. However, categories of endotoxin related to respiratory symptoms. This data suggested that respiratory health status relates to endotoxin levels but not to dust level exposures in the presence of low dust levels and indicates that control measures should include endotoxin as well as dust levels.

Karlsson K, & Malmbergm P 1989, ‘Characterization of exposure to moulds and actinomycetes in agricultural dusts by scanning electron microscopy, fluorescence microscopy and the culture method.’ *Scand Journal Work Environ Health*, vol. 15, pp. 353-359.

Air samples from 79 Swedish farmers were analysed by scanning electron miroscopy, fluorescence microscopy and the culture method. The total count for microorganisms was similar for all three techniques. When the counts were assessed by CFU’s the average count was one-sixth of the total count.

Kift RL, Davidson ME, Mulley RC & Reed SG (2004), ‘Is there a possible health risk workers while working with sheep and wool?’ *Collage of Science Technology and the Environment (CSTE) 'Innovation' Conference,* Penrith, NSW, University of Western Sydney.

This paper is from an Australian study that sampled for the concentrations of respirable and inspirable dusts (sample rate at 1.9 and 2 L/min, respectively) according to AS2985 and AS3640. The sampling period was for 2 –hours and was conducted 3 times during the sampling day. The bioaerosol concentrations were also found using an Andersen Instruments 2-stage bioaerosol impactor according to a method developed by Kift, 2002. The samples were taken from 2 sheep shearing sheds on three different occasions in the central highlands of NSW. The sampling was undertaken in summer and found:

Location	**Respirable Dust** (mg /m^3)		**Inspirable Dust** (mg /m^3)	
	Static Sampling Result	Personal Sampling Result	Static Sampling Result	Personal Sampling Result
Farm 1a (16-2-04)	-	1.07±0.45(4)	0.51± 0.12(6)	1.93±0.67 (4)
Farm 1b (4-3-04)	-	0.17±0.04(6)	0.56± 0.06(9)	1.94±0.38(6)
Farm 2 (19-3-04)	0.22±0.03 (3)	0.24±0.04(3)	0.64±0.10 (12)	1.06± 0.26(3)

Location	Respirable dusts (mg /m^3)	Inspirable dusts (mg /m^3)	Bacteria (CFU /m^3)	Fungi (CFU /m^3)
Farm 1a (16-2-04)	1.07±0.45(4)	1.08± 0.34(10)	2781±596 (12)	4854±611 (12)
Farm 1b (4-3-04)	0.17±0.04(6)	1.11±0.23(15)	6146±1941(18)	5706±1019(18)
Farm 2 (19-3-04)	0.23±0.02(6)	0.72±0.10(15)	2668±296(18)	3525±412(18)

The paper concluded that the sheds sampled were not over current recommended standards for dust and bioaerosols.

Kift RL, Mulley RC & Reed SG 2004, ‘Potential health effects of exposure to dust from handling deer’, *Aust Deer Farming,* Winter, pp 17-22.

Is a review for a professional journal on what was found in the study of worker exposure to dust and bioaerosol. Most of the dato in the article have previously been presented in the paper by Kift et al. 2002a. In addition the following data was presented.

Table 16: Types of fungi found at each farm and percentage of each type. Number of samples collected at each farm is shown in brackets ( )

	Zygomycota %	**Ascomycota %**	**Basidioycota %**	**Deutermycota %**
Farm A (64)	8	41	13	39
Farm B (35)	0	40	20	40
Farm C (42)	2	36	26	36

Table 17: Percentage of different Types of Fungi Measured at Each Site. Number of samples collected at each farm is shown in brackets ( )

	Gram Positive %	**Gram Negative %**
Farm A (22)	82	18
Farm B (18)	72	28
Farm C (19)	89	11

Kift RL, Reed SG & Mulley RC 2002a, 'Inhalation exposure to dusts and bioaerosols of workers handling deer', *AIOH2002 Conference*, Geelong, Victoria, Australia, pp. 136-143.

This paper reported on repeat monitoring undertaken at 3 deer farms inside the animal handling building. The results measured in this study averaged at 1.64 mg mg/m^3 for respirable dusts and 2.27 mg mg/m^3 for inspirable dusts. The average level of fungi measured was 905 CFU mg/m^3. The bacteria levels measured were 2529 CFU mg/m^3. In relation to the bacteria identification they were only identifies as gram positive and gram negative with the majority being gram positive.
The respirable data was collected using a cyclone at flow rate of 1.9 L/min; inspirable at a flow rate of 2 L/min and the bioaerosol were collected on agar plates using a 2 stage Anderson impactor at a flow rate of 28.3 L/min.

Table 18: Mean (± SE) Respirable and Inspirable Dust Levels for Each of the Deer Handling Sheds Monitored During Routine Deer Management Procedures. Number of samples collected at each farm is shown in brackets ( )

Location	Respirable (mg /m^3)	Inspirable (mg /m^3)
Farm A	2.75 ± 1.81 (6)	2.99 ± 1.21 (11)
Farm B	1.54 ± 0.65 (6)	1.90 ± 0.55 (11)
Farm C	0.63 ± 0.33 (7)	1.92 ± 0.44 (10)

Table 19: Mean (± SE) Bacteria Counts for Each of the Deer Handling Sheds Monitored During Routine Deer Management Procedures. Number of samples collected at each farm is shown in brackets ( )

Location	Before Use (CFU /m^3)	During Use (CFU /m^3)	After Use (CFU/m^3)
Farm A	2034 ± 969 (9)	7048 ± 1255 (9)	3454 ± 771 (9)
Farm B	456 ± 132 (9)	2454 ± 610 (9)	700 ± 340 (9)
Farm C	1086 ± 490 (6)	4609 ± 868 (9)	830 ± 135 (6)

Table 20: Mean (± SE) Fungi Counts for Each of the Deer Handling Sheds Monitored During Routine Deer Management Procedures. Number of samples collected at each farm is shown in brackets ( )

Location	Before Use (CFU /m^3)	During Use (CFU /m^3)	After Use (CFU/m^3)
Farm A	677 ± 213 (9)	3785 ± 754 (9)	645 ± 89 (9)
Farm B	113 ± 38 (9)	167 ± 46 (9)	31 ± 9 (9)
Farm C	49 ± 16 (6)	2599 ± 1119 (9)	84 ± 14 (6)

Kift RL, Reed SG & Mulley RC 2002b, ‘Development of a Method for Bioaerosol Sampling in the Agricultural Industries’, *AIOH2002 Conference*, Geelong, Victoria, Australia, pp. 130-135

This paper investigated a method of measuring bacteria and fungi in a range of animal handling industries:
It showed that the levels of bacteria were very high in comparison to bacteria. The average levels measure were for bacteria >515 CFU/m^3, for deer, >345 CFU/m^3 for diary cattle and for horse feeding >630 CFU/m^3. Whereas fungi levels were much lower at 27 CFU/m^3, for deer, 25 CFU/m^3 for diary cattle and for horse feeding 22 CFU/m^3. It would have been interesting to see the % gram negative bacteria in these results.

Kift R, Reed S & Mulley R 2003, ‘Workers Inhalation Assessment while Handling Sheep and Wool’. *Australian Institute of Occupational Hygienists Conference Proceedings 2003*, Adelaide, Australian Institute of Occupational Hygienists.

This paper is from an Australian study that sampled for the concentrations of respirable and inspirable dusts (sample rate at 1.9 and 2 L/min, respectively) according to AS2985 and AS3640. The sampling period was for 2 –hours and was conducted 3 times during the sampling day. The bioaerosol concentrations were also found using an Andersen Instruments 2-stage bioaerosol impactor according to a method developed by Kift, 2002. The samples were taken from 2 sheep shearing sheds in the Southern highlands of NSW. The sampling was undertaken in spring and found:

Location	**Respirable Dust** (mg/m^3)	**Inspirable Dust** (mg/m^3)	**Inspirable Dust** (mg/m^3)
		Static Sampling Result	Personal Sampling Result
Farm 1		0.26 ± 0.01 (2)	0.5 ±0.10 (9)
Farm 2	0.46 ± (6)	0.25 ±0.02 (9)	0.65 ±0.07 (3)

Location	**Respirable dusts** (mg /m^3)	**Inspirable dusts** (mg /m^3)	**Bacteria** (CFU /m^3)	**Fungi** (mg/m^3)
Farm 1	-	0.46 ±0.09 (11)	1271±218 (18)	1832±301 (18)
Farm 2	0.46 ±0.15 (6)	0.35 ±0.06 (12)	1324±199 (18)	1213±132 (18)

The paper concluded that the sheds sampled were not over current recommended standards for dust and bioaerosols.

Kilpelainen M, Terho EO, Helenius H & Koskenvuo M 2000, ‘Farm environment in childhood prevents the development of allergies’, *Clinical and Environmental Allergy,* vol. 30, pp. 201-208.

This was a Finnish study (using a cross sectional questionnaire) determining the effect of childhood farm, rural non-farm and urban environment, as well as family size/structure and other factors on the occurrence of asthma, wheezing and atopic disorders up to young adulthood. 10,667 students aged 18-24 were included in the study.

The size of families has been shown to be inversely related to the occurrence of atopic sensitization, nasal allergies and asthma.

Results/conclusions:

- 4.6% lifetime prevalence of asthma, 6.8% SOB and wheezing, atopic dermatitis 18.2%, and allergic rhinitis/conjunctivitis 21.5%.
- Risk of allergic rhinitis (OR 0.63) during a lifetime on a farm was significantly lower than rural non farm residents
- Highly significant protective effect of farm environments found among subjects
- Parental history of atopic asthma was most powerful risk for asthma was (OR 2.32), allergic rhinitis (OR 2.25), and atopic dermatitis (OR 1.71).
- Childhood farm life has a protective effect on development of rhinitis (OR 0.63) and for diagnosed asthma and episodic wheezing (analysed together- OR 0.71), but not for atopic dermatitis.
- Urban childhood did not show an increase of incidence when compared with rural non-farm residence.
- Childhood farm environment has a protective effect against allergic rhinitis and more weakly against asthma and wheezing.
- Environmental exposure to microorganisms such as mycobacteria, actinomycetes may also play an immunological role.

Kimbell-Dunn MR, Fishwick RD, Bradshaw L, Erkinjuntti-Pekkanen R & Pearce N 2001, 'Work-related respiratory symptoms in New Zealand farmers', *American Journal of Industrial Medicine*, vol. 39, pp. 292-300.

This paper reports the findings of a population based postal survey of New Zealand farmers. Farmers were asked about type and amount of farming exposure and work related respiratory symptoms including questions based on the European Community Respiratory Health Survey. Symptoms questions are described in detail, as are questions design to elicit Farmer's Lung or ODTS. Of 1706, the majority had animals, 86% and either cattle or beef, 75% and 95% regular used agricultural chemicals. Wheat and oat farmers had amongst the highest complaints of breathy problems at work (32.5% and 34.7%) and shortness of breath (21.8% and 29.6%). Farmers exposed to animals, those work in with pigs, chickens, deer or horses and in poultry, pig and deer sheds had the highest rates. For respiratory symptoms at work these ranged from 20.3 to 27.8%. Symptoms associated with ODTS/FL were highest in farmers working with hay, grain and cattle. Prevalence odds ratios comparing symptoms of farmers exposed to farmers non exposed were adjusted for smoking status (LR analysis). For both pigs and poultry, these were statistically significant for breathing problems at work (ORS, 2:1 and 2.2:1 respectively).

Kirkhorn SR & Schenker MB 2001, 'Current Health Effects of Agricultural Work: Respiratory Disease, Cancer, Reproductive Effects, Musculoskeletal Injuries and Pesticide- Related Illnesses', *Journal of Agricultural Safety and Health*, vol. 8, pp. 199-214.

This is a state of the art review article that summarises new respiratory syndromes related to confined animal feeding operations and pesticide use, cancers linked to agriculture and agricultural ergonomics.

The authors suggest that increasing evidence shows endotoxins (in organic dusts) to be a significant contributor to respiratory disease in grain storage and confined farming activities (in swine and poultry). Studies have also shown 'significant dose-response relationships to occur with exposures to total dust, respirable dust, endotoxins, and ammonia and cross-shift decrements in pulmonary functions (in swine and poultry operations).' Studies have also shown total dust concentrations of 2.4 to 2.5 mg/m^3, respirable dust of 0.16 to 0.23 mg/m^3, endotoxin of 640 to 1000 ng/m^3 and ammonia of 7 to 12 PPM. TLV s for organic dusts, respirable dusts and endotoxins are recommended following more recent dose-response relationship findings.

Respiratory diseases of most relevance to this project discussed are; Organic dust exposure (ODTS), inorganic dust exposure and other respiratory diseases (e.g. FHP). They recommend for future research medical surveillance with baseline spirometry and ongoing screening. Also, study into causes and prevention of chronic asthma, ODTS and end stage irreversible pulmonary conditions. They also recommend prospective studies on large numbers of participants to determine dose- response relationships between respiratory illness, pulmonary measurements, measurements of total and respirable dusts, endotoxins; ammonia and other gases associated with confined farming. They also state improved case definitions and diagnostic techniques are needed. Exposure limits for organic dusts, and endotoxins have been set but ammonia exposure limits may be set too high. They recommend pilot studies be set up to compare facilities at the recommended levels to controls. Exposure limits should be pursued and encouraged as a step towards regulatory limits.

Kirychuk SP, Senthilselvan A, Dosman JA, Juorio V, Feddes J, Wilson P et al. 2003, 'Respiratory symptoms and lung function in poultry confinement workers in Western Canada', *Canadian respiratory Journal*, vol. 10, pp. 375-380.

Self reported chronic respiratory symptoms and spirometry were measured in poultry farmers in three provinces in Canada in the winter months. About 20% of all registered producers agreed to participate. Three hundred and three subjects worked for at least 2 hours per day in confinement buildings housing at least 1000 poultry. Two age and sex matched population based control groups were also enrolled, each control subject living within 100 kilometres of his/her matched study subject. Combined poultry grain farming is common in Canada. Despite this there were some significant differences between the groups; a higher proportion of women in the non farmers group compared with floor based poultry workers and grain farmers; older average age of grain farmers compared with floor based poultry workers. The purpose of the grain farmers group was to control for the confounding effects of grain farming on respiratory symptoms. A self reported questionnaire was based on an American Thoracic Society questionnaire. Spirometry was carried out off-site and at least half an hour from work exposure.

When the findings were adjusted for age, sex and smoking status, cage based workers and floor based workers had significantly ($p<0.05$) higher prevalence of chronic cough (15.5%, 18.9% versus 1.7%) and chronic phlegm (17.1%, 19.8% versus 8.7%) compared with non farmers. Current and chronic symptoms of cough, wheeze, phlegm and breathlessness were also higher in caged based workers than in floor based workers, but only current symptoms of cough and wheeze reached statistical significance ($p<0.05$, findings reported as part of bar chart only). There were significant differences in some spirometry measures between each of the groups. FEV_1 and FEF_{25-75} were significantly lower in caged based poultry workers.

Not all findings are presented in this paper. For example the prevalence of symptoms are presented in a bar chart and statements about the significance of various comparisons are made, eg, non farmers had significantly higher symptoms of wheeze than floor based workers.

Kirychuk S, Senthilselvan A, Dosman JA, Zhou C, Barber EM, Rhodes CS & Hurst TS 1998. 'Predictors of longitudinal changes in pulmonary function among swine confinement workers', *Canadian Respiratory Journal*, vol. 5, pp. 472-478.

This paper reports on follow-up findings in 1994/95 of 42 subjects from a cohort of 98 male swine confinement workers initially assembled in 1989 (Zedja *et al.* 1993). Each was still working for at least 2 hours each day in a barn. Those included in the follow up study did not differ significantly from those not included in age, baseline lung function tests, amount of time spent in barns, weight and smoking status. They were taller ($p<0.05$). At follow-up the same respiratory symptom questionnaire was used. Environmental measurements were carried out using the same methods at baseline and averaged for the different barn locations and summer and winter months. The same disposable spirometer was used at both times according to American Thoracic Society standards. Personal sampling for respirable dusts was only performed at follow-up. An annual decline in both FEV_1 (-53.9 mL/year) and FVC (48.9 mL/year) was observed in the 42 subjects. The negative shift declines observed at baseline had significant ($p<0.05$) but low to moderate correlations with these annual declines, 0.34 between baseline shift decline in FEV_1 and annual rate of decline in FEV_1 and 0.38 between baseline percentage cross-shift declines in FVC and annual FVC decline. The baseline percentage shift changes were statistically significant predictors in regression modelling for these outcomes adjust for age, smoking status, height and work hours. These models were repeated including the follow-up exposure measures. Of these only endotoxin levels were significant predictors of annual decline for both FVC and FEV_1. Sample size may have been inadequate for multiple regression modelling.

This study was to determine predictors of longitudinal changes in pulmonary function in swine confinement workers.

Across shift pulmonary function (FEV1 and FCV) was recorded, and again 5 years later. Indoor environmental measurements were also analysed.

