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Organic dust exposure in dairy farmers in an alpine region

Richard L. Cathomas[a], Hermann Brüesch[b], Remo Fehr[b], Walter H. Reinhart[a], Max Kuhn[a]

[a] Department of Internal Medicine, Kantonsspital, Chur, Switzerland
[b] Department of the Environment, Kanton Graubünden, Chur, Switzerland

Summary

Objectives: Epidemiological studies suggest that farmers are at an increased risk for chronic obstructive pulmonary disease because of exposure to organic dust. We assessed the proportion of farmers among patients with end stage lung disease and we measured the seasonal exposure of dairy farmers to organic dust in a rural alpine region in Switzerland.

Methods: Six dairy farms of different sizes and infrastructures were chosen for measurements of organic dust (PM_{10} = particles with a 50% cut-off aerodynamic diameter of 10 µm). Indoor measurements were performed during 3–5 days at each farm in late winter, summer and early winter of one year.

Results: 17 measurements of organic dust were carried out on 6 different farms. The concentrations of PM_{10} ranged from 109–2207 µg/m^3 for daily barn activities in winter months and from 76–4862 µg/m^3 for hay storage in summertime. Exposure depended on farm infrastructure and season. It was higher in smaller and older cattle buildings and during the late winter months. The farmers were exposed to the measured amount of organic dust (PM_{10}) for 5 to 6 hours per day during the winter (approximately 900–1260 hours/year).

Conclusions: The study confirms a moderate to high exposure to organic dust (PM_{10}) in these farmers, which, together with epidemiological data, suggests that such exposure over many years could be a major risk factor for the development of chronic obstructive pulmonary disease in dairy farmers.

Key words: organic dust exposure; PM_{10}; dairy farmers; chronic obstructive lung disease

Introduction

An association between farming and respiratory diseases was recognized in the 18th century [1]. In the 20th century medicine first focused on acute lung diseases in farmers such as hypersensitivity pneumonitis or the organic dust toxic shock syndrome (ODTS) and allergic asthma [2]. In the last few years interest has turned to chronic obstructive pulmonary diseases (COPD). A previous publication based on Swiss mortality data demonstrated a higher mortality rate from COPD, but a lower mortality from lung cancer among dairy farmers [3], suggesting either that smoking is not a major cause of COPD in this group or that farmers may smoke less than the average population. In California mortality studies found significantly elevated mortality rates among farmers for all respiratory diseases [4]. Furthermore, several epidemiological studies in Northern and Central Europe reported a significantly higher prevalence of respiratory symptoms related to COPD such as cough and phlegm for dairy farmers compared with the general population [5–9]. A longitudinal study in dairy farmers in the French province of Doubs concluded that dairy farming is associated with a loss in respiratory function correlating with the duration of exposure [10].

Dairy farmers are exposed to organic dusts of a complex nature as characterised in detail by Kullman et al. [11]. Toxic and immunogenic dust constituents include histamine, endotoxins, mite antigen, cow urine antigen and microrganisms (yeast and moulds, mesophilic and thermophilic bacteria) [11]. All these substances are known to be biologically active and some can induce chronic airway inflammation [7, 12, 13]. Only dust particles smaller than 10 µm can enter the lower airway system. [14] This PM_{10} dust fraction (PM_{10} = particles with a 50% cut-off aerodynamic diameter of 10 µm) may therefore play a role in the development of obstructive airway diseases.

Although organic dust exposure is recognised as an important pathophysiological factor, little data exist on the degree of exposure to organic dust (PM_{10}). In this study we estimated the frequency

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of exposure to organic dust during farming activities in patients with end stage COPD on long-term oxygen treatment in the Canton of Graubünden, a rural alpine Swiss region, and we measured the concentration of organic dust (PM_{10}) in several dairy farms in the same area during different seasonal activities.

