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Glass fiber exposure assessment during ceiling installation by European Standard EN 689: study of airborne fiber distribution

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ABSTRACT

Synthetic vitreous fibers belong to a class of inorganic fibers that include glass wool, rock and slag wool, and refractory ceramic fibers. They are used as thermal and acoustical insulation. The aim of this work is to evaluate the exposure of installers of ceiling panels to glass fibers and to study the size distribution of airborne fibers during working day. Thirty two personal samplings were carried out during the installation of pressed mineral wool panels employed as false ceilings. The fibers collected on the filter were analyzed and measured by scanning electron microscope equipped with energy–dispersive X–ray analysis. Four workers were investigated for eight working days. The mean exposure value was around 0.006 fiber/cm^3 with a maximum value of 0.036 fiber/cm^3. The worker exposure evaluated by EN 689 was always below the threshold limit value set by American Conference of Governmental Industrial Hygienists (1 fiber/cm^3). The experimental data were analyzed to calculate some statistical parameters and to verify the normality plots of fiber–length and fiber–diameter measurements using Kolmogorov–Smirnov test. The geometric mean diameter and length of airborne fibers were 1.2 µm and 22.8 µm, respectively. The airborne fiber distributions were log–normal and when the fibers are dispersed into air during handling or cutting only thin fibers remains airborne.

Keywords:
Risk assessment
Glass fibres
Size distributions
Kolmogorov–Smirnov test
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1. Introduction

Synthetic vitreous fibers (SVF) also known as man–made mineral fibers (MMMF) or synthetic mineral fibers (SMF) and man–made vitreous fibers (MMVF), belong to a class of inorganic fibers that include glass wool, rock and slag wool, and refractory ceramic fibers.

Significant commercial production of SVF began in the early twentieth century. According to the International Agency for Research on Cancer (IARC), most of these fibers produced are used for thermal or acoustical insulation. Usage for this purpose is divided about equally between glass wool (3 million tons, used predominantly in North America) and rock and slag wool (3 million tons, used predominantly in Europe and in the rest of the world). The ceramic fibers are widely used as insulation in processes at high temperatures (around 150 000 tons, of which 50 000 in Europe). Recently, Alkaline Earth Silicate Wools (AES) have been produced, which are replacing ceramic fibers in some applications (IARC, 2002).

Main types of SVF are glass wool (formed by either blowing or spinning a molten mass of glass) and fiber glass used in thermal and sound insulation in residential, commercial and industrial situations. They are also used in many construction materials. Slag wool or rock wool (produced from a molten mass of slag or rock) is used in thermal, acoustic and fire protection; refractory ceramic fiber (RCF) (made from molten kaolin clays or mixtures of silica, alumina, and other metal oxides) is used in high temperature insulation for power stations, furnace linings, gas turbines, kilns; biosoluble high–temperature alternative to RCF is used in high temperature insulation for power stations, furnace linings, gas turbines, kilns, and fire protection.

In 2002 the IARC concluded that epidemiologic studies published since the previous IARC (IARC, 1988) assessment provided no evidence of increased risks of lung cancer or mesothelioma from occupational exposure during the manufacture of MMVF and inadequate evidence overall of any excess cancer risk (IARC, 2002).

IARC concluded that there was a sufficient evidence in experimental animals for the carcinogenicity of certain special purpose glass fibers and of refractory ceramic fibers; limited evidence in experimental animals for the carcinogenicity of insulation glass wool, rock (stone) wool, and slag wool; and inadequate evidence in experimental animals for the carcinogenicity of continuous glass filament and certain newly developed, less biopersistent fibers such as X–607 (consisting of amorphous fibers, which are produced by melting a combination of CaO, MgO, SiO_2, products made from these fibers are generally used in applications with temperatures less than 900°C) and MMVF34 (consisting of aluminum silicates and alkaline earth silicates, products made from these fibers are generally used in high temperatures applications). Insulation glass wool, rock (stone) wool, slag wool, and continuous filament glass were classified in

IARC Group 3, not classifiable as to carcinogenic to humans because of the inadequate evidence of carcinogenicity in humans and the relatively low biopersistence of these materials.

