ORIGINAL ARTICLES AAEM

Ann Agric Environ Med 2002, 9, 71–78

# QUALITATIVE AND QUANTITATIVE ANALYSIS OF AGRICULTURAL DUST IN WORKING ENVIRONMENT

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Mołocznik A: Qualitative and quantitative analysis of agricultural dust in working environment. *Ann Agric Environ Med* 2002, **9**, 71–78.

**Abstract:** The presented quantitative and qualitative analysis of dust in agricultural working environment is a continuation of the process of recognizing the exposure to dust among private farmers. The study covers the following: determination of respirable fraction of dust in the respiratory zone (on the background of total dust) while performing individual farming activities which constitute an annual work cycle, organic and mineral components of settled dust for basic groups of farming activities, and the main mineral pathogenic component - free silica in airborne and settled dust. The study was conducted on 5 farms specialising in: cultivation of cereals, root plants, vegetables, dairy cattle and swine breeding and mixed production. The analysis of settled dust covered 17 types of dust accompanying field work and farm/indoor activities. Studies of airborne dust were conducted on farmers while performing 40 main work activities which contributed to the annual work cycle. Results of the study confirmed the following: agricultural work activities are accompanied by a high level of dustiness and showed the presence of a respirable fraction in airborne dust of up to 25%, a higher level of pathogenic free silica $SiO_2$ in settled dust samples in the working environment of a farmer, compared to dust in respiratory zone, a comparable level of $SiO_2$ in total and respirable airborne dust, and a high level of organic component in settled dust at work activities with plant material. These results indicated that the evaluation of farmers' exposure to dust should be based on the examination of samples taken in the respiratory zone while performing individual work activities.

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**Key words: agricultural dust, airborne dust, total dust, respirable dust, settled dust, organic component, mineral component, free silica.**

## INTRODUCTION

The studies of dustiness in agricultural working environment conducted by the Institute of Agricultural Medicine in recent years were biased towards the determination of farmers' exposure to dust [12, 13, 15, 16, 17]. These were therefore pioneer studies, carried out for the first time from the aspect of a workplace, considering the whole farming work cycle and all changes associated with the variety of work activities within this cycle, levels of dustiness at performing these activities and time of exposure. On the one hand, the studies verified the strategy of measurement and evaluation of exposure to dust in changeable conditions, on the other, they showed the potential health risk for farming population caused by respirable dust.

Dust present in agricultural working environment (agricultural dust) results from performing such work activities as: shredding, mixing and pouring from one place to another. These are typical dispersed sources, and the dust aerosol produced is a multi-dimensional set of particles - so-called dispersed dust. On an average farm, a farmer performs working activities contributing to various production processes. In plant and animal production the sources of dust are seasonal work activities, such as ploughing, harrowing, cultivation, sowing, crop harvesting,

Received: 15 April 2002
Accepted: 21 May 2002

threshing, animal breeding, e.g. preparation and provision of fodder, cleaning of animals, and also activities associated with the storage of agricultural crops, and repair and maintenance of agricultural machinery. The above-mentioned work activities take place in contact with soil, plants and animals; the respirable air therefore contains, primarily, particles of these elements. Soil is the primary source of mineral fraction containing the products of weathering of local rocks, inorganic chemical compounds introduced during soil cultivation and crop maintenance - mineral fertilizers, pesticides, industrial wastes and petrol fumes. The mineral soil components which most frequently occur in our area (i.e. brown and podzolic soil) are: silicates, aluminosilicates, clay minerals, aluminium and iron oxides and calcite (calcium carbonate). Among mineral components present in agricultural dust, silica deserves special attention due to its pathogenic properties. Clay fractions, so-called thick and fine dust with a particle size of 20–2 micrometers, are mainly silica. The source of organic fraction in agricultural dust are plants and animals, and the accompanying microbes and organic substance of soil origin. This fraction consists of decomposed parts of plants (e.g. post-harvest remains), organic fertilizers (manure, composts, green manure), decomposed bodies of micro- and macrofauna, as well as decomposed microorganisms [14, 36].

