ORIGINAL ARTICLE

Air pollution from livestock farms, and asthma, allergic rhinitis and COPD among neighbouring residents

Lidwien A M Smit,[1] Mariëtte Hooiveld,[2] Femke van der Sman-de Beer,[2] Annemieke W J Opstal-van Winden,[1] Johan Beekhuizen,[1] Inge M Wouters,[1] C Joris Yzermans,[2] Dick Heederik[1]

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[1]Division Environmental Epidemiology, Institute for Risk Assessment Sciences, Utrecht University, Utrecht, The Netherlands
[2]NIVEL, Netherlands Institute for Health Services Research, Utrecht, The Netherlands

Correspondence to
Dr Lidwien Smit, Division Environmental Epidemiology, Institute for Risk Assessment Sciences, PO Box 80178, Utrecht 3508 TD, The Netherlands; L.A.Smit@uu.nl

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ABSTRACT

Objectives There is an ongoing debate regarding environmental health risks of exposures to dust and microbial agents from livestock farming in the Netherlands. The aims of the study were (1) to investigate associations between indicators of air pollution from livestock farms and asthma, allergic rhinitis and chronic obstructive pulmonary disease (COPD) among neighbouring residents; and (2) to assess associations between farm exposures and endotoxin levels in participants' homes.

Methods Electronic medical records of all 92 548 patients of 27 general practices in a rural area with a high density of animal farms were analysed, followed up by a case-control component using a subsample of the full population. Distance between livestock farms and home address, presence of livestock within 500 m, and particulate matter (PM)10 emissions from farms within 500 m were computed as proxies for farm exposure. Potential confounding was investigated through a case-control questionnaire study in 269 adult patients with asthma and 546 controls. Endotoxin levels were assessed in 493 homes.

Results Modelled PM10 emission was inversely associated with asthma, allergic rhinitis and COPD ($p<0.05$). A smaller distance to the nearest farm, and the presence of swine, goat and sheep farms were also inversely related to respiratory morbidity, whereas mink farms showed positive associations with asthma and allergic rhinitis. Adjustment for confounding in the case-control study did not change results. Farm exposures were not associated with endotoxin levels in neighbouring residents' homes.

Conclusions In conclusion, indicators of air pollution from livestock farms were inversely associated with respiratory morbidity among neighbouring residents.

INTRODUCTION

In the Netherlands, there is an ongoing debate regarding environmental health risks of exposures to dust, endotoxin, and infectious and resistant microorganisms from livestock farming, in particular from swine and poultry farms. Public initiatives against increasingly intensive animal farming often use health concerns—including concerns about asthma or other respiratory diseases—as an argument against expansion of livestock farms. However, scientific evidence on this topic is scarce. An international working group concluded that there is a great need to evaluate health effects from exposures to the toxic gases, vapours, particles and microbial exposures emitted into the environment by large animal farms.[1]

Most information on potential adverse respiratory health effects from animal farm exposures comes from working populations. Swine and poultry farmers are at increased risk of developing respiratory symptoms and accelerated lung function decline associated with COPD and non-allergic asthma due to high levels of endotoxin and other microbial components in stable dust.[1–3] Although ambient exposure levels in the surroundings of animal stables are considerably lower than levels inside stables,[4 5] they can induce clinically important symptoms.[6] It is not known whether indoor exposure levels in non-farm residences are influenced by neighbouring animal farms.

Respiratory health effects among neighbouring residents were reported by studies that examined community-level farm exposures or school proximity to livestock operations.[7–10] Thus far, two studies from Germany [11 12] and two from the USA[13 14] investigated associations between farm exposure variables at the individual level and respiratory health effects. Adults residing in proximity to >12 animal houses experienced a significantly increased prevalence of asthma symptoms and a decreased lung function.[11] A panel study among non-smoking volunteers showed that self-reported hog odour and measured pollutant levels were associated with acute symptoms, in particular upper respiratory symptoms and irritation of the nose and eyes, and there was some indication that $PM_{2.5}$ exposure was associated with a decreased forced expiratory volume in one second.[13]