Methods

All patients in the Canton of Graubünden, Switzerland, with end stage pulmonary disease on long-term oxygen treatment (Registry of the Bündner Lungenliga) were asked about their occupational activities, especially in farming. For this purpose, a questionnaire was distributed inquiring about age, sex, smoking habits, altitude of residence, type of farming and time spent in farming.

For the measurements of organic dust exposure six dairy farms reflecting the heterogeneity of mountain dairy farms were chosen according to their size, year of construction and available infrastructure. Each farm was visited by an investigator prior to the beginning of the measurements to collect detailed information. A structured interview about daily work processes (including assessment of daily and yearly exposure times) and infrastructure of hay storage (grab crane, hay blower, ventilation) was performed with every farmer. One farm had to be replaced during the first measurement period because of logistical problems concerning the measurements inside the cattle building. It was replaced by a farm of comparable size, construction year and infrastructure.

Exposure to organic dust was determined by static area sampling. Sampling devices were placed in the barn in such a way as to allow representative collection of dust reflecting the average exposure during various activities. Measurements inside the cattle buildings were taken to characterise occupational exposures during routine daily activities including milking, feeding, barn cleaning, manure removal, application and chopping of bedding. The sampler was activated only during work inside the cattle building by the farmer or by a timer. The sampling time was 3 to 5 working days (total of 14–30 hours). In summer, the dust exposure during hay storage work inside the barn was measured. Three measurements per farm were carried out from February 2000 to December 2000. The first period was in February during the late winter season. The second measurement period ranged from May to September, representing the summer season with hay storage processes. The third period was in November, representing the early winter months.

To collect the organic dust, we used a cascade impactor (Anderson Mark II®, Particle Size Stack Sampler), which allows measurements with eight different cut off points between 0,5 and 20 µm. The sampling pump provided a constant airflow of 22–23 l/min and was calibrated in the field. Three preliminary measurements were taken in one barn (No. 1) during two preceding years to test the degree and nature of exposure variability as well as the sampling method in use [15]. These results are not included in this study. All filters were desiccated for 48 hours under defined conditions (10% air humidity) and weighed afterwards by the Department of the Environment using an analytical balance (Mettler®). The results were related to the filtered air volume and given as µg/m³.

We measured the following three classes of particles: total suspended particles (TSP), particles with a 50% cut-off aerodynamic diameter of 10 µm (PM_{10}) and particles with a 50% cut-off aerodynamic diameter of 2.5 µm ($PM_{2.5}$).

Results

Questionnaire

A questionnaire asking about agricultural exposure was sent to 94 patients on long-term oxygen therapy; 81 (86%) were returned. Of these, 50 (62%) respondents suffered from end-stage chronic obstructive lung disease and were further analysed. Twenty-three of the 50 (46%) had been active in farming for a mean period of 29 years (range 3–60 years), exclusively in dairy farming. Males were more predominant in the farming group (83%) than in the non-farming group (59%). No difference between the two groups was found for age distribution, altitude of residence or history of smoking. 83 and 82%, respectively, were current or former smokers.

Farming characteristics

The farming characteristics of the six selected dairy farms are shown in table 1. The farms were situated at an altitude of 650 m–1300 m above sea level. One hay barn and livestock building dated from 1890, all others were built after 1980. The owners of farms 1 and 2 both suffered from severe chronic obstructive pulmonary disease (FEV_1 1000 ml and 1200 ml respectively) and required long-term oxygen therapy. The owner of farm 3 had mild chronic obstructive disease (FEV_1 2250 ml). The remainder were without manifest pulmonary disease. Most barns had some kind of ventilation system for the stored hay, but only a minority of cattle buildings were actively ventilated. The percentage of silage and hay for storage differed from farm to farm, but in all at least 50% of the feeding was done with hay. The infrastructure for hay storage and hay feeding ranged from manual work and hay blowers to grab cranes with cabins operated from the barn roof. The main exposure time for organic dust was during the winter months, when the cattle were kept permanently in the cowshed. During these 6–7 winter months daily barn activities occupied 5–6 h irrespective of the farm's infrastructure (range 900–1260 h/winter). In summertime the cattle were kept outdoors on the alpine pastures and organic dust exposure

Table 1

Characteristics of selected dairy farms.

