DGUV
Deutsche Gesetzliche
Unfallversicherung
Spitzenverband

IFA Report 3/2022e

Exposure to Quartz at the Workplace

Occupational exposure to quartz (crystalline silicon dioxide) in respirable dust fractions

Authors: see page 154

Published by: German Social Accident Insurance (DGUV)
Glinkastr. 40
10117 Berlin
Telefon: 49 (0)30 130010,
web address: www.dguv.de
E-Mail: info@dguv.de

– March 2023 –

Publication Database: www.dguv.de/publikationen

ISBN (print): 978-3-948657-55-0
ISBN (online): 978-3-948657-56-7
ISSN: 2190-7994

Abstract

Exposure to quartz at the workplace – Work-related exposure to quartz (crystalline silicon dioxide) from the respirable dust fraction

Quartz is used as an agent or is released, in the form of quartz dust, in a wide range of work processes. Despite technical progress and considerable efforts to reduce exposure to dust, exposure to respirable quartz dust at workplaces remains an important issue. This is evidenced by the number of quartz dust measurements conducted as part of the MGU measurement system for exposure assessment of the German Social Accident Insurance Institutions, which currently stands at around 1,200 measurements per year in 600 different work areas. In 2006, around 100,000 measured values for respirable dust containing quartz were statistically evaluated for BGIA Report 8/2006 “Exposure to quartz at the workplace”.

This new edition of BGIA Report 8/2006 provides a synoptic representation of occupational exposure to respirable dust containing quartz. For this purpose, over 15,100 quartz measurements carried out within the MGU measurement system from January 2005 to December 2016 – which were documented in the MEGA exposure database of the Institute for Occupational Safety and Health of the German Social Accident Insurance, IFA (MEGA stands for Measurement data relating to workplace exposure to hazardous substances) – were sorted into different industries and work areas and statistically evaluated. The data are supplemented with explanations about activities that are subject to exposure, about work processes, about the implementation of protective measures and about the state of the art. IFA Report 4/2022 “Exposure to quartz at the workplace” can be used as a basis for guiding preventative measures, for exposure monitoring and for determining quartz dust exposures during the process of reporting suspected occupational diseases. However, it also makes an important contribution to the discussion among expert committees within the context of the further development of the technical rules for hazardous substances.

Kurzfassung

Quarzexpositionen am Arbeitsplatz – Arbeitsbedingte Exposition gegenüber Quarz (Siliziumdioxid kristallin) in der alveolengängigen Staubfraktion

Quarz wird in einer Fülle von Arbeitsverfahren als Arbeitsstoff eingesetzt bzw. als Quarzstaub freigesetzt. Die Belastung mit alveolengängigem Quarzstaub an Arbeitsplätzen spielt trotz technischen Wandels und erheblicher Anstrengungen zur Minderung der Staubbelastung auch heute noch eine bedeutende Rolle. Dokumentiert wird dies durch die Zahl der Quarzstaubmessungen im Rahmen des Messsystems Gefährdungsermittlung der Unfallversicherungsträger – MGU mit aktuell ca. 1 200 Messungen pro Jahr in 600 verschiedenen Arbeitsbereichen. 2006 wurden für den BGIA Report 8/2006 „Quarzexpositionen am Arbeitsplatz“ ca. 100 000 Messwerte zu quarzhaltigem A-Staub statistisch ausgewertet.

Diese Neuauflage des BGIA Reports 8/2006 stellt eine synoptische Darstellung zur arbeitsbedingten Exposition gegenüber quarzhaltigem A-Staub dar. Hierzu wurden über 15 100 im MGU durchgeführt Messungen zu Quarz aus dem Zeitraum von Januar 2005 bis Dezember 2016, die in der IFA Expositionsdatenbank MEGA (Messdaten zur Exposition gegenüber Gefahrstoffen am Arbeitsplatz) dokumentiert wurden, nach Branchen und Arbeitsbereichen differenziert und statistisch ausgewertet. Die Daten wurden durch Erläuterungen zu exponierten Tätigkeiten, zu Arbeitsverfahren, zur Umsetzung von Schutzmaßnahmen und zum Stand der Technik ergänzt. Der IFA Report 4/2022 „Quarzexpositionen am Arbeitsplatz“ kann als Grundlage zur Lenkung präventiver Maßnahmen, der Expositionsüberwachung und zur Ermittlung zurückliegender Quarzstaubbelastungen bei Berufskrankheiten-Verdachtsanzeigen, aber auch als Beitrag für die Diskussion von Fachgremien im Rahmen der Weiterentwicklung des technischen Regelwerkes zu Gefahrstoffen dienen.

Résumé

Expositions au quartz sur le lieu de travail – Exposition en milieu professionnel au quartz (silice cristalline) présent dans la fraction alvéolaire de la poussière

Le quartz est un matériau largement utilisé ou rejeté sous forme de poussière de quartz par une multitude de procédés industriels. Malgré les progrès technologiques et les efforts considérables déployés pour la minimiser, l'exposition à la poussière alvéolaire de quartz sur le lieu de travail demeure significative. C'est ce dont témoignent les mesures de poussière de quartz effectuées par le système d'évaluation des risques de l'Organisme d'assurance sociale allemande des accidents du travail et des maladies professionnelles, qui en effectue actuellement environ 1200 par an dans 600 secteurs d'activité différents. Quelque 100 000 mesures de poussière alvéolaire de quartz ont été statistiquement analysées en 2006 dans le cadre du rapport 8/2006 de l'Institut allemand de prévention des accidents du travail, intitulé « Expositions au quartz sur le lieu de travail ».

Cette réédition du rapport 8/2006 de l'Institut allemand de prévention des accidents du travail présente une vue synoptique de l'exposition à la poussière alvéolaire de quartz sur le lieu de travail. Pour ce faire, plus de 15 100 mesures de quartz ont été effectuées par le système d'évaluation des risques de l'Organisme d'assurance sociale allemande des accidents du travail et des maladies professionnelles entre janvier 2005 et décembre 2016, puis consignées dans la base de données MEGA (acronyme de « données de mesure d'exposition aux substances dangereuses sur le lieu de travail ») de l'Institut allemand de santé et de sécurité au travail, classées par secteur et par domaine d'activité, et enfin statistiquement analysées. Ces données sont venues compléter les informations sur les activités exposées, les procédés industriels, l'application des mesures de protection et l'état de l'art. Le rapport 4/2022 de l'Institut allemand de santé et de sécurité au travail intitulé « Expositions au quartz sur le lieu de travail » peut servir de base pour orienter les mesures préventives, la surveillance de l'exposition et la détermination des expositions passées à la poussière de quartz dans le cas d'une déclaration de présomption de maladie professionnelle, mais aussi de contribution à la discussion des comités d'experts en vue du développement de la réglementation technique sur les substances dangereuses.

Resumen

Exposiciones al cuarzo en el lugar de trabajo – Exposición al cuarzo relacionada con el trabajo (dióxido de silicio cristalino) en la fracción de polvo respirable.

El cuarzo se utiliza como agente en numerosos procesos de trabajo o bien se libera en forma de polvo de cuarzo: la carga de polvo de cuarzo respirable en los lugares de trabajo sigue siendo relevante hoy en día pese a la transformación tecnológica y a los considerables esfuerzos para reducir la carga de polvo. Esto queda documentado mediante el número de mediciones de polvo de cuarzo en el contexto del sistema de medición para la determinación de peligros del Organismo de Seguro Social Alemán de Accidentes de Trabajo (MGU) con unas 1200 mediciones anuales en 600 áreas de trabajo distintas. En 2006 se evaluaron estadísticamente cerca de 100 000 valores de medición de polvo respirable con cuarzo para el informe del Instituto BGIA 8/2006 "Exposiciones al cuarzo en el lugar de trabajo".

Esta nueva edición del informe del Instituto BGIA 8/2006 es una representación sinóptica de la exposición al polvo respirable con contenido en cuarzo. A tal fin se evaluaron estadística y diferenciadamente más de 15 100 mediciones de cuarzo realizadas por el instituto para la seguridad en el trabajo del organismo MGU del periodo entre enero de 2005 a diciembre de 2016, que se registraron en la base de datos de exposición MEGA (siglas de: datos de medición de la exposición a sustancias peligrosas en el lugar de trabajo). Los datos se completaron mediante notas aclaratorias sobre las actividades sensibles, los procedimientos de trabajo, la implementación de medidas de protección y el estado de la técnica. El informe 4/2022 del instituto para la seguridad en el trabajo del organismo MGU "Exposiciones al cuarzo en el lugar de trabajo" puede servir como base para dirigir medidas preventivas, monitorizar la exposición y determinar antecedentes de cargas de polvo de cuarzo en casos de denuncias por enfermedades laborales, pero también puede contribuir al debate entre los sectores especializados en el contexto de la evolución de los códigos técnicos sobre las sustancias peligrosas.

