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Odour annoyance in the neighbourhood of livestock farming – perceived health and health care seeking behaviour

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Abstract

Introduction and objectives. Odour annoyance forms the main source of environmental stress in residents living in the proximity of animal feeding operations (AFOs) and it has been associated with reduced health. This study aims to gain more insight into the association between AFOs in the neighbourhood, odour annoyance, other environmental stressors, and health, and incorporates health care seeking behaviour for reported symptoms.

Materials and methods. Cross-sectional data from 753 people living in an area in the Netherlands with a high density of AFOs was evaluated. Odour and other environmental annoyances in the neighbourhood, general health and symptom reporting were obtained by questionnaire. Health care utilisation was obtained from electronic medical records of general practices. The number of pigs, poultry and cattle within a 500 m radius from homes was computed using Geographic Information System data. Mutually adjusted multiple Poisson and (ordinal) logistic regression analyses were performed.

Results. The number of pigs, poultry and cattle was equally associated with odour annoyance. This annoyance was associated with reduced general health and increased reporting of respiratory, gastrointestinal, neurological and stress-related symptoms. Participants rarely consulted their general practitioner for reported symptoms. Environmental stressors were weakly associated.

Conclusions. The number of animals around the homes was associated with odour annoyance. Odour annoyance was associated with reduced health, which could be a reason for caution with the construction of new AFOs.

Key words

odours, animal feed/adverse effect, delivery of health care, the Netherlands

INTRODUCTION AND OBJECTIVES

Odour annoyance is common in residents living in the proximity of (concentrated) animal feeding operations (AFO) and forms the main source of environmental annoyance among residents in these areas [1, 2, 3]. AFOs emit several odorous and non-odorous compounds, including endotoxin, particular matter (PM), ammonia, hydrogen sulphide (H_2S), volatile organic compounds and greenhouse gases [4].

Odorous compounds may affect human health via two mechanisms [5]. First, at high concentrations odorants can evoke ocular, nasal and throat irritation and respiratory and gastrointestinal complaints [6]. Irritation and complaints are caused by odorous components rather than the odour itself. Second, odour annoyance can act as a mediator of health symptoms and complaints via aversion, stress or conditioning [7, 8]. Changes in immunoglobulin A responses have been associated with odour intensity in individuals, suggesting that psychophysiological responses can occur [9]. The underlying mechanistic explanation is that these physiologic changes are most likely stress related; however, other mechanisms, including sensitization, may also contribute.

Odour in the neighbourhood of AFOs has been shown to affect human health in several studies, some of which report on perceived odour, while others report on odour annoyance. One study showed that symptom reporting occurred mainly in respondents who complained about odour, indicating a more select group of respondents reporting odour annoyance than just odour alone [10]. Radon et al. found increased prevalence of wheezing without a cold, physician-diagnosed asthma and allergic rhinitis and lower quality of life, but no difference in lung function with increased levels of odour annoyance in residents living in the proximity of (mainly) pig and poultry farms in Germany [2, 11]. Studies conducted in an area in North Carolina, USA, with one of the world's highest concentrations of pig operations showed changes in daily activities [12, 13], increased respiratory symptoms [14], diastolic blood pressure [15], and negative mood [16, 17] with (increased) odour perception in communities in the surroundings of concentrated AFOs, but no differences in lung function, gastrointestinal and neurological symptoms [14].

Although several studies have addressed the possible health effects of odour in the neighbourhood of AFOs, some issues still remain unresolved. First, to what extent odour annoyance is associated with various types of animals is largely unknown. Most research has been dedicated to pig operations, probably since it is well known that these operations in comparison to cattle and poultry operations emit the most offensive odours [18]. Wing and Wolf investigated both cattle and pig operations, and showed associations only between reported health problems and quality of life for pig operations [19]. On the other hand,

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Sucker et al. showed that the source of odour (cattle, pigs, and poultry) had no impact on reported symptoms [10]. Based on current odour emission rates of stables, the odour annoyance is expected to be the highest for pigs, followed by cattle and poultry [20]. It is also unknown to what degree the agreement between self-reported and computed proximity to the nearest AFO influences the association between various animal types and odour annoyance. Second, most studies only report on self-reported health outcomes, and those who do report objective health parameters did not always show an association with odour [14, 15]. An outcome of interest positioned between self-reported health outcomes and objective health parameters is the health care utilisation for reported symptoms. This might give an indication about the severity of the reported symptoms.

