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OCCUPATIONAL RISK RESULTING FROM EXPOSURE TO MINERAL WOOL WHEN INSTALLING INSULATION IN BUILDINGS

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Abstract
Mineral wool is widely used for thermal and sound insulation. The subject of the study is to identify hazards for employees resulting from exposure to mineral wool, when it is used to insulate buildings, and to assess the risk arising from this exposure. When installing mineral wool insulation, respirable mineral fibers, dust, and volatile organic compounds may pose a hazard at workplaces. Based on the results of concentration measurements, it was assessed that the probability of adverse health effects related to the work of insulation installers, resulting from exposure to mineral wool fibers, is low, but for dust associated with exposure, an average health risk was estimated. An additional threat may be the sensitizing effect of substances used as binders and additives improving the utility properties of mineral wool, for example, phenol formaldehyde resins. The paper also contains some information on the labeling of mineral wool; this is very important because the label allows downstream users to recognize mineral wools, the composition and properties of which cause that they are not classified as carcinogens. Int J Occup Med Environ Health. 2020;33(6):757–69

Key words:
mineral wool, insulation, fibers, health effects, toxicity, labeling

INTRODUCTION

The term "man-made mineral fibers" (MMMFs) is the usual name for fibrous inorganic substances produced mainly from rock, clay, blast furnace slag and glass. These fibers, also called man-made vitreous fibers (MMVFs), can be divided into 3 groups:

- glass fibers including glass wool and continuous fibers;
- rock or slag wool, also called mineral wool;
- ceramic fibers made from natural aluminosilicate mineral kaolin, or a synthetic mixture of alumina and purified beach sand for the use in high temperature processes [1].

The production of MMVFs involves melting rock materials at 1500–1600°C, breaking hot lava with air and defibering. To prevent dusting, an oil emulsion is added to the finished fiber, in the form of a rug. Depending on the fiber formation process, the fibers are produced as wool, which is a mass of tangled discontinuous fibers of varying lengths and diameters, or as filaments of indefinite lengths and a more uniform diameter. The fibers are stuck together with a binder and formed into boards, mats, lagging or cords, depending on their subsequent use. In mineral wool products, the binder is a hot melt adhesive, mainly phenol formaldehyde, an acrylic or melamine resin, and may also include a bioresin based on vegetable starch [1].

Mineral wool products are characterized by good insulating properties (thermal, electrical and acoustic), good me-

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chanical strength and chemical resistance. Stone wool can be used to insulate structures exposed to loads and deformations as well as compression. Stone wool slabs or mats are used to insulate double-layer walls, attics, ceilings and flat roofs, as well as floors. Glass wool can be laid wherever heavy loads will not affect it. It works great in attic, 3-layer or ceiling insulation. Glass wool fiber has a typical weighted average diameter ranging 3–5 μm, and rock and slag wool fiber 2–7 μm [2].

The subject of the study is to identify hazards for employees resulting from exposure to mineral wool, when it is used to insulate buildings, and to assess the risk arising from the exposure of employees to mineral wool, widely used for thermal and sound insulation.

METHODS

The work identified the main occupational hazards posed by mineral wool based on a review of available literature, databases and unpublished reports. A search was used for scientific literature and full-text articles using Scopus and Science Direct electronic databases. The dates of publication of the analyzed articles cover the years up to 2018. To assess the carcinogenicity of mineral wool, the classification data according to Regulation (EC) No. 1272/2008 of the European Parliament and of the Council on classification, labeling and packaging of substances (the CLP regulation) were additionally included.

The definitions of a substance, a mixture and an article from Regulation (EC) No. 1907/2006 of the European Parliament and of the Council concerning the registration, evaluation, authorization and restriction of chemicals (the REACH regulation) were used to identify the obligations of producers marketing mineral wool.

RESULTS

Mineral wool – chemical identification

The term "mineral wool" refers to the substance obtained immediately after the defibering of hot lava, its mixture with the binder and additives, and ready-made mineral wool products. The decision whether a product that is being marketed is a chemical substance, a mixture or an article is key to determining the further obligations of mineral wool suppliers.