Thus, agricultural dust is of a dispersed - multidimensional, but also polymorphic - multi-component character.

The reaction of the human body to inhalation of such varied dust in the respiratory zone depends on the structure and morphology of the dust. The structure of the human respiratory system resembles a technical set of narrowing conduits. In such a system a gradual filtration of dust aerosol takes place, which results in the finest components of aerosol penetrating into the narrowest ducts, which within this final section of the respiratory system are the bronchioli and pulmonary alveoli. Thick dust settles in the upper respiratory and tracheo-bronchial region, and, to a high degree, is expectorated and discharged as a result of the natural process of self-purification. The finest dust penetrating into the alveoli may cause the greatest harm due to their large total surface area, compared to that of the upper airways, although dust retained there cannot be treated as biologically neutral. The type and course of body reaction to dust will depend not only on the general quantity of dust potentially respirable, but also on the value of the finest fraction and individual components of recognized pathogenic effect.

In the light of the above-mentioned data concerning agricultural dust and its distribution in the respiratory system, a need appears for the continuation of studies of the exposure of farmers to dust in order to discover the exposure to respirable dust fractions, and also the contents of the 2 basic dust components - mineral and organic. To date, studies of agricultural working environment conducted by the Institute of Agricultural Medicine, as well as data concerning occupational diseases among rural population, have confirmed that in this environment there exists health risk caused by agricultural dust [2, 3, 15, 16, 17, 35].

## MATERIAL

The studies covered airborne dust present in the respiratory zone of a farmer at work and dust settled on the surface of machines, equipment and background at the place where working activities are performed. Studies were conducted on 5 family farms located in the following communes: Lublin, Jastków, Konopnica, and Niemce. These farms carry out specialised production: cultivation of cereals, root plants, vegetables, breeding of dairy cattle and swine (size of the farms being 30–62 ha), and mixed production (18–20 ha). The farms are equipped with tractors and combine harvesters for cereals and root vegetables, and some farms possess machines for harvesting other cultivated plants. The owners of the farms are aged 37–52, and work exclusively in an agricultural environment.

## METHODS

Standardised methods were applied in field and laboratory studies. The level of airborne dust - total and respirable - was determined by a weighing method [23, 24] and personal equipment: AP-2 aspirators, ORMED, Łódź, Poland, and SKC/224-PCEX7 aspirators, SKVC Ltd, Dorset, UK. In both fractions of airborne dust the contents of free silica was determined by colorimetric method [25], with the use of the following spectrophotometers: Specol 11, Carl-Zeiss, Yena, Germany, and Marcel Mini Eco, MARCEL Sp. Z.o.o, Warsaw, Poland. The same method was applied for the determination of this component in settled dust. The contents of organic and mineral components in settled dust was also analysed by the method of total combustion of organic components contained in the sample (total ash) at a temperature of approximately 900ºC [26]. In studies of settled dust, the sample for analysis was the fraction below 100 micrometers. For organic agricultural dust particles, the density of which remains within 1–2 g $cm^{-3}$, this fraction possesses the potential of respirable dust. This means that the particles of this fraction may occur in airborne dust in the respiratory zone long enough to get into the stream of the air inhaled by a farmer at work. Studies of each type of settled dust were based on analysis of the composition of 3 samples. The determinations of the level of free silica in the ash - residues after the combustion of settled dust - were performed 3 times for each ash sample. The level of this component in airborne dust was determined in joint dust samples due to too small weighed portions of dust in individual samples. Dust in the respiratory zone was collected in 2 series covering 2 measurements of total dust concentration each and 2-6 measurements of the level of respirable dust.