Building no.	altitude (meters above sea level)	construction year	no. of cattle	feeding material		ventilation infrastructure		hay storage	duration of exposure	
				hay	silage	barn	cattle building		winter	summer
1	1300	1989	35	50%	50%	partial	no	hay blower	5.5h/d;7mths approx. 1150h/y	1.5h/d; 30days approx. 45h/y
2	1300	1890	6	100%	0%	no	no	manual hay blower	5h/d;6mths approx. 900h/y	1.5h/d;30days approx. 45h/y
3	1250	1980	25	100%	0%	partial	no	hay blower	5h/d;6mths approx. 900h/y	2h/d;20days approx. 40h/y
4	650	1982	50	67%	33%	yes	partial	hay blower	5h/d;7mths approx. 1050h/y	2h/d;15days approx. 30h/y
5	850	1995	70	67%	33%	yes	partial	grab crane	6h/d;6mths approx. 1080h/y	0.5h/d; 20days approx. 10h/y
6	950	1998	70	80%	20%	yes	yes	grab crane	6h/d;7mths approx. 1260h/y	0.5h/d;30days approx. 15h/y

Table 2

Seasonal total (TSP) and respirable (PM$_{10}$) dust concentrations.

Building no.	Sampling season	TSP (µg/m^3)	PM$_{10}$ (µg/m^3)	PM$_{10}$ (% TSP)	PM$_{2.5}$ (µg/m^3)	PM$_{2.5}$ (% PM$_{10}$)
1	early winter	997	638	64%	35	4%
	late winter	2053	1535	75%	110	7%
	summer	4747	2803	59%	192	7%
2	early winter	1727	1295	75%	90	7%
	late winter	3532	2207	62%	196	9%
	summer	7312	4862	66%	385	8%
3	early winter	1469	1275	87%	97	8%
	late winter	1990	1460	73%	88	6%
	summer	2653	1511	57%	76	5%
4	early winter	447	270	60%	9	4%
	late winter	463	247	53%	10	4%
	summer *	–	–	–	–	–
5	early winter	267	154	58%	8	2%
	late winter	154	109	71%	0	0%
	summer	227	76	33%	0	0%
6	early winter	293	200	68%	13	6%
	late winter	225	136	60%	48	35%
	summer	572	329	58%	0	0%

TSP: total suspended particles; PM10: particulate matter <10µm
* no measurement possible for logistic reasons

occurred only during hay storage work. This work was carried out faster using a grab crane than with a hay blower or manually (range 10–45 h/summer).

Dust concentrations

The measured total dust concentrations (TSP) and organic dust concentrations (PM$_{10}$) are listed in table 2. Seventeen measurements were carried out during a total of 68 days. Barn activities in wintertime were characterised by a large variation of total dust (TSP: 154–3532 µg/m^3) and organic dust exposure (PM$_{10}$: 109–2207 µg/m^3). The concentrations of total dust and organic dust (PM$_{10}$) during winter time barn activities were higher in the older and smaller cattle buildings 1–3, all located above 1000 m (TSP: 1469–3532 µg/m^3; PM$_{10}$: 1275–2207 µg/m^3) than in the newer and larger cattle buildings 4–6, located below 1000 m (TSP: 154–463 µg/m^3; PM$_{10}$: 109–247 µg/m^3). The older farms 1–3 at a higher altitude were either lacking or had an insufficient ventilation system in the barn and cattle buildings. In cattle buildings with a high level of organic dust, the samples collected in the early winter months (November) were lower than those collected in the late winter months (February).