There is no doubt that garneted lava is a substance. Mineral wool is mainly composed of oxides of silicon, aluminum, iron, boron, alkali metals and alkaline earth metals (sodium, potassium, calcium, magnesium and barium). The percentage of individual oxides varies, not only depending on the type of mineral wool (glass, rock, slag) but also within a given type – in the case of silicon oxide in glass wool, even several dozen mass percent [3]. Despite the complex and variable chemical composition, mineral wool is legally recognized as a chemical substance, according to the definition of a substance in the REACH regulation [4]. The substance means a chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition. Such a definition includes substances with an indefinite and variable composition in a certain range, the so-called UVCB substances (substances of unknown or variable composition, complex reaction products or biological materials).

However, attention should be paid to the specificity of the production process – mineral wool in this form is not marketed, because at the production stage, binders (resins) and other substances that provide the desired useful properties are added to the mineral wool carpet. Therefore, it can be assumed that the product obtained in this process is a mixture.

The final stage of production is the formation of ready-made rolls, plates, sheets, etc., and mineral wool is marketed in these forms. Mineral wool articles are most commonly used as insulation materials in construction.

Table 1. Obligations of the producers of mineral wool depending on its recognition as a chemical substance, a chemical mixture or an article under the REACH and CLP regulations [4,5]

Obligation	Chemical substance* or chemical mixture**	Article***
Classification in accordance with Article 4 of the CLP regulation [5]	yes	no
Labeling in accordance with Article 4 of the CLP regulation [5]	yes, if as a result of classification or analysis of the composition, the labeling is required	no
Communication of information in the supply chain in accordance with the REACH regulation [4]	yes, in accordance with Articles 31, 32 and 34 of the REACH regulation [4]	yes – only if it contains >0.1% of SVHC, in accordance with Article 33 of the REACH regulation [4], providing the recipient (including the consumer, if he requests such information) with data on SVHC substances contained in articles, and information enabling safe use of the article is obligatory
Preparation of a safety data sheet in accordance with Annex II to the REACH regulation [4]	yes, if required according to Article 31 of the REACH regulation [4]	no

CLP regulation – Regulation (EC) No. 1272/2008 of the European Parliament and of the Council on classification, labeling and packaging of substances; REACH regulation – Regulation (EC) No. 1907/2006 of the European Parliament and of the Council concerning the registration, evaluation, authorization and restriction of chemicals; SVHC – substance of very high concern.
* Mineral wool with variable composition (Index No. 650-016-00-2).
** Mineral wool obtained after adding binders and additives.
*** Mineral wool after forming into a specific shape.

It is difficult to define precisely the boundary between the mixture in a solid form and the article, as with other substances and mixtures in the form of solids, but mineral wool producers usually treat these products as articles.

Table 1 presents the obligations of producers marketing mineral wool, depending on the occurrence at the stage of the chemical substance, as a chemical mixture or an article, in the light of the REACH regulation [4] and the CLP regulation [5].

Identification of the main occupational hazards posed by mineral wool

Toxicity of mineral fibers

The inhalation toxicity of mineral fibers is usually determined by 3 factors [2,6–13]:
- fiber dose (cumulative exposure to respirable fibers);
- fiber dimension (the shape ratio, the fiber diameter and length); respiratory mineral fibers with a diameter (d) of <3 μm, a length (l) of >5 μm, and a length to diameter ratio (l/d) of >3 are considered a health hazard;
- fiber durability, which is measured by the time spent in the lungs – biopersistence or biosolubility; biosolubility is understood as the half-life of fiber dissolution in body fluids and in the lung tissue; studies have shown that mineral fibers with a high Al_2O_3 content are more biosoluble than those with a high SiO_2 content; it has been specified that a "maximum limit" of 43% SiO_2 and a "minimum limit" of 18% Al_2O_3, and 23% of the sum of CaO+MgO should ensure that the fibers are biosoluble [14].