**Table 1.** Composition of selected types of dust settled on surfaces inside tractor cabin, combine harvester and agricultural equipment while performing agricultural activities.

| Settled dust sampling site | Contents of organic fraction in settled dust, (%) | Contents of mineral fraction (ash) in settled dust, (%) | Level of $SiO_2$ in settled dust, (%) |
|---|---|---|---|
| Tractor - cultivation of soil | 1.2-5.7 | 94.3-98.9 | 28.2-65.2 |
| Tractor - maintenance of crops | 3.0-6.2 | 93.8-97.0 | 28.0-61.0 |
| Tractor - hay making and raking | 18.2-36.0 | 64.0-81.8 | 19.2-54.0 |
| Combine harvester - harvesting of wheat | 48.0-82.3 | 17.7-52.0 | 5.3-34.3 |
| Combine harvester - harvesting of rye | 61.0-72.0 | 28.0-39.0 | 8.3-24.7 |
| Tractor and potato harvester - potato digging | 6.4-10.0 | 90.0-93.6 | 27.0-60.8 |
| Tractor and beet harvester - digging of sugar beet roots | 2.1-3.0 | 97.0-97.9 | 28.9-64.6 |
| Thresher - wheat threshing | 79.0-89.2 | 10.8-21.0 | 3.2-13.9 |
| Thresher - rye threshing | 80.0-85.2 | 14.8-20.0 | 4.5-13.1 |
| Thresher - bean threshing | 76.2-88.0 | 12.0-23.8 | 3.6-15.7 |
| Grain cleaner - cleaning of grain | 94.0-95.6 | 4.4-6.0 | 1.2-3.4 |
| Mixer - mixing of dry components of fodder | 94.0-96.6 | 3.4-6.0 | 0.8-3.0 |
| Grain mill - grinding of grain for fodder in a farmhouse | 93.6-97.7 | 2.3-6.4 | 0.7-4.2 |
| Sorting machine and packing machine - sorting and packing potatoes in a farmhouse | 2.0-3.4 | 96.6-98.0 | 27.1-64.3 |
| Circular saw - cutting of tree trunks into planks | 82.0-96.9 | 3.1-18.0 | 0.9-11.3 |
| Circular saw - cutting of thin tree trunks | 81.6-93.4 | 6.6-18.4 | 17-12.1 |

## RESULTS

The following 7 groups of work activities were distinguished which contribute to the typical technologies applied on farms carrying out basic plant and animal production:

- cultivation and treatment activities: spring ploughing, post-harvest ploughing, harrowing, cultivation, disk harrowing, work with deep plough, cultivation with aggregate, rolling of soil, mechanical and manual cultivation of crops.
- fertilizing: sowing of mineral fertilizers, fertilizing with natural fertilizers;
- sowing, planting: sowing seeds with a grain drill, potato planting, manual sowing and planting;
- plant treatment: chemical spraying of crops, treatment of seed-grain;
- plant harvesting: harvesting of cereals with combine or cutter, collecting and pressing straw, cutting of plants with Orkan, harvesting of leguminous plants and sweet corn with a combine, cutting leaves or tops, digging of potatoes and beetroots, manual harvesting and vegetable sorting, manual harvesting of fruits;
- farming activities: care of animals (cattle and swine), grain threshing, bean threshing, sorting and packing of potatoes, crushing of grain, cleaning of grain, mixing of fodder, cutting of wood with chain and circular saws, cleaning activities;
- other activities: manual reloading, work with Cyklop and Tur loaders, repair, transport.

**Settled dust**. The studies of settled dust covered 17 types of dust accompanying the above-mentioned work activities. Table 1 and Figure 1 present the results of study of these types of dust. The mineral fraction constitutes the main component of dust settled on a tractor during cultivation and treatment activities and harvesting of root crops, also of dust settled on potato sorting machine and packer - from 90.0–98.9%. The greatest percentage of organic fraction was noted in dust settled on grain mill, corn cleaner and mixer - from 93.6–97.7%. Combine harvesting of cereals is a source of dust with similar percentages of both fractions, the organic component being dominant. However, dust settled on the surface of a thresher during stationary grain threshing in a farm room contained up to 1/4 mineral component. Here, we should expect the presence of a considerable number of microbes, especially during threshing performed in winter, when the conditions of storage of the crops (sheaves of cereals, bean haulms) are conducive to the development of microorganisms.