As the hay making period was short and simultaneous on all farms on sunny days, measurements during the hay storage process in summer could only be made in five of the six farms. The concentrations for TSP and PM$_{10}$ measured inside the barn during the hay storage process yielded the highest values with 227–7312 μg/m^3 for total dust concentrations and 76–4862 μg/m^3 for particulate matter <10 μm (PM$_{10}$). As in winter, both values were almost 10 times higher in the older and smaller farms, 1–3, than in the newer, larger farms, 4–6, which had modern equipment such as a grab crane.

Particle size distribution of organic dust

Particles with a 50% cut-off aerodynamic diameter of 10 μm (PM$_{10}$) accounted for the majority of total dust concentration in our measurements (63%, range 33–87%; table 2). Therefore, the thoracic and respirable fraction (PM$_{10}$) constituted the most important part of organic dust. Within the PM$_{10}$-fraction particles between 2.5 μm–10 μm were predominant. In 16 of 17 measurements (94%) the proportion of particle matter <2.5 μm (PM$_{2.5}$) was below 10% of total PM$_{10}$. The particle size distribution varied slightly with the season. In summer, during hay storage, larger particles (PM$_{10}$; table 2) tended to be more abundant than during winter barn activities.

Discussion

Our survey of patients with end stage chronic obstructive lung disease treated with long-term oxygen reveals that almost 50% had worked in farming for periods of time varying from 3 to 60 years. This is much higher than the percentage of the general population working in agriculture, which was 6% in 1970 and 3% in 2000 [16], indicating an overrepresentation of farmers among patients with end stage pulmonary disease in the Canton of Graubünden. Although these preliminary and not well elaborated observations should not be over interpreted, they suggest and corroborate an association between chronic lung disease and environmental factors in farming.

Measurement of organic dust (PM$_{10}$) in different farms showed a substantial exposure to these irritative substances. The values measured are well above the threshold value for outdoor air pollution in Switzerland, which has been set at 20 μg/m^3 PM$_{10}$. According to the SAPALDIA study, [20] the measured outdoor PM$_{10}$ values in Switzerland range between 10 and 33 μg/m^3 with the lowest concentrations in rural regions and above 1000 m sea level. Outdoor PM$_{10}$ derives largely from combustion sources and differs widely from organic dust measured in dairy farms in terms of composition and epidemiology. Exposure to inorganic outdoor PM$_{10}$ affects the entire population, whereas exposure to organic dust affects only specific subgroups. Both types of exposure are of epidemiological relevance. The pathomechanism by which outdoor PM$_{10}$ particles lead to deterioration in lung function [17] causing respiratory morbidity and mortality [18–20] is not well understood. It seems that epithelial injury and airway inflammation occurs. [21] Highly active components such as histamine and endotoxins have been identified in organic dust [11] and these might be responsible for airway inflammation. In particular, it has been suggested that endotoxins play a predominant role [13]. Another important factor is the size of the particles as this determines the pulmonary structure that will be involved. Particles of 2.5–7 μm diameter are primarily deposited in the distal bronchi and bronchioli. [22] Approximately 50% of particles of 3–4 μm diameter and, most importantly, the fraction of particles of 1–2 μm diameter are deposited in the alveoli. Particles <0.5 μm diameter are largely exhaled [22].

Our results are comparable to those found in two other studies measuring the exposure to organic dust during dairy farm work in Finland [23] and the United States [11], although the Finnish study reported only values for total dust concentrations and the American study values for inhalable (cut-off point 100 μm) and respirable dust (cut-off point 4 μm) but not for PM$_{10}$. Both these studies measured personal and area samples and both consistently found that personal dust exposure measurements were higher than measurements collected by area samples [11]. Another large study on airborne dust concentrations in livestock buildings in Northern Europe [24] using area sampling found much lower dust concentrations in cattle buildings. These samples however were collected day and night without reference to the farm work being done at the time of sampling. Compared with the study of Kullman et al. [11] we found a larger proportion of PM$_{10}$ particles (63% *vs* 26% of TSP) and the distribution within PM$_{10}$ showed a higher proportion of particles sized 2.5–10 μm. The reason for these differences remains unclear but they are probably due to a different hay composition and quality.