In contrast, refractory ceramic fibers and certain special–purpose glass fibers (104 E–glass and 475 glass fibers that are low alkali glass fibers) not used as insulating materials were classified in IARC Group 2B, possibly carcinogenic to humans, because of their relatively high biopersistence (IARC, 2002).

The IARC decisions of 2002 were strongly criticized by some specialists (Wardenbach et al., 2005). According to them the explanations of the IARC working group for the conflicting results of earlier rat inhalation studies with refractory ceramic fibers and amphibole asbestos are not sufficiently supported by the published data.

Then, it was noted in an IARC meeting (WHO, 2006) that the wool–like synthetic vitreous fibers (including glass wool/fibrous glass, mineral wool, special purpose vitreous silicates, and refractory ceramic fibers) contained respirable fibers. For these fibers, the major determinants of hazard are biopersistence, fiber dimensions and chemical/physical properties. The available epidemiologic data were not informative, due to mixed (vitreous fiber) exposures or other design limitations. Based on inhalation exposure studies, intraperitoneal injection studies and biopersistence studies, it was concluded that the carcinogenic hazard could vary from high to low, with high for the biopersistent fibers and low for non–biopersistent fibers.

Currently, in Italy the reference directive is that published by European Commission (EC) in 1997 (Directive 97/69/EC) implemented with two Italian Decrees (Italian Ministry of Health, DM, 1998; Italian Ministry of Health, DM, 1999) without taking into account the IARC amendments. The European Directive classifies mineral wool fibers as hazardous substances. This classification is based on their chemistry, size, and biopersistence. Refractory ceramic fibers have an alkali and alkaline earth oxides (Na_2O+K_2O+CaO+MgO+BaO) content less than or equal to 18% by weight; mineral wool are defined as consisting of man–made vitreous (silicate) fibers with random orientation with an alkaline oxide and an alkaline earth oxides (Na_2O+K_2O+CaO+MgO+BaO) content greater than 18% by weight.

According to this European Directive, the refractory ceramic fibers are classified as category 2 (substances that should be regarded as if they are carcinogenic to man) and they are labeled with risk phrases R49, (may cause cancer by inhalation) and R38 (skin irritant) while the mineral wools are classified as category 3 (substances which cause concern for man owing to possible carcinogenic effects but in respect to which the available information is not adequate for making a satisfactory assessment) and labeled with risk phrases R40 (limited evidence of a carcinogenic effect) and R38 (Table 1).

SVF will not be labeled as carcinogenic if, according to the Directive, fulfill one of these notes: Note R "The classification as a carcinogen need not to be applied to fibers with a length weighted geometric mean diameter less than two standard errors greater than 6 µm" or Note Q: "The classification as a carcinogen need not to be applied if it can be shown that the substance fulfils one of the following conditions: a short–term biopersistence test by inhalation has shown that the fibers longer than 20 µm have a weighted half life less than 10 days, or a short–term biopersistence test by intratracheal instillation has shown that the fibers longer than 20 µm have a weighted half life less than 40 days, or an appropriate intraperitoneal test has shown no evidence of excess carcinogenicity, or absence of relevant pathogenicity or neoplastic changes in a suitable long–term inhalation test.

Risk assessment, in general, is the fundamental factor in the safety process of choosing the measure for prevention and protection in order to guarantee the safety of workers. Because of the potential risks associated with SVF, the precautions recom–mended for protecting those working with SVF must always be taken.

***Table 1**. Classification and labeling of man–made mineral fibers according to European Directive 97/69/CE*

Type of fibers	Symbol	Classification	Chemical Risk and Safety Phrases
Refractory ceramic fibers [a]		Carcinogen Category 2 Irritant	R 49: May cause cancer by inhalation R 38: Skin irritant S 53: Avoid exposure–obtain special instructions before use S 45: In case of accident or if you feel unwell, seek medical advice immediately
Refractory ceramic fibers [a]		Irritant	R 38: Skin irritant S 53: Avoid exposure–obtain special instructions before use S 45: In case of accident or if you feel unwell, seek medical advice immediately
Mineral wools [b] (glass, rock, slag)		Carcinogen Category 3 Irritant	R 40: Limited evidence of a carcinogenic effect R 38: Skin irritant S 2: Keep out of the reach of children S 36/37: Wear suitable protective clothing and gloves
Mineral wools [b] (glass, rock, slag) excused from category 3 (they meet note Q and note R standards), as loose wools		Irritant	R 38: Skin irritant S 2: Keep out of the reach of children S 36/37: Wear suitable protective clothing and gloves