Table of Contents

1 Introduction ... 10

2 Information on quartz as a substance (incl. cristobalite and tridymite) ... 11
2.1 Identification ... 11
2.2 Properties ... 12
2.3 Health hazards ... 18

3 Limit values and regulations ... 20
3.1 Limit values and their development (since 2005) ... 20
3.2 Regulations ... 20

4 Measurement procedures ... 21
4.1 Sampling methods ... 21
4.2 Analysis methods ... 22
4.3 Comments on the measurement strategy and assessment of measured values ... 25

5 Occurrence ... 27
5.1 Natural occurrence ... 27
5.2 Synthetically manufactured crystalline SiO_2 modifications ... 28

6 Use and appearance ... 29
6.1 Quartz ... 29
6.2 Cristobalite ... 32
6.3 Tridymite ... 32

7 Data situation and evaluation strategy ... 33
7.1 Selection criteria for statistical evaluations ... 33
7.2 Data situation ... 33
7.3 Evaluation strategy ... 34
7.4 Tables of results, abbreviations and footnotes ... 34
7.5 Quartz and cristobalite in the same working area ... 36

8 Extraction and processing of stones, earths and raw materials ... 37
8.1 Extraction and processing of limestone and dolomite ... 37
8.2 Mining ... 38
8.3 Extraction and processing of gravel and sand ... 39
8.4 Extraction and processing of natural stone and other raw materials ... 42
8.5 Natural stone industry – production, treatment and processing of natural stone, masonry work ... 46
8.6 Mineral grinding mills (coloured earths) ... 51
8.7 Production of gypsum products, insulation panels and lightweight panels ... 52
8.8 Asphalt mixing plants ... 53
8.9 Production of cement and lime ... 54
8.10 Production of dry building materials ... 55
8.11 Concrete industry (stationary operation) ... 57

9 Ceramic and glass industries ... 63
9.1 Glass, production and processing ... 63
9.2 Glass fibres, mineral fibres, production and processing ... 66
9.3 Quartz glass (including growing of crystal), production and processing ... 68
9.4 Clay and kaolin, extraction ... 69
9.5 Refractory products, production ... 70
9.6 Sand-lime brick, production ... 77
9.7 Porcelain and ceramics (industrial), production ... 78
9.8 Sanitary ceramics, production ... 82

9.9 Technical ceramics, production ... 86
9.10 Wall and floor tiles, production ... 89
9.11 Structural ceramics, production ... 92
9.12 Furnace and stove tiles, production ... 94
9.13 Abrasive tools, production ... 95
9.14 Brickwork and tilework, production ... 97

10 Chemical, pharmaceutical, rubber and plastics industries ... 102
10.1 Chemical and pharmaceutical industries, paints ... 102
10.2 Roofing felt and bitumen sheeting, production ... 105
10.3 Foundry auxiliaries, production ... 105
10.4 Rubber goods, production and processing ... 106
10.5 Plastics, production and processing ... 106

11 Wood and paper industries ... 108
11.1 Wood processing ... 108
11.2 Paper and board, production and processing ... 108

12 Foundries, metal manufacturing ... 109
12.1 Foundries ... 109
12.2 Metal production ... 119

13 Metalworking and processing, mechanical and vehicle engineering, workshops, paint shops ... 120
13.1 Metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops ... 120
13.2 Repairs, maintenance, workshop operations in other industries ... 125

14 Electrical and precision engineering industries and trades ... 127
14.1 Electrical engineering ... 127
14.2 Jewellery, production and processing ... 128
14.3 Dental laboratory ... 129
14.4 Electrical installation work at construction sites ... 130
14.5 Friction linings ... 130

15 Research institutes, educational facilities, energy production, transport ... 131
15.1 Research and test institutions and laboratories, design studios ... 131
15.2 Vocational colleges and training centres for the construction trade ... 132
15.3 Transport ... 133
15.4 Energy production ... 134

16 Wholesalers and retailers, beverage production ... 135
16.1 Wholesalers and retailers of various building materials ... 135
16.2 Wholesalers in chemical products ... 136
16.3 Breweries and beverage manufacturers, filtration ... 137

17 Waste disposal, recycling ... 140
17.1 Waste collection, disposal, incineration and recycling (excluding glass recycling), wastewater disposal ... 140
17.2 Electronic scrap recycling ... 140
17.3 Glass recycling ... 141
17.4 Building material recycling and screening facilities ... 142

18 Construction industry ... 144
18.1 Brickwork and clinker construction ... 144
18.2 Rendering ... 144
18.3 Demolition work ... 145
18.4 Earthworks, levelling, compaction and paving ... 145
18.5 Construction of tiled stoves, chimneys and furnaces, incl. industrial furnaces ... 146
18.6 Roofing ... 146
18.7 Concrete construction ... 146
18.8 Cleaning of construction sites ... 146
18.9 Blasting ... 147
18.10 Road works ... 148
18.11 Tunnelling ... 149
18.12 Other activities in the construction industry ... 150

References ... 151

1 Introduction

Quartz is used as an agent or is released in the form of quartz dust, in a wide range of work processes. The main applications of quartz are as a filler in the rubber, plastics and paint industries, as glass sand in the glass industry, as foundry sand in the foundry industry and as a component of various raw materials and products in the construction industry. Furthermore, quartz is used as a raw material in the chemical, ceramics and glass industries and as filter sand in wastewater treatment, in the chemical industry and in the production of beverages. In the treatment of precious stones, different varieties of quartz are treated as precious and semi-precious stones. In addition, quartz is also sometimes used as a grinding, polishing or abrasive agent.

Despite technical progress and considerable efforts to reduce exposure to dust, exposure to respirable quartz-bearing dust at workplaces remains an important issue. Since the 1950s, the social accident insurance institutions have carried out extensive series of measurements on quartz exposure in a variety of industries. This is evidenced by the number of quartz dust measurements conducted as part of the MGU measurement system for exposure assessment of the German Social Accident Insurance Institutions, which currently stands at around 1,200 measurements per year in 600 different work areas. Today's established analysis methods for the detection of quartz have been in use since the early 1970s.

Set against this background, there is a need for a synoptic presentation of quartz as a basis for guiding preventive measures, for monitoring exposure and for determining past exposure to quartz dust in suspected occupational disease reports, but also as a contribution to the discussion of expert committees who are involved in the further development of technical regulations on hazardous substances.

The number of occupational silicosis cases caused by exposure to quartz dust has fallen steadily over the past decades owing to the success of preventive measures. Since then, quartz has been classified as carcinogenic by the International Agency for Research on Cancer (IARC) and the Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (DFG), also known as the MAK Commission. The Committee for Hazardous Substances (AGS) classified quartz and cristobalite (respirable dust fraction) as carcinogenic to humans in 2002. Since then, cases of lung cancer can be recognised as occupational disease no. 4112 under the German Occupational Diseases Ordinance for cases of silicosis or silicotuberculosis. Following the publication of the Technical Rules for Hazardous Substances (TRGS) 906, *List of carcinogenic activities and processes according to section 3 (2) no. 3 of the German Ordinance on Hazardous Substances* in July 2005, activities and processes involving exposure of employees to respirable quartz or cristobalite dusts are listed as carcinogenic.

2 Information on quartz as a substance (incl. cristobalite and tridymite)

2.1 Identification

The silicon dioxide modifications (SiO_2 modifications) generally described as quartz, cristobalite and tridymite in everyday speech and also in regulations are low-temperature modifications of low quartz, low cristobalite and low tridymite (cf. section 2.2). These are the substances referred to in **Tables 1** and **2**. They are also the modifications that can be encountered in work areas.

Table 1:
Characteristics of quartz, cristobalite and tridymite; data from [1]

Common name	Quartz	Cristobalite	Tridymite
EEC/EINECS number[1]	238-878-4	238-455-4	239-487-1
CAS name[2]	Quartz	Cristobalite	Tridymite
CAS number[2]	14808-60-7	14464-46-1	15468-32-3
MGU hazardous material code[3]	1262	12621	12622
ZVG number[4]	4410	570103	570262
Molecular formula	SiO_2	SiO_2	SiO_2

[1] Registration number in the European Inventory of Existing Commercial Chemical Substances
[2] Registration number in the Chemical Abstracts Service
[3] Hazardous substance key in the MGU
[4] Identification number in the GESTIS substance database

Table 2:
Physical properties of low quartz, cristobalite and tridymite; data from [1, 4]

Common name	Quartz	Cristobalite	Tridymite
Name of phase	Low quartz	Low cristobalite	Low tridymite
Melting temperature in °C	1,610	1,713	-
Density (at 20 °C) in g/cm³	2.65	2.33	2.27
Crystalline structure	Trigonal	Tetragonal	Monoclinic
Refractive indices	n_o=1.553 n_E=1.544	n_o=1.484 n_E=1.487	n_x=1.470 n_y=1.474
Molar mass in g/mol	60	60	60

2.2 Properties

The commonly used term “crystalline silica” as a generic term for the various crystalline SiO_2 modifications is misleading. SiO_2 is an oxide that is not dissolved in aqueous solution until it has turned into orthosilicic acid ($SiO_2 + 2\,H_2O \dashrightarrow H_4SiO_4$) [2]. Below, therefore, we will always use the term “SiO_2 modifications”. Under normal conditions, there are five stable SiO_2 modifications: low quartz, low tridymite, low cristobalite, coesite and stishovite. The stability ranges of these phases are shown in **Figure 1**.

Technical and safety datasheets often mention SiO_2 as a component. Here, a distinction must be made between the crystalline SiO_2 phase (i.e. quartz, cristobalite or tridymite) and the silicon dioxide component in a chemical analysis (where silicon is identified and shown as SiO_2). In the second instance, the value for SiO_2 does not reflect the quartz content (see **Table 3** and **Figure 2**). The term “silica”, commonly used in the English-speaking world, does not usually refer to the result of a chemical analysis, but to the material composition, which is mostly quartz. However, it is only through further admixtures that we can determine clearly whether the proportion is quartz, cristobalite or tridymite (crystalline silica) or whether it is a proportion of amorphous silica.

