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STUDIES OF THE LEVEL OF FARMERS' EXPOSURE TO DUST ON PRIVATE FARMS – BASED ON FRACTION ANALYSES

Agnieszka Buczaj

Department of Physical Occupational Hazards, Institute of Agricultural Medicine, Lublin, Poland

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Abstract: Studies of the level of exposure to dust among farmers on private farms covered the measurements of dustiness while they performed work activities from the aspect of farmer's exposure to individual fractions of the dust inhaled and potentially deposited in individual sections of the airways. The measurements were carried out in the respiratory zone while performing activities contributing to working processes in mixed agricultural production on private farms in an annual work cycle. The article presents the results of studies of the concentrations of inhalable, extrathoracic, thoracic, thoraco-bronchial and alveolic fractions, which allowed the assessment of the percentage distribution of dust deposited in individual sections of the airways, and enabled the estimation of an annual farmers' exposure to individual dust fractions while performing specific work activities on farms. The results of the assessment of farmers' annual exposure to individual fractions of dust indicated that the activities for which the highest values of mean annual weighted concentrations were noted, with respect to all fractions, were: sorting and packing of potatoes, harvesting cereals with a combine harvester, grain crushing, potato digging, and tending stock in cattle and swine breeding. The results obtained will allow the expansion of knowledge concerning the effect of agricultural dust on the human body, and enable the determination of the effect of dust deposited in individual sections of the respiratory system on the state of health of farmers. In future, this will also allow the development of the criteria of hygienic evaluation for dust penetrating into the region of the chest.

Address for correspondence: Dr. Engin. Agnieszka Buczaj, Department of Physical Occupational Hazards, Institute of Agricultural Medicine, Lublin, Jaczewskiego 2, Poland. E-mail: aneska@o2.pl

Key words: agricultural dust, farmers' exposure to dust, level of farmers' exposure to dust, fraction analyses.

INTRODUCTION

The agricultural working environment is associated with many hazardous and strenuous factors. Agricultural dust, an element of the thermal environment, and biological agents most often accompanies farmers at work [1, 2, 3, 7, 9].

Studies of dust in the agricultural working environment conducted by the Institute of Agricultural Medicine (IMW) confirmed a high level of farmers' exposure to agricultural dust while performing work activities contributing to basic agricultural production processes [4, 5, 6, 7]. These studies focused on the measurement of the total dust fraction (inhalable) and respirable fraction (dust penetrating into the pulmonary alveoli). The pathogenic effect of agricultural dust concerns not only the pulmonary alveoli, but also the chest (bronchi and bronchioli), therefore it is important to conduct comprehensive studies of dust fractions inhaled and deposited in individual sections of the airways. According to the recommendations PN-EN-481:1998 [8], the evaluation should cover exposure to the following dust fractions: inhalable (particles inhaled through the nose and mouth), extrathoracic (respirable fraction which does not penetrate beyond the thorax), thoracic (respirable fraction

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penetrating beyond the thorax), thoraco-bronchial (fraction penetrating deeper, beyond the thorax; however, not reaching the non-ciliary airways), and alveolic, i.e. particles of the fraction penetrating into the pulmonary alveoli.

The objective of the study was examination of the agricultural dust fractions, based on EU standards implemented into the Polish legislation concerning the measurements and evaluation of exposure to dust, as well as the determination of the level of farmers' exposure to individual dust fractions while performing work activities, which contribute to the processes of plant and animal production on a private farm in an annual work cycle.

MATERIAL AND METHODS

The studies were carried out on family farms located in the communes of: Lublin, Konopnica, Niemce and Mełgiew. These farms are engaged in a mixed plant-animal production typical of Polish agriculture. The size of the farms is within 10–45 ha, while the number of breeding stock is up to 25 cattle and 60 swine. Production on these farms covers the cultivation of cereals (wheat, sweet corn) and root plants (potatoes, beet roots), as well as dairy cattle and swine breeding. The farms are equipped primarily with agricultural tractors, grain and root plant combine harvesters, machines for the cultivation of soil, production of fodder and equipment for mechanical milking.