In our study we observed large, about 20-fold, differences in the exposure to organic dust (PM$_{10}$), which depended on the characteristics of the farm, i.e. the age, size and infrastructure. Very high levels of organic dust (PM$_{10}$) were measured in smaller, older barns and cattle buildings and only moderately elevated levels in newer and larger buildings. Moreover, the installation of adequate hay and cattle building ventilation systems reduced the amount of organic dust (PM$_{10}$) indoors. Seasonal differences in exposure were found for duration as well as level of exposure. Although the organic dust concentrations (PM$_{10}$) were higher during hay making in summer, the exposure time was short. For this reason exposure in winter appears to be much greater and is therefore more likely to contribute to lung damage. It has recently been demonstrated that the prevalence of chronic cough and phlegm correlated with the time spent in animal quarters [9]. Another interesting difference was found between the early and late winter months with higher amounts of PM_{10} in the late winter months. This effect was moderate and probably due to dustier hay after prolonged storage in the late winter months.

There are some methodological limitations to our study. The number of evaluated farms was small, measurements were taken by area sampling and no detailed analysis of dust constituents has been made. Given the extended measurements of dust in dairy farms in the United States with characterisation of the different components [11], which revealed the complex organic nature of this dust, we presume that the dust measured in Swiss dairy farms may be similar and, therefore, regarded our measured dust PM_{10} as organic dust PM_{10}.

Although we cannot prove an exposure response relationship, our data support the hypothesis of an association between long-term exposure to organic dust (PM_{10}) in dairy farming and the epidemiological findings of higher morbidity for COPD-related symptoms [5–9] and higher mortality due to chronic obstructive pulmonary diseases among dairy farm workers [3, 4].

In conclusion, dairy farmers in the Canton of Graubünden, a rural alpine region in Switzerland, are exposed to moderate to high amounts of organic dust (PM_{10}) during daily barn activities depending on the size, construction year and infrastructure of the farm buildings. Together with epidemiological data such as the high prevalence of farmers among patients with end stage pulmonary disease in this study, we conclude that this burden of dust exposure during many years could be a major risk factor for developing chronic obstructive pulmonary disease. It is important that general practitioners and pneumologists are aware of this potential association. They should encourage preventive measures such as appropriate ventilation of farm buildings or the use of respiration masks, especially for patients at risk or with first symptoms of lung disease. Furthermore, threshold values for indoor organic dust (PM_{10}), in addition to the existing outdoor values, should be established.

Correspondence:
Max Kuhn, MD
Department of Internal Medicine
Kantonsspital
CH-7000 Chur
E-Mail: max.kuhn@ksc.gr.ch

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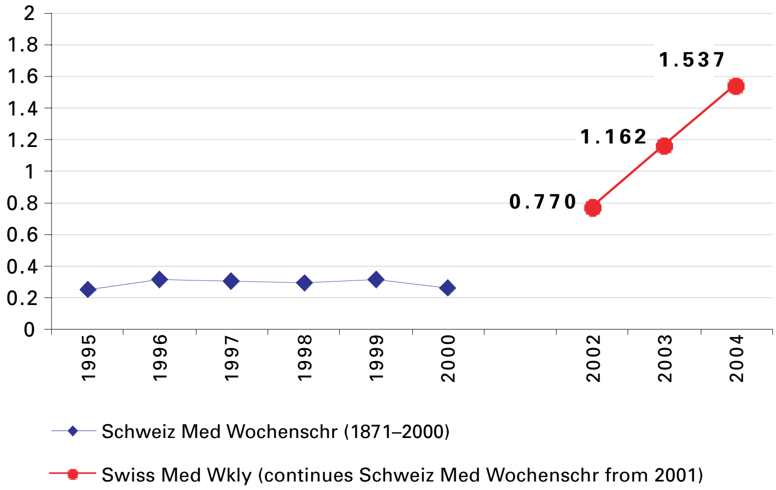

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