The present study investigated respiratory outcomes, farm exposure variables and indoor endotoxin levels among neighbouring residents of animal farms in the Dutch provinces of Noord-Brabant and Limburg, a highly populated area in the south of the Netherlands with a high density of farm animals. The aims of the study were (1) to investigate associations between indicators of air pollution from livestock farms and asthma, allergic rhinitis and COPD using a geographic information system and electronic medical records of all 92 548 patients of 27 general practices; (2) to investigate potential confounding of these associations through a questionnaire survey in a subsample of 269 adult patients with asthma and 546 controls; and (3) to assess associations between indicators of air pollution from livestock farms and endotoxin levels in 493 patients' homes.

METHODS

Study population and GP medical data

Data collection and study population were described previously.[15] In brief, general practices in small towns and villages (population <25 000) in the eastern part of the province of Noord-Brabant and the northern part of the province of Limburg were requested to participate. Practices were only included in the study if they met predefined registration quality criteria.[15] Twenty-seven out of 55 practices met these criteria and were included in the analysis. Morbidity data for the year 2009 of all 105 870 enlisted patients were collected from electronic medical records using the International Classification of Primary Care (ICPC). Asthma was defined as one or more episodes coded as ICPC R96. COPD was defined as R91 (chronic bronchitis) or R95 (pulmonary emphysema/COPD). The ICPC code for hay fever/allergic rhinitis is R97. We excluded 3942 patients (3.7%) who had a high likelihood to be living on a farm (distance between home address and animals tables <50 m). Data of all 92 548 patients aged 70 years or younger were used: 22 406 children (0–17 years) and 70 142 adults (18–70 years). The study was carried out according to Dutch legislation on privacy and the Code of Conduct for Medical Research. Patients' privacy was ensured by keeping medical information and address records separated at all times, by using a Trusted Third Party. Address records were used to create a dataset containing exposure variables which could not be used to trace individual addresses. Exposure data were linked to the ICPC codes of interest, age and sex. Medical ethical approval or obtaining informed consent from individual patients was not required for this research.

Exposures from livestock farms

Data on farm characteristics in the study area (precise coordinates, type and number of animals) were obtained from the provincial database of mandatory environmental licences for keeping livestock in 2009. The median (IQR) of permitted animals per farm in the study area was 1242 (591–2441) pigs (n=3383 farms), 29 400 (11 800–72 000) chickens or other poultry (n=1005 farms), 122 (60–196) cows (n=4298 farms), 1309 (480–1726) goats (n=77 farms), 115 (80–200) sheep (n=230 farms) and 4000 (2800–6000) mink (n=111 farms). Patients' residential addresses were geocoded, and distances between the home address and all animal farms within a 500 m and 1000 m radius were calculated using a geographic information system (ArcGis 9.3.1, Esri, Redlands, California, USA). The following farm exposure variables were considered: (1) distance to nearest farm (quartiles); (2) binary variables indicating the presence of one or more farms within 500 m and 1000 m from the home address; (3) total number of farms within 500 m and 1000 m (continuous variables) (4) binary variables indicating the presence of a specific type of animal farm (swine, poultry, cattle, goat, sheep or mink) within 500 m and 1000 m; and (5) PM10 emission from all farms within 500 m and 1000 m from the home address. For each farm, modelled fine dust emission levels (PM10, g per year) were available from the farm licence database. Emissions were computed by summing the products of estimated PM10 emission factors (g per year per animal), and the number of animals per stable, as commonly used for dust emission and dispersion calculations for farms in the Netherlands. PM10 emission factors were estimated based on a measurement programme involving 24-h emission measurements.[16,17] These emission factors are used in environmental licensing and are available for each combination of livestock category and housing type. To allow for atmospheric dispersion and dilution of the pollutants, we calculated weighted dust emissions from all farms within 500 m and 1000 m from the home address by summing the products of the squared inverse of the distance between a farm and home address and the farm's fine dust emission (PM10, g per year per m^2).

