ارزیابی اثرات ذرات هوابرد در هوای تنفسی کارگران در فضای یک کارخانه نساجی

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چکیده

شناخت ناهنجاری‌های تنفسی در محیط‌های پر گرد و غبار نقش مـهمی در پیشـگیری و کـاهش هزینـه‌های درمـانی دارد. در ایـن تحقیق، ذرات هوابرد از یک کارخانه بافت فاستونی به کمک یک پمپ مکنده مجهز به فیلتر PVC که به بدن کارگر وصل شده بـود جمع‌آوری گردیده و سپس با بهره‌گیری از میکروسکوپ الکترونی SEM به بررسی مورفولوژی و اندازه ذرات گرد و غبار مسـتقر بـر روی غشاء فیلتر پمپ پرداخته شد. اطلاعات به دست آمده در خصوص مورفولوژی ذرات جمع‌آوری شـده و انـدازه آنـها می‌توانـد در شناسایی هر چه بهتر علائم بیماریهای تنفسی و پیشگیری از ابتلاء کارگران به این قبیل ناهنجاریها اطلاعات جامعی در اختیار پزشک معالج قرار دهد.

کلمات کلیدی:

ذرات هوابرد، پشم، کارخانه نساجی، میکروسکوپ الکترونی.

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Research

Evaluation of Airborne Dust Concentration in Worker's Breathing Zone of a Textile Mill

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Abstract:
Airborne dust samples were gathered from the vicinity of various commonly performed processes in the wool-preparation industry. Samples of wool airborne dust were collected on membrane filters during the processing of wool lots. The chemical composition of inorganic particles present in total in spirable and respirable dust fractions, was determined by means of Scanning Electron Microscope (SEM). The widely differing morphologies of the particles collected raise questions about the validity of trying to correlate minor respiratory symptoms with dust concentrations, as particle types will penetrate the respiratory system more easily than others. The results are discussed with respect to the used sampling methodology.

Key words:
Airborne dust, Wool, Textile Mill, SEM, Respirable dust, Indoor pollution.

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Introduction

Dust is generally defined as an aerosol of solid particles, mechanically produced, with individual diameters of 0.1 m upwards (Health and Safety Executive, 1986). Exposure limits have been defined for many kinds of industrial dusts dispersed in the workspaces, as a function of the health hazard they present, with the aim of protecting workers from possible respiratory diseases. ISO and the ACGIH (American Conference of Governmental Industrial Hygienists) definitions of inspirable (International Standards Organisation, 1983) dust are the mass concentration of ambient airborne particles inspired through the nose and mouth, during breathing which is available for deposition anywhere in the respiratory tract. The aim of this work was deepen the understanding of factors of relevance to the problem by conducting a survey of the nature of airborne wool dust in an industrial environment.

Wool in its raw state contains a variety of associated materials, which are regarded as impurities (Dusenbury, 1963). Among them, mineral impurities, such as dust and dirt, are picked up by the animal from the pasture during its growth and may account for 5-20% of raw weight. Most foreign inorganic materials are removed by scouring. However, a certain amount remains as a deposit on the fiber surface or trapped within the entangled fiber mass and becomes a preferential target of the strong mechanical stresses developed during carding (Bownass, 1984).

Substantial quantities of airborne dust are generated during the processing stages of wool textiles, especially during the combing and carding operations. In these processes, dust is associated with the raw material and also arises as a consequence of the mechanical stresses to which the fibers are subjected. During carding and combing, about 40% of the fibers are broken under normal operating conditions (Love, 1988), developing fragments in the form of airborne dust.

Aims of the current project

The aims of this investigation were as follows:

- to collect samples of the dust produced by different processes in wool textile mill,
- to obtain quantitative data on the dust present in the working atmosphere,
- to identify components in the dust which could possibly pose particular health hazards,
- to produce size distribution of dust particles,
- to advise the wool processing industry of the results of the project with regard to improving the health of the workforce, thus leading to reduction in working time lost through illness.

Experimental details

1- Sampling techniques

The gravimetric concentration of airborne dust, in an occupational environment is determined by drawing a measured volume of air through a filter medium, and calculating the mass of dust collected on the filter by weighting the filter before and after sampling.

In the current embodiment, the sampling apparatus consists of a pump that produces a defined air volume flow through a filter assembled in a duct. The air intake is refulated to simulate the aerodynamic conditions of human breathing (air velocity 1/1– 1/2 m/s). The filters used were relatively flat and easy to coat with electrically conducting material and all particles were easily visible. In addition, they had pores of a precisely controlled size (0.8 μ m) and it was possible to measure this size directly by icroscopy, thereby providing an independently measured lower boundary to the collected dust-particle size.