The analysis of ash in order to determine the contents of free silica showed the presence of this component in various samples - from 30–66% of the ash mass. For the mass of the whole ash sample, $SiO_2$ constituted from 0.9% in settled dust on fodder mixer to 64.6% in dust settled on a tractor and beets combine harvester during harvesting of beetroots. The spread of the results obtained resulted from a non-uniform morphology of the collected samples of settled dust, which, in turn, is associated with the heterogeneous character of dust, both in airborne and settled phases.

**Table 2**. Total and respirable dust at agricultural activities.

| Type of work activity | Range of dust concentrations | | Range of Ct/Cr (%) | Level of $SiO_2$ in dust | |
|---|---|---|---|---|---|
| | Total Ct (mg $m^{-3}$) | Respirable Cr (mg $m^{-3}$) | | Total (%) | Respirable (%) |
| Crop cultivating and maintenance activities | | | | | |
| Spring ploughing | 7.7-23.8 | 1.0-3.1 | 12.9-13.2 | 9.1; 17.0 | 6.1; 20.5 |
| Post-harvest ploughing | 14.5-81.2 | 1.9-10.8 | 13.3 | | |
| Harrowing | 11.1-26.1 | 1.1-2.5 | 9.7 | | |
| Cultivation of soil | 5.1-15.7 | 0.5-1.6 | 10.0 | 8.5-18.0 | 5.2-17.0 |
| Disk harrowing, work with a disk harrow | 3.1-13.0 | 0.3-1.3 | 10.0 | | |
| Cultivation with an agricultural unit | 11.5-17.2 | 1.2-1.8 | 10.0 | | |
| Rolling of soil | 4.7-21.6 | 1.2-5.5 | 25.5 | | |
| Mechanical crop cultivation | 4.5-31.8 | 0.7-5.2 | 16.4 | 11.2; 22.0 | 10.3; 19.8 |
| Manual crop cultivation - weeding | 3.3-16.8 | 0.5-2.4 | 13.9-14.0 | 7.4; 20.5 | 12.0; 18.6 |
| Fertilizing | | | | | |
| Sowing mineral fertilizers | 4.4-17.2 | 0.3-1.2 | 7.2-7.3 | 6.9; 13.2 | 8.1; 17.4 |
| Fertilizing with natural fertilizers | 4.1-7.2 | 0.2-0.4 | 5.8-5.9 | | |
| Sowing and planting | | | | | |
| Sowing seeds with a seeder | 5.6-11.3 | 0.4-0.9 | 7.5 | | |
| Potato planting | 7.2-28.0 | 0.5-2.1 | 7.5 | 9.1-15.2 | 10.0-14.8 |
| Manual sowing, planting | 4.8-11.5 | 0.2-0.4 | 3.8 | | |
| Plant protection activities | | | | | |
| Spraying | 2.3-5.1 | 0.2-0.6 | 9.1-11.2 | 16.2 | 21.0 |