Case-control study

Potential confounding was investigated through a case-control questionnaire study. A sample of 758 patients diagnosed with asthma ('cases') and 1519 patients diagnosed with low back pain without radiation ('controls') was randomly selected from the adult GP patient population (age ≥18 years). Cases and controls received a letter from their GPs explaining the purpose of the study, along with a questionnaire with items on home characteristics, smoking habits, education, profession and farm childhood. We did not offer any (financial) incentives for participation. Questions were mostly adopted from the Dutch version of the European Community Respiratory Health Survey questionnaire.[18] In total, 317 cases and 662 controls returned a completed questionnaire (response 42% in cases and 44% in controls). Responders were more often living within 500 m of a farm than non-responders (63% vs 60%), but the difference was not statistically significant (p=0.11). Participants aged >70 years (n=70), subjects with missing data (n=42), and subjects who reported to be living and/or working on a farm (n=52) were excluded; data of 815 subjects were analysed (269 cases and 546 controls). Participants were older (cases: 49.4 years vs 45.0 years, controls: 52.7 years vs 47.1 years) and more often female (cases: 63.0% vs 57.6%, controls: 63.6% vs 56.9%) than patients with asthma and low back pain in the source population.

Domestic endotoxin exposure assessment

Electrostatic dustfall collectors (EDCs) that capture settling dust[19] were sent along with the case-control questionnaire. EDCs are plastic sample holders equipped with two electrostatic cloths with an exposure area of 0.0209 m^2. Participants were asked to put the EDC on a place at least 150 cm above ground in the living room, and to return the sampler after 2 weeks. Cloths were stored at −20°C until extraction and endotoxin analysis in the limulus amebocyte lysate (LAL) assay as described elsewhere.[20] In total, 863 duplicate cloths from 281 cases (response 38%) and 582 controls (39%) were stored. For financial reasons, we analysed endotoxin levels in a random sample of 493 EDCs with a sampling period of 12–16 days, from participants with complete questionnaire data. Results were expressed as endotoxin units (EU) per m^2.

Statistical analysis

Associations between farm exposure variables and asthma, allergic rhinitis and COPD were analysed by means of logistic regression analysis, with adjustment for age group (child/adult), age and gender. To evaluate potential heterogeneity of effects by age group, we tested for interaction. Standardised household income, a proxy for socioeconomic status (SES), was obtained from Statistics Netherlands for 84.9% of the study population (18 796 children and 59 779 adults).[15] For privacy protection reasons, analyses using SES information had to be completed onsite at Statistics Netherlands. Therefore, SES-adjusted analyses were limited to a number of key associations, stratified by age group. We did sensitivity analyses with generalised estimating equations to adjust for possible correlation in household or practice, but results were not different from those obtained by the initial models. Multiple logistic regression models were used to mutually adjust for the presence of separate types of farm animals around the home address. Weighted PM10 emissions were log-transformed to reduce skewness. ORs and 95% CIs for an IQR increase in exposure were calculated (ie, ORs for subjects at the 75th percentile of exposure versus subjects at the 25th percentile) by taking the exponent of regression coefficients and their CI after multiplying by the IQR of log-transformed exposure. The IQR for ln(PM10, g/y/m^2) was 7.65, corresponding to a 2100-fold increase ($\exp^{7.65}$) in exposure for non-transformed values. The role of a series of potential confounders in associations between farm exposures and asthma in adults was investigated through the case-control questionnaire study by means of logistic regression analysis. First, we explored whether personal characteristics (potential confounders) differed between subjects living within 500 m of one or more farms and subjects living at >500 m from a farm. Then, associations between farm exposure variables and asthma were analysed with adjustment for age and gender only (as in the source population) and with adjustment for the full set of potential confounding variables. Associations between farm exposure variables and log-transformed domestic endotoxin levels were assessed by means of multiple linear regression analysis, adjusting for case-control status and other potential determinants of endotoxin levels.