[a] *Fibers with random orientation with an alkaline oxide and an alkaline earth oxides (Na_2O + K_2O + CaO + MgO + BaO) content less than or equal to18% by weight.*

[b] *Fibers with random orientation with an alkaline oxide and an alkaline earth oxides (Na_2O + K_2O + CaO + MgO + BaO) content greater than 18% by weight.*

Handling, cutting, blowing or sawing glass wool and mineral wool without dust control can release fibers into air. Short–term health effects include sneezing, coughing and temporary irritation of skin, eyes, and nose. Higher exposure may cause difficulty in breathing, congestion, and chest tightness.

Although exposure to SVF during their production, processing and use is thought to have been higher in the past, current average exposure levels are generally less than 0.5 fiber/cm^3 as an 8–hour time weighted average (Jacob et al., 1993; Marchant et al., 2002). The concentrations of SVF measured in outdoor and indoor air in non–occupational settings are generally much lower than in occupational settings related to their production or removal (Schneider et al., 1996).

In this work, exposure to SVF of some installers of ceiling panels was evaluated by application of European Standard EN 689 (EN 689, 1995) and the size distribution of airborne respirable fibers were studied.

This European Standard was prepared by the Technical Committee CEN/TC 137 and published by the European Committee for Standardization (CEN). It gives guidance for the assessment of exposure to chemical agents in workplace atmospheres. It describes a strategy to compare workers' exposure by inhalation with relevant limit values for chemical agents in the workplace and a measurement strategy.

2. Methods

Thirty two personal samplings were carried out during the installation of pressed mineral wool panels employed as false ceilings. Four workers were investigated for eight working days. The panels have dimensions of 600 mm x 600 mm and a thickness of 10 mm. The ceiling consists of a light metal structure suspended carrier on which the panels are fixed. The workers put the panels on the frame and cut them to fit the shape of the ceiling.

A summary of the technical details of these materials is shown in Table 2. The samplings and analysis were carried out according to the World Health Organization reference method described by the WHO/EURO Technical Committee (WHO, 1985). Each worker wore a personal sampler (Airchek 2000 model, SKC Inc., Eighty Four, PA, USA) with an open faced filter holder fitted with an electrically conducting cowl at a flow rate of about 2 L/min. The sampling line was previously calibrated using a primary calibrator (DryCal DC–Lite, BIOS International Corporation, Butler, NJ, USA). The samples were collected on polycarbonate filters of 0.8 µm pore size. The volume of air was established in relation to the quantity of the airborne dust, average about 800 L and not less than 700 L. A quarter of each filter was analyzed by scanning electron microscope (SEM: LEO 440, LEO Electron Microscopy Ltd, Cambridge, UK) equipped with energy–dispersive X–ray analysis (EDS: INCA Energy 400, Oxford Instruments, Abington, UK) that have allowed the identification of chemical composition.

The observation area for each filter was 1 mm^2 at a magnifi–cation of X2000. All the countable fibers detected in the observation areas were analyzed by EDS and their diameters and lengths were measured. A countable or respirable fiber is a particle longer than 5 µm, with a width less than 3 µm and with a length: width ratio (aspect ratio) greater than 3:1 (WHO, 1985).

The experimental data were analyzed to calculate the main statistical parameters. The size distributions obtained for each sample were studied using Kolmogorov–Smirnov test for normality by SigmaStat program.

3. Results

The personal exposure to vitreous fibers was evaluated for each worker. The concentration values of vitreous fibers are shown in Table 3 with the lower (λ_L) and upper confidence limits (λ_U) for the Poisson distribution with a 95% probability. It is well known that the probability of discovering *n* fibers of a given fiber class in *N* counting image fields can be described using the Poisson distribution (VDI, 1991).