The scope of the study covered the following:

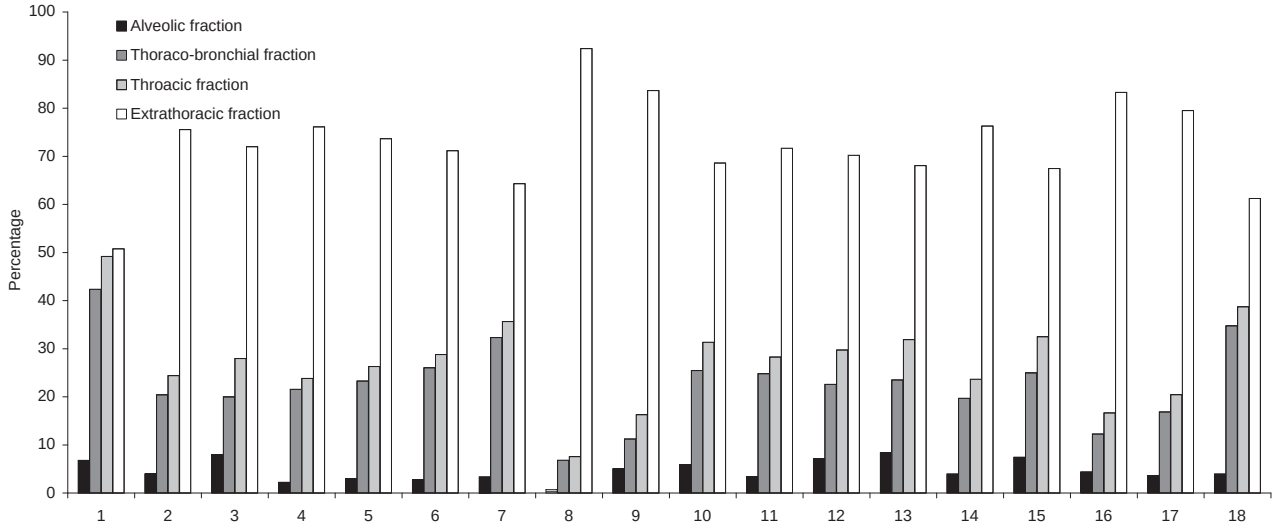
- measurements of dustiness accompanying farmers while performing individual farming activities, with the division into fractions penetrating and deposited in individual sections of the airways;
- determination of mass concentrations of individual dust fractions and assessment of the percentage distribution of dust deposited in individual sections of the airways;
- assessment of farmers' exposure to individual fractions of agricultural dust.

The determinations of the total dust, respirable dust, dust penetrating into the chest region, and intermediate fractions (extrathoracic and thoraco-bronchial) were performed based on EU standards concerning measurements and evaluation of exposure to dust in the work environment implemented into Polish legislation.

The samples were taken in the farmer's respiratory zone while performing individual work activities. The measurements of mass concentrations were conducted in 3 series for individual work activities, covering the subsequent 1 minute measurements of the concentrations of

Table 1. Results of fraction measurements of dust concentrations while performing selected agricultural activities.