Finally, risk perception and expectations play an important role in the mechanism of odour as a mediator of health symptoms. Possibly, persons reporting odour annoyance from AFOs in the neighbourhood represent a subgroup that is generally less able to cope with environmental annoyances such as noise and odour. It is unknown whether persons reporting odour annoyance in the neighbourhood of AFOs generally are more sensitive to other environmental stressors (noise, air pollution, and traffic), and how these other environmental annoyances impact on the association between odour annoyance and health.

The expansion of (concentrated) AFOs has created concerns worldwide with regard to the health of residents living in the proximity of AFOs [1, 2]. The objective of the presented study is to gain more insight into the associations between AFOs in the neighbourhood, odour annoyance, other environmental stressors and health, by using data from residents living in an area in the Netherlands with a high density of (concentrated) AFOs. The study addresses the following questions:

1) What is the association between the presence of pigs, poultry, and cattle in the neighbourhood and odour annoyance? Does the agreement between self-reported and computed proximity to the nearest AFO influence this association?
2) What is the association between odour annoyance and health, and health care utilisation?
3) Do people who report odour annoyance also report other environmental stressors more often? And do other environmental stressors affect the association between odour annoyance and health?

MATERIALS AND METHOD

Study design and population. Secondary analyses were performed using data from two cross-sectional samples of patients diagnosed with asthma and lower back pain without radiation from a case-control study on potential health effects of (concentrated) AFOs in the Netherlands [21, 22, 23]. In short, general practices outside the larger cities in the southeastern part of the Netherlands were asked to participate. A sample of 758 patients diagnosed with asthma and 1,519 patients diagnosed with lower back pain without radiation was randomly selected from the adult general practitioner (GP) patient population (age ≥18 years) of 20 general practices. In June 2010, patients received a questionnaire via their GP addressing home characteristics, residential environment, smoking habits, nationality, education, occupation, self-reported symptoms, and farm childhood. After two weeks, a reminder was sent. In total, 317 asthma and 662 lower back pain patients returned a completed questionnaire (response 42% in asthma patients and 44% in lower back pain patients). Participants were more often female, of higher age and the distance to AFO was smaller compared with non-participants. Health care utilisation (morbidity data) was obtained from electronic medical records (EMR) of GPs. All Dutch inhabitants are obligatory listed in a general practice and the GP acts as gatekeeper for specialized, secondary health care. Therefore, the EMR kept by the GP provided the most complete picture of people's health. EMR data for 2010 was available for five of the 20 practices. Morbidity was recorded using the International Classification of Primary Care (ICPC [24]). Participants who reported to be living and/or working on a farm (n=52) were excluded, as were participants with missing data (n=174), leaving 753 subjects for analysis. Participants' privacy was ensured by keeping medical information and address records separated at all times by using a Trusted Third Party. According to the Dutch Medical Research Involving Human Subjects Act this study did not require ethical approval.

MEASUREMENTS

Odour and other environmental annoyance. The experience of odour annoyance or other environmental annoyances was based on the question: 'Do you face the following environmental problems/annoyances in your neighbourhood?' The source of environmental annoyances was not specified. Environmental annoyances included odour, noise, traffic, and air pollution.

Exposures from animal feeding operations. Data on farm characteristics in the study area (geographic location, type and number of animals) were obtained from the provincial database of mandatory environmental licences for keeping livestock in 2009. Participants' residential addresses were geocoded, and distances between the home address and all AFOs within a 500 m radius were calculated using a geographic information system (ArcGis 9.3.1, Esri, Redlands, CA, USA). To estimate both the association between the presence and the intensity of AFOs in the neighbourhood and odour annoyance, the number of cattle, pigs and poultry within a 500 m radius were categorised into quartiles plus a 'no animal' category.