Notably, MMMFs are insoluble in water and are hardly absorbed through the skin. The main effect of mineral fibers is mechanical action, and irritation of the skin and mucosa, characteristic of a foreign body. Secondary damage to the skin may be bacterial infections resulting from scratches and lichen, as well as urticaria, but industry reports on this subject are scarce. Dermatitis following irritation with mineral fibers may be associated with complications such as urticaria or eczema, sometimes mistaken for an allergic reaction.

Long-term effects of exposure to mineral fibers, characterized by pathological changes in the respiratory system, are also possible. They include the non-cancerous effect of respirable fibers on the respiratory system, mainly inflammation, fibrosis and functional disorders of the respiratory system, and potential carcinogenic effects. The suspicion of carcinogenic effects of mineral fibers in humans is mainly due to the similarity of their physical properties to the properties of asbestos fibers (similar fiber dimensions, a possibility of penetration into the respiratory system, and an ability to form free radicals). The basic differences between synthetic mineral fibers and asbestos are that mineral fibers are an amorphous synthetic material, resulting from the transformation of natural structures, and asbestos are naturally occurring fibers with a crystalline structure that allows the fibers to break along the crystalline planes and, as a result, creates fibers with diameters of 4 nm, which are easily transferred to the alveoli [6–13].

Moreover, MMVFs differ from asbestos fibers in their ability to produce fine dust, as well as in brittleness. Synthetic mineral fibers usually break transversely, not longitudinally, so "critical" (i.e., long and thin) fibers do not form very easily. Due to the dissolution and transverse cracking of the fibers, MMVFs are removed faster from the lungs. In addition, the biostability of mineral fibers in body fluids is less than the durability of asbestos fibers, and the crystal structure and durability of fibers are important factors affecting carcinogenic properties [3]. The lung half-life of mineral fibers with a length of >20 μm is <10 days [15,16], while insoluble amphibole fibers with a length of >15 μm are not removed from the alveolar area [17].

The majority of information about the carcinogenic effect of mineral fibers comes from epidemiological studies of employees exposed to these fibers in the process of their production. A major complication of this research is the fact that most workers exposed to fibers were simultaneously exposed to other carcinogens, including asbestos. Epidemiological data are most widely described for 2 large groups of workers producing MMVFs in the USA and Europe. Exposure usually includes several types of fibers and it is not always well defined to what fibers the workers are exposed. For some studies, exposure measurements have been combined with past exposure and individual work history. In the European cohort, there was occasional exposure to asbestos fibers resulting from its incidental processing. These observations were excluded from the study, but it is known that exposure to asbestos may have occurred in all factories where risk assessments were carried out.

Smoking was another disturbing factor whose role and possible interactions with the fibers were not taken into account. Study restrictions were related to the possible misclassification of exposure, because fibers exposure levels were low for most of the study population. The incorrect classification of pleural mesothelioma was also questioned, the assessment was mainly based on information from the death cards of the exposed workers. As a result of these studies, in 1988 the International Agency for Research on Cancer classified glass and rock wool as group 2B, i.e., factors likely to be carcinogenic to humans, and in 2002 reclassified it into group 3, i.e., factors that cannot be classified in terms of human carcinogenicity [18,19].

Recently, using a comet assay, Chinese researchers have shown that synthetic mineral fibers may be cytotoxic, although to a lesser extent than chrysotile asbestos [20]. Chinese studies have been evaluated by other scientists [21,22]. Grieve [21] considered them important and put the following scientific thesis forward: "Since chrysotile asbestos causes lung cancer, mesothelioma and other cancers, will replacement of asbestos with mineral wool fiber prevent this disease in the light of Chinese research?" The polemics of the researchers showed serious limitations in the Chinese study. It was emphasized that these were short-term *in vitro* tests which did not allow to accurately predict DNA damage, and their short duration could not take into account differences in the durability of the tested fibers. Short-term studies can give a wrong idea about the possible long-term biological effects. The long-term retention of synthetic vitreous fibers in the lung can lead to their transformation, e.g., dissolution and cracking, which reduce their biological activity. Moreover, the fibers preparation, as described in the article, raises serious concerns [22].