RESULTS

Characteristics of the study population

Characteristics of the patients are shown in table 1. The geometric mean distance to the nearest farm was 378 m in children and 403 m in adults. More than half of the patients was living within 500 m of at least one animal farm (children: 61.6%, adults: 57.8%), with a high percentage in particular of cattle and pig farms. Almost 95% of all patients were living within 1000 m of one or more animal farms (data not shown).

Table 1 Characteristics of the study population

Characteristic	Children	Adults
N	22 406	70 142
Male gender, n (%)	11 527 (51.5)	36 003 (51.3)
Age (years, mean±SD)	8.9 (5.1)	44.8 (14.4)
Asthma, n (%)	681 (3.0)	1 759 (2.5)
Allergic rhinitis, n (%)	457 (2.0)	1746 (2.5)
COPD, n (%)	0 (0.0)	912 (1.3)
PM10 emission from farms within 500 m (g/y/m^2, GM (IQR))	0.083 (0.001–2.70)	0.059 (0.001–2.10)
Distance to nearest animal farm (m, GM (IQR))	378 (270–620)	403 (290–650)
One or more farms within 500 m, n (%)	13 800 (61.6)	40 519 (57.8)
Number of farms within 500 m (mean±SD)	1.72 (2.10)	1.55 (1.99)
Presence of farm animals within 500 m, n (%)		
Swine	7641 (34.1)	22 542 (32.1)
Poultry	3578 (16.0)	9890 (14.1)
Cattle	10 649 (47.5)	30 760 (43.9)
Goats	612 (2.7)	1548 (2.2)
Sheep	2978 (13.3)	8271 (11.8)
Mink	433 (1.9)	1284 (1.8)

GM, geometric mean.

Associations between farm exposure variables and respiratory outcomes

Indicators of air pollution from livestock farms were inversely associated with asthma, allergic rhinitis and COPD (table 2). The negative association with farm-related PM10 was statistically significant for all outcomes. Patients living very close to a farm (50–280 m to the nearest farm; 4th quartile) had significantly lower odds of allergic rhinitis and COPD compared with patients living at more than 640 m from the nearest farm (1st quartile, reference group). The number of farms within 500 m was negatively associated with asthma and COPD. In general, the presence of specific farm animals within 500 m was also inversely related to respiratory outcomes (table 2). After mutual adjustment for separate types of farm animals, the inverse associations of the presence of goat and sheep with asthma, goat with allergic rhinitis, and swine with COPD remained significant (data not shown). Positive associations were found only for the presence of mink farms within 500 m: significantly increased ORs for asthma and allergic rhinitis were observed. Associations in children and adults showed a similar magnitude and the same direction of association, except for the association between the presence of goat farms and asthma (P interaction=0.02; children: OR 1.02 (0.64–1.62), adults: OR 0.48 (0.30–0.75)). Adjustment for SES did not alter results (see online supplementary tables S1–S3). The risk estimates showed the same direction of association when exposure variables within 1000 m of the home were analysed, but associations were generally weaker and less often statistically significant (see online supplementary table S4). In a sensitivity analysis of those living at less than 50 m from a farm (excluded from study population, high probability that many of them are farmers) versus those living at more than 640 m from the nearest farm, we found a clear inverse association for all outcomes: OR (95% CI) for asthma 0.77 (0.61 to 0.97), allergic rhinitis 0.56 (0.42 to 0.74) and COPD 0.41 (0.23 to 0.72).

Role of potential confounders

In the case-control subpopulation, living within 500 m of at least one livestock farm was significantly associated with a younger age, a higher education, being raised on a farm and having one or more pets at home (univariate analysis, table 3). ORs remained statistically significant after mutual adjustment, except for age. Other home characteristics and lifestyle factors such as smoking habits or occupation were not related to farm proximity (table 3). Similar inverse associations between farm exposures and asthma (case-status) were found as in the source population. Risk estimates moved further away from unity when adjusted for the full set of potential confounders, but overall, only a modest effect of adjustment was observed (table 4).