Environmental conditions:

	1990		**1995**	
	Winter	Summer	Winter	Summer
Ammonia (ppm)	16.8	7.6	14.5	5.7
Carbon dioxide (ppm)	4439	1237	4081	1170
Respirable dust (mg/m^3))	0.17	0.09	0.44	0.19
Endotoxin (EU/mg)	590	181.7	358	398
Airborne endotoxin (EU/m^3)	88.1	16.5	108	48

Results showed that shift change is an important predictor of longitudinal changes in lung function in swine confinement workers and that endotoxin exposures may mediate annual decline in FEV1 of these workers.

Kolbeck KG, Ehnhage A, Juto JE, Forsberg S, Gyllenhammar H, Palmberg L et al. 2000, 'Airway reactivity and exhaled NO following swine dust exposure in healthy subject', *Respiratory Medicine*, vol. 94, pp. 1065-1072.

This report investigates the nasal inflammatory response and mucosal reactivity to swine dust exposure and whether nitric oxide metabolism is involved in the inflammatory process.

Nitric oxide in expired air, nasal histamine test (NH), nasal lavage (NAL) and bronchial histamine challenges were studied before and after a 3hr exposure to swine dust in a swine confinement building. Group 1 had NAL preformed after NH while group 2 was reversed.

Nasal histamine response increased significantly in group 1 but not in group 2. Albumin levels in NAL were higher before and after dust exposure in group 1. Bronchial histamine responsiveness increased following exposure. Nitric oxide in expired air decreased following bronchial histamine challenge at baseline but was otherwise unaltered.

Short time exposure to swine dust increases non-specific reactivity of both nose and bronchi. Nasal lavage procedure interferes with nasal histamine test when preformed with connection to each other. The inflammatory reaction may involve NO metabolism.

Kotimaa MH, Terho EO & Husman K 1987, 'Airborne moulds and actinomycetes in the work environment of farmers.' *Eur J. Respine Dis*, vol. 52 (suppl.), pp. 91-100.

This Finnish study investigated the concentration of spores framers were exposed to when working with hay or grain. The Petri dish methods and latter a six-stage Andersen sampler were used. The level of exposure varied from 10^4 CFU/m^3 to 10^7 CFU/m^3. In hay, the fungi of the A. glaucuc group dominated. In the grain the most common moulds were Cladosporium spp. and Penicillium spp.

Krahmer M, Fox K, Fox A, Saraf A, & Larsson L 1998, 'Total and viable Airborne Bacterial Load in Two Different Agricultural Environments Using Gas Chromatography-Tandem Mass Spectrometry and Culture: A Prototype Study', *American Industrial Hygiene Association Journal*, vol. 59, pp. 524-531.

This is an American study that looked at total (viable and nonviable) bacterial load in astable and in a dairy. Gas chromatography-tandem mass spectrometry measurement of muramic acid (a component of gram positive and gram negative bacterial peptidoglycan). When assessing gram-negative concentrations, 3-hydroxy fatty acids (markers of bacterial lipopolysaccharides) were assessed. Cultural samples were also taken as a comparison. Muramic acid and 3-hydroxy fatty acid concentrations showed a correlation, and dust and muramic acid levels also correlated. Total bacterial load (from muramic acid) were higher that expected from the cultural samples.

Krysillska-Traczyk E, Kiecana I, Perkowski J, & Dutkiewicz J 2001, 'Levels of fungi and mycotoxins in samples of grain and grain dusts collected on farms in Eastern Poland', *Annals of Agricultural and Environmental Medicine*, vol. 8, no. 2, pp. 269-274.

In study on wheat grain and grain dust in the Lublin province of eastern Poland carried out in 2001, found that farmers were exposed to notable quantities of *fusaria* and/or fusariotoxins. This study collected 10 samples of stored wheat grain and 10 samples of grain dust which was released during use of a threshing machine. The potential problem with *fusaria* and fusariotoxins is that they are mycotoxins whose potential health effects and not completely known.

Kullman GJ, Thorne PS, Waldron PF, Marx JJ, Ault B, Lewis DM, Siegel PD, Olenchock SA & Merchant JA 1998, 'Organic dust exposures from work in dairy barns', *AIHA Journal*, vol. 59, pp. 403-413.

This paper reports on an environmental survey that monitored exposures to organic dusts (total, inhalable and respirable) and its constituents (endotoxin, bacteria, fungi, histamine, cow urine antigen, mite antigen, ammonia, carbon dioxide and hydrogen sulphide) in 85 central Wisconsin dairy barns.

Table 21: Results for inhalable, respirable and total dust sampling in dairy barns.

Dust Sampled	GM (mg /m^3)	Range (mgm^3)
Inhalable (static)	0.74	0.007*-6.93
Inhalable (pers)	1.78	0.007*-53.6
Respirable (static)	0.07	0.007*-8.03
Total (inside)	0.74	0.007*-6.5
Total (outside)	0.03	0.007*-0.95

*below detection range

Table 22: Exposure levels for bioaerosol constituents monitored in dairy barns

Sample	GM	Range
Total histamine (picomoles mg/m^3)	11.8	0.71-224
Total spores/bacteria (organisms mg/m^3)	1.2×10^7	$1.5 \times 10^4 – 2.6 \times 10^8$
Total cow urine antigen (µg/m^3)	167	0.007-4580
Total mite antigen (µg/m^3)	0.01	0.0007-2.17
Endotoxin (EU/m^3) Inhalable Respirable	 647 16.8	 25.4-34800 0.16-1380
Viable mesophilic yeast (CFU/m^3) Filtration Impinger	 9.7×10^3 1.7×10^4	 2.1×10^2-2.9×10^5 1.3×10^3-2.5×10^8
Viable moulds (CFU/m^3) Filtration Impinger	 1.9×10^4 1.1×10^4	 1.7×10^3-1.6×10^6 2.9×10^2-1.2×10^6
Mesophilic bacteria (CFU/m^3) Filtration Impinger	 3.4×10^5 5.8×10^5	 8.9×10^3-5.2×10^6 6.1×10^4-4.1×10^8
Thermophilic bacteria (CFU/m^3) Filtration Impinger	 3.4×10^3 3.6×10^3	 1.5×10^2-7.3×10^5 3.6×10^4-3.4×10^4

Lacey J & Dutkiewicz J 1994, ‘Bioaerosols and occupational lung disease’, *Journal of Aerosol Science*, vol. 25, pp.1371-1404.

This article reviews the spectrum of agents involved with occupational lung disease, the work environments affected, disease characteristics and prevention.

Detail is given about the components of bioaerosols- i.e. the specific microorganisms (viruses, bacteria, actinomycetes, fungi, endotoxins, mycotoxins, insects etc.) involved with examples of disease caused.

Occupations discussed include; agriculture (crop, grain handling, sawmills, food processing, meat), academic institutions, vet. medicine facilities, engineering/construction etc.

Diseases and their prevention are discussed in detail; rhinitis, bronchitis, alveolitis, ODTS, inhalation fever, infection etc.

Lacey J 1986 ‘Collection, Detection, and Identification of Agents in Farm Dusts Implicated in Respiratory Disease’ *American Journal of Industrial Medicine*, vol. 10, pp. 311-313.

This is an old review article that talks about different ways to identify different agents that may be making people sick in their work environment.

Laitinen S, Kangas J, Husman K, Susitaival P 2001, ‘Evaluation of exposure to airborne bacterial endotoxins and peptidoglycans in selected work environments,’ *Annals of Agricultural and Environmental Medicine*, vol. 8, pp. 213-219.

The aim of this study was to assess workers exposure to endotoxins and peptidogylycans, as well as associated reported symptoms, in Finland. 14 sites were tested, including slaughter houses, grain storage areas, animal feed industry, garbage handling, cotton mill, printing, wood plant, metal work area.
Air samples of endotoxins were collected at a flow rate of 2.2 L/min on glass fibre filters.

The LAL test was used to detect biologically active endotoxins, while total endotoxin levels were determined using gas spectrophotometry (GC-MS) (for 3-hydroxy (OH) fatty acids, as well as for muramic acid in peptidoglycans). Self reported symptoms correlated more accurately with biologically active endotoxins rather than total values. 50% of 77 workers tested had respiratory symptoms, 27% eye symptoms and 10% fevers. When endotoxin levels were > 25 ng/m^3 respiratory symptoms seemed to be more common. The authors found that LAL assay as well as GC-MS seemed a good method for assessing workers exposure to airborne bacteria.

The authors state that LAL test has 2 main limitations; it detects mainly biologically active endotoxins and other substances which may also activate it. Biologically active endotoxin is dependent on bacterial species and may be free or cell bound. This was why the authors also used gas chromatography as an additional test.

They also determined airborne cultivable bacteria using a 6 stage impactor (Andersen) at a flow rate of 28.3L/min.

Biologically active endotoxin ranged from <0.02 to 38,000 ng/m^3. Total endotoxin levels ranged from 29-66,000 ng/m^3. Even within the same workplace endotoxin levels varied considerably. Muramic acid (peptidoglycan levels) was measured up to 1700 ng/m^3. Total cultivable bacteria were measured at 30-160,000 CFU/m^3. Highest concentrations of endotoxin, muramic acid and bacteria were found in grain/vegetable storage houses. 50% of 77 workers questioned had respiratory symptoms in 24 hrs after bacterial samples were collected. Nasal obstruction, sneezing, discharge most common symptoms (36%). To a lesser extent (20%) fatigue, eye irritation, sore throat etc.

When endotoxin levels were > 25 ng/m^3, workers reporting symptoms were much higher. 13 workers exposed to >150 ng/m^3 reported at least one symptom.

Authors conclude that precise information relating dose-response relationships between endotoxin exposure and symptoms is not available in the literature. Dutch Expert Committee on Occupational Exposures has recommended health based occupational standard exposure limit of 4.5 ng/m^3 (50EU/m^3). This study had endotoxin levels in all worksites (except printery) greater than 4.5 ng/m^3. The GC-MS analysis, (based on total load of bacterial material in air) gives much greater levels of airborne endotoxins than the LAL test. This study showed no association between symptoms and levels of total endotoxin measured. But some fatty acids (3-OH) were associated with reported symptoms.

Highest levels of muramic acid (peptidoglycans) were found in the air of grain/vegetable storage areas. Most sample of muramic acid were below level of detection and weren't associated with related symptoms.

Lange JH 2000, 'Reduced cancer rates in agricultural workers: a benefit of environmental and occupational endotoxin exposure', *Medical Hypotheses*, vol. 55, no. 5, pp. 383-385.

This paper states that several epidemiological studies have suggested that workers employed in agricultural industries have reduced rates of cancer. Previous studies have suggested low tobacco usage and healthy worker effect to be the reason for these low rates. Other recent studies have suggested that endotoxin may be the reason for these low cancer rates. This paper gives evidence and suggests a hypothesis for endotoxin- mediated reduced cancer rates in such workers exposed to dust.

The theory of environmental exposure and related events is well known in the literature, although the mechanism is not fully understood.
This article gives human dose responses to endotoxins- calculated using airborne concentrations reported in the literature. Criteria for these calculations used were: 70 kg man, breathing 15 m^3 of air in an 8 hr day. If LPS measurements were not reported for respirable dust, a 25% concentration of endotoxin in total airborne dust was used as an estimate of the respirable fraction. The % of respirable dust (25% total dust) is based on approx average ratio of respirable/total dust reported in Olenchock (ref: Olenchock, May, Pratt, Morey Occupational exposures to airborne endotoxins in agriculture. In: Watson, Levin, and Novitsky. Detection of bacterial endotoxins with limulus amebocyte lysate test. NY: Allan Liss, 1980:475-487). Exposures as low as 2 ng/m^3 have been suggested as eliciting a physiological response.

Data from table 1 below suggests frequent exposure doses > 10 ng/ m^3 can be expected to occur in agriculture and other industries.

Table 23. Endotoxin exposure from various agricultural operations (data from literature)

Operation	**Exposure concn** (ng/m^3)	**Exposure dose** (ng/kg-body wt)
Grain terminal (respirable fraction)	0.74	3.53
Grain mill	5,490	6,405
Farm silo (respirable fraction)	1,320	6,160
Poultry facility (respirable fraction)	40 (mean concn)	186.7
Piggeries (geometric mean)	15	9.5
Compost plants	38	44.3
Farms (respirable fraction)	7,400	34,533.3

Lange JH 2003, 'Endotoxin: does it have a role in prevention of lung cancer?' *Thorax*, vol. 58, no. 1, pp. 92.

There have been suggestions that endotoxin exposure, mostly from organic dusts, results in reduced lung cancer rates. This reduced lung cancer rate was first identified in textile workers and later in agricultural and other groups exposed to endotoxin.

Lappalainen S, Nikulin M, Berg S, Parikka P, Hintikka E & Pasanen A 1996, 'Fusarium toxins and fungi associated with handling of grain on eight Finnish farms', *Atmospheric Environment*, vol. 30, no. 17, pp. 3059-3065.

This study assessed farmers' exposure to airborne dust, fungi and Fusarium toxins during the drying and milling of grain and feeding of cattle. 8 Finnish farms were sampled between September 1993 and March 1994. On two farms only grain was cultivated. At each farm, 2 fungal spore samples were collected simultaneously at flow rates of 2 L/min and 3 L/min using polycarbonate filters in open faced plastic filter holders (20-60 min sampling time). One sample for mycotoxin was collected on a glass fibre filter at a flow rate of 833 L/min, and air volumes of dust samples collected on glass fibre filters using the high volume sampler ranged from 16.7 to 50 m^3.

Sample	**Exposure**		
	Grain Drying	**Grain Milling**	**Cattle Feeding**
Viable Fungi (CFU /m^3)			
Mesophilic	1.4 x 104	6.8 x 104	7.6 x 104
Xerophilic	6.8 x 103	6.4 x 104	1.1 x 105
Thermophilic	2.2 x 102	1.9 x 103	6.6 x 103
Total Spores (spores / m^3)	2.0 x 106	2.7 x 106	1.7 x 106
Dust (mg / m^3)	1.07	16.22	1.40

Dust exposure was highest during grain milling (16.22 mg/m^3) followed by cattle feeding (1.4 mg/m^3) and grain drying (1.07 mg/m^3). Viable fungi exposure was lowest during grain drying, and total spore counts were lowest during cattle feeding. None of the air samples collected were toxic in the cytotoxicity test or in the yeast-cell toxicity test. Seven grain samples were cytotoxic but none of them were toxic during the yeast cell toxicity test. Three *Fusarium* sp were isolated from a mouldy partly dried oat sample, one of which, F. *culmorum* was cytotoxic. The authors conclude that conclusions on Finnish farmer exposure to mycotoxins cannot be drawn due to the small data set, and indicate that it may be assumed that farmers could be exposed to toxigenic fungi and *Fusarium* toxins in the agricultural environment.

Larsson BM, Larsson K, Malmberg P & Palmberg L 2002, 'Airways inflammation after exposure in a swine confinement building during cleaning procedure', *American Journal of Industrial Medicine*, vol. 41, no. 4, pp. 250-258.

The purpose of this paper is to study the health effects from exposure during cleaning of the swine confinement building and to evaluate the effect of a reparatory protection device.

16 subjects were exposed for 3 hr during cleaning of a swine confinement building with a high pressure cleaner. 7 were equipped with a mask.

Bronchial responsiveness increased in all subjects following exposure, significantly more in the group exposed without a mask.

Exposure to dust aerosols during the cleaning of the interior of a swine confinement building induces increased bronchial responsiveness and an acute inflammation reaction in the upper airways. The use of a mask attenuated particles in this environment could be important factors in the development of increased bronchial responsiveness.

Larsson B, Larsson K, Malmberg P, Martensson L & Palmberg L 1999, 'Airway response in Naïve Subjects to Exposure in Poultry Houses: Comparison between Cage rearing system and Alternative Rearing System for Laying Hens', *American Journal of Industrial Medicine*, vol. 35, pp. 142-149.

This study investigates acute health effects from exposure in poultry houses and to compare them health effects observed in a cage rearing system and the alternative 'cage-less' rearing system for laying hens.

To assess acute respiratory symptom and immunologic reactions to exposure from poultry houses. Thirty-four non-smoking urban dwellers were randomly allocated to three hours in a cage rearing poultry house with fresh bedding, cage rearing poultry house with old bedding and a non cage rearing poultry house. None had prior allergic or airways disease. Measurements are described in detail. Only one person reported severe symptoms of chill (group membership not reported). FVC was reported to be similar in all three groups.

The personal air exposure samples were collected at a flow rate of 1.9 to 2 L/min using IOM sampling heads. The endotoxins were analysed using the LAL method.

	Loose laying /new bedding	**Loose laying /old bedding**	**Cage rearing**
Inhalable dust (mg/m^3)	4.8	4.1	2.4
Endotoxins (ng/m^3)	125	96	106

A 3hr exposure in confined buildings for egg production induces an acute inflammatory reaction in the upper airways and increased bronchial responsiveness. There is a tendency towards stronger reactions in the group exposed in the buildings with loose housing for laying hens.