| Crop harvesting | | | | | |
| Combine harvesting of cereals | 31.7-72.9 | 3.9-8.8 | 12.2 | 9.3-10.4 | 8.8-13.2 |
| Harvesting of straw, pressing | 4.0-17.9 | 0.3-1.5 | 8.0-8.1 | 8.5; 15.7 | 14.6 |
| Cutting plants with Orkan | 4.4-10.0 | 0.3-0.6 | 6.1 | 12.2 | 14.1 |
| Combine harvesting of beans | 10.0-18.2 | 1.2-2.2 | 12.0-12.1 | 9.0-12.8 | 6.3-11.9 |
| Cutting green fodder with a mower | 2.7-6.3 | 0.4-0.9 | 13.9-14.1 | 9.6 | 10.2 |
| Hay making, raking | 3.5-7.8 | 0.3-0.6 | 7.9-8.0 | | |
| Rolling, pressing of hay | 5.3-8.4 | 0.4-0.7 | 7.9-8.1 | 11.5 | 12.0 |
| Combine harvesting of sweet corn | 4.4-13.9 | 0.8-2.5 | 17.7-17.8 | 9.0-12.8 | 6.3-11.9 |
| Cutting of leaves, tops | 5.4-19.9 | 0.4-1.4 | 7.0 | 13.1 | 13.1 |
| Potato digging | 7.5-30.6 | 0.9-3.8 | 12.4 | 4.1-17.2 | 6.0-18.0 |
| Sugar beet roots digging | 5.1-9.8 | 0.6-1.2 | 12.4 | 18.0 | 18.0 |
| Manual harvesting and sorting of vegetables | 4.1-10.1 | 0.2-0.5 | 5.1-5.2 | 11.2 | 10.0 |
| Farm/indoor activities | | | | | |
| Care of farm animals - cattle | 1.7-7.0 | 0.2-0.7 | 9.4-9.6 | | |
| Care of farm animals- swine | 2.6-8.9 | 0.2-0.8 | 9.2-9.4 | 2.2; 7.0 | 4.2 |
| Threshing of grain | 26.2-95.4 | 2.8-10.0 | 10.5 | | |
| Threshing of beans | 18.1-40.0 | 1.5-3.3 | 8.3 | 1.1-9.0 | 1.0-7.9 |
| Crushing of grain | 26.3-78.7 | 3.7-10.6 | 13.9 | | |
| Cleaning of grain | 12.4-36.9 | 1.7-5.1 | 13.9 | 32.8-5.9 | to 3.2 |
| Mixing of fodder | 13.0-21.8 | 0.7-1.2 | 5.5 | | |
| Sorting and packing of potatoes | 53.8-85.8 | 6.0-9.6 | 11.2 | 10.5-20.5 | 9.6-16.2 |
| Cutting wood with circular saw | 11.3-28.2 | 0.7-1.8 | 6.2 | to 3.0 | to 3.0 |
| Other activities (reloading, repair, transport) | | | | | |
| Manual reloading of dusty materials (grain, straw) | 13.7-40.0 | 2.4-6.9 | 17.2 | 3.6-9.0 | 3.0-7.9 |
| Manual reloading of low-dusty materials (ensilage, manure) | 0.8-1.6 | 0.1-0.3 | 17.5 | 4.8 | 4.8 |
| Work with loader (soil, manure) | 0.7-2.0 | 0.04-0.1 | 5.0-5.1 | | |
| Transport (by field track) | 2.8-6.3 | 0.7-1.6 | 25.0-25.1 | 14.2 | 14.2 |