Livestock farm exposures and endotoxin levels in patients' homes

The geometric mean endotoxin level in patients' homes was 1873 EU/m^2, which is similar to previously measured domestic endotoxin levels using EDCs.[19 21] PM10 emissions from farms within 500 m from the home and asthma (case-status) were not associated with domestic endotoxin level (table 5). Distance to nearest farm, the number of farms, or the presence of specific farm animals within 500 m from the home were also not related

Table 2 Association of animal farm exposures and asthma, allergic rhinitis and COPD in 22 406 children and 70 142 adults

Exposure	Asthma OR (95% CI)	Allergic rhinitis	COPD
PM10 emission from farms within 500 m†	**0.91 (0.84 to 0.98)**	**0.91 (0.84 to 0.99)**	**0.81 (0.71 to 0.92)**
Distance to nearest farm†			
>640 m (reference)	1	1	1
440–640 m	0.94 (0.84 to 1.05)	0.96 (0.85 to 1.09)	0.91 (0.76 to 1.09)
280–440 m	0.90 (0.80 to 1.01)	1.01 (0.90 to 1.14)	0.84 (0.70 to 1.01)
50–280 m	0.94 (0.84 to 1.05)	**0.85 (0.76 to 0.96)**	**0.66 (0.55 to 0.80)**
One or more farms within 500 m	0.93 (0.86 to 1.01)	0.98 (0.90 to 1.07)	**0.80 (0.70 to 0.92)**
Number of farms within 500 m	**0.98 (0.96 to 0.99)**	0.98 (0.96 to 1.00)	**0.94 (0.90 to 0.97)**
Presence of farm animals within 500 m			
Swine	0.92 (0.84 to 1.00)	0.95 (0.87 to 1.05)	**0.77 (0.66 to 0.90)***
Poultry	0.90 (0.80 to 1.01)	0.90 (0.79 to 1.02)	0.95 (0.78 to 1.16)
Cattle	**0.92 (0.85 to 0.99)**	0.99 (0.91 to 1.08)	**0.80 (0.70 to 0.92)**
Goat	**0.65 (0.47 to 0.90)***	**0.62 (0.43 to 0.88)***	0.54 (0.29 to 1.01)
Sheep	**0.83 (0.73 to 0.95)***	0.92 (0.80 to 1.05)	**0.79 (0.63 to 0.99)**
Mink	**1.44 (1.12 to 1.86)***	**1.63 (1.27 to 2.10)***	0.65 (0.35 to 1.23)

ORs and 95% CI were adjusted for age, sex and age group (child/adult). COPD was analysed in 43 657 adults aged >40 years. Bold type indicates statistical significance (p<0.05).
*p<0.05 after adjustment for the presence of other types of farm animals in a multiple logistic regression analysis. PM10, distance and number of farms were tested in an univariate analysis only.
†OR and 95% CI for an IQR increase in log-transformed exposure. IQR for ln(PM10, g/y/m^2)=7.65, corresponding to a 2100-fold increase (exp$^{7.65}$) for non-transformed values.

to endotoxin levels (p>0.30, data not shown). A younger age of the participating resident (<50 years), visible mould in the home, vacuum cleaning more than weekly, living on a farm, and keeping one or more pets were associated with a 1.3–1.7-fold increase of endotoxin levels (table 5). The presence of children in the household was not a significant determinant after adjustment for the participant's age, and was not included in the model. Endotoxin levels were a factor 1.08 higher in subjects with self-reported hay fever (p=0.43, not included in the model).

DISCUSSION

Indicators of air pollution from livestock farms in the south of the Netherlands were associated with a lower prevalence of asthma, allergic rhinitis and COPD among neighbouring residents. Living within close proximity to one or more livestock farms was associated with a higher education, being raised on a farm and having one or more pets at home. However, significant inverse associations remained after adjustment for these potential confounders.