Larsson, K, Malmberg, P, Eklund, A, Belin, L, & Blaschke, E 1988, 'Exposure to Microorganisms, Airway Inflammatory Changes and Immune Reactions in Asymptomatic Dairy Farmers' *International Archives of Allergy and Applied Immunology*, vol. 87, pp. 127-133.

In this Scandinavian study, the background levels for the total count of airborne microorganisms in the farmers work environment were $1.51 \pm 0.58 \times 10^7$ CFU/m^3. During animal tending the range was $0.42\text{-}5.10 \times 10^7$ microorganisms/m^3 of air. When the maximal exposure was obtained it was a 15-fold increase to $0.11\text{-}6.5 \times 10^8$ (worst case estimate).

Lenhart, SW, Morris, PD, Akin, RE, Olenchock, SA, Service, WS & Boone, WP 1990, 'Organic Dust, Endotoxin and Ammonia Exposures in the North Carolina Poultry Processing Industry', *Applied Occupational and Environmental Hygiene*, vol. 5, No 9, pp. 611-618.

This paper describes a sampling program undertaken to ascertain exposures of workers in various activities in the poultry industry.

The personal samples were collected using methods that were commonly in use in USA in the early 1990's which consisted of respirable samples collected on a 10mm Dorr-Oliver cyclone at a flow rate of 1.7 L/min whereas the inhalable dust samples were collected on a 37mm cassette at a flow rate of 1.5 L/min. The filters the samples were collected on were PVC filters. Endotoxin analysis was undertaken on both the inhalable and the respirable samples using the LAL method. No comment was made about sample handling.

The results obtained include:

Activity	Dust Levels (mg/m^3)		Endotoxin (ng /m^3)	
	Respirable	Inhalable	Respirable	Inhalable
Broiler Growers	1.22 ± 1.66	24.2 ± 1.56	7 ± 2.11	210 ± 2.01
Chicken Catching Crews	2.34±1.79	30.6 ± 1.92	17±2.25	380±2.54

Liao C & Singh S 1998, 'Modeling dust-borne odor dynamics in swine housing based on age and size distributions of airborne dust,' *Applied Mathematical Modelling*, vol. 22, pp. 671-685.

This article describes an analytical mathematical model characterizing the adsorption of odor on the surface of airborne dust in swine buildings. This enables engineers to evaluate the performance of ventilation systems in reducing odor emitted from stored manure.

Liesivuori J, Kotimaa M, Laitinen S, Louhelainen K, Ponni J, Sarantila R & Husman K 1994, *'Airborne endotoxin concentrations in different work conditions'*, vol. 25, pp. 123-124.

Short article reporting on endotoxin exposure levels recorded for different industries between 1986 and 1991. Airborne endotoxin exposure levels of 16 EU /m^3 were recorded for dairy farms, 460 EU/m^3 for swine buildings and 315 EU /m^3 for poultry buildings.

Lin W-H, & Li C-S 2003, 'Influence of Storage on the Fungal Concentration Determination of Impinger and Filter Samples' *American Industrial Hygiene Association Journal*, vol. 64, pp. 102-107.

In this Taiwanese study spores of *Penicillium citrinum* and cells of *Candida famata* were aerosolised and collected using AGI-30 impingers, Nuclepore filters and gelatine filters. Filters were stored at 25 and 4^{o}C. The cultivability of *Penicillium* spores decreased as storage time increased.

Louhelainen K, 1997, 'Farmers' Exposure to Dusts and Gases in Dairy Farms', Doctoral dissertation, Kuopio University Publications C. Natural and Environmental Science 69

This is a dissertation that has brought together data that has been published in a number of papers. Each of the relevant papers will be reviewed individually.

The dissertation reports on both personal and static dust exposures, microorganisms and endotoxins in Finnish Dairy Farms. The papers cover in this thesis are:

- Louhelainen, K, Kangas, J., Husman, K. & Terho, E.O, 1987, 'Total concentrations of dust in the air during farm work', Eur. J. Respir. Dis. 71, suppl 152, 73-79
- Handela, R., Louhelainen, K. & Pasanen, A-L, 1995, 'Prevalence of microfungi in Finnish cow barns and some aspects of the occurrence of *Wallemia sebi* and *Fusaria'*, Scand. J. Work Environ. Health, 21, 223-228.
- Louhelainen, K., Kangas, J., Reiman, M. & Kalliokoski, P., 1997, 'Farmers' exposure to dusts and gases in modern Finnish cubicle cow houses', Agricultural and Food Science in Finland, vol. 6 No. 3, p. 207-217

Louhelainen K, Kangas J, Husman K & Terho EO 1987, 'Total concentrations of dust in the air during farm work', *European Journal of Respiratory Disease,* vol. 71, (suppl 152) pp. 73-79.

This paper reports on monitoring undertaken in cow houses, piggeries and poultry yards with floors and poultry yards with coops.

	Personal Samples (± SE) mg /m^3	**Static Samples (± SE)** mg /m^3
Cow houses	5.6 ± 0.4 (30)	1.0 ± 0.3 (10)
piggeries	12.6 ± 1.9 (25)	8.5 ± 0.6 (6)
Poultry yards with coops	7.2 ± 1.3 (11)	5.0 ± 1.0 (6)
Poultry yards with floor	13.0 ± 3.1 (13)	6.0 ± 0.9 (11)

Note: number of samples are presented in ()

In addition this paper reports dust exposure during other activities on the farm in relation to preparing food for the animals. Some of these activities generate higher dust exposures that working directly with the animals themselves. Such as hay baling 9.9 ± 1.1 mg/m^3, hay making 4.4 ± 1.4 mg/m^3 and emptying grain drier 22.0 ±2.4 mg/m^3.

Louhelainen K, Kangas J, Reiman M & Kalliokoski P 1997, 'Farmers' exposure to dusts and gases in modern Finnish cubicle cow houses', *Agricultural and Food Science in Finland*, vol. 6, No. 3, pp. 207-217.

This study investigated 26 family farms which milked between 20 to 30 cows, the cow house were less than 5 years old. Samples were collected on a membrane filter at between 2 to 2.5 L/min for personal exposures and stationary samples collected at 20 to 25 L/min.

	Personal mg /m^3		**Stationary** mg/m^3	
	Milking	Feeding	Milking palor	Feeding aisle
Cold Barn	0.3	1.8	0.1	0.7
Tied barn	0.8	0.3	0.2	0.2
cubicle	1.1	1.9	0.3	0.8

This paper also reports on the concentration of bovine epithelial antigen present. Average personal samples ranged from 0.9 to 23.4 µg /m^3. Bovine Dander antigen also ranged from 90 to 320 ng/m^3. Average concentration total spores was recorded as 1.2x10^5 CFU /m^3.

Lundholm M, Palmgren U & Malmberg P 1986, 'Exposure to endotoxin in the farm environment', *American Journal of Industrial Medicine*, vol. 10, pp. 314-315.

This is a study performed to determine endotoxin levels using LAL method. Dust was collected on cellulose acetate filters using personal samplers (10-20 L/min, total sampling volume 100-800L). Samples were collected in a farm environment (not well described at all!) and samples were collected during harvest time inside and outside a tractor cabin. (as well as in an open tractor). The sampling flow rate varied form 10 to 20 L/min. In 29/59 samples endotoxin levels were > 0.2 µg/m^3. 6 samples showed very high values (>20 µg/m^3). Results varied from 0.01 µg/m^3 to >100 µg/m^3. During

harvesting, higher values were found outside the tractor cabin, with low values inside the ventilated cabin. The open tractor also had lower values.

Macher J 1999, '*Bioaerosols Assessment and Control Cincinnati*', ACGIH.

This book draws on the experiences of many people working within the fields of industrial hygiene, indoor environments, and other fields that deal with airborne contaminants. It provides a guide to the recognition, evaluation, and control of biologically derived contaminates. The book gives a basic overview of the topics that are related to bioaerosols including information on the health effects, how to investigate for bioaerosols, and how to interpret the data after collection. Also included and of some importance to this project, are the case studies. These outline specific sampling methods and also examples of respiratory infections from bioaerosols. The book also gives a basic breakdown of the possible bioaerosols that could be found in different occupational environments. Information on these bioaerosols includes information on characteristics, health effects, sampling collection, sample analysis, data interpretation and remediation and prevention. It is a very in-depth book, which can at times make it difficult to find the exact information that is needed. This book confirms that bioaerosols can have negative health impacts in occupation environments, these ideas was also supported Dutkiewicz (1997).

Macher JM, Huang F-Y, Flores M 1991, 'A two-year study of microbiological indoor air quality in a new apartment' *Archives of Environmental Health*, vol. 46, pp. 25-29.

The concentrations of spores in livestock confinement buildings may reach 10^4-10^5cfm /m^3 compared with median urban concentrations of 10^2 CFU/m^3 indoors and outdoors.

Mackiewicz B 1998, 'Study on exposure of pig farm workers to bioaerosols, immunologic reactivity and health effects', *Annals of Agricultural and Environmental Medicine*, vol. 5, no. 2, pp. 169-75.

This study investigated the composition and concentration of airborne microflora in a swine building as well as assessing the health of the workers.

Total concentrations of microorganisms in the air ranged from 613.7 – 1246.7 x10^3 CFU/m^3.

Work related symptoms were reported by 58.5% of the workers. No abnormal findings were present upon physical and spirometric examinations.

Common occurrence of work related respiratory disease in swine workers, mostly corresponding to Organic Dust Toxic Syndrome. (ODTS).

McDonald C 2000, *Epidemiology of work related diseases*, BMJ Publishing Group.

The author of this book is a professor Emeritus in Occupational Medicine at the University of London and a Professor Emeritus in Epidemiology at McGill University in Montreal, Canada. He draws on this knowledge in both of these complementary fields, to pass on this information about epidemiology and occupational diseases. This book tries to present information about the epidemiology of the main types of occupational disease, it does this by reviewing the different research methods that are used to gain the information. The book gives information on a different range of diseases that can be contracted form an occupational environment, this includes chapters about occupational cancer, non-malignant diseases, and the methodology used. The most important chapter of this book, in regard to the project, is the chapter entitled 'work in agriculture'. This chapter outlines the different places that agricultural workers could be exposed to; this includes chemical, crop, livestock and equipment exposure. There is also an outline of diseases including respiratory, renal, reproductive, neurological, dermatosis and zoonoses. This chapter also talks about different control measures that can be used. It is a very good chapter that is going to be very helpful to give an overview of the epidemiology of agricultural diseases. However, a negative is that the book does not go into great detail. The different diseases that can be found are simular to the research of Dosman and Cockcroft 1989.

Michel O, Kips J, Duchateau J, Vertongen F, Robert L, Collet H et al. 1996, ‘Severity of Asthma Is Related to Endotoxin in House Dust’ *American Journal of Respiratory and Critical Care Medicine*, vol. 154, pp. 1641-1646.

What is clear is that in occupational settings, endotoxin is frequently above 100 ng/m^3 air. This can occur in swine and poultry confinement buildings, cotton industries, and waste handling.

Michel O, Nagy A-M, Schroeven M, Duchateau J, Neve J, Fondu P & Sergysels R 1997, ‘Dose-Response Relationship to Inhaled Endotoxin in Normal Subjects’ *American Journal of Respiratory and Critical Care Medicine*, vol. 156, pp. 1157-1164.

In this Belgian study nine people were exposed to different concentrations of LPS. It was found that the no-response threshold to an acute inhalation of LPS is less than 0.5 µg.

Molocznik A & Zagórski J 1998, ‘Exposure of Female Farmers to Dust on Family Farms’, *Annals of Agricultural and Environmental Medicine*, vol. 7, pp. 43-50.

This paper reported on dust exposures that had been measured on women working on family farms. The methods of collecting the dust samples were mentioned but not the sampling flow rates.

The average results that were reported are:

- General Range: 1.3 to 57.5 mg/m^3
- Cultivation: 5.1-23.6 mg/m^3
- Fertilizing: 4.2-9.9 mg/m^3
- Sowing and planting: 3.0-7.5 mg/m^3
- Plant harvesting: 3.3-19.3 mg/m^3
- Household activities: 3.0-57.5 mg/m^3
- Other activities: 1.3-3.9 mg/m^3

The levels of silica range from 0 to ~11% of dust concentrations. These levels would be a concern with the higher dust exposures.

Molocznik A & Zagórski J 2000, ‘Exposure to Dust Among Agricultural Workers’, *Annals of Agricultural and Environmental Medicine*, vol. 5, pp. 127-130.

This paper reports on a survey that collected dust levels from general farmers. The activities of the farmers in relation to duct exposures have not been well defined. Also the methods of collecting the samples have not been defined in manner that allows the reader to understand how the samples were collected. The authors refer to Polish Standards that are not available in English.

Molocznik A 2002, ‘Qualitative and quantitative analysis of agricultural dust in working environment’, *Annals of Agricultural and Environmental Medicine*, vol. 9, pp. 71-78.

This study reported on total and respirable dust exposures during various farming activities that make up the annual work cycle. The study also observed the main mineral components of dust to which workers were exposed. Dust concentrations during cattle handling ranged from 1.7-7.0 mg/m^3 for total dust, and 0.2-0.7 mg/m^3 for respirable dust. For swine handling total dust concentrations ranged from 2.6-8.9 mg/m^3, and respirable dust from 0.2-0.8 mg/m^3. Respirable dust from swine handling contained 4% free silica.

The methods for collecting the data are in polish and sampling flow rates were not given the papers.

Morris PD, Lenhart SW & Service WS 1991, ‘Respiratory symptoms and pulmonary function in chicken catchers in poultry confinement units’, *American Journal of Industrial Medicine*, vol. 19, pp. 195-204.

Chicken catchers spend most of the workday in confinement buildings. In a study of 59 catchers in North Carolina, symptom prevalence rates were compared with those predicted for a reference population of 1,400 blue collar workers studied by NIOSH in 1985. For all symptoms, more chicken catchers reported symptoms than would have been predicted based on this reference population. Questionnaire based on one previously developed by Medical Research Council of Great Britain. For three categories of symptoms (chronic cough, chronic phlegm and chronic wheezing), the odds ratios (2.64, 4.07, 5.12) were statistically significant ($p<.05$). Of interest was a slight but statistically significant ($p<0.05$) decrease in FEV_1 and FVC during the working day, suggesting a reversible occupational effect. Those who had worked for five or more years had a higher prevalence of all categories of symptoms than workers of less than five years.

Murphy DJ 1992, ‘*Safety and health for production agriculture’*, American Society of Agricultural Engineers.

Dr Murphy is a professor and extension safety specialist at the Agricultural and Biological Engineering Department of Penn State University, USA. This book tries to cover the important aspects of farm safety and health. Included is an overview of possible hazards that can be found in agriculture. This includes a section on respiratory hazards, which talks about the dangers associated with animal housing and toxic dusts found in animal housing areas. Also included in the book are statistics on the regularity of farm injuries, and ways to overcome the problems associated with the issues outlined. This book is relevant for the project as it outlines and offers suggestions in how to overcome many different problems to do with agricultural production. The section on respiratory diseases also includes information relevant to the project, as this section also supports the claims made by Dosman, and Cockcroft (1989) that there is an association between animals’ handlers and respiratory diseases.

Netto GF & Johnson ES 2003, ‘Mortality in workers in poultry slaughtering/processing plants: the Missouri poultry cohort study’, *Occupational and Environmental Medicine*, vol. 60, pp. 784-788.

The authors hypothesised that exposure to viruses prevalent in chicken meat, including retroviruses could result in increased cancer mortality in workers in the slaughtering industries. They carried out a retrospective cohort study of 7700 Missouri workers in poultry slaughtering plants using union records of occupation, and population datasets of mortality and motor accidents, as well as personal interviews. The reference group for these analyses was the general US population. Four hundred and fifty nine deaths had been documented in this cohort. No significant increases in deaths from cancer was found, however, over a 21 year period, from 1969, males but not females, had a higher proportionate mortality rate than the US general population for deaths due to non malignant respiratory diseases 1.8 for all males and 1.9 for white males. Although the authors reported the later as being statistically significant the 95% CI was 1 to 3.5. Also of note was the finding that both male and female workers had significantly higher proportionate and standardised mortality rate for senility and ill defined conditions. For example, the PMR for these conditions for all males was 6 (95% CI, 2.6-10.1). The associations require further investigation and support. In addition to the problems of accuracy when relying on population datasets for information such as cause of death, the number of observed deaths in each category was small, eg, eight for all males in the senility and ill-defined conditions category.

Nielsen EM, Engberg J & Madsen M 1997, ‘Distribution of serotypes of *Campylobacter jejuni* and *C. coli* from Danish patients, poultry, cattle and swine,’ *FEMS Immunology and Med Microbiology,* vol. 19, pp. 47-56.

This article discusses the serotype of *Campylobacter jejuni* and *C coli* in poultry. These organisms commonly cause human cases of gastroenteritis.