Type of work activity	Measurement with a laser meter GRIMM 1.108 [mg/m^3]					
	Inhaled fraction		Thoracic fraction		Alveolic fraction	
	mean	dispersion	mean	dispersion	mean	dispersion
Ploughing	19.1	14.1–25.0	9.4	7.9–11.2	1.3	1.1–1.5
Cultivation	14.5	7.2–28.7	4.1	2.2–8.5	0.5	0.3–0.8
Machine crop cultivation	13.3	4.2–45.0	3.5	1.2–10.1	0.4	0.15–1.0
Sowing seeds with a sower	8.4	5.0–13.1	2.5	1.7–4.9	0.6	0.4–0.7
Potato planting	11.9	8.0–24.9	3.8	3.0–5.2	1.0	0.6–1.7
Harvesting of cereals with a combine harvester	47.5	29.7–73.5	11.6	4.2–28.2	1.9	0.4–3.9
Straw pressing	8.8	3.6–19.3	2.1	1.4–5.2	0.2	0.03–0.5
Harvesting of sweet corn with a combine harvester	8.3	4.0–15.1	1.7	0.9–2.9	0.3	0.05–0.4
Mowing of green forage	2.5	0.8–11.8	0.7	0.2–4.3	0.2	0.08–0.7
Hay making and raking	5.1	2.7–7.4	1.6	1.4–1.9	0.3	0–0.3
Potato digging	28.8	18.1–79.3	8.3	4.1–18.3	0.8	0.2–2.1
Beetroot digging with a combine	8.0	7.1–9.0	2.6	2.2–3.1	0.6	0.4–0.9
Stock tending – cattle	3.8	2.1–5.0	0.9	0.5–1.9	0.15	0.08–1.3
Stock tending – swine	5.7	3.7–9.2	0.95	0.6–1.4	0.25	0.1–0.3
Grain crushing	50.54	28.1–98.8	18.04	10.8–46.8	1.7	0.9–2.8
Potato sorting	75.3	40.7–93.0	29.18	15.7–35.6	2.98	1.7–4.2
Wood-cutting with a power saw	7.9	6.1–9.9	0.6	0.4–0.9	0.06	0.04–0.1
Wood-cutting with a circular saw	17.8	8.9–26.7	2.9	1.7–4.1	0.9	0.4–1.3



1 – Ploughing, 2 – Harvesting of cereals with a combine harvester, 3 – Mowing of green forage, 4 – Straw pressing, 5 – Machine crop cultivation, 6 – Potato digging, 7 – Grain crushing, 8 – Wood-cutting with a power saw, 9 – Wood-cutting with a circular saw, 10 – Hay making and raking, 11 – Cultivation, 12 – Sowing seeds with a sower, 13 – Potato planting, 14 – Beetroot digging with a combine, 15 – Stock tending - cattle, 16 – Stock tending – swine, 17 – Harvesting of sweet corn with a combine harvester, 18 – Potato sorting.

Figure 1. Percentage content of fractions in inhaled dust for individual work activities.

individual fractions of dust deposited in the sections of the airways (respirable, thoracic and alveolic fractions). The concentrations of individual dust fractions were measured by means of a laser dust meter GRIMM 1.108. The duration of measurement series was from 15–50 minutes, and depended on the intensity of dustiness during an individual work activity.

As many as 18 work activities characteristic of plant-animal production were selected for the study, based on investigations conducted in the agricultural work environment by the IMW [4, 5, 6].

Annual farmers' exposure to individual dust fractions was assessed according to the methodology developed by the IMW [4, 5]. Indispensable data concerning the time schedule of farmers' work were taken from the study by the IMW [4, 6, 7] and from the results of studies contained in the report from the realization of the research task entitled: 'Determination of the actual level of farmers' exposure to agricultural dust on private farms of various production profiles' by Dr. A. Mołocznik, ordered by the Central Institute of Labour Protection within a long-term study: 'Safety and protection of human health in the work environment'.

RESULTS

Table 1 presents the results of the measurements of fraction dust concentrations, geometrical mean values from 3 measurement series for individual work activities and dispersion of mean concentrations in series.

Mean concentration of inhaled dust remained within the range 2.5–75.3 mg/m^3. The maximum concentration of inhaled dust was observed during sorting and packing of potatoes: 75.3 (40.7–93.0) mg/m^3, and while grain crushing: 50.54 (28.1–98.8) mg/m^3. The lowest concentrations were noted during the mowing of green forage: 2.5 (0.8–11.8) mg/m^3 and tending of the stock in cattle breeding: 3.8 (2.1–5.0) mg/m^3.