Table 3 Association between personal characteristics and living within 500 m of one or more farms in 815 questionnaire participants

Characteristic	n (%)/mean (SD)	OR (95% CI)
Female gender	524 (64.3)	1.06 (0.79 to 1.43)
Age (per 10 years)	49.8 (12.3)	**0.88 (0.79 to 0.99)**
Educational level*		
Medium vs low	343 (43.6)	1.34 (0.96 to 1.86)
High vs low	179 (22.8)	**1.73 (1.16 to 2.59)**
Smoking habits		
Ex-smoker vs never smoker	350 (43.4)	0.83 (0.60 to 1.14)
Current smoker vs never smoker	152 (18.9)	0.85 (0.57 to 1.27)
Occupational exposure to vapours, gases, dust or fumes	239 (29.9)	1.02 (0.75 to 1.40)
Number of years in the present home (per 10 years)	18.0 (12.4)	0.94 (0.84 to 1.06)
Farm childhood	184 (24.7)	**1.52 (1.06 to 2.18)**
Visible mould	100 (12.4)	1.09 (0.70 to 1.68)
One or more pets	385 (47.4)	**1.55 (1.16 to 2.06)**
Hay fever	233 (29.4)	1.30 (0.92 to 1.83)

ORs and 95% CI were adjusted for case-control status. Bold type indicates statistical significance (p<0.05).
*Educational level: low, lower secondary school or less; medium, intermediate vocational education or upper secondary school; high, upper vocational education or university.

Table 4 Association of animal farm exposures and asthma in 815 questionnaire participants

Exposure	Adjusted for age and sex OR (95% CI)	Adjusted for other potential confounders*
PM10 emission from farms within 500 m†	0.76 (0.57 to 1.03)	**0.70 (0.49 to 0.99)**
Distance to nearest farm†		
>640 m (reference)	1	1
440–640 m	0.65 (0.42 to 1.01)	0.72 (0.43 to 1.20)
280–440 m	**0.50 (0.32 to 0.78)**	**0.51 (0.30 to 0.87)**
50–280 m	0.70 (0.46 to 1.04)	0.62 (0.38 to 1.01)
One or more farms within 500 m	**0.73 (0.54 to 0.98)**	**0.69 (0.48 to 0.99)**
Presence of farm animals within 500 m		
Swine	**0.66 (0.48 to 0.91)**	**0.58 (0.40 to 0.85)**
Poultry	0.88 (0.57 to 1.36)	0.90 (0.53 to 1.51)
Cattle	0.78 (0.58 to 1.04)	0.75 (0.52 to 1.07)
Goat	**0.12 (0.02 to 0.89)**	0.19 (0.02 to 1.56)
Sheep	0.64 (0.39 to 1.04)	**0.53 (0.29 to 0.95)**
Mink	2.30 (0.66 to 8.06)	3.55 (0.88 to 14.38)

*ORs and 95% CI were adjusted for sex, age, educational level, smoking habits, occupational exposure to vapours, gases, dust, or fumes, number of years in the present home, farm childhood, visible mould in the home, having one or more pets, and hay fever. Bold type indicates statistical significance (p<0.05).
†OR and 95% CI for an IQR increase in log-transformed exposure. IQR for ln(PM10, g/y/m^2)=7.65, corresponding to a 2100-fold increase (exp$^{7.65}$) for non-transformed values.

Table 5 Multiple linear regression analysis of determinants of endotoxin exposure levels in 493 homes

Determinant	n	exp^{β} (95% CI)
Intercept	493	996 (845 to 1174)
Asthma (case)	159	1.04 (0.87 to 1.23)
PM10 emission from farms within 500 m*	493	0.97 (0.83 to 1.13)
Age, <50 years	200	**1.34 (1.13 to 1.58)**
Visible mould	71	**1.33 (1.06 to 1.67)**
Vacuum cleaning, >weekly	287	**1.35 (1.15 to 1.59)**
Living on a farm	13	1.62 (0.97 to 2.71)
One or more pets	229	**1.69 (1.44 to 1.99)**

Bold type indicates statistical significance (p<0.05).
*exp^{β} and 95% CI for an IQR increase in log-transformed exposure. IQR for ln(PM10, g/y/m^2)=7.65, corresponding to a 2100-fold increase ($exp^{7.65}$) for non-transformed values.