Health symptoms and health care utilisation. Participants were asked to note whether they had experienced symptoms in the last month (Tab. 1). Analyses were conducted on each symptom separately, as well as for clusters of respiratory, gastrointestinal, neurological, and stress-related symptoms. In addition, participants were asked to rate their general health using a 5 point Likert scale (bad to very good).

Health care seeking for reported symptoms was evaluated by searching for concurrent ICPC-codes (Tab. 2) in the EMR in a time period of 45 days before and 3 months after participants filled in the questionnaire.

Agreement between self-reported and computed proximity to nearest AFO. Participants estimated the distance

Table 1. Association between odour annoyance in neighbourhood and general health (N=746) and (cluster of) symptoms in last month (N=751; asthma:250, lower back pain: 501) based on multiple ordinal logistic, logistic and Poisson regression analyses

		Reporting odour annoyance in neighbourhood[$]	Reporting odour annoyance in neighbourhood adjusted for other environmental annoyances[$]
Outcome variables	Mean (SD)	OR(95%CI)	OR (95%CI)
General health[#]	3.53 (0.84)	**0.73 (0.53- 0.99)**	0.85 (0.61–1.18)
Reported number of symptoms	Median (IQR)	RR (95%CI)	RR (95%CI)
Respiratory symptoms	1 (0–2)	**1.22 (1.07–1.38)**	**1.18 (1.03–1.36)**
Gastrointestinal symptoms	1 (0–2)	**1.40 (1.21–1.62)**	**1.37 (1.16–1.60)**
Neurological symptoms	1 (0–1)	1.20 (0.99–1.45)	1.14 (0.93–1.39)
Stress related symptoms	Asthma: 1 (1–2)) Lower back pain: 1 (0–2)	Asthma: 1.00 (0.80–1.24) Lower back pain: **1.40 (1.19–1.64)**	Asthma: 0.93 (0.73–1.18) Lower back pain: **1.27 (1.07–1.52)**
Specific reported symptoms	Percentage	OR (95% CI)	OR (95% CI)
Respiratory symptoms			
Cold/flu	39.4	**1.43 (1.02–2.00)**	1.38 (0.97–1.99)
Cough	47.0	**1.43 (1.02–2.00)**	1.33(0.93–1.91)
Shortness of breath/difficulty breathing	31.2	1.47 (0.99–2.18)	1.38 (0.90–2.11)
Sore throat	23.4	1.39 (0.95–2.03)	1.35 (0.90–2.04)
Gastrointestinal symptoms			
Reflux/gastric acid	21.0	1.46 (0.99–2.15)	1.25 (0.82–1.90)
Stomach complaints	15.3	**1.58 (1.03–2.43)**	1.56 (0.98–2.48)
Stomach ache (pain in belly)	17.8	**1.73 (1.15–2.62)**	**1.73 (1.11–2.79)**
Diarrhoea	21.7	1.44 (0.98–2.11)	1.46 (0.97–2.21)
Nauseous	14.4	1.25 (0.79–1.97)	1.20 (0.74–1.97)
Obstipation	14.0	**2.04 (1.29–3.22)**	**2.04 (1.26–3.31)**
Neurological symptoms			
Headache	47.4	1.23 (0.88–1.73)	1.10 (0.76–1.58)
Dizziness	20.2	**1.62 (1.10–2.37)**	**1.54 (1.02–2.33)**
Stress related symptoms			
Fatigue	62.3	1.29 (0.91–1.83)	1.05 (0.72–1.53)
Sleeping problems	Asthma:45.6 Lower back pain: 40.5	Asthma:0.77 (0.44–1.37) Lower back pain: **2.17 (1.41–3.34)**	Asthma: 0.72(0.39–1.33) Lower back pain: **1.72 (1.08–2.76)**
Anxiousness	11.9	**1.67 (1.04–2.69)**	1.48 (0.89–2.47)
Sadness	Ashtma: 28.8 Lower back pain: 27.3	Asthma: 1.10 (0.58–2.08) Lower back pain: **2.37 (1.50–3.74)**	Asthma: 0.96 (0.48–1.91) Lower back pain: **1.90 (1.15–3.13)**