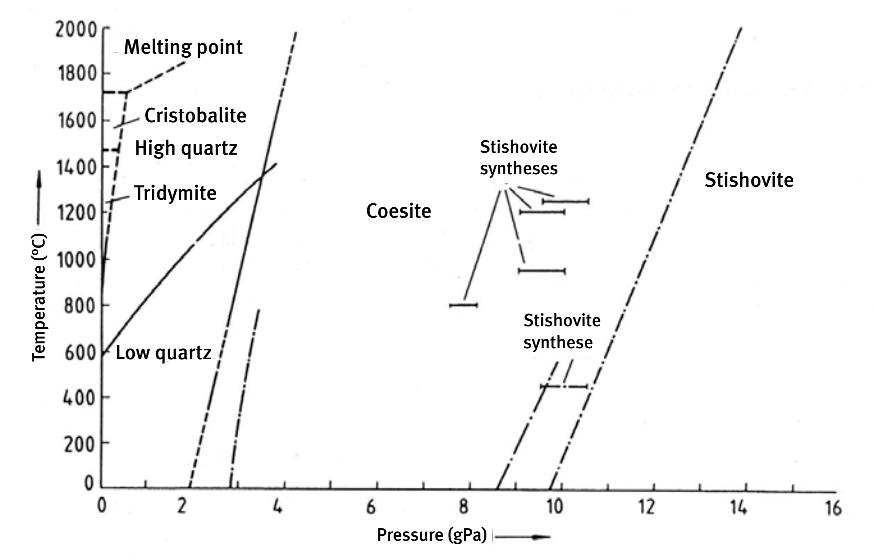


Figure 1:
Phase diagram of SiO_2 [3], solid curves: experimentally determined phase boundaries, dashed curves: extrapolated phase boundaries, dotted curves: computed phase boundaries. Source: IFA

Table 3:
Examples of elemental compositions and phase compositions of different materials (simplified, only relevant main constituents, details in mass %)

Materials	Elemental composition determined through chemical analysis	Phase composition (also: material composition, modal composition), identified through a phase analysis
Basalt	SiO_2: 52.4%, Al_2O_3: 15.9%, Fe_2O_3: 4.0%, FeO: 3.0%, MgO: 9.8%, CaO: 8.3%, Na_2O: 2.6%	Quartz: 0%, plagioclase (feldspar): 56%, clinopyroxene: 26%, olivine: 12%, Fe-Ti ores: 4%
Granite	SiO_2 72.0%, Al_2O_3: 14.8%, Fe_2O_3: 1.1%, FeO: 0.7%, Na_2O: 3.6%, K_2O: 5.0%	Quartz: 34%, potash feldspar: 33%, plagioclase: 24%, mica: 8%
Wollastonite	SiO_2 51.7%, CaO: 48.3%	Quartz: 0%, wollastonite: 100%
Talcum	SiO_2 60.5%, Al_2O_3: 1.4%, FeO: 0.5%, MgO: 31.2%	Quartz: ‹ 1%, talcum: 95 %, chlorite: 4%

Depending on the pressure, low quartz reversibly transforms into high quartz at temperatures of 573 °C or higher (**Figure 3**). This is a displacive transformation, which means that there is only a shift in the atomic positions in the crystalline structure and thus also a change in the Si-O-Si bond angles. Once the temperature falls below the transformation temperature, this is reversed. As a result, only low quartz occurs in dusts occurring through work areas. This is especially important when other compound names containing the word quartz are used for low quartz and high quartz. The use of such synonyms is not internationally consistent. If quartz-bearing materials are heated to no more than about 850 °C, quartz continues to be present after cooling (e.g. when samples are annealed during their preparation for analysis).

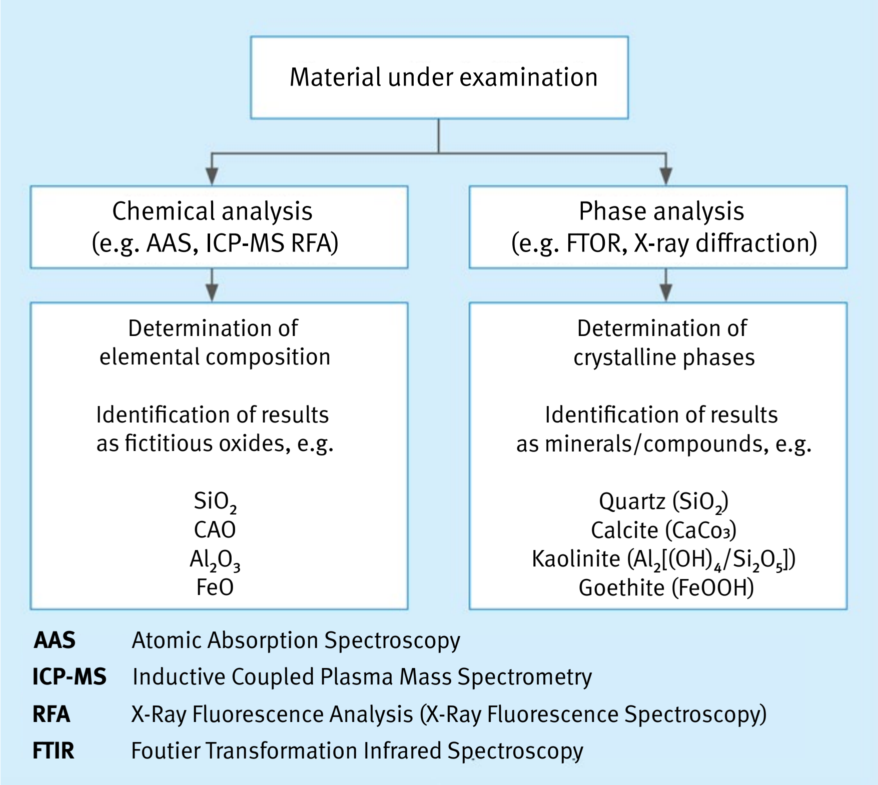


Figure 2:
Analysis chart for inorganic materials
Source: IFA

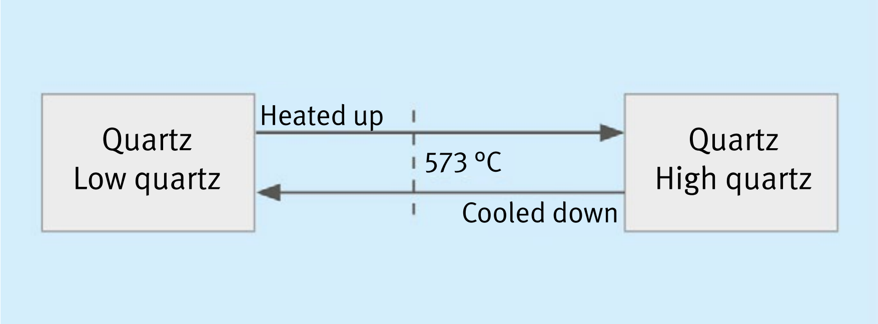


Figure 3:
Reversible transformation of quartz (schematic presentation)
Source: IFA

At low pressures, high tridymite is formed from high quartz through further heating at 870 °C and, from it, high cristobalite at 1,470 °C [2] (**Figure 4**). This transformation takes place, for example, in the manufacturing and use of silica bricks for furnace construction. Temperatures above 1,730 °C cause SiO_2 to melt. Transformations of high quartz into high tridymite and high cristobalite take place after a long time lag.

The high tridymite and cristobalite that are formed at high temperatures are each displacively transformed into the relevant low-temperature modifications when cooled down to below 250 °C and 270 °C, respectively [4].

When heated rapidly, high quartz can therefore be melted without prior phase transformation. Conversely, rapid cooling of an SiO_2 melt will result in amorphous quartz glass (Figure 5). In such a case, crystallisation is prevented by the high viscosity of the molten mass.

When producing silicon through a reduction of the SiO_2 oxide, fumes are released that largely consist of amorphous silicic acid (silica fumes) (see section 6.1).

At very high pressures above 2 gPa, coesite is formed. Coesite is a high-pressure modification of quartz that changes into stishovite when the pressure exceeds 2 gPa (Figure 1). In nature, coesite and stishovite only occur as a result of meteorite impact.

Other crystalline SiO_2 modifications include keatite (so far only produced synthetically), melanophlogite (so far only observed in Sicilian sulphur deposits) and fibrous SiO_2 (which – under normal conditions and in the presence of water – rapidly disintegrates into silica gel in the air).

Another process for the formation of crystalline SiO_2 modifications is recrystallisation from amorphous phases. For example, the amorphous silica of diatomaceous earths (diatom skeletons from opal) is largely transformed into cristobalite when heated or calcined at temperatures between 600 and approx. 1,200 °C (**Figure 6**).

Cristobalite can also form from aluminium silicate fibres and high temperature glass fibres (AES). If amorphous fibres have been made from a silicate melt and are then permanently heated to high temperatures between 1,000 and 1,400 °C, e.g. by using them in an industrial furnace, then this produces cristobalite in the fibres.

In an occupational hygiene assessment of a workplace for airborne respirable dusts, the SiO_2 modifications that are of interest are low quartz, low cristobalite and low tridymite. The other crystalline phases are of very little importance.

The basic building blocks in the short-range order of crystalline SiO_2 modifications are SiO_4 tetrahedra. An Si atom is surrounded by O atoms and indeed right at their centre. Each of the O atoms connects two tetrahedra with each other (oxygen bridges). Thus, four half O atoms can each be formally assigned to one Si atom. Hence, the gross composition of the formula: SiO_2. If the tetrahedra are linked systematically, according to a certain symmetry, this creates a long-range order of the basic building blocks and therefore a crystal structure. If no long-range order can be established, i.e. if the SiO_4 tetrahedra are connected randomly, then the modification is an amorphous SiO_2 modification. The generic term that is generally used for all amorphous SiO_2 modifications is “amorphous silica”. We distinguish between anhydrous and hydrous amorphous silica. An overview of the diversity of crystalline and amorphous SiO_2 modification can be seen in Figure 7.