According to the rules currently in force in the European Union, the mineral wool (man-made vitreous [silicate] fibers with random orientation, with an alkaline oxide and alkali earth oxide [$Na_2O+K_2O+CaO+MgO+BaO$] content of >18% by weight) has been classified as carcinogen Category 2 and assigned the hazard phrase H351: "Suspected of causing cancer." The placing of a substance in Category 2 is done on the basis of evidence obtained from human and/or animal studies, but which are not sufficiently convincing to place the substance in Category 1A or 1B, based on the strength of evidence together with additional considerations. Such evidence may be derived either from limited evidence of carcinogenicity in human studies or from limited evidence of carcinogenicity in animal studies. Additional notes Q and R have been included in the list of substances with a harmonized classification, specifying the conditions under which the classification of wool as a carcinogen is not required. Note Q is based on biopersistence and toxicity studies, and Note R relates to the dimensions of fibers. Fibers meeting the conditions of Note Q are known as biosoluble [5]. According to Note Q, it is not required to classify mineral wool as a carcinogenic substance if it can be demonstrated that it meets 1 of the following 4 conditions [5]:

– a short-term biopersistence test by inhalation has shown that fibers longer than 20 μm have a weighted half-life shorter than 10 days; or
– a short-term biopersistence test by intratracheal instillation has shown that fibers longer than 20 μm have a weighted half-life shorter than 40 days; or
– an appropriate intra-peritoneal test has shown no evidence of excess carcinogenicity; or
– there have been no relevant pathogenicity or neoplastic changes in a suitable long-term inhalation test.

Other hazards

The emission of volatile organic compounds (VOCs) from binders may be another potential occupational hazard identified at the mineral wool insulation fitter's workplace. The binders and the additives contained in them allow obtaining appropriate functional properties of wool (mechanical strength, low thermal conductivity, fire resistance, etc.). The binders are aqueous mixtures of a complex composition. The basic component of the binder contains a reactive thermosetting composition. The most popular are binders based on phenol formaldehyde resins. Literature data indicate the possibility of emissions of many VOCs from binders at mineral wool production sites. Although the type of VOCs emitted depends on the resin and other raw materials used for the production of the binder, including catalysts, the most frequently mentioned VOCs are phenol, hydroxymethylphenol, formaldehyde, as well as ammonia and trimethylamine. The content of volatile components in the ready mineral wool is minimal, but manufacturers pay attention to the possibility of the release of products of thermal decomposition of the substances forming the mineral wool binder when the mineral wool is exposed to elevated temperature. The released substances in high concentrations may irritate the eyes and respiratory system [23–25].

Allergic reactions can occur as a result of direct contact with the fiber binder. Several cases of allergic contact dermatitis have been reported in workers exposed to MMVFs. As occlusive patch tests have shown, epoxy resins or phenol formaldehyde resins used to bind mineral fibers are responsible for sensitization [26,27]. In the production plant of mineral wool and insulation materials, 25% of 259 employees had skin diseases due to allergies to the components of the binder used in the production of insulation, mainly phenol formaldehyde resins, resorcinol, formaldehyde and furfural [28].

Another occupational hazard resulting from exposure to mineral wool is the result of the formation of a large amount of dust during installation of the insulation material. The most dust-forming technical processes include: milling, crushing, screening, transport, mixing, cutting, grinding, and polishing. The ingress of dust into the respiratory tract and the deposition in different sections of the respiratory system depend on the size of the dust particles. The smallest particles with a diameter of <7 μm are the most harmful, because they penetrate into the gas exchange area and, as a consequence, lead to the development of pneumoconiosis, many cancers and alveolitis. Dust generated at mineral wool insulation installation places includes various chemicals, primarily amorphous silica, components of binders, impregnants, oils, greases, and building materials, differing in their particle size. In turn, the particle size depends on what material is used and what tools are employed to process it.