[$] Adjusted for smoking status, growing up at farm, age, gender, nationality, marital status, education and asthma/lower back pain; [#]5 point Likert scale (bad to very good)

Table 2. ICPC codes along reported symptoms

	ICPC-code
Respiratory symptoms	
Cold/flu	R07:sneezing/nasal congestion
Cough	R05: cough
Shortness of breath/ difficulty breathing	R02: shortness of breath/dyspnoea
Sore throat	R21: throat symptom/complaint
Gastrointestinal symptoms	
Reflux/gastric acid	D03: heartburn
Stomach complaints	D02: abdominal pain epigastric
Stomach ache (pain in belly)	D01: abdominal pain/general cramps
Diarrhoea	D11: diarrhoea
Nauseous	D09: nausea
Obstipation	D12: constipation
Neurological symptoms	
Headache	N01: headache
Dizziness	N17: vertigo/dizziness

Table 2. ICPC codes along reported symptoms (Continuation)

	ICPC-code
Stress related symptoms	
Tiredness	A04: weakness/general tiredness
Sleeping problems	P06: sleep disturbance
Anxiousness	P01: feeling anxious/nervous/tense
Sadness	P03: feeling depressed

(within categories) from home to the nearest AFO. Based on the difference between the estimated and computed distance, participants were divided into three categories: correctly estimated distance, underestimated distance, and overestimated distance.

Statistical analyses. The association between the number of animals in a 500 m radius and odour annoyance (dependent variable) was analysed with mutually adjusted multiple logistic regression analysis. The association was adjusted for years living in the current home, hours per day around/in house,

smoking status, growing up on a farm, age, gender, nationality, marital status, presence of other animals in a 500 m radius, and asthma/lower back pain. Multiple ordinal logistic (general health), logistic and Poisson (health symptoms) regression analyses were used to assess the association between odour annoyance and health (dependent variable). These analyses were adjusted for the same variables except for years in current house, hours per day around/in house, and presence of other animals. Spearman's correlation coefficients between all environmental stressors were calculated to evaluate whether patients reporting odour annoyance also report other environmental stressors more often. To control for potential differences between asthma and lower back pain patients, a variable *asthma/lower back pain* in all analyses was added and checked for interaction-effects between odour and *asthma/lower back pain*. If an interaction effect was present, analyses were performed separately for asthma and lower back pain patients. To check for potential clustering of health and odour annoyance within general practices, multilevel analyses was additionally performed, which showed similar results compared with the initial analyses and are therefore not reported. All analyses were performed using Stata 12.

RESULTS

Characteristics of study population. Participants were more often female (63%) than male, were frequently educated at a medium level, were mostly married or living together, and were regularly ex-smokers (Tab. 3). Nearly a quarter of the participants grew up on a farm. Almost one-third of the participants reported odour annoyance in the neighbourhood. Participants were frequently living within 500 m of pigs (35.2%), poultry (13.9%), and cattle (52.9%). Half of the participants overestimated the distance from home to the nearest AFO (54.0%).

Association between type and number of animals and odour annoyance. The highest category of animals in a 500 m radius from home was associated with a higher odds of odour annoyance (Tab. 4). This was the case for all