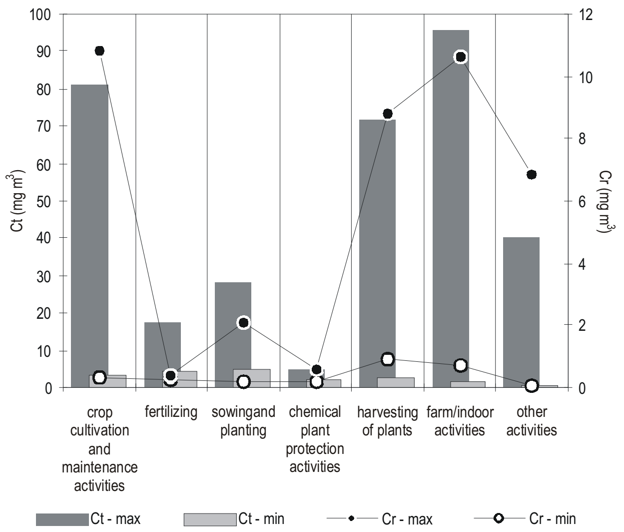


**Figure 1**. Concentration of total dust Sc and respirable dust Sr at work activities on private farms.

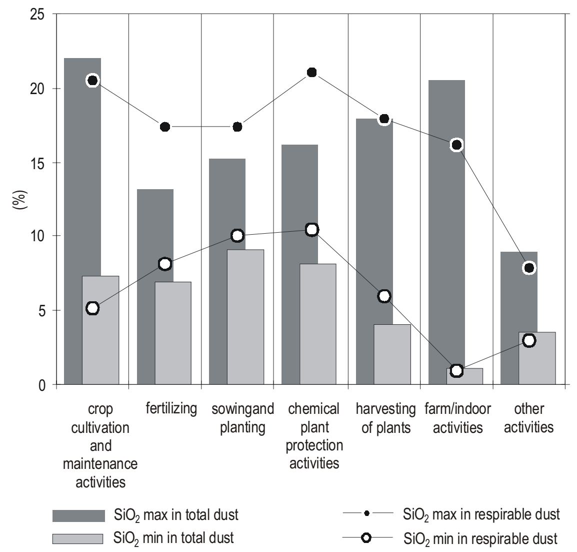


**Figure 3**. Percentage of $SiO_2$ in airborne dust.

**Airborne dust**. Table 2 presents results of the measurements of the concentration of total and repirable dust, as well as results of determinations of the level of free silica $SiO_2$ in this dust. The considerable spread of values obtained is noteworthy. This is associated primarily with non-stable release of dust in the course of work, changeable conditions accompanying work at the subsequent measurement cycles, and finally, with the previously mentioned heterogeneous character of airborne dust, especially in a space not isolated from external conditions. In the mass of inhaled total dust, respirable dust occurs in the quantity of 5.0–25.1%, and most often constitutes up to 10% of total dust. The lowest percentage of respirable dust was observed during manual sowing and planting, work with a loader, cutting plants with Orkan, and cutting leaves and tops, whereas the highest percentage of this dust was noted during transport, sweet corn combine harvesting, and manual reloading. The compilation of results of measurements of airborne dust concentrations, presented in Figure 1, confirms that the highest risk caused by dust occurs at farm/indoor, cultivation and treatment activities.