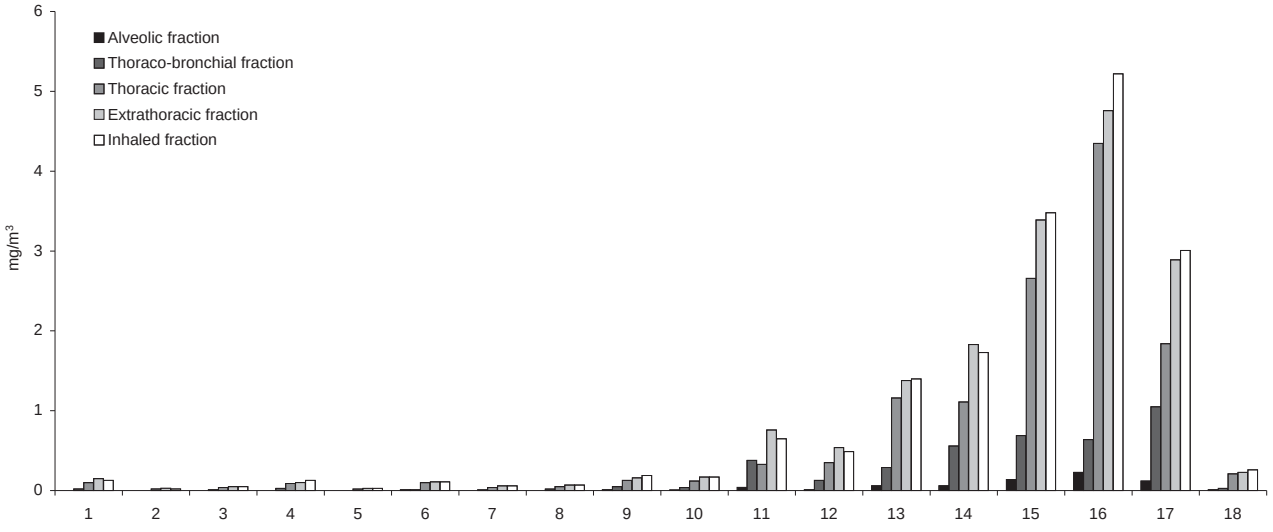
Based on the results of measurements of inhaled, thoracic and alveolic fractions, the concentrations of intermediate dust fractions were determined – extrathoracic and thoraco-bronchial, and the average percentage contribution of individual fractions in inhaled dust calculated (Fig. 1).

The percentage of the fraction deposited in the head region (extrathoracic fraction) for the work activities examined was within the range 50.79–92.41%.

The highest values for extrathoracic fraction were noted with respect to the cutting of wood with a power saw. For this work activity, the percentage of alveolic fraction was the lowest, which evidences the coarse-grained character of the dust inhaled while performing this activity, the majority of which (92.41%) is retained in the nosopharynx and is removed from there.

The lowest values for dust deposited in the head region were observed during ploughing, grain crushing and potatoes sorting. In the case of ploughing, the contents of thoracic dust fraction penetrating beyond the larynx, as well as dust deposited in the thoraco-bronchial section, was the highest. Also in the case of grain crushing and potato sorting the contents of thoracic fraction and dust deposited in the thoraco-bronchial section was the lowest. This evidences the deposition of dust inhaled while performing these activities in the thoracic and thoraco-bronchial sections of the respiratory system.

The percentage of dust potentially deposited in the pulmonary alveoli remained within the range 0.76–8.40%. The lowest values were observed for wood cutting with a



1 – Harvesting of sweet corn, 2 – Mowing of green forage, 3 – Straw pressing, 4 – Machine crop cultivation, 5 – Wood-cutting with a power saw, 6 – Wood-cutting with a circular saw, 7 – Potato planting, 8 – Hay making and raking, 9 – Cultivation, 10 – Sowing seeds with a sower, 11 – Ploughing, 12 – Potato digging, 13 – Harvesting of cereals, 14 – Grain crushing, 15 – Stock tending – cattle, 16 – Stock tending – swine, 17 – Potato sorting, 18 – Beetroot digging with a combine.