Once the occupational exposure was quantified, it was necessary to determine if it was above or below the *LV* (exposure limit value). In this regard, EN 689 provides indications of extreme utility (EN 689, 1995). According to EN 689 the risk index *I* is calculated and obtained by the ratio between occupational exposure concentration (OEC) for a conventional 8–hour workday and *LV*. If the risk index is less than 0.1 then the exposure will be less than *LV* as shown in Table 3. The threshold limit value (*TLV*) set by American Conference of Governmental Industrial Hygienists (ACGIH) was chosen as *LV* for vitreous fibers, glass wool, rock wool,

Table 2. *Data sheet of pressed mineral wool panels employed as false ceilings*

Composition–information about components	
Substance	Rock wool (artificial mineral fiber containing alkaline oxides and earth alkali > 18% by wt)
Chemical Risk and Safety Phrases	R38 Skin Irritant S36/37 Wear suitable protective clothing and gloves
Exposure Limit Value	TLV–TWA 1 fiber/cm^3
Physical – chemical properties of mineral wool	
Physical Appearance	Solid
Shape	Rock wool having homogeneous structure in pressed panels
Mean Fiber Diameter	3–5 µm
Length Weighted Geometric Mean Diameter Less Two Standard Errors	< 6 µm
Toxicological information	
Chronic Toxicity	No chronic effects under normal conditions of use
Weighted Half life	It is inferior than the limits set in tests described in note Q of Dir 97/69/EEC (biosoluble fibers)
Local effects	
Skin Contact	Temporary itch or redness due to a mechanical irritation which disappear in few days time
Eyes Contact	Risk of temporary irritation or inflammation
Inhalation	Risk of irritation of the throat or nasal mucosa
Ingestion	Risk of upper aero–digestive tract irritation

***Table 3**. Occupational exposure concentration (OEC) to FVS for a conventional 8–hours workday with the lower (λ_L) and upper confidence limits (λ_U) during the installation of pressed panel used for false ceilings*

Worker	*OEC* (f/cm^3)	λ_L (f/cm^3)	λ_U (f/cm^3)	*I = OEC/LV*	Exposure condition
1	0.009	0.003	0.018	0.009	< 0.1
2	0.004	0.001	0.011	0.004	< 0.1
3	0.000	0.000	0.004	0.000	< 0.1
4	0.001	0.000	0.007	0.001	< 0.1
1	0.004	0.001	0.011	0.004	< 0.1
2	0.007	0.002	0.015	0.007	< 0.1
3	0.004	0.001	0.011	0.004	< 0.1
4	0.000	0.000	0.004	0.000	< 0.1
1	0.004	0.001	0.011	0.004	< 0.1
2	0.001	0.000	0.007	0.001	< 0.1
3	0.013	0.006	0.024	0.013	< 0.1
4	0.001	0.000	0.007	0.001	< 0.1
1	0.005	0.001	0.013	0.005	< 0.1
2	0.005	0.001	0.013	0.005	< 0.1
3	0.000	0.000	0.004	0.000	< 0.1
4	0.010	0.004	0.019	0.010	< 0.1
1	0.011	0.005	0.020	0.011	< 0.1
2	0.004	0.001	0.011	0.004	< 0.1
3	0.001	0.000	0.006	0.001	< 0.1
4	0.001	0.000	0.007	0.001	< 0.1
1	0.025	0.010	0.036	0.025	< 0.1
2	0.007	0.002	0.015	0.007	< 0.1
3	0.010	0.004	0.020	0.010	< 0.1
4	0.015	0.009	0.027	0.015	< 0.1
1	0.003	0.001	0.009	0.003	< 0.1
2	0.005	0.001	0.013	0.005	< 0.1
3	0.013	0.006	0.024	0.013	< 0.1
4	0.000	0.000	0.004	0.000	< 0.1
1	0.005	0.001	0.013	0.005	< 0.1
2	0.000	0.000	0.004	0.000	< 0.1
3	0.022	0.010	0.034	0.022	< 0.1
4	0.010	0.004	0.019	0.010	< 0.1

The index I is calculated by the ratio between OEC and the limit value (LV) set by ACGIH that is 1 f/cm^3.

slag wool, continuous filament fiberglass and for special purposes (ACGIH, 2009). This value is equal to 1 fiber/cm^3 (8–hour time–weighted average).