Results of the present analyses were somewhat unexpected, as the study was initiated by public health concerns related to intensive livestock farming. We did not find support for the hypothesis that farm exposures adversely affect respiratory health; on the contrary, findings may indicate less respiratory morbidity among residents living in the vicinity of livestock farms. Most studies on this topic come from North Carolina, where industrial hog farms that cause widespread pollution are clustered in low-income minority communities. The situation in North Carolina, where people who can afford to move away from neighbouring farms often do so,[22] is difficult to compare with our study area. The neighbouring residents of farms in this study often have a farming (family) background, have been raised within the region, and are not characterised by a low SES and a minority background. Several, mainly European, studies have shown that farm children have a lower risk of respiratory allergies than their peers living in the same rural community.[23–25] This protective effect was also observed among children of Dutch farmers.[25] There is also some evidence of protective effects of farm exposures on atopic asthma and allergy in non-farming residents of rural areas.[9 26] The reduced prevalence of asthma and allergy in farm children has been attributed to higher endotoxin levels and more diverse exposures to microbial components in the farm environment.[27 28] It has been argued that especially microbial exposures in early childhood contribute to the reduction of allergic sensitisation,[24] and that this protective effect continues in early adulthood.[29 30] However, several studies have shown that farm exposures during adulthood may also protect against atopy and allergic asthma.[26 31–34]

Endotoxin levels that have been shown to cause acute respiratory effects can be found several 100 m downwind of animal farms.[5 35 36] Therefore, as in the study by Radon *et al*,[11] we used a distance of 500 m to define our exposure variables. We collected week-averaged ambient PM10 and endotoxin PM10 at five sampling locations in the study area and one urban background location.[36] Measured PM10 and endotoxin were positively associated with modelled PM10 and the number of farms around the sampling locations.[36] Despite higher outdoor endotoxin concentrations, we did not find associations between farm exposure variables and indoor endotoxin levels in homes of neighbouring residents. Other well-known determinants of house dust endotoxin such as the presence of pets, visible mould and living on a farm were significantly associated with increased endotoxin levels. Vacuum cleaning more than once a week was also associated with increased levels of endotoxin in airborne dust, which could be related to unmeasured home characteristics or to increased dust deposition. These findings suggest that indoor endotoxin sources predominate outdoor contributions from livestock operations.

Case-control questionnaires and EDC samplers were returned by ∼40% of recipients. Response did not differ between patients with asthma and controls, and associations between farm exposures and asthma were comparable with those obtained in the source population, suggesting that self-selection and subsequent bias was minimal. Evaluating GP-registered respiratory outcomes has certain advantages over the use of questionnaire surveys. Selection bias was unlikely to have influenced results, since we studied a large sample of GP practices, and all patients were included in the data analysis. Moreover, results were not affected by recall bias. Using GP records also has limitations: positive diagnoses were restricted to patients who sought medical treatment for their symptoms, likely resulting in a high specificity but a low sensitivity, in particular for a condition like hay fever/allergic rhinitis. Objective test results, such as skin prick tests or spirometry were not available. Thus, we could not distinguish between atopic and non-atopic asthma. Studies among adult farmers found that higher endotoxin exposure levels protected against atopy, respiratory allergies and atopic asthma.[31–34] However, the reduction in occurrence of atopic conditions among farmers was paralleled by an increased risk of non-atopic asthma, respiratory symptoms and bronchial hyper-responsiveness. In the present study, we found an inverse association between farm exposures and COPD, which conflicts with previous findings in farmers. It is not biologically plausible that farm-related exposures may protect against COPD. Confounding by major risk factors for COPD like smoking habits and occupation could have influenced the observed inverse associations, but this information was not available for the source population. Temporality is an important issue in our study, and we cannot draw conclusions on causality due to the cross-sectional study design. Only the current address was available, and another explanation of the inverse associations could relate to selective migration of less healthy residents from rural to urban areas. Among case-control respondents, patients with asthma more often had plans to move house than controls (11% vs 6%, OR 2.0, p=0.03), but there was no evidence of a link with farm proximity.