Another important aspect in this context is the difference between amorphous silicas and other amorphous substances. Window panes, for example, contain high levels of SiO_2. In addition, such substances also have other oxidic components (e.g. Al_2O_3, CaO, MgO, Fe_2O_3, Na_2O). The SiO_2 content in such materials is not called amorphous silica. This is especially important prior to an analysis of air or material samples. One essential requirement for determining the presence and concentration of amorphous silica is information about the material used or formed in the work area (e.g. information from the safety datasheet [5]).

Figure 4:
Transformation of quartz through slow heating (schematic presentation). Source: IFA

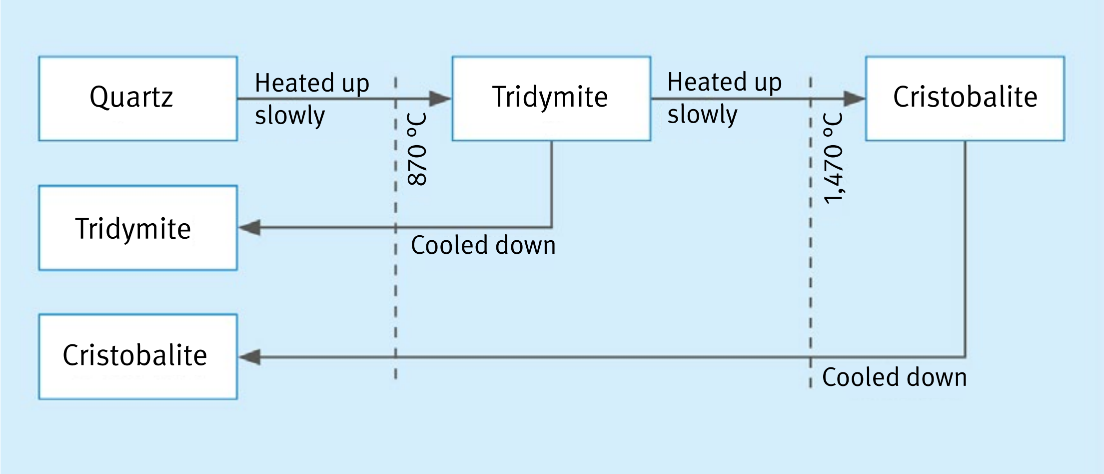


Figure 5:
Transformation of quartz through rapid heating/melting (schematic presentation). Source: IFA

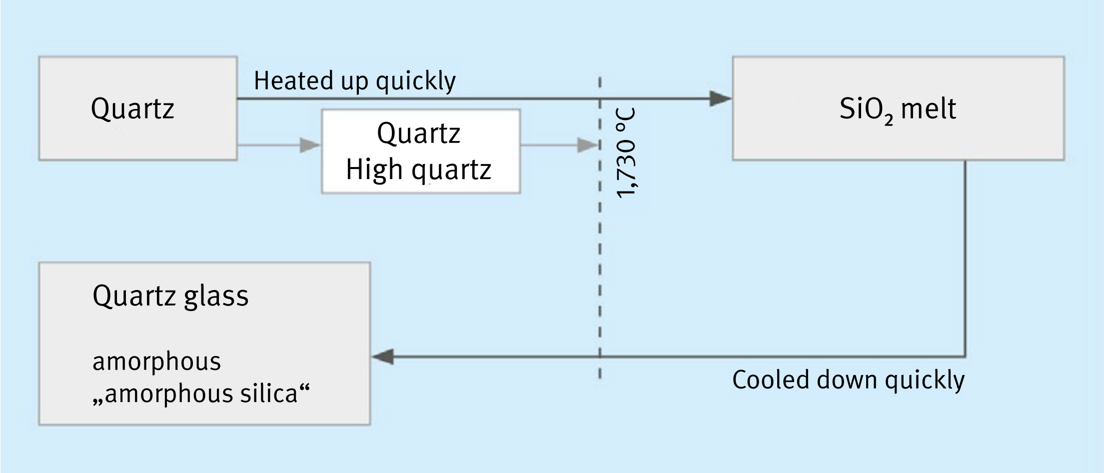


Figure 6:
Conversion of amorphous silica through annealing/calcination (schematic presentation). Source: IFA

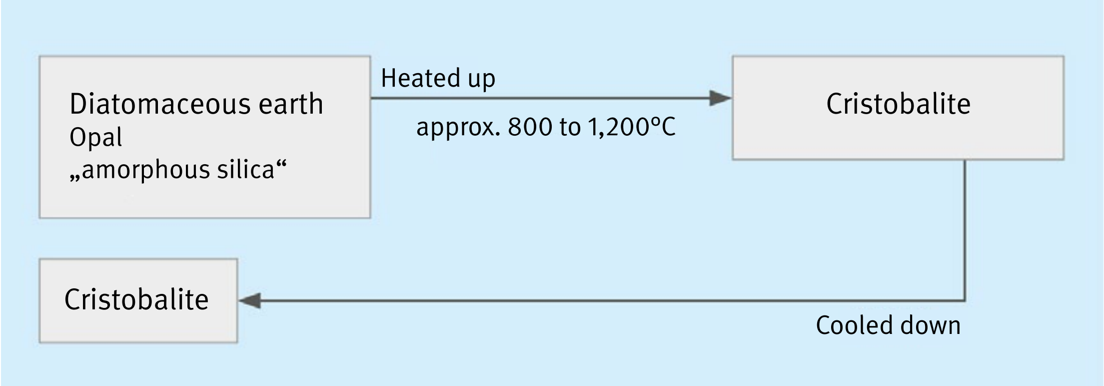
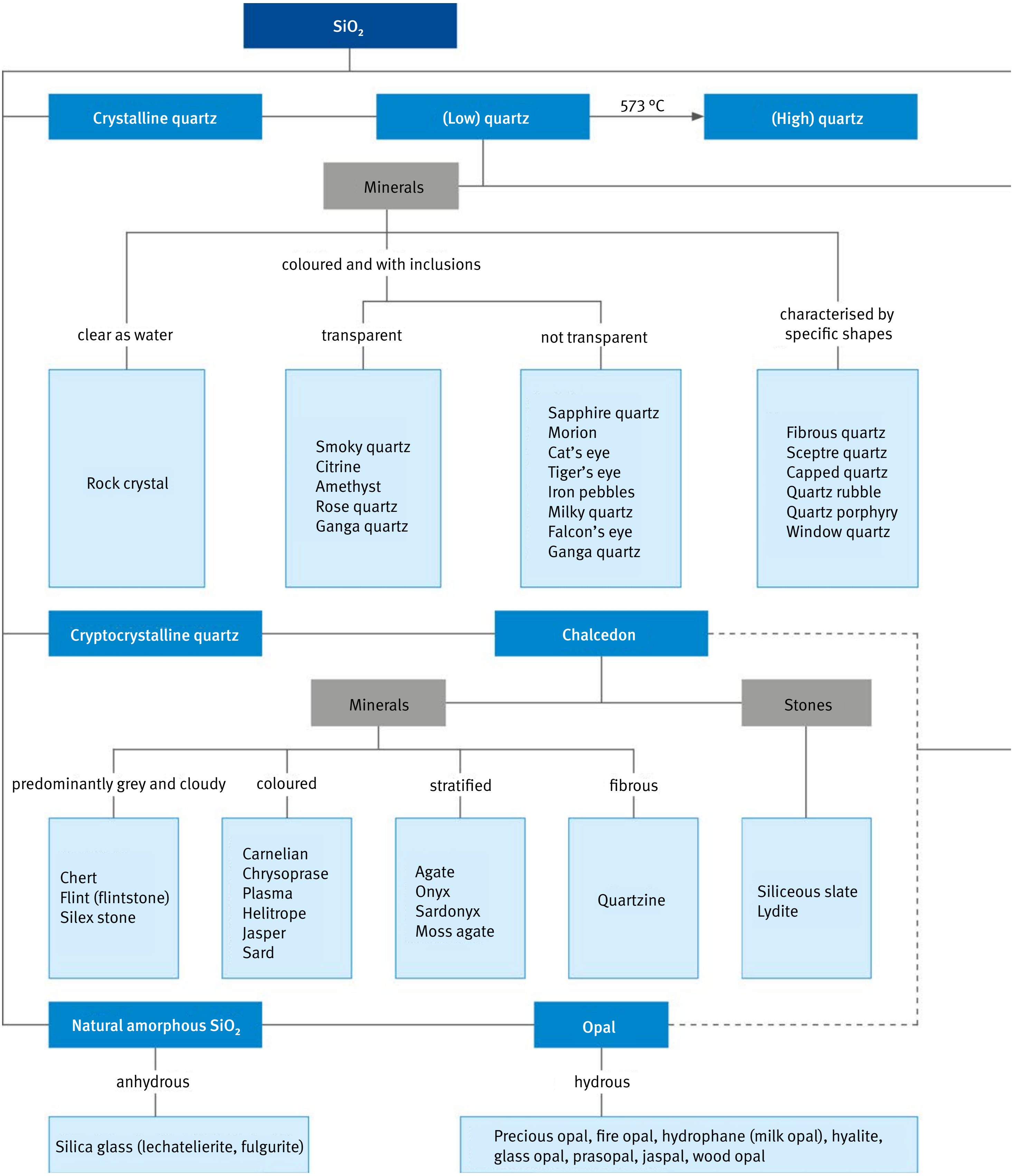
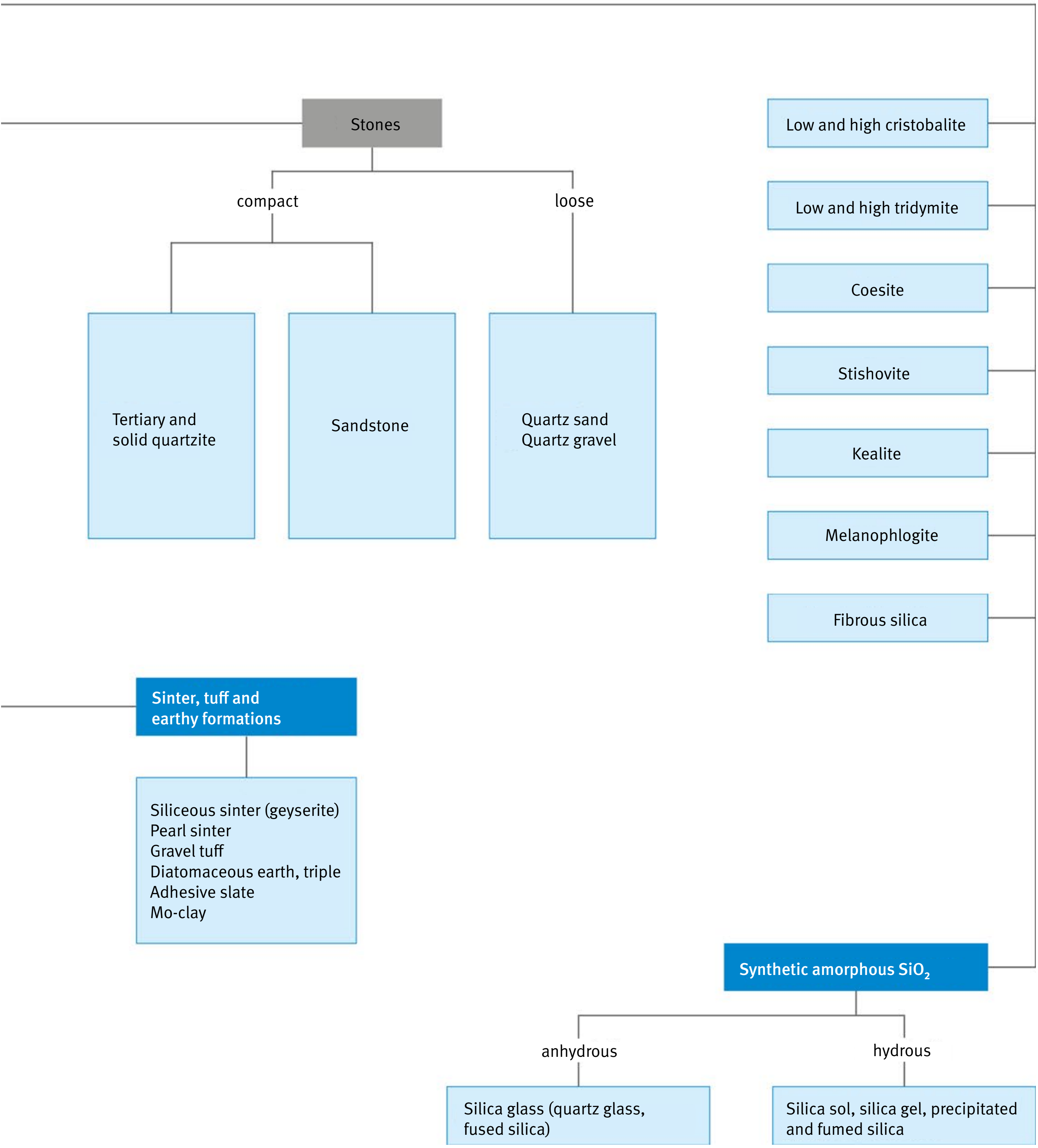