Fibers collected on sampling filters and observed by SEM were very thin and long. All fibers observed were countable fibers. An example of SEM image of these fibers is shown in Figure 1 and their EDS analysis in Figure 2. The measure of the length often exceeded 200 times that of the diameter.

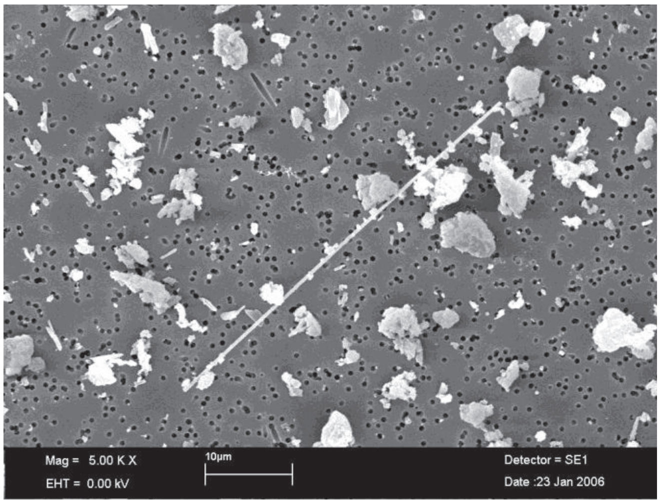

***Figure 1**. SEM image of a glass fiber collected on a polycarbonate filter.*

Table 4 shows some of the main statistical parameters that characterize the size distributions. The Kolmogorov–Smirnov test with Lilliefors significance correction (Lilliefors, 1967; Dallal and Wilkinson, 1986) was applied to size distributions, and the Kolmogorov–Smirnov Distance parameter (KS Distance) was calculated. The correction of Lilliefors is used when the mean and standard deviation are not known but must be estimated from the sample. The KS Distance parameter is the maximum cumulative distance between the experimental histogram and the Gaussian distribution curve. Kurtosis, asymmetry, KS Distance and significance level for log–normal size distribution are shown in Table 5.

***Table 4**. Parameters of the size distribution of airborne respirable fibers collected on filters*

Statistical parameters	Diameter	Length
Arithmetic mean (μm)	1.27	37.52
Median (μm)	1.12	28.05
Geometric mean (μm)	1.21	27.77
Arithmetic standard deviation (μm)	0.75	27.96
Geometric standard deviation (μm)	1.97	2.29
Kurtosis	1.34	3.83
Skewness	1.40	1.58
K–S Distance	0.182	0.143
Significance	< 0.001	< 0.001
Minimum value (μm)	0.1	5.0
Maximum value (μm)	2.7	180.0

***Table 5**. Parameters of the size log–normal distribution of airborne respirable fibers collected on filters*

Statistical parameters	ln (d)	ln (l)
Kurtosis	0.431	– 0.352
Skewness	– 0.780	0.168
K–S Distance	0.072	0.047
Significance	> 0.2	> 0.2

Figures 3 and 4 show normality plots of fiber–length and fiber–diameter measurements, respectively. The size distribution of lengths and diameters of fibers collected on the filter are shown in Figures 5 and 6.