Dusts monitored at mineral wool insulation installation places can be classified to the group of dusts not classified due to toxicity and can be divided – based on the type of biological action harmful to humans – to dusts irritating to mucous membranes of the respiratory tract, causing fibrosis and sensitization. In the case of fibrosing dust (silicon dioxide, sand, ceramic dust, and dust containing glass fibers), the effect of their penetration into the lungs is permanent damage to the alveoli in the form of pulmonary fibrosis. It is believed that water-insoluble forms of amorphous silica may have a fibrotic effect, but it is weaker than that of pure crystalline silica.

Bacterial and fungal infections can occur as complications of silicosis. These diseases are likely to occur due to a decrease in the function of silica phagocytic macrophages. Some dusts are irritating. These include, for example, organic dust, glass particles, aluminum, resins, chalk dust, and coal. These dusts can cause irritation to the upper respiratory tract and may induce chronic bronchitis due to constant irritation. The factor responsible for the development of chronic bronchitis is the responsible fraction of dust retained in the bronchi, characterized by particle sizes with diameters of >10 μm; the disease often occurs after not very long (up to 2 years) but intense exposure to dust, and is also associated with cigarette smoking. Sensitizing dusts cause allergic reactions on the skin and in the respiratory system. These include primarily organic dust, animal dust, and metal dust. Plain building dust has not been found to cause asthma, but its presence is particularly troublesome for those suffering from this disease. In many patients, asthma symptoms get worse, which necessitates an increase in the dose of medication [29].

It should be emphasized that there is also a group of dusts insoluble or poorly soluble in body fluids, which do not cause pneumoconiosis, but with a sufficiently high concentration in the work environment, usually >10 mg/m^3, can significantly reduce visibility, and accumulate in the eyes and ears causing unpleasant sensations. They can also damage the skin or mucous membranes due to chemical or mechanical effects, e.g., during intensive skin cleaning. In the past, the term "dust causing nuisance" was used for such dusts.

Diseases caused by the effects of dust belong to the most common occupational diseases in Poland. According to the Central Register of Occupational Diseases maintained by the Nofer Institute of Occupational Medicine, 610 cases of pneumoconiosis were registered in 2014 and 415 in 2017. For comparison, pleural or pericardial disease caused by asbestos dust accounted for 37 cases in 2017 [30].

Occupational exposure limit (OEL) for mineral fibers in Poland

Currently in Poland, an acceptable level of occupational exposure has been established for respirable fibers at 1 fiber/cm^3 (as time-weighted average [TWA]). Respirable fibers are defined as fibers with a length of >5 µm, a maximum diameter of <3 µm, and a length to diameter ratio of >3 µm. For mineral fibers, the short-term exposure limit or ceiling was not established [31]. Where it is necessary to monitor exposure additionally to dust, the exposure refers to the OEL-TWA value for the respirable fraction of dust not classified for toxicity of 10 mg/m^3. It should be emphasized that when measuring concentrations of dust not classified for toxicity, there is currently an obligation to simultaneously determine the concentrations of respirable crystalline silica fraction.

Fiber concentration levels in the air of the working environment during insulation

There are only few measurements of fiber concentrations in the air of the working environment during insulation. According to the Central Institute for Labor Protection – National Research Institute (Centralny Instytut Ochrony Pracy – CIOP) [32], the following average concentrations of respirable fibers, and dusts associated with exposure to fibers, were measured at the workplaces in Poland in 2001:

- 0.15 fiber/cm^3 and 12.7 mg/m^3 – during the disassembly and assembly of thermal insulation (mineral wool) on thermal screens;
- 0.07 fiber/cm^3 and 1.3 mg/m^3 – during the disassembly and assembly of thermal insulation (mineral wool mats) on the heating pipeline;
- 0.03 fiber/cm^3 and 11.5 mg/m^3 – during the installation of thermal insulation (mineral wool plates on fans).

