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Review

A systematic review of the public health risks of bioaerosols from intensive farming

Philippa Douglas[a,1], Sarah Robertson[b,1], Rebecca Gay[b], Anna L. Hansell[a,c,*], Timothy W. Gant[b,**]

[a] UK Small Area Health Statistics Unit, MRC-PHE Centre for Environment and Health, Imperial College London, London, United Kingdom
[b] Centre for Radiation, Chemical and Environmental Hazards, Public Health England, Harwell Campus, Didcot, Oxfordshire, United Kingdom
[c] Public Health and Primary Care, Imperial College Healthcare NHS Trust, United Kingdom

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ABSTRACT

Background: Population growth, increasing food demands, and economic efficiency have been major driving forces behind farming intensification over recent decades. However, biological emissions (bioaerosols) from intensified livestock farming may have the potential to impact human health. Bioaerosols from intensive livestock farming have been reported to cause symptoms and/or illnesses in occupational-settings and there is concern about the potential health effects on people who live near the intensive farms. As well as adverse health effects, some potential beneficial effects have been attributed to farm exposures in early life. The aim of the study was to undertake a systematic review to evaluate potential for adverse health outcomes in populations living near intensive livestock farms.

Material and methods: Two electronic databases (PubMed and Scopus) and bibliographies were searched for studies reporting associations between health outcomes and bioaerosol emissions related to intensive farming published between January 1960 and April 2017, including both occupational and community studies. Two authors independently assessed studies for inclusion and extracted data. Risk of bias was assessed using a customized score.

Results: 38 health studies met the inclusion criteria (21 occupational and 1 community study measured bioaerosol concentrations, 16 community studies using a proxy measure for exposure). The majority of occupational studies found a negative impact on respiratory health outcomes and increases in inflammatory biomarkers among farm workers exposed to bioaerosols. Studies investigating the health of communities living near intensive farms had mixed findings. All four studies of asthma in children found increased reported asthma prevalence among children living or attending schools near an intensive farm. Papers principally investigated respiratory and immune system outcomes.

Conclusions: The review indicated a potential impact of intensive farming on childhood respiratory health, based on a small number of studies using self-reported outcomes, but supported by findings from occupational studies. Further research is needed to measure and monitor exposure in community settings and relate this to objectively measured health outcomes.

Abbreviations: AFO, Animal feeding operation; AHR, Airway hyper-responsiveness; ATS, American thoracic society; BAL, Bronchoalveolar lavage; BAT, Best available technique; BPI, Bactericidal permeability-increasing; BREF, Reference document; CAFOs, Concentrated animal feeding operations; CAP, Community-acquired pneumonia; CI, Confidence interval; COPD, Chronic obstructive pulmonary disease; CRP, C-reactive protein; ECP, Eosinophilic cationic protein; EMR, Electronic medical records; ERS, European respiratory society; EU, Endotoxin units; FEF25-75, Forced expiratory flow between 25 and 75%; FEV1, Forced expiratory volume in the first second; FVC, Forced vital capacity; GI, Gastrointestinal; GP, General practitioner; GRADE, Grads of recommendations, assessment, development and evaluation; ICS, Inhaled corticosteroid; IED, Industrial emissions directive; IL, Interleukin; ISAAC, International study of asthma and allergies in childhood; LPS, Lipopolysaccharides; MBL, Mannose-binding lectin; MRC, Medical research council; MOOSE, Meta-analyses and systematic reviews of observational studies; NIHR HPRU, National institute for health research health protection research unit; OR, Odds ratio; PEF, Peak expiratory flow; PHE, Public health England; PM10, Particles with aerodynamic diameter 10 µm or less; PR, Prevalence ratios; RR, Relative risk; RV, Residual volume; SD, Standard deviation; SSLW, Steady state live weight; TLC, Total lung capacity; TLR, Toll-like receptor; TNF, Tumour necrosis factor; VC, Vital capacity; WBC, White blood count; WIBS, Wideband integrated bioaerosol sensor