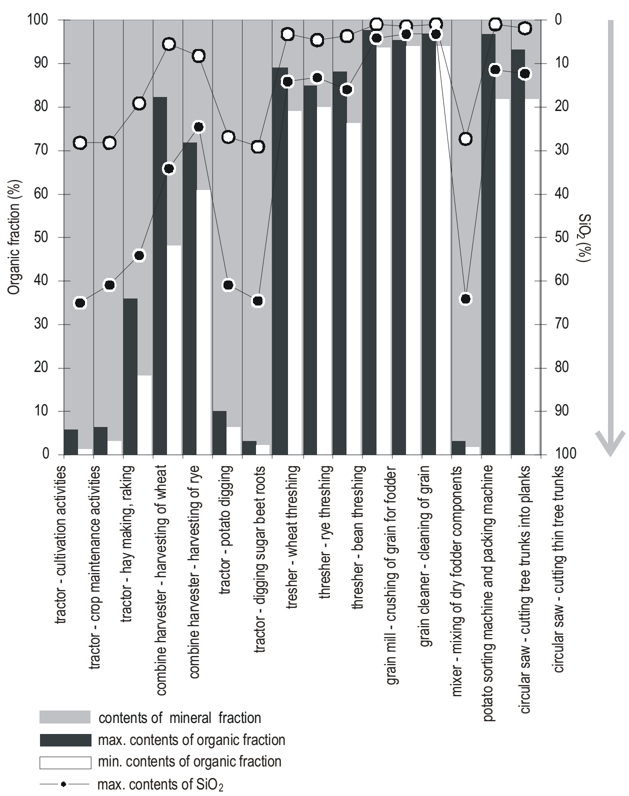


**Figure 2**. Contents of organic and mineral fractions, and free silica $SiO_2$ in settled dust.

Studies of the level of free silica in airborne dust showed the greatest amounts of this mineral component in dust accompanying mechanical and manual treatment of crop, spring ploughing and beets digging. A relatively low level of $SiO_2$ was noted in dust during reloading and animal care activities. The analyses indicated that the levels of free silica generally remained on a similar level in both fractions examined. Slightly greater levels of silica were noted in respirable dust during chemical plant protection and fertilizing - work activities performed in a closed cabin, which resulted in a greater amount of fine particles penetrating into the interior of the cabin through leaks (Fig. 3). Figure 4 presents the range of concentrations of free silica dust - total and respirable - obtained for 7 groups of agricultural activities. The highest values of concentrations and the greatest spread of these values were noted in the group of cultivation and treatment activities, as well as household activities. The comparison of the levels of $SiO_2$ in settled and airborne dust (Fig. 5) showed that greater amounts of these components were present in settled dust. This is due to thicker silica fractions which do not occur in the airborne phase in the respiratory zone. Due to a higher density of $SiO_2$ particles

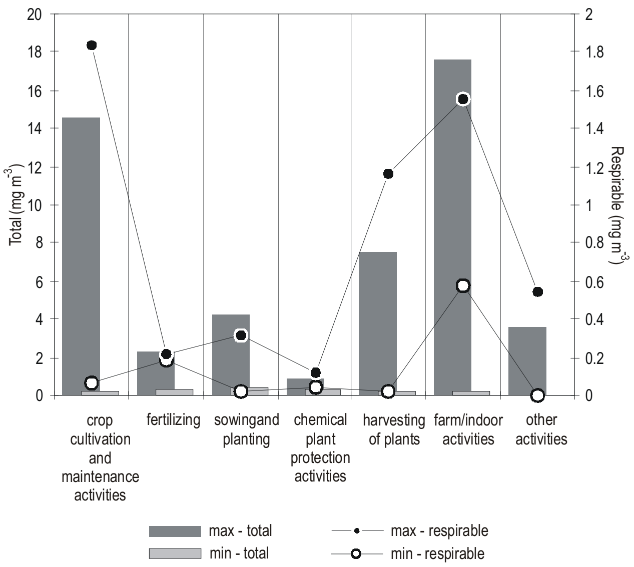


**Figure 4**. Concentration of free silica $SiO_2$ in respirable zone.

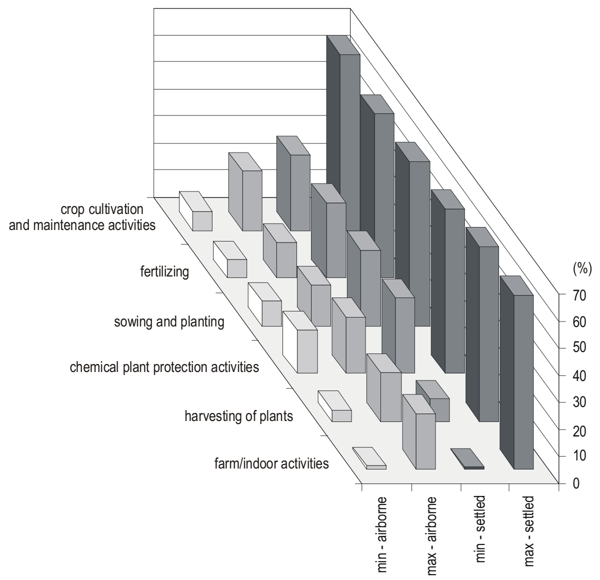


**Figure 5**. Level of $SiO_2$ in settled and airborne dust in respiratory zone.

(ρ quartz is 2.645 g cm$^{-3}$) the level of this component in airborne dust is smaller than that of a lighter organic component, compared to static settled dust.