Nieuwenhuijsen M, Kruize H & Schenker MB 1998, ‘Exposure to Dusts and Its Particle Size Distribution in California Agriculture’ *American Industrial Hygiene Association Journal*, vol. 58, pp. 34-38.

In a Californian study the task being carried out by the farmer was investigated. It was found that those working in the dairy farming industry could be exposed to many different concentrations depending on the task. The average dust concentration for milking was 0.7 mg/m^3, manure removal was 2.6 mg/m^3 and the highest levels recorded were found in the feeding operation (25.9 mg/m^3).

Oberdorster G 1995, ‘Lung Particle Overload: Implications for Occupational Exposures to Particles’ *Regulatory Toxicology and Pharmacology*, vol. 27, pp. 123-135.

This is a review article about the development of lung fibrosis, lung tumours and other related lung diseases and conditions developed from exposure to aerosol particles.

Olenchock SA, Lewis DM & Mull JC 1989, ‘Effects of different extraction protocols on endotoxin analyses of airborne grain dusts’, *Scandinavian Journal of Work Environmental Health*, vol. 15, pp. 430-435.

This is a highly technical article describing different extraction solutions used in the LAL to extract endotoxin from wheat and oats. The article is dated (1989) perhaps newer methods and technology now exists for this test.

Olenchock SA, May JJ, Pratt DS & Morey PR 1986, ‘Endotoxins in the Agricultural Environment’ *American Journal of Industrial Medicine*, vol. 10, pp. 323-324.

This is a very small review article. It gives very brief information about endotoxins, what they are, what they can do and how to test for them. It is also includes some information on exposure levels from other farm related studies.

Olenchock SA, May JJ, Pratt DS & Morey PR 1986, ‘Endotoxins in the agricultural environment,’ *American Journal of Industrial Medicine,* vol. 10, pp. 323-324.

These authors quantified the gram neg bacterial endotoxins in airborne dusts from several silos when the surface of the moldy silage was removed. Airborne dusts were separated into aerodynamic sizes and endotoxins in each size fraction being estimated. A spectrophotometric variation of the LAL assay used to determine endotoxin levels. Respirable dusts in one silo had a mean of 46.4 ng of endotoxin/mg dust (*total dust endotoxin* level 87.3 ng/m^3). Another silo had a mean of 5.4 ng/mg (*total dust endotoxin* was 8.8 ng/mg).

In the *respirable dust fraction* mean endotoxin was 1.32 µg/m^3 (total dust endotoxins was 8.85 µg/m^3) and the other silo mean endotoxin was 0.05 µg/m^3 (total dust endotoxin was 0.12 µg/m^3). Each silo showed endotoxins to be present in every particle range, with the larger particles containing high concentrations of endotoxin per weight.

Authors found a variation in airborne endotoxin levels ranging from 2 ng/m^3 for smallest particles up to 400ng/m^3 for larger particles. They conclude that gram negative bacterial endotoxins are present in silage and associated dust. Both respirable and total dust fractions contained endotoxins (as well as every aerodynamic size particle).

Olenchock SA, May JJ, Pratt DS, Placitelli LA & Parker JE 1990, ‘Presence of endotoxins in different agricultural environments,’ *American Journal of Industrial Medicine*, vol. 18, pp. 279-284.

A study was made measuring endotoxin levels in 2 different farming activities (bedding chopping of baled corn stalks and oat bin unloading).

Total dust collected using 2 piece cassettes 37mm, 5 *u*m pore size and PVC filters, with flow pumps set at 2 L/min. Respirable dust measured using PVC filters through 2 piece cassettes with 10 mm cyclones, flow rate 1.7 L/min. Dust particles separated into aerodynamic sizes by a Jones cassette impactor. Area and personal dust samples were collected.

Endotoxin levels during the chopping of bedding materials ranged from 511-27096 EU /m^3, while total dust levels ranged from 11-69 mg/m^3. The dust fractions containing the highest endotoxin levels varied between barns with the 3.5 µm fraction highest in one barn, while the 20 µm fraction providing the highest endotoxin levels in the other two barns. Endotoxin results for this study may be unreliable because the authors do not identify if LAL assay interference tests were carried to check for possible enhancement or inhibition of the assay.

Every aerodynamically separated fraction from the bedding chopper contained endotoxins. Thus ‘endotoxins are carried on particles that can reach the entire respiratory tract’. Differing processes within each barn showed varying endotoxin levels i.e. similar processes dint necessarily have similar endotoxin levels.

Omland O 2002, ‘Exposure and respiratory health in farming in temperate zones--a review of the literature’, *Annals of Agricultural Environmental Medicine,* vol. 9, no. 2, pp. 119-36.

This is an interesting report reviewing past studies that have been conducted on farming populations in 1) exposure to dust, bacteria, endotoxins, moulds and ammonia, 2) sensitisation to common airborne allergens, 3) prevalence, incidence and risk factors of chronic bronchitis, asthma and bronchial hyperresponsiveness and 4) measurements of lung function.

Total Dust mg/m^3 in swine confinements

Country	Mean
US	6.8
NL	2.6
US	4.53
FIN	12.6
NL	2.4
US	3.45

Respiratory dust mg/m^3 in swine confinements

Country	Mean
US	0.3
D	0.3
US	0.23
US	0.26

This report is well worth reading in full, particularly the reference list.

O'Sullivan S, Dahlen SE, Larsson K, Larsson BM, Malmberg P, Kumlin M & Palmberg L 1998, ‘Exposure of healthy volunteers to swine house dust increases formation of leukotrienes, prostaglandin D2, and bronchial responsiveness to methacholine’, *Thorax*, vol. 53, no. 12, pp. 1041-1046.

This report looks at the risk of leukotrienes, prostaglandin D2, and bronchial responsiveness to methacholine from swine houses. 10 people exposed in a swine farm for 3 hours. Urine was collected before and after. Methacholine FEV decreased. Swine dust exposure induced a 24 fold increase in the total cell number and a 12 fold increase in IL-8 levels in the nasal lavage fluid. Cysteinyl leukotrienes and other mast cell mediators contribute to the development of increased bronchial responsiveness following inhalation of organic swine dust.

Paik S & Vincent JH 2002, ‘Filter and Cassette Mass Instability in Ascertaining the Limit of Detection of Inhalable Airborne Particulates’ *American Industrial Hygiene Association Journal*, vol. 69, pp. 698-702.

This is an American study that studied possible reason for loss when gravimetric analysis is used. The study three types of filters (Teflon, glass fibre and PVC) and three types of weighting cassettes (Plastic, nickel-plated plastic, and stainless steel). It found only minor differences between filter types and cassette types.

Pande BN, Krysinska-Traczyk E, Prazmo Z et al. 2000, ‘Occupational biohazards in agricultural dusts from India,’ *Annals of Agricultural Environmental Medicine*, vol. 7, pp. 133-139.

16 samples of settled dust (due to granular plant handling) from Southern India were analysed by plating for microorganisms (quantitative and qualitative analysis) and LAL test for endotoxins. Total microorganism count ranged from 1.4 x 10^5-8.45 x 10^8 CFU/g (median 8.36 x 10^6 CFU/g). Gram positive bacteria was 87.84%, with gram negative 11.12%, fungi were 1.24% and thermophilic actinomycetes 0.01%. Endotoxin concentration ranged from12.5- 62500 µg/g (median 781.25 µg/g).

Dust from maize had the highest endotoxin levels (6250 and 62500 μg/g) and also pearl millet (6250 and 12500 μg/g)'

Diluted plating was done for bacteria- i.e. 1 g of sample suspended into sterile PBS, shaken and diluted out into 10 fold dilutions and plated onto blood agar, EMB, TSB and malt agar. For endotoxin the LAL assay was used.

Authors indicate that Indian agricultural workers are at risk due to allergenic microorganisms and endotoxins present in high levels

Pasanen A, Kalliokoski P, Pasanen P, Salmi T & Tossavainen A 1989, 'Fungi Carried from Farmers' Work into Farm Homes', *American Industrial Hygiene Association Journal*, vol. 50, no. 12, pp. 631-633.

Previous results showed that in a cow barn the airborne viable spore levels were 10^3 to 10^5 CFU/m^3, and the total spore counts were 10^4 to 10^7 spores/m^3 depending on the work situation.

Pearson C & Sharples T 1995, 'Airborne dust concentrations in livestock buildings and the effect of feed', *Journal of Agricultural Engineering Research,* vol. 60, pp. 145-154.

This paper is a review of past literature regarding the dust caused from feed in livestock housing.

Addresses adverse effects of dust onto man and animal, and proposed methods that have been suggested to combat this problem.

Claims these methods are successful however they are also uneconomic. More needs to be done on ways to reduce the dust rather than simply control it.
Future research into practical feed formulations is needed.

The benefits of animal production need to be quantified before the economics of the various dust control methods can be evaluated.

Pedersen B, Iversen M, Larsen BB & Dahl R 1996, 'Pig farmers have signs of bronchial inflammation and increased numbers of lymphocytes and neutrophils in BAL fluid', *European Respiratory Journal,* vol. 9, pp. 524-530.

This study was done to investigate whether pig farmers had inflammation of the bronchial mucosa and activation of bronchoalveolar lavage (BAL) cells. This study was carried out in Denmark and consisted of 27 non smoking pig farmers and 53 non smoking healthy medical students as controls. Farmers had worked long term, at least 4 years in farming, as well as at least 2 years and an average of 11 years, as pig farmers. . The participants underwent lung function tests (FEV_1), histamine challenge, and bronchoscopy and BAL. Scores for macroscopic bronchial inflammation (bronchoscopy) were significantly higher in pig farmers. More pig farmers had a positive histamine challenge than controls ($p>0.05$). There was no difference in BAL cell concentrations; however pig farmers had significantly increased median concentrations of lymphocytes and neutrophils. A number of factors may have influenced the direction of these findings. For example, farmers were older than controls with an average age of 38years compared with 24 years for control subjects. In addition, seven farmers were reported to have mild respiratory symptoms for which they had not sought medical investigation or treatment. Further, visual assessment at bronchoscopy was not blind.

Pedersen S, Nonnenmann M, Rautianinen R, Demmers TGM Banhazi T & Lyngbye M 2001, 'Dust in Pig Buildings', *Journal of. Agricultural Safety and Health*, vol. 6, no. 4, pp. 261-274.

This paper reviews the various impact of dust on pigs and methods of potentially reducing dust levels indoors. The authors have recommended the following exposure levels to maintain pig health:

- Total Dust 3.7 mg/m^3
- Respirable dust 0.23 mg/m^3
- Total Endotoxin: 1540 CFU/m^3

Petro W, Bergmann KC, Heinze R, Muller E, Wuthe H & Vogel J 1978, 'Long-term occupational inhalation of organic dust--effect on pulmonary function' *International archives of occupational and environmental health,* Nov 15; vol. 42, no. 2, pp. 119-27.

This report addresses the health effects of workers at a poultry farm.

All subjects were exposed to organics dusts and poultry antigens. Subjects were examined by means of counter-immunelectrophoresis, systematic interviewing for case histories and registration of respiratory symptoms.

A disorder of pulmonary function was recorded in 40 from 42 workers. Disorders were characterised by obstruction of the airways and slight inhomogeneity.

2 workers had allergic alveolitis; obstruction of the larger airways with concomitant restriction, marked inhomogeneity and disorder of diffusion.
These disorders, relatively discrete lead to mild PO2 reduction in individuals, where as mild hypoxaemia was recorded from subjects with allergic alveolitis.

Phillips VR, Holden MR, Sneath RW, Short JL, White RP, Hartung J et al. 1998, 'The Development of Robust Methods for Measuring Concentrations and Emission Rates of Gaseous Particulate Air Pollutants in Livestock Buildings ' *Journal of Agricultural Engineering Research,* vol. 70, pp. 11-24.

This is the first (introduction) section for a very large European study that includes many different articles. This article is focussed on pollutant emissions from livestock building and there impacts on the surrounding environment. The results were from a sow unit averaged over 24 hours were: ammonia 0.86g NH_3/h, inhalable dust 0.19 g/h, respirable dust 0.02 g/h, and total bacteria 2.3 M (CFU)/(hpu).

Pillai SD, & Ricke SC 2002, 'Bioaerosols from municipal and animal wastes: background and contemporary issues' *Canadian Journal of Microbiology,* vol. 48, no. 8, pp. 681-696.

Endotoxin concentrations were found to be at least tenfold higher in swine barns than sawmills.

Prami G, Zeitier-Feicht M, Hartmann A & Riedel H 1990, 'Dust exposure of man and animal in swine confinement buildings: Benefits of full shift continuous registration', *Journal of Aerosol Science,* vol. 21, no.1, pp. 5751-5754.

This report assesses past methodology in identifying emission sources of dust in swine confinements. The report proposes that traditional gravimetric sampling is insufficient and instead a full shift continuous registration would be better. Continually registered the man and pigs personal exposure in two farms. This style of measurement located an inadvertent emission source. There are improvements that need to take place in the management of swine confinements. Full shift continuous registration is better than gravimetric sampling.

Predicala BZ, Urban JE, Maghirang RG, Jerez SB & Goodband RD 2002, 'Assessment of bioaerosols in swine barns by filtration and impaction', *Curr Microbiol*, vol. 44, pp. 136-140.

The paper was aimed at determined the levels of airborne total and respiratory micro-organisms that may be present in a pig shed and well as identify the most common types present. In addition the paper evaluate two common methods of measuring airborne micro-organisms, impaction and filtration. The two sample collection methods are:

- impaction using a 6 stage viable sampler (Andersen Cascade Impactor), using R2A agar, at a flow rate of 28.3 L/min for 1 minute.
- filtration using a 0.45μm cellulose nitrate membrane filters, that have been sterilised with UV. The samples were collected at a flow rate of 2L/min for 3 minutes. The total bioaerosols samples were collected in a 47mm open face filter holder and the respirable were collected in 37 mm cyclone.

The results of the study are

	Total CFU/min^3	Respirable CFU/min^3
Impaction	8.4×10^4	2.8×10^4
Filtration	6×10^4	9×10^3

The authors reported that there is significant difference between the two methods with the impaction method measuring higher concentrations. The typical species detected were *Staphylococcus, Pseudomonas, Bacillus, Listeria, Enterococcus,Nocardia, Lactobacillus*, and *Penicillium*

Preller L, Heederik D, Kromhout H, Boleij JSM & Tiele, MJ 1995, 'Determinants of dust and endotoxin exposure of pig farmers: development of a control strategy using empirical modeling', *Annals of Occupational Hygiene*, vol. 39, no.5, pp.545-557.

This study measured personal dust and endotoxin exposure in 189 Dutch pig farmers. 8h measurements were taken for 2 days (one summer and one winter day). Mean TWA exposure for dust was 3 mg/m^3 and for endotoxin was 130 ng/m^3. Empirical statistical modeling was used to determine activities and farm characteristics associated with exposure levels. Multiple least-squares regression analysis, aspects of hygiene and feeding were major characteristics with dust exposure. Other characteristics such as flooring and feeding explained variations in endotoxin levels obtained. Frequent activities such as feeding, moving active animals, teeth cutting etc were associated with dust and endotoxin exposure.

Methods: 3 different farms were selected (i.e. breeding, finishing and combination of breeding/finishing farms) in the Netherlands. Personal samples collected for inhalable dust and endotoxins. Sample used - 6mm diameter inlet, airflow 2.1 L/min, Teflon filters (1 μm Millipore). Endotoxin was measured using kinetic LAL assay. Data was collected on site characteristics- e.g. number of animals, feeding method, floor/bedding type etc. Statistical analysis was performed (see article for full details).

Discussion of results: 198 farmers tested had high mean levels of dust (3 mg/m^3) and endotoxins (130 ng/m^3). This was similar to studies by other researchers.

Researchers using cotton dust exposure have shown levels of endotoxin in chronic respiratory sufferers have a no-effect level of 9 ng/m^3. Healthy people have a no-effect endotoxin level of 33 ng/m^3. Threshold levels of 100 ng/m^3 have been proposed by an international working group (in 1986) and a few years later 30 ng/m^3 (1988).

Purdy CW, Straus DC, Parker DB, Wilson SC & Clark RN 2004, ‘Comparison of the type and number of microorganisms and concentration of endotoxin in the air of feed yards in the Southern High Plains’, *American Journal of Veterinary Research*, vol. 65, no. 1, pp. 45-52.

This paper relates to measure exposures in 7 feed yards. It investigated the impact of seasons on levels such as summer and winter as well as position of monitors including upwind, downwind and on-site. Samples were collected using either a 2-stage or a 6-stage Anderson impactor at 1 metre high There was significant difference between summer and winter (2.63 ng/m^3 and 8.37 ng/m^3) respectively. This was in conflict with the results for the number of microbes, which were higher in summer than winter.

The bacteria exposures were broken down to 3 types of bacteria: mesophilic bacteria (1,441 ± 195 CFU/m^3), anaerobic bacteria (751 ± 133 CFU/m^3) or thermophilic bacteria (54 ± 10 CFU/m^3). 18 types of bacteria were identified using an automated identification system.