Other measurements carried out during the assembly and replacement of thermal insulation materials showed that the weighted average concentrations of total dust ranged 1.3–14.3 mg/m^3 (on average 7.3 mg/m^3), and the concentrations of respirable mineral fibers ranged 0.029–0.510 fiber/cm^3 (0.18 fiber/cm^3 on average) [33]. Although high ceiling values of respirable fibers were measured, they were usually <1 fiber/cm^3 [34–36].

Respirable fibers levels measured in static samples collected in the lofts during installation were generally <0.1 fiber/cm^3. In living spaces, respirable fiber levels were <0.006 fiber/cm^3. Static gravimetric concentrations in the lofts ranged 0.3–6.5 mg/m^3, and in the living spaces 0.11–0.44 mg/m^3, but in both environments most of this dust was not MMMFs [35].

Pilot studies of work environment air, carried out in 2018 in the positions of employees performing works related to insulating the attic of the building and grinding the external walls, allowed the assessment of the concentration levels, and then the exposure assessment. The measurements were carried out in June and July 2018, and in September and November 2018 [37].

Installation works included the preparation of mineral wool, cutting and spreading the material between the rafters in the attic using hand tools, lubrication with glue using hand tools, gluing wool to the ceiling of the garage (works on scaffolding), auxiliary and cleaning works, grinding mineral wool using sandpaper, facade cleaning, dowelling, gluing. Four different types of mineral wool were used for the assembly process: Ursa Glasswool Gold 35, Rockwool Fasrock G, Rockwool Frontrock Max E, and Climawool DF1.

Air was sampled by individual dosimetry. Filters with collected dust containing respirable fibers were made transparent in boiling acetone vapors. Fibers present in randomly selected 200 fields of view were counted using a phase contrast microscope fitted with a Walton-Beckett mesh. The result expressed in the number of respirable fibers/cm^3 was obtained from the number of fibers on

Table 2. Results of measurements of concentrations of respirable mineral fibers and the inhalable fraction of dust at 12 workplaces of mineral wool insulation fitters, carried out in June–July and September–November 2018 in the positions of employees performing works related to insulating building attics and grinding external walls [37]

Place of sampling/Sample No./Workplace	Concentration (M±SD)	
	respirable mineral fibers [fiber/cm³]	dust – inhalable fraction [mg/cm³]
Residential building (RB1)		
1a Senior insulation fitter I (RB1)	0.007±0.0009	3.52±0.60
1b Senior insulation fitter II (RB1)	0.009±0.0010	9.79±1.67
Garage (G) – newly-built residential building		
2a Senior insulation fitter I (G)	0.008±0.0012	1.47±0.26
2b Senior insulation fitter II (G)	0.006±0.0009	1.25±0.22
2c Senior insulation fitter III (G)	0.008±0.0012	2.51±0.44
2d Senior insulation fitter IV (G)	0.005±0.0008	2.74±0.48
2e Senior insulation fitter V (G)	0.005±0.0007	1.3±0.26
School building (SB) – newly-built (sports hall)		
3a Senior insulation fitter I (SB)	0.055±0.0080	1.44±0.00
3b Senior insulation fitter II (SB)	0.035±0.0050	1.08±0.00
3c Senior insulation fitter III (SB)	0.029±0.0040	2.59±0.00
Residential building (RB2)		
4a Senior insulation fitter I (RB2)	0.012±0.0000	4.28±0.00
4b Senior insulation fitter II (RB2)	0.017±0.0000	7.68±0.00

Senior insulation fitter I and II (RB1) – residential building No. 1: preparation of Ursa Glasswool Gold 35 mineral wool, cutting and spreading the material between the rafters in the attic using hand tools, auxiliary and cleaning work.
Senior insulation fitter I–V (G) – garage: preparation of Rockwool Fasrock G mineral wool, cutting and lubrication with glue using hand tools, gluing wool to the ceiling of the garage (scaffolding work), auxiliary and cleaning work.
Senior insulation fitter I–III (SB) – school building (SB): work related to building insulation, grinding of mineral wool Rockwool Frontrock Max E with sandpaper, facade cleaning, studding, gluing, auxiliary and cleaning work. The samples were taken while working on the scaffolding under the installed protective mesh.
Senior insulation fitter I (RB2) – residential building No. 2: preparation of mineral wool Ursa Glasswool Gold 35 and Climawool DF1, cutting and spreading the material between the rafters in the attic in a residential building using hand tools, auxiliary and cleaning work.

the filter. Table 2 presents the results of concentration measurements.