## DISCUSSION

In Poland, studies of dust in agricultural working environment seem to be the domain of the Institute of Agricultural Medicine. International reports refer to selected types of work activities and elements of evaluation of exposure to agricultural dust, i.e. total and respirable dust, silica (quartz) or microbes. These studies are more or less complex, but do not, however, lead to the evaluation of exposure of a farmer from the aspect of a workplace. Generally, the results of foreign studies should not be precisely applied to Polish agriculture, because dust, heterogeneous in its nature, is characteristic of specific environmental conditions (climate, type of soil), as well as technical and technological. Dustiness in animal rooms was on a similar level [1, 7, 22, 31, 33, 34], while it varied considerably during field work [10, 18, 19]. Similar variations were observed in the results of studies of the contents of free silica in airborne dust [1, 6, 9, 29, 30, 32].

The main source of microbes on farms are breeding animals and cultivated plants, especially during their storage, whereas soil does not create a significant risk [19]. The results of the studies which have been conducted by the Institute until today indicate a high content of microbes and bacterial endotoxin in the air of animal rooms and farm buildings used for grain threshing and storage [2, 3, 4, 38]. International reports, which mainly concern bacterial endotoxin in this environment, also confirma considerable pollution of the air with these factors [1, 5, 8, 11, 20, 21, 31, 33].

The present studies of settled dust should be considered as a preliminary recognition of the proportion between the 2 main dust fractions containing basic pathogens. This allows us to draw conclusions concerning risk while performing individual farming work activities. In order to assess the exposure, dust should be taken primarily in the respiratory zone as its composition may differ from that of settled dust. This is confirmed by comparative studies of the level of main mineral pathogen - free silica - in airborne and settled dust [5]. Occasionally, it is necessary to conduct studies of settled dust, because with the use of personal measurement methods of airborne dust it is often difficult to obtain samples of a mass which would be sufficient for further laboratory analyses.

The potential negative health effects of exposure to dust among farmers are determined by the level of exposure and type of dust, i.e. type and contents of pathogenic factors. Hence, it is important to conduct more comprehensive studies which would correctly evaluate the existing risk and allow for the planning of properly biased prophylactic actions.

In order to determine the actual health risk among rural population it is extremely important to conduct more comprehensive studies of dust and recognize dust fraction penetrating into individual sections of the airways (inhalable, extrathoracic, tracheobronichial, tchoracic and respirable fractions) [27, 28], because biological effects of mineral and organic pathogens are induced by dust deposited in various sections of the respiratory system. Such studies will be the continuation of the present report. Similarly, more comprehensive studies should be undertaken of the organic fraction of agricultural dust.

## CONCLUSIONS

The results of the studies of dust in agricultural working environment showed:

- a high level of dustiness accompanying agricultural work activities;

- the contents of respirable fraction in airborne dust up to 25%;
- the presence in airborne dust of pathogenic free silica in all dust samples analysed; the highest during mechanical and manual maintenance of crops, sorting and packing potatoes, field cultivation activities, beets and potato digging;
- a higher level of $SiO_2$ in the samples of settled dust collected in the working zone of farmers compared to dust in the respiratory zone; a comparable level of $SiO_2$ in both fractions of airborne dust **-** total and respirable;
- a high level of organic component in the samples of settled dust on the surface of threshers during threshing grain and beans in farm buildings in winter season; the presence of especially high levels of pathogenic microflora should be anticipated due to conditions of storage conducive to its development.

The results obtained allow us to presume that the evaluation of exposure should be based on the analysis of samples taken mainly in the respiratory zone of a farmer, due to the heterogeneous character of agricultural dust and its varied composition.

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