The fungi exposures were broken down into 2 types: mesophilic fungi (78 ± 7 CFU/m^3) and thermophilic fungi (2 ± 0.2 CFU/m^3). Eighteen genera of bacteria were identified by use of an.

Radon K, Weber C, Iversen M, Danuser B, Pedersen S & Nowak D 2001, ‘Exposure assessment and lung function in pig and poultry farmers’, *Occupational and Environmental Medicine*, vol. 58, no. 6, pp. 405-416.

The sample in this study was a subsample from a multi centre European study of farmers randomly selected from regional professional organisations. Thirty-six poultry farmers in Switzerland were compared with that of 36 pig farmers in Denmark. There was no significant difference in age, smoker status, history of asthma or bronchitis or respiratory symptoms between the two groups. Pig farmers were predominantly male (90%) than poultry farmers (67%). Methods are well described and standardised. Spirometry assessments were analysed blind by one reviewer according to American Thoracic Society criteria. Self reported symptoms questionnaire was based on BMRC criteria. Spirometry findings were age and height adjusted and compared with reference values according to the European Community for Steel and Coal criteria. Except for MMEF, all spirometry measures were higher than expected for both groups of farmers. Poultry farmers had significantly lower values for all spirometry measures (FEV_1, FVC, MMEF) than pig farmers and may be explained by the gender difference between the groups. However, poultry farmers also had higher environmental exposure levels to total dust, endotoxin, bacteria and ammonia ($p<0.05$ for all comparisons). Pig farmers had higher exposure to total fungi ($p<0.05$). No significant change in spirometry was observed before and after work in animal buildings. For all farmers, farmers without respiratory symptoms had significantly higher FEV_1, FVV and MMEF findings ($p<0.05$). The findings of comparisons with farm characteristics were as follows

Poultry

Univariate comparisons of spirometry with farm characteristics, building temperature, total dust level and so forth were inconclusive. The numbers were small and data skewed requiring non parametric statistical tests. The only significant finding ($p<0.05$) was that FVC was lower when an air porous inlet was present.

Pig

As for poultry, comparisons were inconclusive. The presence of a controlled humidity sensor was associated with significantly higher $FEV_{1,}$ FVC and MMEF than when a sensor was absent. Higher temperatures (>19°) were associated with significantly lower $FEV_{1,}$ FVC and MMEF ($p<0.05$).

Personal exposure data was collected on both pig and poultry farmers for dust endotoxin fungi and bacteria. Dust samples were collected at a flow rate of 3.7 L/min on glass fibre filters, then endotoxin analysis was undertaken on the filters using the LAL method. Airborne micro-organisms where collected on polycarbonate filers at a flow rate of 1 L/min. The results presented follow:

	Pig Farmers			Poultry Farmers		
	Median	Min	Max	Median	Min	Max
Dust (mg/m^3)	4.0	1.1	13.8	7.0	0.4	21.8
Endotoxin (ng/m^3)	58	1.3	1101.7	257.6	19.0	1634.8
Bacteria (CFU/m^3)	4.2 x 10^6	<DL	1.6x 10^8	4.7 x 10^7	2.7 x 10^7	4.2x 10^{10}
Fungi (CFU/m^3)	8.7 x 10^6	<DL	1.4x 10^8	2.0 x 10^7	<DL	1.1 x 10^9

Radon K, Danuser B, Iversen M, Monso E, Weberj C, Hartung J et al., 2002, Air contaminants in different European farming environments, *Annals of Agricultural Environmental Medicine*, vol. 9; 41-48.

This article reports on the exposure of farms to dust, endotoxin, bioaerosols and gases in Danish, German, Spanish and Swiss swine and poultry confinement houses. Dust, endotoxins and microbiological concentrations were determined in crop and animal farms by personal sampling. Table 1: Environmental measurements (median and range) for study centres.

Sample Type	**Denmark (swine)**	**Germany (swine)**	Switzerland **(poultry)**
Total Dust (mg/m^3)	3.95 (1.11-13.75)	5.00 (<DL-76.7)	7.01 (0.42-21.75)
Endotoxin (total dust) (ng/m^3)	58.01 (1.30-1101.7)	76.30 (0.01-2090.1)	257.58 (18.99-1634.8)
Ammonia (ppm)	6 (<5-14)	10 (<5-60)	12 (<5-40)
Carbon Dioxide (ppm)	1200 (800-2500)	1500 (300->3000)	2100 (600->3000)
Total fungi (cells/m^3)	8.7 x 10^6 (<DL-1.4x10^8)	-	2.0 x 10^7 (<DL-1.1x10^9)
Viable Fungi (CFU/m^3)	3.8 x 10^5 (<DL-4.3x10^6)	-	4.4 x 10^5 (1.4x10^4-1.1x10^8)
Total Bacteria (cells/m^3)	4.2 x 10^8 (<DL-16.0x10^9)	-	4.7 x 10^9 (2.7x10^7-4.2x10^{10})
Viable Bacteria (CFU/m^3)	5.8 x 10^6 (<DL-1.6x10^8)	-	7.9 x 10^7 (5.7x10^5-1.6x10^9)

<DL indicates results were below the detection limit

Dust concentrations in swine and poultry buildings were comparable, while endotoxin concentrations were highest in poultry houses. Ammonia and carbon dioxide levels were highest in poultry buildings, which also had the lowest temperature and air velocity readings. Poultry houses had the highest total and viable fungi levels.

The air sampling flow rates for dusts was 3.7 L/min. The fungi and Bacteria were sampled at a flow rate of 1 L/min using a method developed by ‘Palmgren U, Ström G, Blomquist G, Malmberg P

(1986). Collection of airborne microorganisms on Nuclepore filters, estimation and analysis - CAMNEA method, J. Appl Bact vol. 61 pp 401-406

Rask-Andersen A, Malberg P, Lundhom M 1989, ‘Endotoxin levels in farming: absence of symptoms despite high level exposure levels,’ *British Journal of Industrial Medicine*, vol. 46, pp.412-416.

Aims here were to: ‘measure endotoxin exposure during different farming activities, to study respirability of dust fractions containing endotoxins, to correlate endotoxin exposure to symptoms and to compare endotoxin exposure with other exposures associated with symptoms.’ Endotoxin levels were measured in farms where 11 workers had febrile or allergic alveolitis and also in farms with 17 workers who had no symptoms. Samples were collected in 8 reference dairy farms (background levels) and in all farms during handling of hazardous (to health) materials. Parallel samplers (cyclone sampler with cutoff 5 um and one without) were used in reference farms to measure dust (total) and endotoxin levels in the respirable fraction. Levels of endotoxin in ‘symptom’ farms ranged from <0.01- >50 $\mu g/m^3$ (median 6.4, mean 2.2 $\mu g/m^3$), while reference farms had vales of <0.01- >50 $\mu g/m^3$ (median 42 $\mu g/m^3$, mean 29 $\mu g/m^3$). 75% of endotoxin activity was found in the non respirable fraction, with no correlation being found between exposure to endotoxin and symptoms in farmers. High endotoxin levels found in environments where no symptoms existed raise concerns that the Limulus amoebocyte lysate assay (LAL), may be giving non specific high results (i.e. it may be sensitive to other dust components other than endotoxins). *They suggest that the recommended assay (LAL) may not be a suitable assay for measuring endotoxins in farming environments.*

Methods used: Personal samplers used (Millipore, diam 37mm), polycarbonate filters pore size 0.4 µm, airflow 1 L/min. Total spores from microorganisms were counted using epifluorescence microscopy. Total dust and endotoxin levels were collected using a cellulose acetate filter (0.8 µm millipore), airflow 10 L/min. Endotoxin measured using LAL assay.

Conclusions: Gram negative bacteria adhering to organic material may explain why high endotoxin levels were found in the non respirable dust fractions. (Refer Olenchock et al. ‘Endotoxins in agric environment’ *Am J Ind Med* 1986, 10:323-24). Half of the samples of respirable dust had endotoxin levels above 10 ug/m^3.

They suggest that the recommended assay (LAL) may not be a suitable assay for measuring endotoxins in farming environments. LAL is a highly specific test but some disagree with this and believe that other components in dust (such as cell wall dextrans, mannans) may interact with the LAL test.

Rask-Anderson A 1989, ‘Organic dust toxic syndrome among farmers’ *British Journal of Industrial Medicine*, 1989 vol. 46, pp. 233-8.

This study investigates the clinical symptoms as well as the exposure conditions in 80 farmers who suffered organic dust toxic syndrome.

The farmers were examined by a physician. 44% of farmers had one attack, and the remainder had several, often years apart. Attacks were more common in autumn and were provoked by handing grain. Often the materials being handled were extremely mouldy.

Having mould in a working environment is often unavoidable due to weather conditions. Hence people working with these materials should wear a mask to avoid unnecessary illness.

Rautiala S, Kangas J, Louhelainen K & Reiman M 2003, ‘Farmers’ Exposure to Airborne Microoganisms in Composting Swine Confinement Buildings’, *AIHA Journal*, vol. 64, pp673-677.

This paper reports on the microbial monitoring undertaken at 12 composting swine confinement houses and 7 traditional floe swineries. Of the composting swinery 7 used sawdust and 5 used peat. Air sampling was undertaken using a 6-stage Anderson Cascade Impactor at 28.3 L/min with plates containing varying agars according the microbes being assessed. In this study in addition to obtaining air concentration a number of fungi were identified.

	Total Fungi x 10^2 CFU/m^3	**Gram –ve Bacteria** x 10^2 CFU/m^3
Traditional swinery	3670	430
Composting swinery, sawdust, background	1950	150
Composting swinery, sawdust, turning	5740	160
Composting swinery, peat, background	14900	1100
Composting swinery, peat, turning	35300	700

Rearson CC & Sharples TJ 1995, ‘Airborne Dust Concentrations in Livestock Buildings and the Effect of Feed’, *Journal of Agricultural Engineering Research*, vol. 60, pp 145-154.

This is a review paper which discusses arrange of issues that impact on dust levels in respect to animal feed.

Reboux G, Piarroux, R, Mauny, F, Madroszyk, A, Millon, L, Bardonnet, K, et al. 2001, ‘Role of Moulds in Farmer's Lung Disease in Eastern France’ *American Journal of Respiratory and Critical Care Medicine,* vol. 163, pp. 1534-1539.

In a French study the maximum values for the concentration of microorganisms per cubic meter of air varied from 6.5×10^5 CFU/m^3 for moulds and from 10^3 to 6.4×10^5 CFU/m^3 for actinomycetes. It was also found that the peak exposure found was a the beginning of work shifts and the time taken for the concentration of microbes to double was, on average 5 mins. At the end of the work shift, the microbial concentration returned to initial values in 12 of 22 cases for fungi and 9 of 22 cases for actinomycetes.

Reed SG, Kift RL & Mulley RC, 2003a, Exposure of Dairy Workers to Dusts and Bioaerosols, *Safety2003*, Hong Kong, March 2003.

This paper reported on a preliminary survey of workers exposures to dusts and bioaerosols in a diary farm. The average personal respirable dust exposure was 2.72 mg/m^3. Whereas the average static respirable dust levels 0.16 mg/m^3 and inspirable dust was 0.20 mg/m^3. The average bacterial count was 1419 CFU/m^3 and the fungal count was 1801 CFU/m^3.

Reed SG, Kift RL & Mulley RC, 2003b, Exposure of Horse Handlers to Dusts and Bioaerosols, *Safety2003*, Hong Kong, March 2003

This paper describes a pilot study of workers exposure assessment undertaken when preparing food for horses. The monitoring was only undertaken over 2 days at one stable. The average personal respirable measurements was 14.97 mg/m^3. The average static measurements were 1.24 mg/m^3 for respirable levels and for 1.08 mg/m^3 for inspirable levels. The average bacteria levels were 864 CFU/m^3 and the fungal levels were 1494 CFU/m^3.

Reynolds S & Milton D 1993, ‘Comparison of methods for analysis of airborne endotoxin’, *Applied Occupational and Environmental Hygiene,* vol. 8, no. 9, pp. 761-767.

This study compared the use of endpoint and kinetic LAL assays for monitoring endotoxin levels in poultry confinement buildings (hen and brooder). Endotoxin levels in hen buildings ranged from 3132 (kinetic) to 4593 (endpoint) EU/m^3, and from 1274 (kinetic) to 1164 (endpoint) EU/m^3 in brooder buildings.

Reynolds SJ, Donham KJ, Whitten P, Merchet JA, Burmeiter LF & Popendorf 1996, 'Longitudinal Evaluation of Dose-Response Relationships for Environmental Exposures and Pulmonary Function in Swine Production Workers', *American Journal of Industrial Medicine*, vol. 29 pp 33-40.

This paper describes the types of health symptoms workers in the swine industry may suffer.

Air samples were collected for total dust at a flow rate on 2 L/min on a closed face cassette; respirable was collected on a cyclone at the flow rate of 1.7 L/min. Endotoxin analysis was undertaken of the filters using an endpoint LAL.

The analysis of the data looked at not pony total averages but compare length of time in the industry against cross shift change in FEV1. An average the results for each sampling period was analysed and compared to see if there was any significant change. The average results for the 1st sampling period were: total dust 4.55 mg/m^3, respirable 0.23 mg/m^3, total endotoxin 202.67 EU/m^3 and respirable endotoxin 16.95 EU/m^3. For the 2nd period: total dust 3.45 mg/m^3, respirable 0.26 mg/m^3, total endotoxin 176.12 EU/m^3 and respirable endotoxin 11.86EU/m^3. There was a statistical significance in the respirable endotoxin between the 2 periods.

Reynolds SJ, Parker D, Vesley D, Smith D & Woellner R 1993, 'Cross-sectional epidemiological study of respiratory disease in turkey farmers', *American Journal of Industrial Medicine,* vol. 24, pp. 713-722.

This was a two phase cross-sectional prevalence study of 95 workers in Turkey barns (mean age 37 years and 90% males) in Minnesota. All turkey producers were approached, 47% participated. Participation by the largest producer represented 67% of subjects. Measurements included spirometry and a questionnaire for self reported respiratory symptoms and history, which was based on the American thoracic Society standard for respiratory disease. Measurements were carried out in both winter and summer. Cross-shift spirometry measurements were examined for 40 subjects. Environmental dust, endotoxin, bacterial and ammonia levels were measured in three different types of randomly selected test barns (hen, brooder and tom barns) from 39 in which the subjects worked. Environmental measures were highest in winter in all of the barns. Each barn held at least 10,000 birds.

Symptoms of cough, wheeze, phlegm, breathlessness and allergies were all increased in winter. For example, the prevalence of cough was 39.7% in winter and 22.2% in summer. This seasonal trend was statistically significant for cough phlegm and allergies. When examined according to smoking status, this difference was more evident in smokers than in ex and former smokers. For example, the prevalence of cough in smokers in winter was 57.7% compared to 22.7 in summer; the corresponding figures for never smokers were 31.3% and 27.3%. Some symptoms increased for never smokers, eg, the prevalence of symptoms of breathless increased from 0% in winter to 9.1% in summer. However, stratification according to smoking status resulted in small number of subjects in each cell (15-25) and most of findings on stratification were not statistically significant.

FEV_1 and FVC were both lower than predicted in all seasons, 89.3% to 95.7%, and lower for the winter months ($p<0.05$ for both). Statistically significant cross-shift declines in both were also reported, an average of –2.7% FEV_1 and - 2.5% FVC with no significant change in the FEV_1/FVC ratio. FEV_1 (!=-0.46, $p<0.05$) and FVC (!=-0.47, $p<0.05$) were moderately and negatively correlated with years worked in the industry. Data were stratified according to; spirometry findings and smoking status, spirometry and years of work in the industry. These findings were inconclusive possibly due to small numbers in each cell.

Reynolds S, Thorne P, Donham K, Croteau E, Kelly K, Lewis D et al. 2002, 'Comparison of Endotoxin Assays using Agricultural Dusts', *AIHA Journal*, vol. 63, pp. 430-438.

The article compares the use of different methods for analysing endotoxin in organic dusts from chicken and swine barns, and corn processing facilities. In chicken dust endotoxin concentrations ranged from 764-37190 EU/m^3, while swine dust had 434-40650 EU/m^3.

Rhyder G 1993 *Occupational Hygiene Survey of a piggery*, WorkCover Authority NSW.

This is a consultancy report on employee exposure to dust when working in a piggery in NSW. Dust monitoring was undertaken according to AS3640: 1989 using a 7-hole sampler.

Results presented in the report are Boar Shed 9.9 mg/m^3, Farrowing Shed 3.9 mg/m^3, Weaner Shed/farrowing Shed mg mg/m^3, Weaner Shed 37 mg/m^3, Finisher Shed 3.6 mg/m^3 and mixed areas 6.7 mg/m^3. As the main food was grain bases an exposure standard of 4 mg/m^3 was used.

Bioaerosols such as bacteria were collected on a settling plate and using a RCS but the results are reported as total numbers on the plates not as an air concentration.