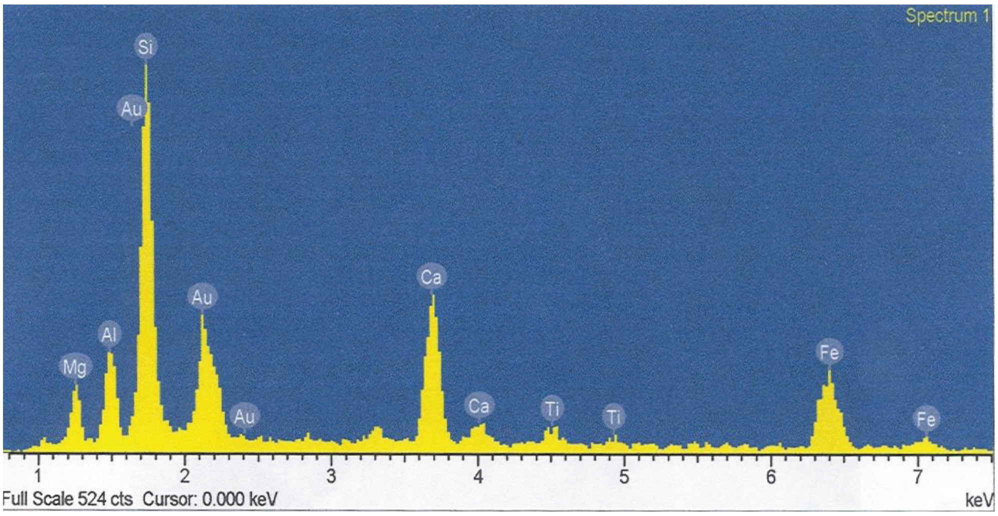

***Figure 2**. EDS analysis of the fiber shown in Figure 1.*

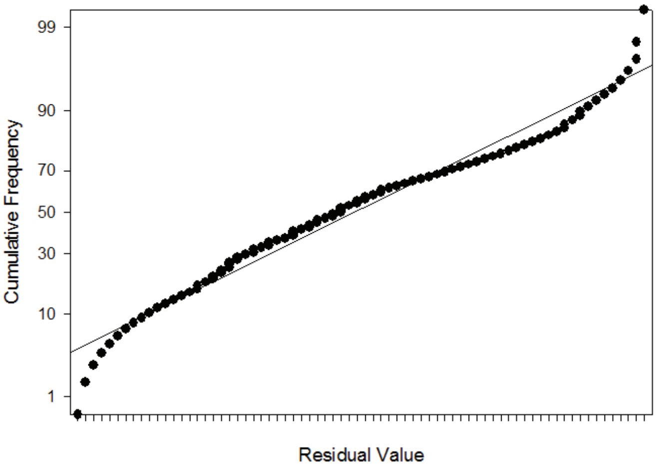

***Figure 3**. Normality plot of fiber–diameter measurements.*

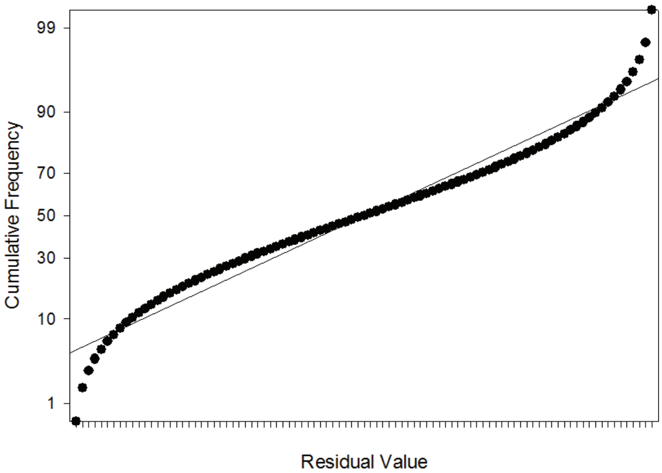

***Figure 4**. Normality plot of fiber– length measurements.*

4. Discussion

Commonly, for technical reasons, pollutants in the working environment cannot be collected in a full shift, and they must be sampled in a series of consecutive sampling periods. The combined result of such consecutive measurements is reported as the time–weighted average concentration–TWA (ACGIH, 2009).

The results of those measurements can be compared with appropriate standards such as *TLV* values which may be for a measurement period of 15 min or for a working week. In the case of *TLV* values for a working week, measurements should be taken over an 8–h period each day throughout a 5–day working week. In practice, a series of consecutive sampling periods is used according to some standard methods (EN 481, 1993; EN 482, 1994; EN 689,1995; EN ISO 10882–1, 2001).