Table 3. Characteristics of study population

Patient characteristics	Total study population (N=753)	Odour annoyance (N=221)	No odour annoyance (N=532)
Asthma patients	33.5	36.2	32.3
Lower back pain patients	66.5	63.8	67.7
Gender (female)	63.3	64.7	62.8
Age			
18–39	18.1	13.6	19.7
40–49	23.6	26.7	22.4
50–59	29.7	30.8	29.3
60 and older	28.7	29.0	28.6
Education*			
Low	34.5	27.6	37.4
Medium	42.9	45.7	41.7
High	22.6	26.7	20.9
Nationality			
Dutch	94.7	92.3	95.5
Western immigrant	3.5	5.0	2.8
Non-western immigrant	1.9	2.3	1.7
Marital status			
Married/living together	83.3	84.6	82.7
Unmarried	8.2	8.1	8.3
Divorced/widowed	8.5	7.2	9.0
Grown up on a farm	24.3	28.1	22.7
Smoking			
Non-smoker	16.6	16.3	16.7
Environmental tobacco smoke	21.2	19.0	22.2
Ex-smoker	44.1	47.1	42.9
Current smoker	18.1	17.6	18.2
Year in current home (n=736)			
0–4	16.6	14.5	17.4
5–9	14.7	13.2	15.3
10–14	12.1	12.3	12.0
15–24	26.5	26.8	26.4
25 or more	30.2	33.2	28.9
Hours per day around/in house (n=743)			
<8	6.9	6.0	7.2
8–15	49.8	56.4	47.0
16–19	27.1	25.2	27.8
20–24	16.3	12.4	17.9
Estimated distance to AFO (N=733)			
Underestimated (less than real distance)	14.7	23.7	11.0
Equal	31.2	34.0	30.1
Overestimated (more than real distance)	54.0	42.3	58.9
Environmental annoyances			
Odour annoyance	29.3	100	0
Noise annoyance	28.3	43.9	21.8
Air pollution	16.1	37.1	7.3
Traffic annoyance	41.1	53.8	37.2
Number of animals in 500 m radius			
Pigs			
0	64.8	55.7	68.7
1–390	9.2	8.1	9.6
391–1,130	8.4	8.6	8.3
1,131–2,655	8.8	10.9	7.9
2,656 or more	8.9	16.7	5.6
Poultry			
0	86.1	81.0	88.2
1–3,050	3.5	5.0	2.8
3,051–23,470	3.5	2.7	3.8
23,471–39,900	3.6	4.5	3.2
39,901 or more	3.5	6.8	2.1
Cattle			
0	47.1	38.9	50.6
1–50	15.7	12.7	16.9
51–180	11.6	8.6	12.8
181–400	12.5	19.0	9.8
401 or more	13.1	20.8	10.0
Other animals in 500 m radius (sheep, rabbits and horses)	26.6	35.3	22.9

* 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 between the number of animals in 500 m radius and odour annoyance in neighbourhood (N=711) based on mutually adjusted multiple logistic regression analysis[$]

	No adjustment correctness perceived distance	Adjusted for correctness perceived distance
	OR (95% CI)	OR (95% CI)
Pigs (ref = No.)		
1–390	1.02 (0.51–2.06)	1.01 (0.50–2.06)
391–1,130	1.18 (0.60–2.32)	1.07 (0.54–2.13)
1,131–2,655	1.04 (0.52–2.09)	0.97 (0.48–1.96)
2,656 or more	**2.30 (1.18–4.46)**	**2.22 (1.13–4.36)**
Poultry (ref = No.)		
1–3,050	1.14 (0.46–2.88)	1.27 (0.50–3.22)
3,051–23,470	0.64 (0.23–1.79)	0.67 (0.24–1.89)
23,471–39,900	1.26 (0.50–3.15)	1.12 (0.44–2.83)
39,901 and more	**2.95 (1.08–8.06**)	**3.18 (1.16–8.72)**
Cattle (ref = No.)		
1–50	0.99 (0.59–1.77)	1.15 (0.63–2.09)
51–180	0.63 (0.32–1.23)	0.66 (0.33–1.32)
181–400	**1.83 (1.04–3.23)**	**1.79 (1.01–3.20)**
401 or more	**2.32 (1.22–4.39)**	**2.27 (1.19–4.34)**
Perceived distance (ref = correct)		
Underestimated		**1.77 (1.04–3.01)**
Overestimated		**0.67 (0.44–1.02)**