Riedler J, Braun-Fahrlander C, Eder W, Schreuer M, Waser M, Maisch S et al. 2001 'Exposure to Farming in Early Life and Development of Asthma and Allergy: a cross-sectional survey', *The Lancet*, vol. 358, pp. 1129-1133.

It has been found that the timing of exposure to farm characteristics in or even, before the first year of life, and amount and duration of exposure from the first to the fifth year of life are crucial for this protective effect.

Rylander R & Morey P 1982, 'Airborne Endotoxin in industries processing vegetable fibers,' *American Industrial Hygiene Association Journal*, vol. 43, no. 11, pp. 811-812.

This is a study where airborne lipopolysaccharides (LPS) levels were determined at different sites processing vegetable fibers. LAL assay test was used. Levels of LPS obtained were often over limits causing health effects (i.e. 0.5 μg/m^3). Processes such as weaving had lower values, while higher levels were found in flax carding rooms. Results obtained showed differences in values obtained with the same processes at different mills. The results obtained here were in keeping with previous byssinosis studies performed in the textile industry.

Rylander R 1986 'Lung Disease Caused by Organic Dusts in the Farm Environment' *American Journal of Industrial Medicine*, vol. 10, pp. 221-227.

This is a review article. It outlines the different lung related diseases that may be acquired from exposure to organic dusts. This disease includes: inflammation, HP, asthma, and toxic fever.

Rylander R 1997 'Evaluation of the Risks of Endotoxin Exposures' *International Journal of Occupational and Environmental Health*, vol. 3 Jan-Mar no. 1 (suppl.) pp. S32-S36.

It has also been suggested that 0.2 µg/m^3, or 200 ng/m^3, of endotoxin in the environment is a level where toxic pneumonitis will not develop among normal individuals. A small decrease in FEV1has also been found after exposure to 30 µg of endotoxin but not at 2 0µg. In an experiment on cotton workers and previously unexposed persons, the threshold values for FEV1 decreases after four-hour exposures were 0.17 µg/m^3 among non-smoking cotton workers and students and 0.08 µg/m^3 among smoking cotton workers. In relation to airways inflammation it is suggested that 0.01µg/m^3 or 10ng/m^3 will not lead to an increased risk in normal subjects.

Rylander R, Donham KJ, Hjort C, Brouwer R & Heederik D 1989, 'Effects of exposure to dust in swine confinement buildings a working group report', *Scan J. Work Environ Health*, vol. 15, pp. 309-312.

This paper is a review paper discussing typical symptoms that a worker in the pig industry may suffer due to exposure to dust.

Sarica S, Asan A, Otkum MT & Ture M 2002, 'Monitoring Indoor Airborne Fungi and Bacteria in the Different Areas of Trakya University Hospital, Edirne, Turkey', *Indoor and Built Environment,* vol. 11, pp. 285-292.

This Turkish study carried out monthly monitoring for airborne fungi in 6 different hospitals. The outdated Petri dish method was used. The samples were collected for 10 minutes and the average number of fungi colonies counted was 155 CFU. The average bacteria colonies was 535 CFU. *Staphylococcus* spp. was the most common bacterial species. *Cladosporium* and *Penicillium* were the most common fungal genera.

Scarpino P & Quinn H 1998, 'Bioaerosol Distribution Patterns Adjacent to Two Swine-Growing-Finishing housed confinement units in the American Midwest', *Journal of Aerosol Science*, vol. 29, no. 1, pp. 553-554.

This brief report determined the presence of microbes from swine growing and finishing in downwind areas from these activities.

Neighbours in close proximity to swine operations complained of serious odours, personal discomfort due to the odours, loss of sleep, possible allergic manifestations and respiratory difficulties.

A series of bioaerosol studies were conducted around two swine operations that assessed microbial (bacteria and fungi) numbers and types released in air emissions from these operations. Antibiotic sensitivities of staphylococcal air isolates were also made at one facility. The samples were collected a 6-stage Anderson Impactor but no flow rate was stated.

Results were achieved for both fungi and bacteria. There were variations reported for both sites monitored including between seasons. The results for fungi samples collected in a farmhouse were 1130 CFU/m^3. All the outside results varied both below and above this figure whereas bacteria results ranged form 380 to 1614 CFU/m^3.

Animal confinement facilities should be sites with consideration of the location of human habitation. The use of antibiotics in animal feed should be reviewed to minimize the development of antibiotic-resistant bacteria.

Schenker MB (Chair) 1998, 'Respiratory Health hazards in Agriculture', *American Journal of Respiratory and Critical Care Medicine*, vol. 58, no 2, part 2 (whole edition).

This is a collection of papers of a conference held in February 1998. The papers are a review of the current knowledge and have condensed data that has been presented elsewhere.

Schwartz DA, Donham KJ, Olenchock SA, Popendorf WJ, Scott Van Fossen D, Burmeister LF & Merchant JA 1995, 'Determinants of longitudinal changes in spirometric functioning among swine confinement operators', *American Journal of Respiratory and Critical Care Medicine*, vol. 151, pp. 47-53.

This paper reports the findings of a longitudinal study of swine farmers in East Iowa. Other papers from the same study are also included in this bibliography (Donham et al. 1995, Schwartz et al. 1995). The potential farmers were randomly selected from swine farmers in East Iowa from lists stratified according to number of swine and county. Of 2019 farmers approach by mail 48% responded and 465 had swine confinement facilities. From these 207 were randomly selected from a stratified list based on estimated level of exposure, high, medium and low using building characteristics and number of hours worked in buildings. All farms have at least 400 swine. Controls were selected from neighbourhood farms and did not work in confinement buildings or had not done so for at least five years. The groups were similar in age, gender, smoking status and atopy. Measurements collected by field researchers included lung function tests and respiratory symptoms questionnaire based on the American Thoracic Society Questionnaire, exposure histories and personal sampling. The average concentrations of total dust and endotoxin exposure for 168 confinement workers were significantly higher than for 127 neighbourhood control farmers. The percentage decrease in both FEV_1 and FVC over five years was higher for the control group than for the swine confinement workers, -0.84 compared with -1.15 for FEV_1. However cross-shift declines were higher for swine confinement workers at any time during the study (no significance testing reported for these comparisons). Multiple regression modelling for FEV_1 found that the percentage of cross-shift decline was a statistically significant predictor, and total endotoxin level and working in swine confinement were both significant negative predictors when adjusted for age, height, smoking, smoking pack years and years follow. Only percentage of cross-shift decline was a significant predictor in modelling for FVC.

Seedorf J, Hurting J, Schrader M, Linker KH, Phillips VR, Holden MR et al. 1998, 'Concentrations of Emissions of Airborne Endotoxins and Micro-organisms in Livestock Buildings in Northern Europe', *Journal of Agriculture and Engineering Research*, vol. 70, pp.97-109.

This is the finding of a study determining levels of endotoxins and microorganisms in 241 livestock buildings (cattle, poultry and pigs) in UK, Netherlands, Denmark and Germany. Measurements were taken day and night with endotoxin levels being determined from inhalable and respirable fractions of dust. The inhalable dust samples were collected at a flow rate of 2 L/min and respirable dust at a flow rate of 1.9 L/min these samples were then analysed for endotoxins using a LAL method modified by kinetic-turbidimetric analysis. The microbial samples were collected using automatic bacteria sampler that is still being validated.

The lowest endotoxin levels were found in cattle houses (inhalable endotoxins were 52.3 – 186.5 ng/m^3 and respirable endotoxins were 7.4- 18.9 ng/m^3). Poultry had the highest endotoxin levels (inhalable 338.9 - 860 and respirable 29.6 - 71.8 ng/m^3). Endotoxin levels were higher during the day than night. The highest emission rate for total microorganisms (bacteria and fungi) was measured for broilers (6.43 log CFU/m^3), while the laying hens had the highest emission rates for bacteria. Microorganisms were measured in this study using a newly developed automated machine (similar to a slit air sampler).

The authors suggest 'studies of transmission, distribution and biological effects of airborne microbes and endotoxins are needed to estimate and evaluate the hazards of bioaerosols in livestock units'

The lowest levels of endotoxin were found in the cattle houses 15.1 ng/m^3, compared to pig (135.1 ng/m^3) and chickens (785.7 ng/m^3). The highest total bacteria concentrations were found in the chicken houses with mean concentrations of 6.43 log cfm/m^3. For pigs the mean concentration was 5.1 log cfm/m^3 and for cattle, 4.3 CFU/m^3. The composition of airborne microorganisms in all of the livestock buildings in this study was characterized mainly of two types of Gram-positive bacteria. *Staphylococcus* spp. and Streptococcus spp with a relative concentration of 90% or more of total bacteria collected.
Some of the results are reported against country and industry type.

Seedorf J, Takai H, Pedersen S, Johnsen JO, Metz JHM, Groot Koerkamp PWG, Uenk GH et al. 1998, ‘Concentrations and emissions of airborne dust in livestock buildings in northern’, *Europe Journal of Agricultural Engineering research*, vol. 70, pp. 59-77.

This report measured the concentrations and emissions of airborne endotoxins and microorganisms in livestock buildings. It looks at a range of animals and different measurement methods.

Measurements were made during the day and night. Endotoxins were determined from dust samples, separated into inhalable and respirable fractions. Airborne microorganisms were classified as total bacteria, *Enterobacteriaceae* and total fungi.

A new automated bioaerosol sampler was developed, allowing remote independent sampling of airborne microorganisms.

The lowest endotoxin concentrations were found in cattle houses. The highest were in poultry house, especially percheries, with an overall mean of 69 2ng/m^3 for inhalable and 49 ng/m^3 for respirable fractions.

Comparing to other animal industries, poultry houses had the highest levels of airborne bacteria and fungi, with an average values of 692 ng/m^3 for inhalable dust fractions.

Selim MI, Juchems AM & Popendorf W 1998, ‘Assessing airborne aflatoxin B1 during on-farm grain handling activities’, *American Industrial Hygiene Association Journal*, vol. 59, no. 4, pp. 252-256.

Studies looking for the concentration of aflatoxin in farms have found that the rage of concentration is quite large from 23 to 5100 ng/g in settled dust from swine buildings.

Senthilselvan A, Zhang Y, Dosman JA, Barber EM, Holfeld LE, Kirychuk SP et al. 1997, Positive Human Health Effects of Dust Suppression and Canola in Swine Barns, American *Journal of Respiratory Critical Care Medicine*, vol. 156, pp. 410 417.

This paper the effect on canola air in suppressing dust in swine sheds.

The study investigated a number of health related factors such as lung function as well as monitoring dust exposure. Personal dust samples were collect at a flow rate of 3.94 L/min. Also area samples collected at the same flow rate. Endotoxin analysis was undertaken on the dust sampled using an LAL method. Results are compare a treated room against an untreated (control) room are summarised below

	Control Room	**Treated Room**
Personal Dust (mg/m^3)	2.41±0.09	0.15 ± 0.02
Area Dust (mg/m^3)	3.8 ± 0.2	0.6 ± 0.3
Personal Endotoxin (EU/m^3)	3983.5± 498.3	452.3 ± 65.8
Area Endotoxin (EU/m^3)	7030.1 ± 610.1	565.7 ± 102.1

A single sample crossover trial involving 20 non smoking healthy male subjects who were not farmers was carried out. The results suggested that the canola oil dust control method was effective in improving the indoor air quality in swine barns. Subjects were exposed to each barn for five hours. Study methods are well described, however they do not account for an unexpected finding that mean personal endotoxin concentrations were significantly higher following exposure in the treated barn whereas inhalable and respirable dust concentrations were reduced. Acute respiratory symptoms were significantly fewer in the treated barns, deterioration in FEV_1 less and sensitivity to methacholine decreased.

Simpson JCG, Niven RM, Pickering CAC, Fletcher AM, Oldham LA & Francis HM 1998, 'Prevalence and predictors of work related respiratory symptoms in workers exposed to organic dusts', Occupational and Environmental Medicine, vol. 55, pp. 668-672.

The aims of this cross-sectional prevalence survey of respiratory symptoms in a range of textile and farming industries in the UK were to measure the prevalence of work related upper and lower respiratory tract symptoms in workers exposed to organic dusts and predict their occurrence. The three groups of subjects of interest here were those involved in swine farming (43 subjects), poultry farming (84 subjects) and animal feeding (34 subjects). Volunteer workers across all industries were interviewed according to a standardised questionnaire based on the MRC respiratory questionnaire. Symptoms were considered work related if they improved on holidays or leave days. Respectively, the prevalence of lower respiratory tract symptoms (wheeze, chest tightness, cough, phlegm and SOB) and upper respiratory tract symptoms (eye and nasal irritation) were 23%, 38% and 12% and 34%, 45%, 38%. These were higher than in any other industries for poultry farm workers. Personal dust exposures were measure on a sub sample of subjects and attributed to the remaining workers in a particular industry (average 25% of workers in each industry). Upper and lower respiratory tract symptoms were modelled separately by Cox regression analysis. Statistically significant predictors of LRTS were a history of asthma, history of bronchitis, current smoking, dust or endotoxin concentrations (increasing with increasing concentrations) and ethnicity (white subjects had higher risk). Significant predictors of URTS were ethnicity (white subjects had higher risks), gender (females had higher risk) and dust or endotoxin concentrations (increasing with increasing concentrations). Industry group was not a significant predictor. However, sample size in each industry category may have been too low for multiple regression.

Simpson JCG, Niven RM, Pickering CAC, Oldham LA, Fletcher AM & Francis HM 1999, Comparative Personal Exposure to Organic Dusts and Endotoxin, *Annals of Occupational Hygiene*, vol. 43, No 2, pp. 107-115.

This paper is a comparative study of personal exposure and endotoxins. The dust samples were collected using an IOM sample head at a flow rate of 2 L/min. The dust samples were later analysed for endotoxin concentration using the LAL test method. The median concentration for each industry sampled was reported with maximum and minim levels. The areas reported that are interest are:

- Inhalable dust concentrations:
  - Swine 6.71 (0.09 – 10.09) mg/m3
  - Poultry 11.53 (1.49 – 34.49) mg/m3
  - Animal feeding 6.7 (2.99-9.07) mg/m3
  - Grain 3.34 (0.08-72.51) mg/m3

- Endotoxin concentrations
  - Swine 631 (60 – 14923) ng/m3
  - Poultry 11993 (755 – 71995) ng/m3
  - Animal feeding 31 (6 - 85) ng/m3
  - Grain 105 (3 - 2247) ng/m3

Comparative exposure analysis of poultry workers shows that workers:

- catching are exposure to median levels of dust at 10.68 (5.22-34.49) mg/m^3. and median levels of endotoxins are 12730 (755-71997) ng/m^3; whereas
- shacking are exposure to median levels of dust at 12.2 (1.49-21.37) mg/m^3. and median levels of endotoxins are 9666 (1038-55829) ng/m^3;

Smid T, Heederik D, Houba R & Quanjer PH 1994, 'Dust- and endotoxin-related acute lung function changes and work-related symptoms in workers in the animal feed industry', *American Journal of Industrial Medicine*, vol. 25, pp.877-888.

This paper presents results from a study on work related respiratory symptoms (i.e. cough, phlegm, SOB, chest tightness, eye irritation, nasal irritation, sneezing) and across-shift and across-week lung function changes related to dust and endotoxin exposure in the Dutch animal feed industry.

265 exposed animal feed worker (average age 39 y) and 175 external controls (average age 36 y) were surveyed with a self-administered questionnaire (age, smoker, work related symptoms etc.). Lung function tests were performed on 119 workers (i.e. maximum mid expiratory flow rate (MMEF), maximum mid expiratory flow rate at 50% vital capacity (MEF50) and 25%, (MEF25 and)(FEV1,). Personal inspirable dust samples were collected (8-hr, 50% cut off diam of 30um), as well as endotoxin levels determined (LAL assay).

Table 111 Prevalence of symptoms during work among animal feed workers (n= 265), controls (n= 15)

	Production workers (n) %	**Controls (n)** %	**OR**	**OR (adjusted)**
Cough	23 (9)	2 (1)	8.2	6.9
Phlegm	15 (6)	5 (3)	2.0	2.0
SOB	12 (5)	6 (3)	1.3	1.1
Chest tightness	13 (5)	4 (2)	2.2	2.2
Eye irritation	21 (8)	10 (6)	1.4	1.5
Nasal irritation	41 (15)	6 (3)	5.2	5.7
Sneezing	55 (21)	13 (7)	3.3	3.4

Work related symptoms were all elevated in the exposed groups- with cough, (Odds ratio, OR 6.9), nasal irritation (OR5.7) and sneezing (OR3.4) being significant statistically. Symptoms after work showed much lower prevalence's but comparable OR values. Lung function tests showed that the average endotoxin exposure is related to larger across shift decreases then average dust exposure. Across-week and exposure related cross-shift changes of MMEF and MEF50 were detected and clearly related to exposure.

OR values were of respiratory symptoms were clearly elevated, but the prevalence of symptoms in the exposed group was low. Other studies such as this have shown higher prevalence of symptoms. The authors suggest that self-administered questionnaires have a low sensitivity compared to oral interviews.