The positive association of mink farms with asthma and allergic rhinitis is not easily explained. Fur workers can become sensitised to allergens in mink fur or urine,[37] but it is not known whether mink sensitisation occurs in neighbouring residents. These associations should be interpreted with caution and need to be substantiated by objective endpoint measurements.

Most previous studies among neighbouring residents of animal farms found adverse effects of farm exposures on respiratory outcomes. School proximity to intensive swine operations was associated with increased odds of asthma and current wheezing among children and adolescents.[7 10] Quality of life was reduced due to respiratory symptoms and livestock odour in adult residents of a community near an industrial swine operation.[8] On the other hand, inverse associations between county-specific farm exposures and asthma were found in school children.[9] Interpretation of all of the above studies is limited by the absence of exposure estimates at the individual level. In the present study, individual exposure estimates were calculated using detailed information on location and farm type. Only a few other epidemiological studies estimated individual exposures to air pollution from livestock farms. In a German study, an increased prevalence of asthma symptoms and a decreased lung function in adults living near >12 animal houses was shown.[11] Interestingly, a large number of animal farms was also associated with a decreased prevalence of allergic sensitisation and bronchial hyper-responsiveness to methacholine, but these associations were not statistically significant.[11] A smaller German study estimated individual ammonia exposure levels, and found a positive association with allergic sensitisation and a lower forced expiratory volume in one second.[12] A recent study observed a positive association between environmental exposure to swine farms and childhood asthma in rural Iowa.[14] A North Carolina panel study in adult volunteers who were mostly free of chronic respiratory diseases showed that measured pollutant levels were associated with acute physical symptoms.[13] This finding requires further investigation in other populations, because it suggests that farm-related exposures may also be relevant for patients with pre-existing asthma or COPD, that is, by causing exacerbations. Even if farm exposures are inversely related to asthma and respiratory allergies as we observed in our study, it cannot be precluded that adverse effects on respiratory health of susceptible individuals may occur during peak exposures. Interestingly, airway infections, cough and dyspnoea occurred more frequently among patients with COPD and asthma in the present study area than in a rural control area, indeed suggesting a higher risk of exacerbations.[36]

In conclusion, in this large, population-based study, we found that individually estimated farm exposures were inversely associated with respiratory morbidity in neighbouring residents. A protective effect of farm exposures, possibly due to higher and more diverse microbial exposures, may explain the observed associations with asthma and allergic rhinitis. However, these findings should be confirmed with more objective disease information before firm conclusions can be drawn.

What this paper adds

- In the Netherlands, there is an ongoing debate over the community health risks of emissions from animal farms. Despite concerns among neighbouring residents and general practitioners, scientific evidence on this topic is scarce.
- In this large, population-based study, we found that indicators of air pollution from livestock farms were associated with a lower prevalence of asthma, allergic rhinitis and COPD.
- The prevalence of asthma and allergic rhinitis was increased among those living within 500 m of mink farms.
- Indoor endotoxin levels in homes of neighbouring residents were not associated with farm exposure variables.

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Contributors LAMS, FvdS-dB, MH, IMW, JY and DH conceived and designed the study. FvdS-dB, MH and JY recruited general practitioners and provided the medical data. LAMS, AWJO-vW and JB analysed the data. LAMS wrote the manuscript. All authors read and approved the final version of the manuscript.

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Air pollution from livestock farms, and asthma, allergic rhinitis and COPD among neighbouring residents

Lidwien A M Smit, Mariëtte Hooiveld, Femke van der Sman-de Beer, Annemieke W J Opstal-van Winden, Johan Beekhuizen, Inge M Wouters, C Joris Yzermans and Dick Heederik

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