Figure 2. Values of mean annual weighted concentration for individual dust fractions while performing work activities on a farm of mixed production profile.

power saw (coarse-grained dust), whereas the highest values – for mowing green forage, potato planting, sowing seeds with a sower, ploughing, hay making and raking.

The studies conducted by the IMW to-date have shown that the degree of farmers' exposure to dust depends on the type of work activity performed and duration of exposure. While evaluating farmers' exposure to dust it is necessary to consider the activities accompanied by the highest dustiness, as well as those to which a farmer devotes the greatest amount of time during an annual production cycle.

The highest dust concentrations were noted during the sorting and packing of potatoes, combine harvesting of cereals, grain crushing and potato digging with a combine harvester. For these activities the content of thoraco-bronchial fraction in inhaled dust was 20.42–42.41%, and was the highest for potato sorting and grain crushing. The content of alveolic fraction while performing the above-mentioned activities was within the range 2.78–4.0%, with the highest concentration observed during combine harvesting of cereals and potato sorting and packing.

The tending of the breeding stock is one of the most time-consuming activities for a farmer engaged in mixed production, and covers 35–83% of the total amount of working time on these farms. The content of thoraco-bronchial fraction for cattle tending was 19.74%, and for swine – 12.28%, while the content of the alveolic fraction was 3.95% and 4.39%, respectively.

For the work activities in the study, an attempt was undertaken to assess the annual exposure of a farmer to individual fractions on a farm engaged in mixed production (Fig. 2). For this purpose, mean annual weighted concentrations of individual dust fractions were determined.

Table 2 presents estimated values of mean annual weighted concentration for individual dust fractions while performing work activities on farms of mixed production profile. The highest values for all dust fractions in the study refer to the tending of animals in swine breeding, which results from long-time performance of activities during an annual work cycle. For the inhalable fraction, the highest values were observed, apart from stock tending in swine breeding (5.22 mg/m^3), for stock tending in cattle breeding (3.48 mg/m^3), and sorting and packing of potatoes (3.01 mg/m^3). In addition, high values were noted for grain crushing (1.73 mg/m^3) and harvesting of cereals with a combine harvester (1.4 mg/m^3). The highest mean values for extrathoracic fraction were obtained for stock tending in swine breeding (4.35 mg/m^3), tending of cattle (2.66 mg/m^3), harvesting of cereals with a combine harvester (1.16 mg/m^3), and grain crushing (1.1 mg/m^3). The highest exposure to thoracic fraction of dust was estimated for stock tending in swine breeding, tending of cattle, sorting and packing potatoes. High values were also noted for grain crushing, harvesting of cereals with a combine harvester, ploughing and potato digging. The highest mean annual weighted concentrations for thoraco-bronchial fraction were observed for the sorting of potatoes (1.05 mg/m^3, cattle tending (0.69 mg/m^3), swine tending (0.64 mg/m^3), grain crushing, ploughing and harvesting of cereals with a combine harvester.

The highest exposure to alveolic fraction was also estimated for potato sorting (0.12 mg/m^3), swine tending (0.23 mg/m^3), cattle tending (0.14 mg/m^3), crushing of grain (0.06 mg/m^3), and harvesting of cereals with a combine harvester (0.06 mg/m^3).

Table 2. Values of mean annual weighted concentration for individual dust fractions while performing work activities on farms of mixed production profile [mg/m^3].