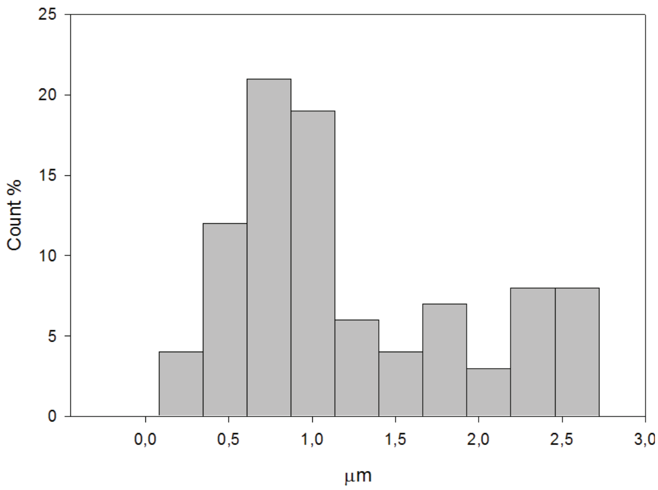

***Figure 5**. Diameter distribution of respirable fibers measured by SEM.*

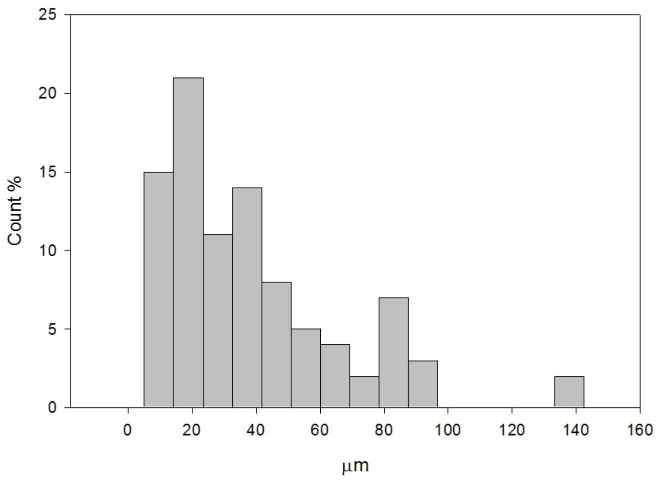

***Figure 6**. Length distribution of respirable fibers measured by SEM.*

In this study the criteria of the EN 689 are used. The European standard EN 689 published a guideline on exposure assessment in which several example strategies were presented. The CEN recommended, for example, that when six or more measurements are collected, the employer should analyze them statistically, estimate the group exceedance fraction, and compare the estimate to a critical value of 0.05.

For situations where the employer must collect fewer measurements the CEN presented general guidance on inter–preting limited datasets and presented example strategies in the appendices. To apply CEN EN 689 the following conditions must be satisfied: (a) the average concentration of dust in a workday should provide a representative description of the occupational exposure, (b) the operating conditions in the workplace must be regularly repeated on the long run, (c) the exposure conditions should not vary significantly; where they appear clearly different, these need to be assessed separately. The strategy is the following: a single measurement is collected from a homogeneous exposure group; the group exposure profile is considered acceptable if this first measurement is less than 10% of the *LV*. Otherwise, two additional measurements are collected. Exposures are acceptable if all three are less than 25% of the *LV*, or all three are less than the limit and the geometric mean is less than 50% of the limit. If any single measurement exceeds the limit the employer should take measures to reduce the exposure and then reevaluate.

According CEN monograph, this strategy does not lead to a specific decision whenever all three measurements are less than the limit but the geometric mean exceeds 50% of the limit. At this point the industrial hygienist uses professional judgment to determine if additional measurements are necessary.

In our survey the measures are always less than 10% of *LV* and thus we can say that the exposure to SVF dispersed in the air for workers handling pressed SVF panel during installation activities are below the reference limit value. The mean exposure value is around the 0.006 fiber/cm^3 with a maximum value of 0.036 fiber/cm^3 corresponding to the panel cutting operation, necessary for a good installation.

According to the technical data sheets, the materials used for the ceiling were panels made of mineral wool fulfilling the following condition described in Note Q of Directive 97/69/EC: a short–term biopersistence test by inhalation has shown that the fibers longer than 20 μm have a weighted half life less than 10 days.