[$]Adjusted for other types of animals, years in current house, hours around/in house, education, smoking status, growing up on a farm, age, gender, nationality, marital status, presence of other animals in a 500 m radius and asthma/lower back pain

animal types, with odds ratios of 2.30 (95%CI:1.18–4.46), 2.95 (95%CI:1.08–8.06), and 2.32 (95%CI: 1.22–4.39) for pigs, poultry, and cattle, respectively. For cattle, the second highest category was also associated with odour annoyance. Adjusting for the correctness of the estimated distance to AFOs hardly changed the associations. Participants who underestimated the distance reported odour annoyance more often, and those who overestimated the distance reported odour annoyance less often compared with participants who perceived the distance correctly. The association between the number of animals within a 500 m radius and odour annoyance did not differ between participants who under-, over- and correctly estimated the distance. Participants aged 40 years or older, immigrants, and participants with a medium or higher education level showed a higher odds of odour annoyance[1].

Association between odour annoyance and health. Odour annoyance in the neighbourhood was negatively associated with general health (OR: 0.73; 95%CI: 0.53- 0.99) and a higher number of reported respiratory (RR: 1.22; 95%CI: 1.07–1.38), and gastrointestinal (1.40; 95%CI:1.21–1.62) symptoms (Tab. 1). An association between the number of reported stress-related symptoms and odour annoyance was found for lower back pain patients only (RR:1.40; 95%CI: 1.19–1.64). Analyses of individual reported symptoms showed significantly higher odds of cold/flu, cough, stomach

1. Estimations of the regression model are available on request from the corresponding author.

Table 5. Health care utilisation for reported symptoms based on EMR-data (N=228[$])

	No. of participants with reported symptoms	% of symptoms recorded in general practice
Respiratory symptoms		
Cold/flu	88	0.0%
Cough	114	4.4%
Shortness of breath/ difficulty breathing	Asthma: 63 Lower back pain: 17	Asthma: 3.2% Lower back pain: 11.8%
Sore throat	47	4.3%
Gastrointestinal symptoms		
Reflux/gastric acid	56	3.6%
Stomach complaints	43	14.0%
Stomach ache (pain in belly)	47	4.3%
Diarrhoea	46	4.4%
Nauseous	33	3.0%
Obstipation	37	8.1%
Neurological symptoms		
Headache	108	4.6%
Dizziness	41	4.9%
Stress related symptoms		
Tiredness	139	1.4%
Sleeping problems	94	3.2%
Anxiousness	28	0.0%
Sadness	69	1.5%

[$] 2010 EMR – data available for 5 general practices only

complaints, stomach ache (pain in belly), obstipation, dizziness, and anxiousness in participants reporting odour annoyance in their neighbourhood. Higher odds of sleeping problems and sadness were found in lower back pain patients only.

Health care utilisation. In general, health care seeking for reported symptoms was rare (Tab. 5). 0% – 14.0% of the reported symptoms were known in the general practice during a 4.5 months' timeframe.

Other environmental annoyances. Environmental annoyances were weakly associated (Tab. 6). Including the other environmental annoyances in the association between odour annoyance and health resulted in somewhat attenuated associations between odour annoyance and general health and stress-related symptoms (Tab. 1).

Table 6. Correlation between environmental annoyances (N=753)

	Odour	Noise	Air pollution
Noise	0.22*		
Air pollution	0.37*	0.36*	
Traffic	0.15*	0.39*	0.26*

*p<0.001; Spearman's correlation coefficient

CONCLUSIONS

The presented study suggests that a high number of pigs, poultry, as well as cattle in a 500 m radius from the home address was associated with increased odour annoyance in the

neighbourhood. Odour annoyance itself was associated with lower general health and increased reporting of respiratory, gastrointestinal, neurological, and (for lower back pain patients) stress-related symptoms. Residents reporting odour annoyance also reported other environmental annoyances more often. In general, health care seeking behaviour for reported symptoms was limited within the timeframe chosen.