The permissible values of respirable fibers (1 fiber/cm³), as well as the measured concentrations of respirable fibers, did not exceed 0.1 of the maximum average concentration (MAC) value at any workplace; no exceedances of the allowable fraction of the inhalable dust were also observed in relation to the value of 10 mg/m³. At most sites, no significant variability in the concentration of respirable fibers and inhaled dust was observed during the work shift [37]. Studies of the fractional composition of glass and rock mineral wool, taken from construction sites during thermal insulation works, were also conducted [37]. Impurities deposited on the filters, collected during construction work in the attic of a residential building, were almost exclusively dust in nature, with individual fiber fragments with a diameter ranging 1.24–8.33 μm and a length of 7.19–76.68 μm. The length to diameter ratio of the observed fibers ranged 3.82:1–51.12:1. It should be emphasized that 68.75% of the marked fibers should be considered respirable. The dust resembled amorphous agglomerates of smaller particles and had total diameters ranging 0.8–13.27 μm. Free crystalline silica was not found in the collected dust at a concentration of >0.1 determination of the analytical method (the determination limit of the method is 0.015 mg/m^3 in the case of an air sample of 700 l). Instead, amorphous silica was identified. The PM_{10} fraction was 35%, while the $PM_{2.5}$ fraction was 3–10%.

CONCLUSIONS

When installing mineral wool insulation at workplaces, respirable mineral fibers, dust, and volatile organic compounds may pose a threat. The main occupational hazards posed by mineral fibers include mechanical action manifested by irritation of the skin and mucosa, characteristic of a foreign body, and distant effects of exposure characterized by pathological changes in the respiratory system resulting from the presence of fibers.

Respirable mineral fibers, with a diameter of <3 μm and a length of >5 μm, are released to the environment during the production, use, assembly work and removal of insulation. Released respirable fibers float in the air and, due to their small size, can penetrate into the gas exchange area. The biggest concerns relate to assessing the lung cancer risk for workers in the construction industry who use or remove rock and slag wool products, and may thus be exposed to high fiber concentrations at short intervals. The data available for risk assessments are very limited for this population.

Part of the material taken during the delamination of the insulation mat, due to the size of the fibers, should not pose a potential threat at workplaces. The fibers are too large and, therefore, too heavy to get into the respiratory system. Coarse mineral fibers can have an adverse effect on health if they have direct contact with the skin and mucous membranes, but they are mainly irritating to the skin and eyes, and the respiratory tract.

Mineral fibers present in the air at workplaces are accompanied by the formation of large amounts of dust. The most dangerous are dust particles with the smallest diameters that can easily penetrate the lungs.

The release and thermal decomposition of the substances forming the mineral wool binder during the work of the insulation fitter are unlikely. However, one should take into account the possibility of allergic reactions as a result of contact with the resins used as binders.

A pilot study conducted in 2018 showed that the likelihood of adverse health effects related to the work of an insulation installer, resulting from exposure to mineral wool fibers, is low. The MAC of respirable fibers in the air of the attic during cutting and spreading the material between the rafters, using hand tools, was small. It amounted to 0.009±0.001 fiber/cm^3, i.e., it did not exceed one-tenth of the permissible value (1 fiber/cm^3). For dust associated with exposure, an average risk was estimated. The measured concentration of dust in the air ranged 0.1–0.98 mg/m^3 of the limit value (10 mg/m^3). The obtained test results are consistent with the results of tests published elsewhere in literature and with the results of CIOP tests, where the maximum weighted average concentrations of total dust were 14.3 mg/m^3 and 12.7 mg/m^3, respectively, and those of respirable mineral fibers 0.510 fiber/cm^3 and 0.191 fiber/cm^3 [32,33].