Figure 7:
Types of formation (varieties and modifications) of SiO_2 – source: from [4], adapted from [6]. Source: IFA




Stones
compact
loose
Tertiary and solid quartzite
Sandstone
Quartz sand
Quartz gravel
Low and high cristobalite
Low and high tridymite
Coesite
Stishovite
Kealite
Melanophlogite
Fibrous silica
Sinter, tuff and earthy formations
Siliceous sinter (geyserite)
Pearl sinter
Gravel tuff
Diatomaceous earth, triple
Adhesive slate
Mo-clay
Synthetic amorphous SiO_2
anhydrous
hydrous
Silica glass (quartz glass, fused silica)
Silica sol, silica gel, precipitated and fumed silica

2.3 Health hazards

Long-term (chronic) exposure to crystalline silica (CS – including quartz, cristobalite and tridymite) has a chronic detrimental effect on the lungs. Compared with barely soluble and insoluble (biostable) dusts that do not have any substance-specific toxicity within the scope of the General Dust Limit Value (GDLV, ASGW in German) [7], this effect is far more severe and occurs even at considerably lower air concentrations. These are chronic obstructive pulmonary disease (COPD) and silicosis (silica dust lung disease), which may also occur in combination with pulmonary tuberculosis (silico-tuberculosis), and lung cancer. Pathological changes in the lungs caused by dust inhalation are collectively known as “pneumoconiosis” (dust lungs). The period between the onset of exposure and the occurrence (latency period) of pneumoconiosis is quite long. For silicosis, the latency period is on average 35 years between the ages of 18 and 50, while for lung cancer it is even longer. However, if exposure is very high (approx. 75 mg/m³ in the inhalable dust fraction), as determined by Jeans for Turkish sandblasters, acute silicosis can develop after only a short time (a few months). The initial symptoms of a respiratory disease caused by quartz exposure can be a cough, phlegm and sometimes chest pain, as well as chronic bronchitis. It is important to diagnose these syndromes as soon as possible, as they can no longer be cured even at an early stage, but they can only be treated with regard to their severity.

How a human organism reacts to dusts absorbed via the respiratory tract (particle sizes up to approx. 150 µm) depends, among other things, on the size, shape and chemical composition of the particles. Inhaled particles that have not yet settled in the nasal cavity can be carried by a person’s breath via the larynx to the trachea and from there into the branching bronchi and bronchioles. The smaller the particles, the deeper they penetrate into the lungs, where CS – and also other bio-resistant dusts – cannot be degraded or dissolved.

Basically, the lungs have different cleaning mechanisms to remove particles deposited in them from the various areas. Mucociliary clearance transports particles deposited in the bronchi and bronchioles back into the pharynx through coordinated movements of the cilia. The smallest particles (with a diameter below 5 µm) then reach the alveoli. The deposited particles are then phagocytosed (i.e. absorbed into the cell interior) by alveolar macrophages which function as scavenger cells (phagocytes). Loaded in this way, the alveolar macrophages then migrate to the bronchial tubes. This process is also known as alveolar or macrophage-mediated clearance. Mucociliary clearance finally removes them from the lungs – together with larger particles already deposited in the bronchi – and they are either swallowed or coughed up. However, it is also possible that particles are not removed but enter the supporting tissue between the alveoli, the so-called lung interstitium, where in turn they may be “devoured” (phagocytosed) by macrophages. However, fine CS dust particles interfere with this process by interacting with cell membranes and other components of the cells lining the lungs (epithelial cells) and immune cells via the reactive groups on the particle surface. This process also kills off microphages, so that the particles stay longer than usual and therefore cause inflammatory reactions. As far as we know at present, long-term exposure to CS leads to chronic inflammatory reactions, which act as causal precursors of COPD, silicosis and lung tumours.

If there is an inflammation of the airways, the lungs initially react by producing a lot of mucus (bronchitis), which causes constriction of the airways. Prolonged exposure can also overstretch the lung tissue, especially the alveoli (pulmonary emphysema), and this can damage and eventually destroy them. This condition is referred to as COPD. One characteristic of silicosis is the formation of fibrosis in the alveoli as a result of a complex chain of reactions initiated by the interaction between CS particles with the alveolar macrophages and the subsequent release of messenger substances. Consequently, inflammatory reactions occur, which contribute to the development of fibrosis. Fibrosis is caused by increased growth of rigid (fibrous) connective tissue within the lungs, which causes them to stiffen and can lead to impaired lung function. Silicosis can also progress after exposure has ended, as dying macrophages release phagocytosed CS again, which then keeps the reaction chain going. Silicosis sufferers are more susceptible to tuberculosis, which can be attributed to reduced macrophage activity. It is considered likely that the mechanism for the development of lung tumours through CS exposure is a correlation between induced chronic inflammatory reactions and an increased growth (proliferation) of epithelial lung cells. Yet cancer may also be caused by direct interaction between reactive functional groups on the surface of the CS particles, on the one hand, and epithelial cells, on the other. Epidemiological studies suggest that the presence of silicosis increases the risk of developing lung cancer.