They also suggest that the across –shift lung function changes are more strongly related to endotoxin than dust exposure. They also suggest that other components of dust may have a causal or contributing factor for developing lung changes (eg. microbiological activity).

The paper reports on a cross-sectional study of 315 workers carried out in 14 Dutch animal feed mills. The study identified that endotoxin was more strongly related with lung function decreases than dust exposure, and that lung function changes occurred at endotoxin levels ranging from 0.2-470 ng/m^3.

Endotoxin results for this study may be unreliable because the authors do not identify if LAL assay interference tests were carried to check for possible enhancement or inhibition of the assay.

Takai H, Jacobson LD & Pedersen S 1996, 'Reduction of Dust Concentration and Exposure in Pig Buildings by Adding Animal Fat in Feed'. *Journal of Agricultural Engineering Research*, vol. 63, no. 2, pp. 113-120.

This report assesses the benefits to reducing the amount of dust in pig buildings by adding animal fat to the feed. The results showed that dust concentrations were reduced by 35-60%.

However, the dust exposure levels were still quite high and gives recommendations of workers wearing a dust mask.

Concentrations of total and respirator dust in rooms and personal monitoring was determined by the gravimetric method.

Total dust was found with a 37mm glass fiber filter (pore size 0.8um) in a cassette with an inlet opening of 5.5mm diameter.

Respiratory dust was sampled by using a cyclone preseparator (50% cut-off effectiveness value of 5μm) attached in front of a glass fiber filter (37mm diameter, pore size 0.8um). Sampling rate for both total and respirable dust was 1.9L/min +- 5%.

Stationary sampling, dust samples were collected at two sample locations. All stationary sampling heights were 1.5m above the floor. Sampling time was approximately 24 hours.

Dust samples were also collected from the herdsman's breathing zone by using a portable total dust sampler. Owing to the brief working interval (10min/day), the amount of dust collected per day was too small to analyze with an acceptable accuracy. Therefore dust was collected for each room on the same filter for the 5 day period.

Location	**Controls**		**4% Fat Added**	
	Respirable dusts (mg/m^3)	Total dusts (mg/m^3)	Respirable dusts (mg/m^3)	Total dusts (mg/m^3)
Weaner	0.27±0.13	3.59±1.44	0.12±0.02	2.26±0.92
Pig Finishing	0.124±0.055	1.99±0.68	0.075±0.026	1.16±0.28

Takai H, Pedersen S, Johnsen JO, Metz HM, Groot Koerkamp PWG, Uenk GH et al. 1998, 'Concentrations and Emissions of Airborne Dust in Livestock Buildings in Northern Europe' *Journal of Agricultural Engineering Research*, vol. 70, pp. 59-77.

This is one paper from a much larger European study. This paper presents the results from this study from field surveys carried out to determine dust concentrations within and dust emissions from cattle, pig and poultry buildings. 329 different buildings were sampled from England, the Netherlands, Denmark and Germany.

The results showed weak seasonal variations. All animals showed increased concentrations during day when compared to night. Dust samples were collected according to EN481, i.e. respirable samples in a cyclone at a flow rate of 1.9 L/min and inhalable dusts on a IOM sampling head at a flow rate of 2 L/min

	Cattle buildings	**Pig buildings**	**Poultry buildings**
Mean inhalable dust concentration mg/m^3	0.38	2.19	3.6

Mean respirable dust concentration mg/m^3	0.07	0.23	0.45

This report advocates the use of animal fat in animal feed to reduce the amount of airborne dust. In that dust concentrations were reduced by 35-60% in pig buildings, while human dust exposure was lowered by 50-70% by adding 4% animal fat to the feed. However, there are still large quantities of dust in the air so workers still need to wear a protective mask.

Respirable dust fraction does not appear to be location-dependant and therefore may be a better indicator for evaluating dust reduction methods. Total dust levels were 3-7 times higher when measured using a personal dust sampler as opposed to a stationary sampler. In conclusion, total and respirable dust can be reduced by the addition of animal fat. Relationships between values from stationary and personal dust samplers need to be explored, and improved dust measurement criteria established for evaluating dust suppression practices.

Tamminga S 1992, ‘Gaseous pollutants produced by farm animal enterprises’, *Farm animals and the environment*, Phillips, C & Piggins, D, CAB International.

This is a section from a book, and hence is a review. The important information reviewed in centred around gases produced from animal manure.

Thelin A, Tegler Ö & Rylander R 1984 ‘Lung reactions during poultry handling related to duct and bacterial endotoxin levels’, *European Journal of Respiratory Disease*, vol. 65, pp. 266-271.

This was a cross-sectional study of three egg and two poultry producing farms in Östergötland, Sweden. The average age of workers was young (mean 32.3 years) compared to other studies in this section. The explanation may be that the majority of subjects (66%) were not permanent farmers, only working in peak times. The authors examined five specific activities; unloading cages, cases pulled to truck, unloading and carrying to truck, loading cages and collecting roaming birds. Thirty-one percent of subjects reported airways irritation and cough.

The dust levels ranged from 5.8 mg/m^3 to 28.1 mg/m^3 and the endotoxin levels from 0.13 µg/m^3 to 1.09 µg/m^3. The highest endotoxin levels (1.09µg/m^3) were found around unloading cages (11 samples). The highest environmental dust levels were around loading cases (28.1 mg/m^3, 6 samples) and unloading cages (23.0 mg/m^3, 11 samples). Dust and endotoxin levels were highly correlated (!=0.70). Cross-shift reductions in FEV_1 averaged at 0.11 litres. Smokers and non smokers not significantly different in cross-shift reductions. The small number limited the statistical comparisons

Thomas DT 1999, ‘Mouldy Straw for Pig Bedding: A Cheap Alternative to Clean Straw or A High Risk?’, BScAg dissertation, University of Western Australia

This is a research report of the effect of mouldy hay as bedding of the growing pigs. Dust samples were collected using the methods outlined in AS 3640 and AS 2985.

The bacteria samples were collected using a 6-stage Anderson Cascade Impactor (ACI). Unfortunately the samples were collected at a flow rate of 1.9 L/min when the ACI requires a flow rate of 28.3 L/min. The results the work are:

Type of Bedding	**Microorganisms**		**Dust Concentrations**	
	Total x10^3 CFU/m^3	Total Fungi x10^3 CFU/m^3	Respirable mg/m^3	Total mg/m^3
No of Samples	6	6	6	6

Clean Straw	44 ± 7.7	1.7 ± 0.37	0.03±0.01	0.12±0.03
Mouldy Hay	59 ± 9.7	4.7 ± 0.86	0.04±0.01	0.20±0.04

The results are for static samples

Thorne PS, Kiekhaefer MS, Whitten P & Donham KJ 1992, 'Comparison of bioaerosol sampling methods in barns housing swine', *Applied and Environmental Microbiology*, vol. 58, pp. 2543-2551.

This paper reviewed three methods to measure airborne microbiological organisms, bacteria and fungi:

- Impaction using the: Andersen microbial sampler method (AMS) at a flow rate of 28.3 L/min for 15 to 90 seconds. The samples were collected onto 20 ml of:
    - Trypticase soyagar (TSA) for a range of environmental microorganisms,
    - MacConkey's medium (MAC) for gram –ve bacteria, or
    - malt extract agar (MEA) for fungi
- Impinger using a all-glass impinger method (AGI-30) containing 20.0 ml of 1% peptone-distilled water with 0.01% Tween 80 and 0.005% antifoam A, at a flow rate of 12.5 L/min for a maximum of 30 minutes, and
- Filtration using the 0.4μm pre size, Nuclepore filters (NFE) loaded into 37 mm diameter closed face collared cassettes. The cassettes were then sterilized with ethylene oxide. The samples were collected at a flow arte of 2 L/min for between 15 to 30 minutes.

	Bacteria CFU/min^3	Fungi CFU/min^3
AMS	7.32×10^4	1.97×10^3
AGI-30	9.64×10^4	5.38×10^3
NFE	7.78×10^4	5.85×10^3

The authors summarised that for sampling in livestock building that the AGI-30 should be the method of choice for total bacteria and fungi and the AMS for bacteria.

Thorne PS, Reynolds SJ, Milton DJ et al. 1997 'Field evaluation of endotoxin air sampling assay methods,' *American Industrial Hygiene Association Journal*, vol. 58, pp.792-799.

This is a study to assess the importance of filter media, extraction and assay protocol and bioaerosol source on the determination of endotoxin levels in poultry and swine buildings. Multiple samples were tested simultaneously at different labs, using glass filter (GF) and polycarbonate (PC) filters. Different extraction methods were parallel tested. Reproducibility between labs was high. This is a highly detailed, technical paper suitable for those in the field.

This article states that inhalation studies with cotton dust have shown 'endotoxin is associated with dose dependent airflow obstruction in the 10-1000 EU/m^3 range.

Virtanen T, Eskelinen T, Husman K & Mantyjarvi R 1992, 'Long and Short-term variability of airborne bovine epithelial antigen concentrations in cowsheds', *International Archives of Allergy and Immunology*, vol. 98, pp. 252-255.

This project follows on from a previous study which observed an association between the airborne animal dust levels and the humoral response of farmers. The current study evaluated the long and short term variability of airborne bovine epithelial antigens (BEA) in cowsheds by randomly collecting airborne particulate samples from 5 cowsheds. Static and personal sampling methods were used on 3 occasions during 1989. Bovine epithelial antigen levels were determined using a new house-made double antibody sandwich ELISA.

Building Number	Total Dust (mg/m^3)		Bovine Epithelial Antigens (mg/m^3)	
	Personal	Static	Personal	Static
CS1	0.82±0.74	0.56±0.15	21.8±7.5	13.0±3.7
CS2	3.15±0.48	0.69±0.29	22.5±6.2	5±3
CS3	0.56±0.56	0.36±0.18	3.2±1.1	2.1±0.6
CS4	0.31±0.2	0.37±0.09	5±0.1	2.1±0.8
CS5	0.83±0.24	0.38±0.05	11.5±1.1	10±3.5

Total dust levels were lower than in the previous cowshed study ranging from 0.31 to 3.15 mg/m^3 for personal sampling and 0.36-0.69 mg/m^3 for static sampling. Airborne BEA levels were higher than the previous study ranging from 3.2-22.5 for personal sampling and 2.1-13 mg/m^3 for static sampling. The authors conclude that it appears a single determination of BEA provides a reliable estimate of general bovine-derived dust levels in cowsheds. Although the authors also acknowledge the study does not identify what samples need to be collected to provide representative exposure data.

Vogelzang PFJ, van der Gulden JWJ, Folgering H, Kolk J, Heederik & D Preller L et al. 1998 'Endotoxin exposure as a major determinant of lung function decline in pig farmers', *American Journal of Respiratory Critical Care Medicine*, vol. 157, pp. 15-18.

This longitudinal study had as its subjects 171 of the same farmers described in Vogelzang et al. (1997); 82 symptomatic and 89 asymptomatic farmers (mean age 39.6 years). Baseline measurements were those reported in 1997. Follow-up measures at 3 years included self-reported symptom questionnaire and spirometry. Average long-term exposure to dust and endotoxin were derived from baseline individual exposure levels using an algorithm which included the findings of the farm surveys (baseline), activity diaries (baseline). The mean decline in FEV_1 was 73ml/year and 55ml/year for FVC. Two different spirometry units were used at follow-up. Analyses according to the unit, showed a reduction in FEV_1 in both cases but less for the water sealed unit than for the dry rolling sealed unit. The decline in FEV_1 is greater than that which would be expected (29 ml/year) and age adjusted according to the European Respiratory Society. Multivariate regression analysis for exposure and FEV_1 showed a statistically significant and positive association for both dust and endotoxin concentrations. For FVC significant and positive associations were found for both dust and endotoxin concentrations. The analyses was adjusted for age, baseline FEV_1 and FVC and smoking. The findings of this study are difficult to evaluate, firstly because of the effect of the second spirometry unit. Secondly, and importantly, the authors make qualitative conclusions about several findings, including throughout the discussion section. However, they do not present the results on which these conclusions are based, for example the results of separate analyses for symptomatic and asymptomatic farmers.

In a study of pig farmers in Holland, by, the estimated long-term average exposure to inhalable dust was 2.63 mg/m^3 and to endotoxin this was 10^5 ng/m^3. The mean annual decline in FEV1 of 73ml is large compared to the expected age-related decline of 29 ml/yr. It also found that after adjustment for age, the decline in FEV1 during a 3-yr period was significantly associated with exposure to endotoxin alone, whereas the decline in FVC was associated with both endotoxin and inhalable dust exposure

Vogelzang PFJ, van der Gulden JWJ, Preller L, Tielen MJM, van Schayck CP & Folgering H 1997 'Bronchial hyperresponsiveness and exposure in pig farmers', *International Achieves of Occupational and Environmental Health*, vol. 70, pp. 327-333.

Ninety four farmers with chronic respiratory symptoms and 100 asymptomatic farmers were studied and identified from an original survey of 2433 pig farmers in the Netherlands (62% response rate). Farmers worked with swine for at least 5 hours per day. Respiratory symptoms were measured in previous surveys followed by medical examinations and interviews. Measurements in this study included spirometry following a histamine provocation test, walk through surveys of farm characteristics (winter), seven day activity diaries in both summer and winter and personal sampling during one workday in summer and winter. Spirometry was performed according to European Respiratory Society guidelines.

The two groups of farmers were significantly different in age and duration of farming, although these differences were small; mean age 41.2 years and mean duration of 17.7 years in symptomatic farmers compared with 37.3 years and 15.1 years in asymptomatic farmers. Significantly more symptomatic farmers smoked, 42% compared with 15%, however a similar proportion reported respiratory symptoms (11% and 7%) in the week prior to histamine challenge. Bronchial responsiveness was greatest for symptomatic farmers and significantly associated with years worked as a pig farmer. Adjusted for age, smoking and baseline FEV_1, increased bronchial responsiveness was significantly associated with individual symptoms (chronic cough, shortness of breath, history of wheeze, chest tightness and more than one symptom). Logistic regression of bronchial responsiveness on farm characteristics were adjusted for age and smoking status. The models reported included all farmers. Significant associations were found between use of quaternary ammonium compounds as disinfectants (OR 6.7) use of wood shavings for bedding (OR 13.3), use of pellets for feeding (OR 4.8) and pit or rook location of air exhaust (compared with side of building OR 2.7). The authors reported that analyses involving exposure measures were not significant, but no results from these analyses were included in the paper.

Personal exposures to inhalable dust were collected in summer and winter at a flow rate of 2 L/min. The dust samples collected were analysed for endotoxin using the LAL method. The average exposure to inhalable dust was 2.7 mg/m^3 and to endotoxin was 111 ng/m^3. In this study they could not find a statistically significant relationship between dust and endotoxin exposure and bronchial responsiveness. Although there did appear to be a relationship between type of flooring and methods of feeding and bronchial responsiveness.

Vogelzang PFJ, Van Gulden, JWJ, Folgering H, Heederik D, Tielen MJ & Van Schayck CP 2000, 'Longitudinal Changes in Bronchial Responsiveness Associated With Swine Confinement Dust Exposure', *Occupational and Environmental Lung Disease*, vol. 117, no. 5, pp. 1488-1495.

In a Dutch study 171 pig farmers were investigated over a three year period. Over this period the average exposure to inhalable dust was 2.63 mg/m^3, and average endotoxin exposure was 10^5 ng/m^3. The average exposure to inhalable dust was associated with increases in bronchial responsiveness. The majority of the dust was generated from the use of wood shavings as bedding material.

Waser M, Schier R, Von Mutius E, Maisch S, Carr D, Riedler J et al. 2004, 'Determinants of endotoxin levels in living environments of farmers' children and their peers from rural areas', *Clinical and Experimental Allergy*, vol. 34, pp. 389-397.

This paper investigates which home and lifestyle features of farm and non farm families contribute to endotoxin levels in different indoor environments. Decreased levels of asthma have been reported in children who have livestock contact. The amount of endotoxin measured in children's mattresses is inversely related to the occurrence of atopic asthma, hay fever and atopic sensitisation in children from farm and non farming families.

Method: Testing was carried out in Austria, Germany, and Switzerland. Small, traditional family run farms were chosen and 90% of farms had farm animals- mainly cows (mean no 35/farm), and only small numbers of pigs, chicken, sheep, goats. 319 farm children and 493 non farm children with a mean age of 9.5 yrs were tested. A questionnaire was taken, dust collected from different study sites- child's mattresses, living room carpet/floor, stable dust (settled dust only). Endotoxin levels measured using kinetic LAL test.

Dust was collected using a Miele vacuum cleaner (1200W, calibrated airflow 200L/min. ALK filter used).