Time for collection needed to be as long as possible to magzimize the quantity of dust collected, but short enough to allow several samples to be collected. Thus a sampling period of 20 minutes was used. The samples were gathered by simply positioning the sampling head with the pump running in the working region of the process in question. The primary concern of this project was to explore the nature of the dust rather than their quantity. It was, therefore, considered not necessary to sample throughout a shift. After collection, samples were placed in static-neutralizing conductive pots and taken back to the laboratory for analysis.

The Chemical Substances TSC Committee of ACGJH recommends the following definitions (American Conference of Governmental Industrial Hygienists-Committee on Threshold Limits, 1991) for particulate materials, which are intended to correspond to the fractions which penetrate to specific regions of the human respiratory system:

- Inhalable dust fraction: (corresponds to the total inspirable fraction) for those materials that are hazardous when deposited anywhere in the respiratory tract.
- Thoracic dust fraction: for those materials that are hazardous when deposited anywhere within the lungs, airways and the gas exchange region (bronchiolar and alveolar tract).
- Respirable dust fraction: for those materials that are dangerous when deposited in the unciliate gas exchange region of the lungs (alveolus).

Such definitions ignore exhalation loss. They represent conventional diameter size ranges correlated with experimental curves for the penetration into the respiratory system of spherical aerosol particles of density 1g/cm³. Airborne dust sampling instruments and their operating characteristics make reference to these recommended values.

2. Analysis methodologies

Three analytical techniques were used as follows:

(i)-Scanning Electron Microscopy (SEM) allowed the morphology of the dust to be explored and facilitated both size and X-ray analyses. To prepare the sample for microscopy, it was gold-coated in order to prevent charging when exposed to the electron beam.

(ii)- Size analysis involved the measurement of the particles.

(iii)-In X-ray analysis, the electron microscope is used to bombard the target with a beam of electrons.

The ACGHI (1991) quantitative definition of the inhalable dust fraction is the mass fraction of particles that are captured according to the collection efficiency, regardless of the sampler orientation with respect to wind direction. It is defined as:

$$E = 50(1 + e^{-006d}) \pm 10$$

For $0 < d \leq 100 \mu m$

Where: E = collective efficiency (%)

D = aerodynamic diameter (μm), defined as the diameter of a sphere of density 1 g/cm³ having, in the gravitational field, the same aerodynamic behavior (terminal velocity in air) as the examined particle.

The membrane filters containing the wool airborne dust were analyzed with a scanning electron microscope (SEM). Small filter sections (approximately 8 x 8 mm) were cut out with a razor blade from the center of each filter. After coating with a thin gold film, the mounted filter sections were firstly observed at low magnification and then scanned at 2000 x. 10 to 20 fields were selected, according to the particle density, in such a way as to exclude specimen edges, ensuring that the same distance existed among consecutive fields, and then each part of the specimen surface was sampled.

4- Results and discussion

Collection efficiencies representative of several sizes of particles are shown in Table 1.

The particulate produced during wool processing is formed by organic and inorganic components, present at the same time on the filter surface. The former have morphological and chemical characteristics that can interfere the analysis of the latter. Microscope magnification is a critical parameter which enables the

Table 1: Particulate Mass (%) for several sizes of particles in each of the respective theoretical mass fractions.

Particle aer. Diam. (μ m)	Inhalable Part.mass(%)	Particle aer. Diam. (μ m)	Thoracic Part.mass(%)	Particle aer. Diam. (μ m)	Respirable Part.mass(%)
0	100	0	100	0	100
1	97	2	94	1	97
2	94	4	89	2	91
5	87	6	80	3	74
10	77	8	67	4	50
20	65	10	50	5	30
30	58	14	23	6	17
40	54	16	15	7	9
50	52	18	9	8	5
100	50	25	2	10	1

detection of dust particles and distinguishes them from the filter surface features. Since the average size of inorganic particles is rather small, and some of them have a diameter lower than 1 μm, the minimum magnification was set to 2000x, in order to miss a significant part of the smallest particles. Most of these small particles were found to be characterized by a relatively high concentration of Ca.

The area of the section removed from membrane filter represented about 5% of the total area, where the wool dust was collected. In order to ascertain whether inorganic dust particles were homogeneously distributed all over the filter surface, three subsamples (inner, middle, and outer) were cut along a radial direction and analyzed about 100 particles for each section. The results of chemical analysis showed that neither the relative elemental abundance, nor the detection frequency of different particle types (Table 2) changed significantly from one section to the other. This indicated that the sampling one section in the middle of the membrane filter was enough to obtain a complete and exhaustive description of the average chemical composition of the inorganic dust fraction.

The minimum number of fields and particles to be analyzed for each filter section, as well as, the field position within the section area, were determined as follows.