The classification as a carcinogen need not to be applied and the material is labeled with the following chemical risk and safety phrases: skin irritant (R38), and Wear suitable protective clothing and gloves (S36/37).

The material does not fulfill the Note R "The classification as a carcinogen need not to be applied to fibers with a length weighted geometric mean diameter less than two standard errors greater than 6 μm". It was decided to study the size distribution of airborne fibers generated during the installation of such panels.

It is known that the airborne fiber distributions are log–normal (Schneider et al., 1983; Holst and Schneider, 1985) while size distributions of mineral wool products (bulk sample) differ significantly from a log–normal distribution (Schneider et al., 1983; Christensen et al., 1993).

Table 5 shows in fact goodness of the fit of size distribution of our data. Skewness and kurtosis are measures of the nature and amount of the departure from normality. If the distribution is normal the expectation of skewness and kurtosis is 0. Skewness (asymmetry) means that one tail of the curve is extended more than the other (Sokal and Rohlf, 1981) and kurtosis gives the peakedness of a curve. Moreover, an additional support is given by the normality test. KS Distance and significance (it is stated that the significance value of 0.2 represents the limit of acceptability of the test) values of the Table 4 show that lengths and diameters measured cannot be described by normal distributions, while the Table 5 fulfills the conditions for log–normality.

Geometric values are reported in Table 4 among the main descriptive statistical parameters of the diameters and lengths, because, as it is known, are the most appropriate parameters for describing log–normal distributions (Vincent, 1995).

At last the mean diameter written on the data sheet (Table 2) is less than that measured in the sampling filter. When the fibers are dispersed into air during handling, cutting etc., only thin fibers will remain airborne. It is a general experience that the measured median diameter and/or mean diameter in an air sample is con–sistently and substantially smaller than the nominal diameter of the product (Esmen et al., 1979).

5. Conclusion

The potential for a fiber to produce toxic effect in the lung has often been described in terms of the "3Ds" that are dose, dimension, and durability. The dose refers to the dose in the lung of the longer fibers that the macrophage cannot remove; the dimension refers to the diameter which determines if the fiber can be inhaled and its durability or biosolubility (ability of a fiber to dissolve in lung fluid). The latter is the key parameter in developing newer fibers. As a result of the EC fiber Directive, nearly all mineral wool insulation used in buildings in Europe are exonerated under the criteria of Note Q of the European Directive 97/69/EC by passing one of the four tests indicated. However, these tests are very expensive and other cheaper tests have been proposed (Zoitos et al., 1997; Eastes et al., 2000) but still they require standardization and experimentation. Unfortunately, also the measurement the length weighted geometric mean diameter of fibers of bulk SVF (Note R) has some problems. A standard procedure is being developed (ECB, 2000).

The size characterization of bulk SVF is very important because it gives the measure of fiber diameters to which the workers can be exposed. It is well known that SVF, unlike asbestos fibers, tend to fracture only transversely to the axis of the fiber. From our studies it appears that materials containing SVF, generally found in public buildings, have a high content of respirable fibers (Camilucci et al., 2001).

Moreover, it would be important to study the exposure of workers who use SVF for building construction applications. Despite our investigation has provided low values for exposure to airborne artificial fibers, it is important to implement all possible prevention and protection measures to minimize the dispersion of dust in the environment and to reduce the risk of exposure.

One of the recommended measures for instance was to isolate the working areas from other processes where manipulating the panels. It is also essential that workers wear personal protective equipment and are fully informed of the requirements and the reasons for doing so, and are given adequate training.

In this regard, a document to which reference is the International Labour Organization (ILO) code of practice that defines major principles and approaches concerning safety requirements and precautions in the use of insulation wools (glass wool, rock wool and slag wool) (ILO, 2001). It provides practical control measures to minimize occupational exposure to fibers and dusts from insulation wools, prevent irritation and discomfort, and avert any long–term health risks involved in working with such products. This code was adopted unanimously by a Meeting of

Experts on Safety in the Use of Insulation Wools, held in Geneva from 17 to 26 January 2000.

Conflict of interest statement

All authors disclose to have no financial and personal relationships with glass fiber or building industry that could inappropriately influence their work.

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