Factors which increased endotoxin levels were:

- increased number of cattle in stables
- generally keeping horses
- feeding cattle with hay, compared with silage + hay
- Using solid and liquid muck together in the stables
- Austrian and Swiss stables had generally higher endotoxin levels than Germany

Conclusions:

- Regular livestock contact (previous studies have shown to be inversely related to allergic disease occurrence), is associated with increased mattress endotoxin levels- in both farm and non farm children
- In non farm children, keeping pets and reduced floor cleaning increased endotoxin levels
- In farm children, parental farm activities, the study area, presence of younger siblings and mattress cleaning frequency contributed to increased endotoxin levels

Endotoxin may be a surrogate marker for a much broader spectrum of microbial compounds than gram-negative bacteria alone

Wathes C, Phillips V, Holden M, Sneath R, Short J, White R et al. 1998, 'Emissions of aerial pollutants in livestock buildings in Northern Europe: Overview of Multinational Project', *Journal of Agricultural Engineering Research*, vol. 70, pp. 3.

In 1997 a major study was undertaken in Denmark, Germany, the Netherlands and England by Wathes et al., (1988); Phillips et al., (1998); Takai et al., (1998); Seedorf et al., (1998); Hinz and Linke, (1998a); Hinz and Linke, (1998b). This paper reflects on the outcomes of the overall study where the dust levels have been reported elsewhere.

The main objective of the project was to undertake a field survey of the emissions of aerial pollutants within and from 329 livestock buildings. The survey covered the major types of livestock housing for cattle, pigs and poultry. In each building seven locations were sampled, outside an eighth site was sampled. The concentrations of airborne dust were measured with modified personal samplers, which separated the dust into the inhalable and respirable size fractions. The bioaerosol concentrations were collected using a specifically designed sampler called a novel automated slit sampler. The mean concentrations of both inhalable and respirable dust were highest in poultry houses (3.6 and 0.45 mg/m3) and were lowest in cattle buildings (0.38 and 0.07 mg/m^3). All of the respirable dust results were not affected by the season that the results were collected in. The dust results were on average 30-40% lower at night than during the day. At no times were dust concentrations in cattle houses hazardous to cattle health. Dust concentrations were lower in the farmers working area than in the area above the animals holding pens. The effects of floor type on dust concentration in cattle and pig buildings were not consistent. The bacteria results were 10 to 100 times greater than the fungi results. Compared with pigs and poultry the endotoxin concentrations in cattle houses were low. In cattle houses the mean aerial concentrations ranged between 7.4 and 63.9 ng/m^3. Poultry had the highest endotoxin concentrations.

Wilhelmsson J, Byrngelsson IL & Ohlson CG 1989, ‘Respiratory symptoms among Swedish swine producers’, American *Journal of Industrial Medicine*, vol. 15, pp. 311-318.

This paper reports the findings of a postal survey of male swine farmers born in or after 1913 and alive in 1985. Potential subjects were identified by the National Bureau of Statistics and based on occupation records. The overall response rate for those still occupational active and ex swine producers was 66%, 307 subjects whose mean age was 53 years. Respiratory symptoms included questions from the British Medical Research Council Respiratory Symptoms. Results were compared with a study of young welders using the same questionnaires and ex farmers were compared with active farmers.

Thirty-four percent of active farmers reported three or more respiratory symptoms compared with 17% of the welders comparison group. The prevalence of symptoms for non active farmers was reported to be similar to that for active farmers. The findings were not included in this paper. Comparisons between smokers and non smokers for active farmers were stratified for age (Mantel-Haenszel odds ratio). For smokers, the OR of 3 or more symptoms was statistically significant 5.25 compared to the smoking welders. The number of farmers in this analysis was 16 and may account for the wide CI, 1.9-14.8. For non smokers, the odds ratio was also high, 2.08 but not statistically significant. Multiple regression analysis with the outcome of number of symptoms excluded ex smokers, and were adjusted for factors such as age, smoking, number of years in farming, estimated yearly exposure to swine confinement buildings and allergic predisposition. Only smoking and estimated yearly accumulated exposure in confinement buildings. A significant interaction effect was identified by ANCOVA between smoking and accumulated exposure ($p<0.05$). Other outcomes included fever and chills, which were reported by 12% of subjects. Recall of exposure time may have been different for older ex farmers than for current farmers.

Williams A 1989, ‘Dust and odour relationships in Broiler House Air’, *Journal of Agricultural Engineering Research*, vol. 44, pp. 175-190.

This report tests the hypothesis that odour concentration is related to dust in broiler house air. This was tested experimentally in terms of particle numbers, dust mass and dust surface area.

A small scale representation of a broiler house was constructed and exhaust air from it was blown through a filtration unit containing coarse and fine fabric filters and an electrostatic precipitator. Samples were taken of raw and filtered air and analysed by particle counting and dynamic dilution olfactometer. Samples for odour measurements were put into the olfactometer both directly and in bags made from ‘tedlar’ film. Dust mass and surface area was calculated by integrating the particle numbers with respect to particle diameters.

Measurements of dust and odour were also made in a commercial broiler house. There was no significant change in odour concentration caused by dust filtration, but dust mass and surface area were significantly reduced. There was no correlation between odour concentration and dust mass or surface area. Total particle numbers changed little with filtration but there was considerable change in particle size distribution as larger particles were filtered out.

Dust content of air was significantly reduced in all respects after the air had been put into ‘tedlar’ odour sampling bags and then resampled.

Dust measurements in a commercial boiler house showed that the particle size distribution was similar to that in the raw air of the experimental house although the actual concentration was higher. The use of a 1m long sampling tube could apparently halve the measured dust concentration indicating a need for sampling tubes to be as short as possible and of the same dimensions to ensure comparability.

An airstream helmet reduced the dust concentration by 96%.

Wilson S, Morrow-Tesch J, Straus D, Cooley J, Wong W & Mitlöhner F et al. 2002, ‘Airborne Microbial Flora in a Cattle Feedlot’, *Applied and Environmental Microbiology,* vol. 68 no. 7, pp. 3238-3242.

This report examined cattle to find the quantity and diversity of the microorganisms in cattle feedlot air. Also the effect of two feeding patters on the generation of airborne dust and the total numbers of microorganism.

Microbial samples were collected, and dust particles that were 2.5 μm or less in diameter were measured with a Dustrak monitor during the evening dust peak for 4 days. An Andersen biological cascade sampler was employed with different medium and incubation combinations for the capture and identification of bacteria and fungi.

Show that when bacteria are considered, only non-pathogenic gram-positive organisms were recovered. Gram-negative may have been present in a viable but nonculturable state. Fungi were recorded in smaller numbers than bacteria, and none was pathogenic.

The results show that one feeding pattern resulted in cattle behaviour that generated levels of downwind dust lower than levels generated from other feeding patterns. However, Andersen sampler results showed that there were no differences between feeding patters in regards to total number or diversity of microorganisms.

This disparity may have been due to the different operating principles of the two systems.

This is a Texan study that is focused on feedlot cattle. The study looked at concentrations of dust and bioaerosols in the air generated in cattle feed lots. The average dust level during feeding was 0.177 mg of dust/m^3. No concentrations are available for microorganisms as only gram-positive bacteria were recovered.

Zejda JE & Dosman JA 1993, ‘Respiratory disorders in agriculture’, *Tubercle and Lung Disease*, vol. 74, pp. 74-86.

Exposure to organic dusts is more frequent than inorganic dusts during outdoor farm work, with exposures ranging between 4 mg /m^3 and 31 mg /m^3 and maximum concentrations as high as 60 mg /m^3. Airborne concentrations of organic dusts associated with routine operations on dairy farms (feeding, cleaning, chopping of bedding) may vary between 0.05 mg/m^3 and 40 mg/m^3, and mean concentrations of the respirable fraction of this dust may range from 1.6 mg/m^3 to 2.5 mg/m^3.

Zejda JE, Hurst TS, Rhodes CS, Barber EM, McDuffie HH & Dosman JA 1993, ‘Respiratory health of swine producers: focus on young workers’, *Chest*, vol. 103, no. 3, pp. 702-708.

This report compares the respiratory health (lung function-FEC, FEV1, FEV1/FVC, FEF25-75, Vmax50 and Vmax25) of swine producers (n=249), grain farmers (n=251), and non-farming control subjects (n=263), separately in all age groups and in young subjects. The study found that after controlling for age, height, and smoking, the functional indices of airflow was significantly lower in swine producers than in grain farmers and non-farming subjects. A relative excess of respiratory symptoms and lower lung function variables were found in swine producers aged 26 to 35 years. The results confirmed that working in swine confinement units is a risk factor for chronic respiratory symptoms and minor lung function changes. The article also concluded that an increased risk in young workers might reflect more intense occupational exposure in this subgroup of swine producers.

Zhang Y, Tanaka A, Dosman JA, Senthilselvan A, Barber EM & Kirychuk SP et al. 1998, 'Acute Respiratory Responses of Human Subjects to Air Quality in a Swine Building', *Journal of Agricultural Engineering Research,* vol. 70, pp. 367-373.

This paper looks at dust exposure and what types of respiratory responses occur in a swine building. The air quality data was collected at a flow rate of 2.8 L/min. The average dust levels measured before the bedding is treated with canola oil was 2.41 mg/m^3 and after treatment was 0 15 mg/m^3. The respective Endotoxin levels were 3984 EU/m^3 and 452 EU/m^3.

Zhiping W, Malmberg P, Larsson B-M, Larsson K, Larsson L, & Saraf A 1996, 'Exposure to Bacteria in Swine-House Dust and Acute Inflammatory Reactions in Humans', *American Journal of Respiratory Critical Care Medicine,* vol. 154, pp. 1261-1266.

This is a Swedish study that was supposed to expose 38 health subjects to swine dust, and then look for correlations between acute health effects and concentrations inhaled. However, to rarely talks about the study and come across as a review of different ways to measure the response to dust in humans.

Zhipping W, Malmberg P, Larsson B, Larsson K, Larsson L & Saraf A 1996, 'Exposure to Bacteria in Swine-House Dust and Acute Inflammatory Reactions in Humans', *American Journal of Respiratory Critical Care Medicine,* vol. 154, pp. 1262-1266.

This paper looks at people health impact at being exposed to a range to contaminants in a swine house. The personal dust samples were collected at a flow rate of ~ 2L/min on an IOM sample head. After weighing the samples were analysed for endotoxins using the LAL method. The samples for were further analysed for LPS_{GC-MS} and peptidoglycan.

The average inhalable dust concentration was 21 (16-21) mg/m^3. The concentration of endotoxin using the LAL method was 1.2 (0.9 to 1.4) µg/m^3 and using the MC-MS method was 3.9 (2.5-4.9) µg/m^3.

The outcome of this study was there appeared to be a link between exposure to microbial contaminants and ill health in respect to respiratory symptoms.

Zucker B & Muller W 2004, 'Investigations on airborne micro-organisms in animal stables: Stability of endotoxins in the environment', *Berl Munch Tierarztl Wschr,* vol. 117, pp. 6-11.

This paper reports on the stability of endotoxin in the air, and endotoxin activity in potential airborne endotoxin sources such as manure (poultry, cattle, swine), fodder, litter, surface dust (poultry and sheep) and drinking water (sheep) over an 84-day period.

Sample Origin	**Endotoxic Activity** (EU/g) **after an incubation of:**	
	0 days	**84 days**
Poultry faeces	8.2×10^6	8.3×10^4
Cattle faeces	8.2×10^4	5.0×10^5
Swine faeces	4.8 x 10 (?)	5.3 x 10 (?)
Laying hen fodder	8.2×10^4	8.4×10^4
Straw 1	2.9×10^3	2.4×10^5
Straw 2	2.3×10^4	1.6×10^4
Hay 1	3.3×10^4	2.4×10^5
Hay 2	5.2×10^5	4.9×10^4
Poultry surface dust	7.0×10^5	8.2×10^5
Sheep surface dust	2.9×10^5	2.8×10^5
Sheep surface dust	4.0×10^5	3.8×10^5
Sheep surface dust	3.2×10^5	2.7×10^5
Sheep surface dust	2.9×10^5	3.3×10^5
Pig urine	1.9×10^5	6.3×10^5
Sheep drinking water	2.0×10^1	1.7×10^1

Zucker BA & Müller W 1998, 'Concentrations of airborne endotoxin in cow and calf stables', *Journal of Aerosol Science,* vol. 29, Issues 1-2, pp. 217-221.

This paper reports on a range of endotoxin s that was measured in cattle and calf stables when they were not being used. The samples were collected as static samples in a liquid impinger containing 50 ml of pyrogen free water at a flow rate of 12.5 L/min and analysed using a LAL QC1000 assay.

	Endotoxin EU /m^3	**Variable gram –ve bacteria** CFU/m^3
Cow stable	35-761	0-8500
Calf stable	44-262	0-3200

On average 0.2 to 6.5% of variable bacteria was gram –ve.

It is expected that the levels would be higher when the stables are in use of they are being cleaned. Levels also may relate to the state of animal health i.e. diarrhoea would expect to result in higher levels.

Zucker B, Draz A & Muller W 2000, 'Comparison of filtration and impingement for sampling airborne endotoxin, *Journal of Aerosol Science,* vol. 31, pp. 751-755.

This study compares filtration and impingement sampling methods for measuring endotoxin exposure in cattle, swine and sheep houses.

Sample Group	Endotoxin Exposure Range (EU/m^3)	
	Impinger Method	Filtration Method
Calf Houses	203-256	191-235
Cattle Houses	132-5012	127-4076
Swine Buildings	1264-6067	607-4306
Sheep Houses	268-1249	152-1108

Zuskin E, Mustajbegovic J, Schachter EN, Kern J, Rienzi N, Goswami S, Marom Z and Maayani S 1995, 'Respiratory function in poultry workers and pharmacologic characterization of poultry dust extract', *Environmental Research*, vol. 70t pp. 11-19.

In this cross-sectional study, respiratory symptoms and spirometry were measure in 343 workers in intensive poultry farm activities. All subjects were growers and/or catchers working in confinement buildings. The findings were compared with those of 200 workers packing in food industries. Methods are described in detail. Self reported symptoms were based on British MRC questionnaire and WHO criteria for occupational asthma. Symptoms are well defined.

The prevalence of chronic cough (males 33.7%, females 19.8%), chronic phlegm (males 27.4%, females 14.3%), chronic bronchitis (males 24.1%, females 12.1%) and chest tightness (males 17.7%, females 23.1%) were all significantly higher in poultry workers than in controls ($p<0.05$). In both males and females all of these outcomes were significantly higher in subjects who have worked for greater than 10 years compared with subjects who had worked for 10 years or less ($p<0.05$). The majority of males were smokers and the authors report that male smokers had higher prevalence for cough phlegm and chronic bronchitis than non smokers ($p<0.01$, findings not included in the paper). The authors reported that stratified analysis according to both smoking status and work duration found that male smokers had significantly higher prevalence of symptoms than non smokers ($p<0.05$). In the case of male smokers, prevalence was significantly higher in those who had worked longer, eg, the prevalence of chronic cough was 37% for work duration of 10 years or less and 60% for those who had worked longer than 10 years. There were no significant differences for asthma (prevalence: males 1.2%, females 1.1%) or dyspnea in any of these comparisons.

The prevalence of acute symptoms during the work shift was high. Examples include eye irritation (males 55.2%, females 67.0%) and cough (males 51.9%, females 54.9%).

For both male and female subjects spirometry findings (FEV_1, FVC and $FEF_{25)}$ were lower than predicted, between 20.5% less (males FVC) and 3.6% lower (males FEF_{25}).

Airborne gram negative bacteria assay and a laboratory experiment using dust extract on the trachea of guinea pigs were also part of this study.

Zuskin E, Zagar Z, Schacter EN, Mustajbegovic J and Kern J 1992, 'Respiratory symptoms and ventilatory capacity in swine confinement workers', *British Journal of Industrial Medicine*, vol. 49 pp.435-440.

This paper reports the findings of cross-sectional controlled study of 59 swine confinement workers in Yugoslavia. Respiratory symptoms and spirometry findings were compared with 46 age and sex match controls working in a fruit juice bottling company. Questionnaires included question from the British Medical Research Council Committee questionnaire on respiratory symptoms. Separate analyses were carried out for men and women. Except for symptoms of asthma for which there was no difference, symptoms were more prevalent in swine confinement workers (chronic cough, cough with phlegm, chronic bronchitis, dyspnoea and chest tightness. For example for men, the prevalence of chronic cough was 41.5% compared to 19.5% in controls ($p<0.05$). In women (18 subjects) the prevalence of chronic cough was 50% compared with 6.7% 15 controls ($p<0.05$). However not all comparisons were statistically significant and likely due to the small sample size. Very high prevalence rates of work shift symptoms were also reported, eg, cough 70.7% in men and 72.2% in women and eye irritation, 46.3% in men and 77.8% in women. Cross shift declines were observed in all lung function tests and statistically significant in both men and women. Stratified analyses according to smoking status for men only performed for symptoms prevalence (significantly higher in smokers for cough with or without phlegm) and cross-shift decline in lung function, which were significant for smokers and non smokers across all measures. Personal samples were taken and levels described but not correlated with symptoms.