100 and 10 fields were scanned on two different sections from the same membrane filter. About 1400 and 150 particles were detected and analyzed, respectively. The results reported in Table 3 show that the two

Table 2: Elemental composition (count %) and detection frequency(%) of inorganic particles in different sections of the same membrane filter.

	Outer Section	Middle Section	Inner Section
Elements	**Count(%)**	**Count(%)**	**Count(%)**
Al	3.0	4.0	3.0
Si	19.0	16.0	22.0
S	7.0	4.0	5.0
Ca	4.0	2.0	4.0
Fe	62.0	68.0	59.0
Others	5.0	6.0	7.0
Particle Type	**Count(%)**	**Count(%)**	**Count(%)**
SLM particles			
Si,Fe,K,Ca,Al	29.3	28.2	28.3
SI,Zi,P,Zr	6.8	5.2	7.5
Si	9.5	13.5	13.7
Ca	0.8	2.5	1.8
HM particles			
Fe	34.4	29.9	28.3
Fe-S	11.1	11.0	11.9
Fe-X	8.1	9.7	8.5
Total No. of Part	123	91	156

SLM: Silicates and Light Metals particles.

sets of data are very similar. The analyses of 10 fields, corresponding to about 150 particles, permits characterization of the sample with an accuracy which is not significantly improved by a tenfold increase of the cumber of fields.

With relation to the field position, the entire section area was divided into 15-20 regions (according to dust density) with an imaginary grid, taking care not to include filter edges. One field was then selected and scanned in the center of each grid unit, the distance between adjacent fields being at least five times the field width. This approach reduced the influence of poor local homogeneity and allowed to achieve a reproducible characterization of the inorganic material collected on the filter surface. In fact, adjacent fields may sometimes differ in particle density, especially for those particles whose detection frequencey is quite low.

Table 3: Elemental composition (count %) and detection frequency(%) of inorganic particles as a function of number of fields scanned.

Elements	**100 Fields/Count%**	**10 Fields/Count%**
Al	3.0	3.0
Si	22.0	22.0
S	5.0	5.0
Ca	4.0	4.0
Fe	58.0	59.0
Others	8.0	7.0
Particle Type	**(%)**	**(%)**
SLM particles		
Si,Fe,K,Ca,Al	28.1	28.9
SI,Zi,P,Zr	6.7	7.7
Si	9.3	13.5
Ca	1.6	13
HM particles		
Fe	33.0	28.8
Fe-S	11.0	11.5
Fe-X	10.3	8.3
Total No. of Part	1398	156

SLM: Silicates and Light Metals particles.

LM : Heavy Metal Particles

The constituent particles of each sample fell into several broad groups, from long fibers, several millimeters in length, to fragments of cortical cells, whose longest dimensions was less than 5 μ m. Representative particles appear in the electron micrographs shown in figures1-4.

5- Conclusions

Dust was found to fall broadly into four categories:

(i) long fibers, with lengths greater than 500 μ m.

(ii) fiber fragments, much shorter lengths of fiber with length/width ratios of less than 10/1 and scales.

(iii)Mineral dust particles, less than 50 μ m in the longest dimension but usually around 20 μ m, and

(iv)Cortical cells with lengths of 50-100 μ m, but with widths of less than 5 μ m.

Inorganic components were found in the earlier stages of processing and decreased in quantity with further treatment. They were identified as soil minerals, but residues from suint and compounds from skin-wool processing were shown to be present in some batches, even after scouring.

Of the inorganic components, the most common substances were silica, presumable from sand, and aluminum silicates, often containing trace amounts of sodium, magnesium, iron and calcium, presumably from clay, both major constituents of soil. In this study it was found that dust on ledges caused damage to the lungs of rodents. The ledge dust was found to contain microscopic growths, possibly of a type of fungus which can produce allergy-inducing spores. These may cause respiratory symptoms. In the light of this, regular feltting of machinery and cleaning of the mill in general would seem to be desirable, especially in warm and humid environments.

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Figure 1: SEM photograph of dust Particles

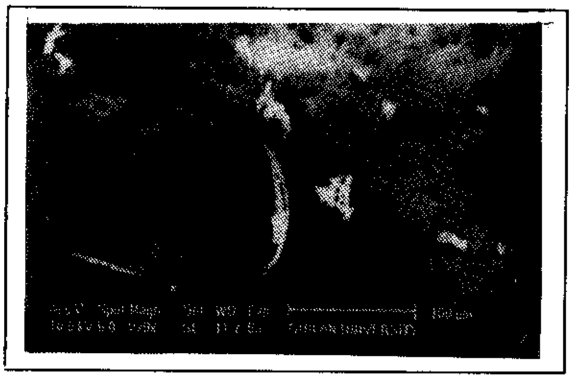

Figure 2: SEM photograph of dust Particles

Figure 3: SEM photograph of dust Particles

Figure 4: SEM photograph of dust Particles

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