It is necessary to take appropriate preventive measures to minimize the risk associated with the work of insulation fitters, resulting primarily from the formation of a large amount of dust. Both Polish health and safety regulations, and regulations in other European Union countries do not provide specific requirements for work with mineral wool. First of all, dust formation in the workplace should be prevented, and once it is created, the spread of dust must be effectively limited by installing foil, hanging curtains, and installing sluices. To avoid skin irritation, protective gloves should be used and exposed parts of the body covered. Protective clothing contaminated with insulating wool material should be changed if necessary and should not be worn outside the workplace. Work should be organized so that employees do not perform insulation work at the level above the head. However, when working overhead, it is recommended to use a headgear and wear safety glasses that meet the requirements of the relevant standards. Inhalation of airborne particles from other sources, including those from cigarette smoke, may increase the risk of respiratory diseases, which is why all mineral wool work and storage areas should be free from pollution from other sources.

It should be emphasized that expanding knowledge of the development and changes in fiber technology is very important. As a result of intensive research on the health effects of synthetic mineral fibers produced in the 1980s and 1990s, their composition has been modified to reduce their fibrogenic and carcinogenic potential by limiting biopersistence. The MMVFs technology is constantly looking for new solutions that aim to create and practically use materials with lower toxicity and better parameters, i.e., a new type of mineral fibers. Manufacturers of insulation materials based on synthetic mineral fibers have developed new techniques and systems for the production of fibers, e.g., HT fibers with high alumina content (18–24% vs. 6–15%) and low silica content (33–43% vs. 43–50%). Research on the composition of a new type of synthetic mineral fibers obtained directly from construction sites in Germany, Finland, the United Kingdom, Denmark, Russia, and China (5 different manufacturers) showed that all tested materials contained SiO_2 with a narrow concentration range of 40–44% [10]. Therefore, for insulation purposes, you should choose the right products – new types of materials certified to minimize the release of respirable fibers and dust during operation.

It should be emphasized that, in the case of finished mineral wool products, the manufacturer is not obliged to affix on the labeling information resulting from the labeling requirements for chemicals. The recipient does not have to be informed whether the product being purchased is treated as a chemical substance, a mixture or an article. Therefore, manufacturers of mineral wool products wanted to introduce signs that would clearly inform the recipient that the mineral wool they used was not classified as carcinogenic. In 2000, the European mineral wool certification council, subordinated to the European Certification Board for Mineral Wool Products (EUCEB), was established, which verifies the compliance of mineral fibers with the exclusion criteria from the classification based on Note Q. If the fibers meet the requirements set out in Note Q, the manufacturer is granted the right to use the EUCEB trademark marking [38]. Thanks to the presence of this mark, the recipient can easily find out that the products are made of mineral wool not classified as carcinogenic. Specifiers, installers, building owners and the public can have complete confidence in the mineral wool products that carry the EUCEB trademark.

Also, the European Association of Insulation Manufacturers (EURIMA) has introduced monitoring schemes ensuring that the chemical composition of mineral wool guaranteeing its adequate biosolubility is kept within defined ranges as well as awards the RAL quality mark. The RAL certificate contains technical product information and product labeling. In Germany, this quality mark is introduced by an independent Quality Assurance Association for Pipe Supports [39]. Through the RAL quality mark, installers and consumers can clearly recognize the mineral wool that has been rated as safe for health throughout Europe [40].

Mineral wool products are most often used as insulation materials in the construction industry. The basic legal act in the European Union regarding building materials is Regulation (EU) No. 305/2011 of the European Parliament and of the Council of March 9, 2011 establishing harmonized conditions for the marketing of construction products [41]. The regulation governs, among others, the obligation to draw up and deliver, and the content of the declaration of performance of a construction product, as well as the use of the CE marking reflecting the conformity of the product with the declared performance in relation to its essential characteristics covered by the harmonized standard or European assessment.

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