Type of work activity	Inhaled fraction	Extrathoracic fraction	Throacic fraction	Thoraco--bronchial fraction	Alveolar fraction
Ploughing	0.65	0.33	0.76	0.38	0.04
Cultivation	0.19	0.13	0.16	0.05	0.01
Machine crop cultivation	0.13	0.09	0.1	0.03	0.004
Sowing seeds with a sower	0.17	0.12	0.17	0.04	0.01
Potato planting	0.06	0.04	0.06	0.01	0.005
Harvesting of cereals with a combine harvester	1.4	1.16	1.38	0.29	0.06
Straw pressing	0.05	0.04	0.05	0.01	0.001
Harvesting of sweet corn with a combine harvester	0.13	0.1	0.15	0.02	0.005
Mowing of green forage	0.02	0.02	0.03	0.004	0.002
Hay making and raking	0.07	0.05	0.07	0.02	0.004
Potato digging	0.49	0.35	0.54	0.13	0.01
Beetroot digging with a combine	0.26	0.21	0.23	0.03	0.01
Stock tending – cattle	3.48	2.66	3.39	0.69	0.14
Stock tending – swine	5.22	4.35	4.76	0.64	0.23
Grain crushing	1.73	1.11	1.83	0.56	0.06
Potato sorting	3.01	1.84	2.89	1.05	0.12
Wood-cutting with a power saw	0.03	0.02	0.03	0.002	0.0002
Wood-cutting with a circular saw	0.11	0.1	0.11	0.01	0.01

The lowest exposure to the inhaled fraction of dust was noted with respect to the mowing of green forage (0.02 mg/m^3), and wood-cutting with a power saw. The values of exposure for extrathoracic, thoracic and thoraco-bronchial fractions were similar.

DISCUSSION

The article presents the results of studies of the concentrations of inhalable dust, thoracic and alveolic, which allowed the estimation of percentage distribution of dust deposited in individual sections of the airways, and enabled the assessment of annual farmer's exposure to individual dust fractions while performing specific activities on a farm.

The studies of dust present in the respiratory zone of a farmer while performing 18 selected work activities showed its generally coarse-grained character, which is evidenced by a high percentage of extrathoracic fraction in the inhaled dust. This dust is deposited in the nosopharynx, from where it is removed due to self-cleaning, indicating also a lower level of pathogenic affinity.

From the aspect of risk created by inhalable dust fractions, attention should be paid to work activities accompanied by the highest dustiness (sorting and packing of potatoes, harvesting of cereals with a combine harvester, potato digging), and activities which are most time-consuming in an annual production cycle (tending of the stock in cattle and swine breeding). Dust accompanying these activities, deposited in a high percent in the thoraco-bronchial and alveolic section, creates health risk due to the contents of free crystal silica and microflora in agricultural dust.

The results of the estimations of annual exposure of a farmer to individual dust fractions confirm that the activities for which the highest dust concentrations were observed, i.e. sorting and packing of potatoes, harvesting of cereals with a combine harvester, grain crushing, and potato digging, are characterised by the highest values of mean weighted annual concentrations with respect to all fractions. Also the activities which consume the greatest amount of farmers' time, such as: tending of the stock in cattle and swine breeding, cause the highest farmer's annual exposure to all dust fractions.

The evaluation of the total annual farmers' exposure to dust at work on farms requires the performance of fraction measurements for all the work activities performed, which will be the subject of further studies.

The results obtained allow for the extension of knowledge of the effect of agricultural dust on the human body,

and determination of the effect of dust deposited in various sections of the respiratory system on the state of health of farmers. In future, this will also enable the development of criteria for hygienic evaluation for dust penetrating into the chest region, not only for total and respirable dust, as it is at present.

CONCLUSIONS

1. Fraction analysis of dust present in farmers' respiratory zone while they perform work activities characteristic of plant-animal production showed a generally coarse-grained character of this dust, which is evidenced by a high percentage of extrathoracic fraction in the inhaled dust.

2. Attention should be paid to work activities accompanied by the greatest dustiness, to which farmers devote the greatest amount of time during an annual production cycle, due to the highest annual exposure of a farmer to all dust fractions while performing these activities.

3. Due to a high degree of exposure of farmers to dust in the agricultural work environment, further studies should be conducted in order to estimate the total annual farmers' exposure to individual dust fractions for all work activities performed by a farmer on a farm during an annual production cycle.

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