2.3.1 Deriving an assessment standard for quartz

The basis for deriving an assessment standard (AS) for exposure to respirable quartz and cristobalite [8] was human data (in epidemiological studies), taking account of both non-carcinogenic and carcinogenic effects. Although the data that is available about the harmful properties of inhaled CS dusts is highly comprehensive, it has not been possible for a number of reasons to establish an ambient air limit that meets the criteria of the AGS for deriving occupational exposure limits (OELs), values similar to OELs or risk-based ambient air limits. All the many studies on the harmful effects of CS particles have so far been inconclusive. These differences in efficacy can be explained by the assumption that the triggering factor for the different carcinogenic and non-carcinogenic action mechanisms is direct interaction of the quartz surface with cell membranes and other parts of the lungs. Freshly crushed CS surfaces are modified during processing by ageing and by various surface treatments (heating, etching, grinding). Such modifications affect surface reactivity, which is reflected in varying degrees of efficacy. The AGS was unable to derive any systematic and specific regulations from these insights. Furthermore, the relevant uncertainties in the exposure estimates, the inclusion of disruptive variables (confounders) such as smoking, and the findings arising from clinical of the case in question, the examination is performed difficult to derive any mandatory quantitative assessment standard (AS) from the data of the studies.

To obtain an AS, the data occurrence of silicosis and lung cancer through inhalation CS exposures were discussed in detail and compared with each other. However, a single COPD study, which would have resulted in an OEL of about 10 µg/m³, was not considered sufficient on its own. The discussions centred around the identification of a threshold value for the avoidance of inflammatory effects in the lungs – effects which must be regarded as precursors to severe secondary diseases. Falling below this threshold would therefore mean full protection against lung damage from quartz dusts. However, it was impossible to interpret the data with any certainty concerning the exact level of this threshold. Depending on the study and perspective, values were discussed that might allow the derivation of an ambient air limit between 10 and 100 µg/m³. As a best estimate, an assessment standard of 50 µg/m³ was set. This value is based on an epidemiological study showing an increased risk for the occurrence of silicosis at air concentrations of 150 µg/m³ or higher. To estimate a value with no adverse effects, a safety factor of 3 was applied. Given the uncertainties in derivation under the current state of science, even compliance with the AS does not necessarily imply the same level of protection as compliance with an OEL. The aim must therefore be to minimise exposure even further, even when the assessment standard under TRGS 559 [9] is being met.

3 Limit values and regulations

3.1 Limit values and their development (since 2005)

Information on limit values for quartz, cristobalite and tridymite and their pre-2005 development in the Federal Republic of Germany and the former German Democratic Republic (GDR) can be found in the 2nd edition of the IFA Quartz Report [10].

In Directive 2019/130/EU, “on the protection of workers from the risks related to exposure to carcinogens or mutagens at work”, the European Union has set a binding occupational exposure limit of 0.1 mg/m³ for alveolar crystalline silica (fine quartz dust) as an average of 8 hours [11]. In Germany, the AS for quartz-containing respirable dust of 0.05 mg/m³, adopted by the AGS and published in 2016, is applicable as the average shift value with an exceedance factor of no more than 8 (depending on the duration of exposure if exposure is reduced) [12]. This was included in the relevant technical rule in 2020, following the revision of the substance-specific Technical Rules for Hazardous Substances, TRGS 559 “Quartz-containing dust” [9]. It must be used and observed in all risk assessment and when checking the effectiveness of protective measures. Yet even if the assessment standard is not reached, a risk of cancer cannot be ruled out at the current state of scientific knowledge. Consequently, even if exposure falls below the AS, it needs to be further minimised in the spirit of the rationale underlying the standard.

3.2 Regulations

For occupational activities involving quartz or cristobalite, the following rules and regulations for the protection of workers’ health and safety must be observed in Germany in addition to the generally applicable rules:

- German Ordinance on Hazardous Substances (GefStoffV) [13], in particular Annex I No. 2.3, “Supplementary Precautions for activities involving exposure to inhalable dusts”,
- German Technical Rules for the Handling of Hazardous Substances (TRGS) 559 – Quartz-Bearing Dust [9],
- TRGS 500 – Protective measures [14] with a detailed section 9, “Protective measures for activities with exposure to dust”,
- TRGS 906 – List of carcinogenic activities and processes according to section 3 (2) no. 3 GefStoffV [15]; activities and processes in which employees are exposed to respirable dusts of crystalline silica in the form of quartz and cristobalite (with the exception of coal mine dust) are carcinogenic activities or processes according to section 3 (2) no. 3 GefStoffV.

In addition to these legal provisions, there is also a range of DGUV informative publications from the accident insurance institutions that can be consulted for risk assessments when working with quartz:

- DGUV Informative Publication 240-011 “Instructions for occupational health precautions in accordance with Social Accident Insurance Institution Principle G 1.1 Mineral Dust, Part 1: Quartz-Bearing Dust” (under revision),
- DGUV Informative Publication 213-730 “Mineral dusts during casting, cast removal and blasting in dental laboratories – recommendations for risk assessment by the accident insurance institutions (EGU) in accordance with the German Ordinance on Hazardous Substances" [16].
- DGUV Informative Publication 213-111 “Dust containing quartz in the ceramics industry”[17].

Other publications listed by the DGUV’s publications portal on “hazardous mineral dust” contain information on risk assessments and the protection of employees working with quartz: https://publikationen.dguv.de/regelwerk/publikationen-nach-fachbereich/rohstoffe-und-chemische-industrie/gesundheitsgefaehrlicher-mineralischer-staub/

4 Measurement procedures

4.1 Sampling methods

4.1.1 Respirable dust, definition and sampling systems

The harmful effect of quartz dust at workplaces is caused by its occurrence in the respirable dust fraction. The quartz load is therefore assessed on the basis of this dust fraction. Until 1993, respirable dust was classified as so-called fine dust, following the definition provided in the Johannesburg Convention in 1959. Theoretically, this particle spectrum corresponds to a collection of dust obtained downstream, after a separation system, with the separating function of a sedimentation separator. The permeability through such a pre-separator in accordance with the Johannesburg Convention has been drawn up for certain aerodynamic diameters in **Table 4** and is shown in **Figure 8**.

Since 1994, TRGS 900 has cited the European standard DIN EN 481 [18] as the basis for its definition of the respirable fraction. The two conventions are not identical, but their differences concerning practical distributions of dust particles are relatively small.

The previously used sampling systems for fine dust measurement could still be used, as their pre-separators had separation functions that showed only minor non-conformance with the function specified in DIN EN 481 [18]. The sampling systems used in the MGU are listed in **Table 5**.

The definitions of the inhalable and respirable fraction in DIN EN 481 are identical to those in DIN ISO 7708, which was adopted as a German standard in 1996 [19].

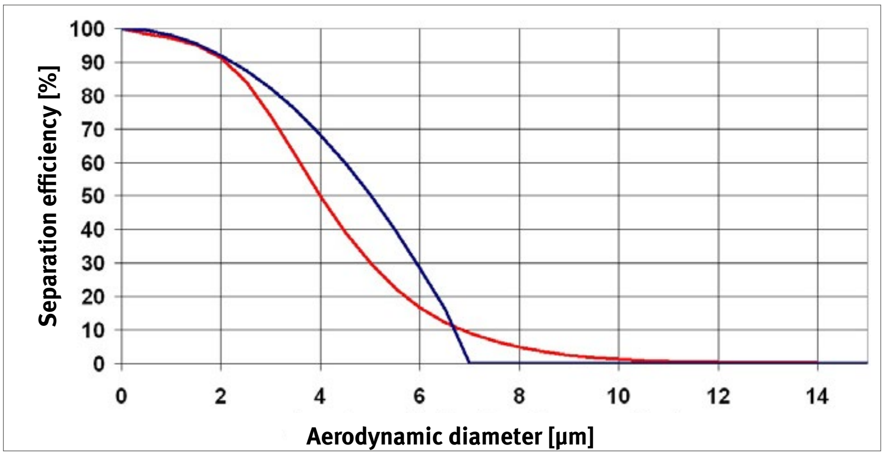


Figure 8:
Separation function for the respirable dust fraction according to the Johannesburg Convention (“fine dust”, blue line) and DIN EN 481 (“respirable dust”, red line). Source: IFA

Table 4:
Permeability of pre-separators according to the Johannesburg Convention and DIN EN 481

Johannesburg Convention (1959)		DIN EN 481 (1993)	
Aerodynamic diameter of dust particles with a density of 1 g/cm³ in µm	Permeability in %	Aerodynamic diameter of dust particles with a density of 1 g/cm³ in µm	Permeability in %
1.5	95	1	97.1
3.5	75	3	73.9
5.0	50	4	50.0
7.1	0	16	0

Table 5:
Currently used sampling systems for a respirable dust fraction with details of the air flow rate

Sampling system	Air flow rate in m³/h
Personal	
FSP-10, with 10-l cyclone and SG 10 pump	0.60
Stationary	
PM 4F cyclone pre-separator	4.0
VC 25F, pre-separation by impaction	22.5

4.2 Analysis methods

All sampling systems listed in Table 5 separate respirable dust on membrane filters. Based on these charged filters and the known throughout of the sample air volume, the quartz-containing respirable dust concentration must be determined in addition to the respirable dust fraction. In principle, the analysis methods available for this purpose are X-ray, infrared spectroscopy and, to a lesser extent, phase-contrast microscopy (estimation of the mass fraction of quartz-containing respirable dust). An X-ray analysis directly identifies not only quartz but also any detectable cristobalite components in the dust, as the peak position of the main cristobalite interference is close to one of the interferences analysed to determine the quartz content. The respirable dust concentration of cristobalite is determined in the same way as in the X-ray method described for quartz. The determination of cristobalite through infrared spectroscopy (IR spectroscopy) presents more problems because the relevant extinction band of cristobalite overlaps with one of the extinction bands of quartz. The X-ray diffractometric and infrared spectroscopic analysis methods for quartz and cristobalite were published in DGUV Informative Publication 213-582 [20]. To determine tridymite, it is possible to use a radiographic method similar to the method for determining quartz. Since tridymite is a polytype substance, it makes sense to use a calibration sample from the relevant work area.