* Corresponding author at: UK Small Area Health Statistics Unit (SAHSU), Department of Epidemiology and Biostatistics School of Public Health, Imperial College London, St. Mary's Campus, Norfolk Place, W2 1PG London.
** Corresponding author at: Centre for Radiation, Chemical and Environmental Hazards, Public Health England, Harwell Campus Didcot, Oxfordshire, OX11 0RQ, United Kingdom.
E-mail addresses: p.douglas@imperial.ac.uk (P. Douglas), Sarah.Robertson3@phe.gov.uk (S. Robertson), Rebecca.Gay@phe.gov.uk (R. Gay), a.hansell@imperial.ac.uk (A.L. Hansell), Tim.Gant@phe.gov.uk (T.W. Gant).
[1] Joint first authors.

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1. Introduction

The current world population of 7.5 billion (2017) is set to rise to almost 10 billion by 2056. An increase in the population means more food is required and thus a growing demand for livestock products. In 2010 the Food and Agriculture Organisation of the United Nations estimated that food production will need to increase by 70% by 2050 to cope with population growth (FAO, 2009). With efforts to meet the food demand of an increasing population there has been widespread adoption of more intensive (achieving higher total output per unit of land) farming (or agricultural) practices. These farms hold large numbers of animals (primarily pigs or poultry), often indoors, typically at high densities. Animal farming contributes to air pollution in many ways, emitting odours, gases (ammonia, hydrogen sulfide), particulates, including dust and airborne biological components (bioaerosols), and a complex mixture of volatile organic compounds. Emissions from farms have been linked with a broad range of adverse health effects, including respiratory disorders and gastrointestinal (GI) problems in farm workers (Iversen et al., 2000; Schiffman 1998), and more recently negative health effects have been documented for residents living nearby intensive farms (O'Connor et al., 2010; O'Connor et al., 2017). Livestock exposure has also been associated with zoonotic infectious diseases (such as Q fever) (Dijkstra et al., 2012; Gyuranecz et al., 2014; Halsby et al., 2017). Symptoms of Q fever in humans range from mild to severe and is caused by *Coxiella Burnetii*, a bacterium mostly commonly found in cattle, sheep and goats (Raoult et al., 2005). In keeping with the hygiene hypothesis (see Section 1.3 below) some studies have shown a protective effect of farming exposure against, for example the development of atopic outcomes (Douwes et al., 2003). The ongoing intensification of livestock production, together with recent cases of Q fever reported in the UK (Halsby et al., 2017) and in the Netherlands (Dijkstra et al., 2012) has urged policy-makers and planners to better understand the dispersion and health impacts of the air emissions to the surrounding area. For policy makers to make better, more informed decisions about how to regulate air emissions there is a need to identify the causative agent(s). Dust emitted as a result of farming practices is primarily organic (of a biological nature), and therefore contains bioaerosols (Dungan 2010). Workplace exposures to bioaerosols in other industries (e.g. waste recycling, composting, cotton processing) have been linked to adverse, mainly respiratory, health effects (Douwes et al., 2000; Douwes et al., 2003; Poulsen et al., 1995). A recent systematic review also reported qualitative evidence linking bioaerosol emissions from composting facilities to poor respiratory health in nearby residents (Pearson et al., 2015). Some studies show the presence of bioaerosols at some distance downwind from their source (Fischer et al., 2008; Hryhorczuk et al., 2001). In order to establish and implement appropriate strategies and effective measures to mitigate risk, it is essential that regulatory authorities have access to the most up-to-date and accurate information, and key gaps in knowledge are highlighted to corroborate future research.