Strengths and limitations of the study. The strengths were the objective assessment at the individual level of the presence of AFOs around the home address, inclusion of the number of various types of animals in the proximity of residents, and the analyses of health care seeking behaviour for reported symptoms through the use of EMR data of general practices. However, a number of points should be considered in the study. There was no information available on the differences in animal houses, such as ventilation and manure handling systems, and practices of land application of manure. Presumably, this could have led to an underestimation of the associations. Furthermore, participants were asked to rate the occurrence of odour annoyance in general. Therefore, it was not possible to pick up seasonal and spatial differences through varying wind speeds and directions which are known to influence odour annoyance [12]. As odour annoyance was asked in general, other sources than AFOs could have contributed to odour annoyance. Selected ICPC-codes and timeframe might have been defined too narrowly. For example, patients could visit their GP for headaches, which could be diagnosed by the GP as migraine (not included in this study), or participants could have visited their GP a long time ago for reported complaints. However, including also diagnosed diseases as migraine and a larger timeframe would have led to an overestimation. Finally, the study population consisted only of asthma and lower back pain patients. For generalization in the general population additional research should be conducted.

On the basis of current odour emission rates of stables, it was expected that the odour annoyance would be the highest for pigs, followed by cattle and poultry. This was not the case, as odour annoyance was fairly similar among the highest category of pigs, poultry and cattle within a 500 m radius. The highest odds ratio were even found for poultry. Thus, for residents in the neighbourhood of AFOs, the type of animal does not seem to influence odour annoyance. In addition, the presented study shows that the correctness of estimated distance highly impacted on odour annoyance in the neighbourhood. Those underestimating the distance were more often annoyed by odour, indicating that perception could play an important role in this type of annoyance.

Odour annoyance was negatively associated with general health and increased reported number of symptoms. Similar findings have been reported for the individual symptoms based on perceived odour [14, 16, 17]. Schinasi et al. found a higher odds of cough and difficulty in breathing, whereas in the current study an association was found between odour annoyance and cough and borderline significant association for difficulty in breathing [14]. An association was also found between odour annoyance and dizziness; however, contrary to Schinasi et al., Schiffman et al. showed more depression and fatigue in participants who reported odour, whereas the current study shows only an association with odour annoyance with feeling depressed (sadness) in lower back pain patients [16]. Horton et al. showed more reporting of anxiousness, similar to the presented study [17]. Radon et al. showed a negative association between odour annoyance and quality of life, and lower general health with odour annoyance, which is in agreement with the current study [11]. In addition, the current study shows that the total number of reported respiratory, gastrointestinal and stress-related symptoms was associated with odour annoyance, and that the health care seeking behaviour for reported symptoms was limited. Although odour annoyance seems to impact on reporting of symptoms, its association with health care utilisation is smaller. The reasons for this discrepancy could be that people might believe that GPs cannot resolve these symptoms (related to AFOs), or that the distance to the general practice might prevent them from visiting a GP for their symptoms.

Residents reporting odour annoyance also reported other environmental annoyances more often, but not on a one-on-one basis. Adjustment for other environmental annoyances resulted in a non-significant association between odour annoyance and general health, and a lower association with stress-related symptoms for lower back pain patients. In the case of general health, it has been stated that emotional health has more impact on general health than physical health. It seems that other stressors influence the association and that response to odour might be mediated by stress, as indicated in the study of Avery et al. [9].

Implications of the results. With the on-going debate on the health risks of AFOs, the presented study shows some new insights important for policy. It shows that the number of animals and not necessarily the presence of animals was associated with odour annoyance. This association was similar for pigs, poultry and cattle, in contrast to expectations based on odour emission models. Policy makers should be aware of the difference between odour itself and odour annoyance, since there is increasing evidence that symptom reporting mainly occurs in residents with complaints about odour. Current setback distances from AFOs are based on the odour emission models and might not correctly have incorporated odour annoyance from different sources. This might be the reason for adaption of these setback distances. Odour annoyance was also shown to be associated with health complaints, which could be a reason for being careful with the construction of new AFOs.

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