Different calibration standards are used worldwide for both X-ray diffraction and infrared spectroscopic analysis (at the IFA: SF600 fine quartz powder). **Table 6** shows the detection limits for quartzcontaining respirable dust in the Sampling system and their dependence on the sampling system and the analysis method.

4.2.1 X-ray diffractometry

The membrane filter charged with the respirable dust fraction first receives a layer of 1.3-butanediol and is then annealed in a porcelain crucible at 550 °C, whereupon it is treated with hydrochloric acid. The residues are then transferred to silver membrane filters via vacuum filtration. The quartz content is detected and quantified through X-ray diffraction using the three characteristic interferences at d = 0.426 nm, d = 0.334 nm and d = 0.182 nm.

Based on a defined respirable dust mass on the membrane filters, a partial section of the filter covered with up to 2 mg of substance is used to carry out the quartz analysis. Next, the membrane filter substance is annealed in porcelain crucibles at up to 650 °C, and the annealed residue is then treated with hydrochloric acid in an ultrasonic bath. In this way, the hydrochloric acid-soluble components such as carbonates and iron oxides are dissolved. The remaining suspension is transferred to a silver filter via vacuum filtration, creating a thin homogeneous layer of fine dust on this filter, which is then analysed using X-ray diffractometry. To obtain a quantitative determination of quartz, it might at first seem sensible to start with the strongest interference of d = 0.334 nm. However, this can be severely disrupted, e.g. by the presence of mica. The second strongest interference of d = 0.426 nm and the third strongest interference of d = 0.182 nm should therefore also be analysed. The latter has proved to be largely free from interferences. If the layers on the silver filter are sufficiently thin, given a substance quantity of up to 2 mg, the mass of the fine quartz dust can be determined directly from the interference intensity on the silver filter – and indeed without having to allow for the mass attenuation coefficients in the available mineral mixture. With thick layers, however, this disregard is no longer acceptable. A detailed description of the analysis method can be found in DGUV Informative Publication 213-582 [20] (for basic guidance, see also [21]). For weakly charged filters with dust masses below 2 mg, it is a good alternative to use IR spectroscopy as it has a more useful detection limit.

4.2.2 IR spectrosscopy

The membrane filter charged with the respirable dust fraction is impregnated with 1,3-butanediol and incinerated at 600 °C. The residues are mixed with potassium bromide at a ratio of 1 to 250 and are then homogenised. From this, a partial quantity of 250 mg is taken and a compressed piece is processed. The maximum amount of dust that is used is therefore 1 mg.

The quantitative analysis is based on the characteristic quartz absorption double band with wave numbers 779 and 798 cm^{-1}. If the quartz content is high, it is also possible to use the weaker band at 695 cm^{-1} for analysis [22].

4.2.3 Phase contrast microscopy (not currently a standard method)

In phase-contrast microscopic quartz analysis, dusts are placed on a microscope slide, mixed with an embedding medium that comes very close to the refractive indices of quartz (e.g. Eugenol: $n_D = 1.542$), covered with a glass plate and examined. Dusts on membrane filters can easily be transferred from the filters to the glass plate as a suspension in the embedding medium using a lancet. Under positive phase contrast (white light), the quartz then stands out from all the other particles, which have different refractive indices and appear colourless, due to a special lighting effect. The quartz content can be estimated after examining about 100 visual fields. Furthermore, observation using crossed polarisers allows a differentiation between isotropic and birefringent mineral components [23]. This method is not used as standard, but is useful if you want to get an instant indication of the magnitude of the quartz content.

4.2.4 Occurrence of amorphous silicas

To determine the proportion of amorphous silica in dusts, an infrared spectroscopic method is used. However, the analysis method does not help to identify the type of amorphous silica in the sample. Neither is it possible to distinguish an amorphous silica from another amorphous material with a high SiO_2 content (e.g. window glass). To determine the concentration of amorphous silica in the work area, it is therefore crucial to have prior knowledge of the materials that are used or which occur. It must be determined in advance whether amorphous silica is used in a particular work process and what type of amorphous silica it is. In addition, it must be borne in mind that amorphous silica can be formed in certain processes, e.g. the melting of quartz sand (quartz glass/silica glass) and the production of silicon (silica fume) (see section 2.2).

Amorphous silicas can also contain portions of crystalline SiO_2 modifications; diatomaceous earth (kieselguhr) is of particular importance. This is a natural raw material consisting of deposits of diatom skeletons. Depending on the deposit, uncalcined diatomaceous earths may contain fractions of quartz. If diatomaceous earths are calcined, cristobalite is produced, the proportion of which is usually between a mass fraction between 50 and 80%. In such cases, amorphous and crystalline SiO_2 modifications must be identified and analysed separately.

4.2.5 Detection limits and the impact of the dust concentration

Under the most favourable conditions – no high dust concentrations and no interference from cross-sensitivity caused by other dust components – the detection limits listed in Table 6 can be achieved using the various sampling systems.

Since the achievable relative detection limit for the determination of quartz is essentially dependent on the amount of dust on the filters, special attention must be paid to the impact of the respirable dust concentration in the relevant work area. To carry out an analysis, only a limited amount of dust from the filter can be used (up to 2 mg for X-ray diffraction or 1 mg for IR spectroscopy). Therefore, the detection limit increases with a higher concentration of respirable dust. For stationary sampling using the PM4F and for personal sampling using FSP-10, the impact of the respirable dust concentration on the relative detection limit for quartz is shown in Table 7. The table compares the relative detection limits when determining quartz-containing respirable dust in air samples for different respirable dust concentrations. It can be clearly seen that the detection limit at a certain dust concentration in the work area cannot be improved any further by increasing the sampling duration. There is a simple rule of thumb: The relative detection limit of the quartz-containing respirable dust concentration in air measurements cannot be lower than one hundredth of the respirable dust concentration in the work area under assessment. In other words, if the respirable dust concentration in a work area is, for instance, 2.5 mg/m^3, the detection limit to determine the quartz content cannot fall below 0.025 mg/m^3 – irrespective of the sampling device, the sampling duration or the analysis method. This correlation is also shown in Figure 9.

Table 6:
Relative detection limits to determine the quartz-containing respirable dust concentration as a function of the sampling system and the sampling duration under the most favourable conditions

Sampling duration in hrs	Relative detection limit in mg/m³ when using the sampling system		
	VC 25F or VC 25I	PM 4F	FSP-10
0.25	0.014	0.040	0.067
0.5	0.007	0.020	0.033
1	0.004	0.010	0.017
2	0.002	0.005	0.008
4	0.0009	0.003	0.004
6	0.0006	0.002	0.003
8	0.0004	0.001	0.002

Table 7:
Relative detection limits for quartz respirable dust for stationary (PM4F) and personal sampling (FSP-10) as a function of the respirable dust concentration and the sampling duration

Sampling duration in hrs	Sampling using PM4F					Sampling using FSP-10				
	Respirable dust concentration in mg/m³					Respirable dust concentration in mg/m³				
	Quartz only	0.3	1.5	3.0	6.0	Quartz only	0.3	1.5	3.0	6.0
0.25	0.040	0.040	0.040	0.040	0.060	0.067	0.067	0.067	0.067	0.067
0.5	0.020	0.020	0.020	0.030		0.033	0.033	0.033	0.033	0.060
1	0.010	0.010	0.015			0.017	0.017	0.017	0.030	
2	0.005	0.005				0.0083	0.0083	0.015		
4	0.0025	0.003				0.0042	0.0042			
6	0.0017					0.0028	0.0030			
8	0.0013					0.0021				

Quartz only: there is pure quartz dust on the filter
Sampling using PM4F: the analysis method is X-ray diffraction (absolute detection limit: 0.04 mg)
Sampling using FSP-10: the analysis method is IR spectroscopy (absolute detection limit: 0.01 mg)

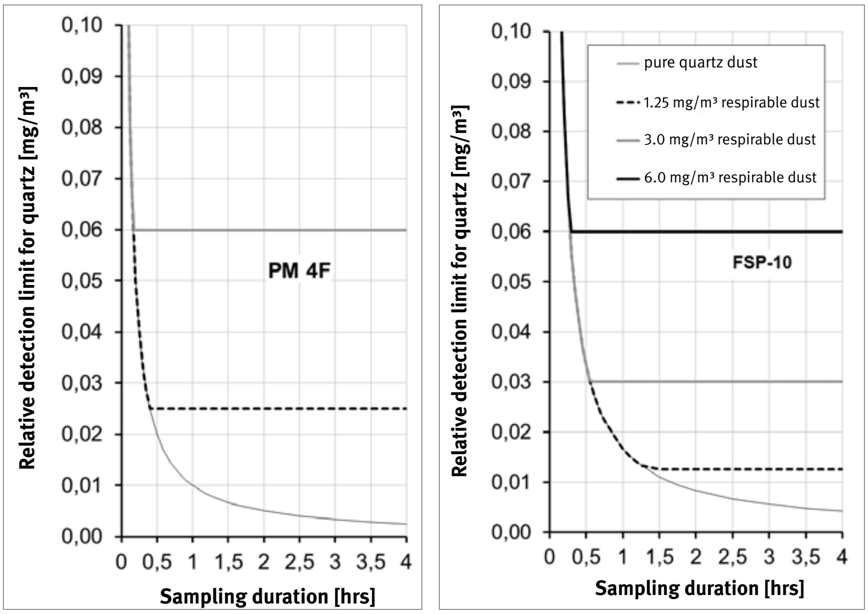


Figure 9:
Relative detection limits to determine the quartz-containing respirable dust concentrations of air samples as a function of the respirable dust concentration and the sampling duration, with the examples of the PM4F and FSP-10 sampling systems. Source: IFA

4.3 Comments on the measurement strategy and assessment of measured values

The measuring strategy in the MGU follows TRGS 402 – Identification and Assessment of Risks from Activities Involving Hazardous Substances: Inhalation Exposure. The work area, the exposure conditions and the measurement strategy are described in detail, following the Technical Rules on Hazardous Substances (TRGS) and the MGU's aim of determining and documenting valid exposure data.