1.1. Regulation of intensive farming

There is no uniform international definition of what constitutes an intensive farm and regulation of such facilities varies between countries. European Union member states intensive farming activities are regulated under the Industrial Emissions Directive (IED) 2010/75/EU (European Union, 2010). Under the IED an intensive farm is defined as rearing poultry or pigs in an installation with more than 40,000 places for poultry or 2000 places for production pigs over 30 kg or 750 places for sows, and will require a permit to operate. To prevent, reduce or otherwise manage environmental and health impacts, pig and poultry farms within the European Union are required to use appropriate operational practices known as the Best Available Techniques (BAT), as described in the Reference Document (BREF) (Santonja et al., 2017). While this does set out requirements for meeting dust emission limits that will help to reduce bioaerosol emissions, there are no specific regulatory limits for bioaerosol emissions. Bioaerosol concentrations and emissions are influenced by a number of factors including: design of animal housing and manure collection system; ventilation; temperature; type of feed; feeding and watering techniques; quality of feed raw materials; use of bedding; cleaning of houses to remove dust deposits; and production method, which are addressed in the BREF (Santonja et al., 2017).

European Union member states implement their own local regulations to ensure compliance with the IED. For example, in England permitting arrangements require operators to undertake a site specific bioaerosol risk assessment if an intensive farming operation is within 100 m of a sensitive human receptor (e.g. a residential house or place of work) (Defra, 2016). The Netherlands considered producing a health-based quantitative risk assessment framework for intensive farms and recommended an exposure limit for the general population of 30 endotoxin units (EU) per cubic metre ($EU\ m^{-3}$), based on applying a safety factor of three to the occupational limit of $90\ EU\ m^{-3}$ (Netherlands HCot, 2012). However, it was concluded that, to date, there was insufficient evidence available to set health based regulatory distances between farms and residential areas. At present in the UK, most farmers do not normally monitor and control emissions to air unless specifically required to do so as a result of local complaints (Commission, 2015).

1.2. Bioaerosol exposure

Bioaerosols consist of viable or non-viable airborne microorganisms, their constituent parts and by-products (Douwes et al., 2003). They are ubiquitous in the environment (indoor and outdoor) and can originate from a range of sources, both natural and anthropogenic. In animal houses, major sources of bioaerosols are animals, animal wastes, feed and bedding material (AirQuality, 2012). The continuing increasing trend in farming intensification is therefore likely to increase bioaerosol concentrations and diversity. Bioaerosols can stay suspended in the air for prolonged periods and potentially travel long distances from their source (Nygard et al., 2008), and as a result may pose health effects to nearby communities with elevated exposures.

1.3. Health effects of bioaerosols

Human exposure to bioaerosols has been associated with a range of acute and chronic adverse health effects and diseases. The most commonly reported are respiratory system problems (e.g. rhinitis, asthma, bronchitis and sinusitis), through both atopic and non-atopic allergic mechanisms as well as non-allergic pathways (Douwes et al., 2003). Other health problems reported include GI distress, fatigue, weakness and headache (Douwes et al., 2003). Bioaerosol exposure occurs primarily through inhalation, although ingestion also contributes. A number of studies, focussing mainly on small-scale family farming, have linked bioaerosol emissions to the potentially fatal disease, Farmer's Lung – the prototype of hypersensitivity pneumonitis (HP; also known as extrinsic allergic alveolitis) (Eduard et al., 2012). However, major stumbling blocks in the study of potential health consequences of exposure to bioaerosols in the agricultural setting have been a lack of information on exposure and difficulties in disentangling the effects of bioaerosol emissions from those of other emissions.

A further need to understand better the composition of bioaerosols is indicated by a consideration of particle size. Bioaerosol particles in air can be suspended in air as single cells or spores or as aggregates. Asthma is a disease of the upper airways. Particles ranging from about 4 µm to 10 µm tend to deposit in the upper airways. Many bioaerosol particles, such as fungal spores and pollen, fall within this size range, although others (e.g. bioaerosol aggregates, spore chains) may be larger and as a result likely remain within the nasal cavity.

Overall these challenges and the consequent lack of valid exposure,