Sampling procedure

Where measurements are carried out on a person, they involve personal sampling systems. The measured values obtained in this way can primarily be used for an individual exposure assessment.

Measurements using stationary sampling systems are also used in the MGU. Stationary measurements are carried out at breathing height and in the immediate vicinity of a worker, though also at a higher risk location, directly at the emission source. Measurement strategies, e.g. the distance of the sampling system from the emission source or from the exposed person, can differ greatly for stationary measurements, depending on the industry and the relevant work area. Such stationary measurements cannot therefore be used for individual exposure estimations without additional information on the distance of the sampling system to the emission source or to the exposed person.

Sampling duration

Metrological averaging of measurements over the entire duration of exposure during one shift is particularly suitable for determining the average shift value. If the sampling duration is shorter than the length of the shift, the minimum number of required measurements distributed over the length of the shift is based on Table 2 in Annex 3 of TRGS 402. For a sampling duration of at least 2 hours, the number of samples should be at least 1.

Measured values with sampling durations of at least 2 hours, which are predominantly applied in the MGU, can be considered comparable to the exposure during a whole shift and comparable with the OLE.

Measured values with sampling durations of less than 2 hours may have been taken to determine exposure during the assessed activity. On the other hand – especially with dust measurements – high dust concentrations may have caused the sampling pump to switch off early, so that measurement was prematurely terminated. If sampling is restricted to a person's working time, and also if the pump turns itself off due to high concentrations of dust, this may contribute to a situation where the measured results are generally higher for measured values with shorter sampling durations than for measured durations above 2 hours.

Local exhaust ventilation
Local exhaust ventilation (LEV) such as extractors are intended to reduce the concentration of hazardous substances in work areas. In the case of measurement results involving dust capture (LEV = yes), the dust released by the work or activity is captured and discharged via an extractor near the emission source. The MGU does not have any details on the effectiveness of LEV equipment at the assessed workplaces. In the case of measurement results without capture (LEV = no), the dust released during the work or activity is not collected.

If no or very little dust is expected as a result of the activity or work process, there is often no need for LEV equipment at such workplaces. Extremely dusty work areas, on the other hand are – where possible – equipped with LEV. As these are usually only installed at workplaces with high levels of dust but cannot prevent all dust exposure there, measured values involving documented LEV equipment can be higher than measured values that do not involve such equipment at virtually dust-free or low-dust workplaces.

5 Occurrence

5.1 Natural occurrence

5.1.1 Quartz

Second only to feldspars, quartz is the most common mineral in the earth's crust. It occurs in various areas of formation (Table 8).

Quartz is a major component in acidic igneous rocks, both intrusive and effusive (e.g. granite, rhyolite). Granites contain between approx. 10 and 50 wt% quartz. The more alkaline the rock, the lower the quartz content. Basalts and gabbros usually contain no quartz at all or only very little. In pegmatitic rocks, one main component is quartz, often in the form of particularly large crystals.

In hydrothermal formations, quartz occurs as a vein, mostly in paragenesis with numerous ore minerals. Under favourable conditions of formation, very pure rock crystals are formed.

The sedimentary rocks formed as a result of erosion sometimes have a very high quartz content. Also, extremely pure sandstone can form due to the special weathering resistance of quartz. Depending on the proportion of additional components (feldspars, layered silicates, carbonates, etc.), smooth transitions to greywackes, arkoses and lime sandstone are formed. In clay stones (silt stones), quartz is usually present at mass fractions between about 20 and 40% [24].

Table 8:
Typical quartz contents of various rocks [25]

Rocks	Quartz content in wt%
Magmatic rocks	
Plutonite (plutonic rocks)	
Silexite, peracidite	› 50
Granite, granodiorite, tonalite, quartz diorite	10 to 50
Quartz syenite, granosyenite, quartz monzonite, quartz diorite	Less than 10
Syenite, monzonite, diorite, gabbro, anorthosite, peridotite, essexite, theralite, basanite, phonolite, tephrite, pyroxenite, hornblendite, dunite, foidolite, nephelinite, fojaite, leucite, melilite	Usually quartz-free
Volcanic rocks (igneous rocks)	
Rhyolite, rhyodacite, dacite, quartz keratophyre, quartz porphyry, quartz porphyrite	10 to 50
Quartz trachyte, quartz latite, quartz sandesite, keratophyre, porphyry, porphyrites	‹ 10
Trachyte, latite, andesite, basalt, foidite, porphyrit, melaphyr, diabase, picrite	Usually quartz-free
Metamorphic rocks	
Quartzite, mica quartzite, quartzitic gneiss, quartz phyllite, quartz mica schist	› 50
Gneiss, phyllite, mica schist, chlorite schist	‹ 50
Talc shale, amphibolite, eclogite, marble, dolomite marble	Quartz-free ‹ 10
Sedimentary rocks	
Sandstone, quartz sandstone, feldspathic sandstone, phyllous sandstone, lime sandstone*, siliceous shale	› 50
Quartz greywacke, (low quartz) greywacke, arkose, quartz arkose, feldspar arkose, siliceous limestone, siliceous slate	10 to 70
Clays, clay slate, shale, slate clay	‹ 50
Chalks, limestone, limestone shale, chalk, marl, gypsum, dolomite	Quartz-free ‹ 10

*naturally formed lime sandstone (for technically produced lime sandstone see section 9.6)

Quartz fractions can also occur in limestone. Furthermore, quartz can be a component of biogenic sedimentary rocks. Deposited opal skeletons of diatoms, radiolarians or siliciferous algae give rise to loose, microporous or even massive rocks (diatomaceous earth, tripolite, siliceous slate, radiolarites), where subsequent recrystallisation can result in cryptocrystalline quartz as well as cristobalite.

Metamorphic rocks form through subsequent transformation processes from both igneous and sedimentary rocks. Quartz contents in metamorphites therefore depend on the source rocks of the metamorphosis. Metamorphosis creates, for example, quartzites from pure sandstones and gneisses from granites.

An overview of the quartz contents of different rock types can be found in [25]. Weathering of rocks leads to soil formation. In this process, some of the rock-forming minerals undergo a transformation. However, the relatively resistant quartz remains largely intact within the weathering layers. Wind erosion and subsequent sedimentation of this material creates, for example, loess soils, which are used intensively in farming. Soils can contain different fractions of quartz, depending on the weathered rock type and the specific processes of soil formation [26].

Opals consist of amorphous silica. Chalcedony in its many varieties (e.g. agate, onyx – see Figure 7) consists of a mixture of crypto-crystalline quartz and amorphous silica.

In the USA, in addition to the limits on quartz, cristobalite and tridymite, there is a further limit for the concentration of fine quartz dust in tripolite. In Germany, tripolite is referred to as *Tripel* and, in older literature as *terra tripolitana* [27]. In the TLV list (list of threshold limit values), tripolite is also categorised as a crystalline form of SiO_2. From a mineralogical point of view, however, the term *Tripel* (tripolite) is used as a synonym for silica, which consists of sedimented skeletons of radiolarians and diatoms and is thus a variety of opal ($SiO_2 + nH_2O$, amorphous) [26]. American tripolite, which is used as an abrasive for surface treatment, is described in [27] as amorphous silica without crystalline SiO_2. In addition to SiO_2, this product contains approx. 8% other components (including iron, aluminium, and – to a lesser extent – also magnesium, manganese, titanium).

5.1.2 Cristobalite

Cristobalite occurs in the cavities of acidic to intermediate effusive rocks such as trachytes and andesites. Cristobalite also occurs sporadically in the groundmass of trachytes [2]. Furthermore, it is present in many agates and sometimes in bentonite (found in Wyoming, USA). Cristobalite can also be formed in biogenic sediments from siliceous organisms as a result of subsequent crystallisation.

5.1.3 Tridymite

Natural tridymite usually contains small amounts of alkalis. It occurs sporadically and mostly only in small amounts in the cavities of acidic to intermediate effusive rocks (trachyte, andesite).

5.2 Synthetically manufactured crystalline SiO_2 modifications

5.2.1 Quartz

Low quartz is synthetically manufactured through hydrothermal synthesis. It crystallises in an autoclave. Crystallisation occurs from an SiO_2-saturated aqueous solution on seed crystal plates in a temperature gradient (detailed description in [28]). Global production in 1982 was about 300,000 tonnes per year.

5.2.2 Cristobalite

The starting product for the synthetic manufacturing of cristobalite is quartz sands. They are treated in a rotary kiln with the addition of catalysts (alkali compounds) at approx. 1,50 °C. The resulting cristobalite sands have a cristobalite content of 85 to 90 wt% (determined by X-ray) as well as SiO_2 glass phase [4]. Cristobalite may also occur in silica bricks produced in Siemens-Martin furnaces and as a devitrification product of quartz glasses. Calcined diatomaceous earths can have high levels of cristobalite.

5.2.3 Tridymite

Cristobalite can be converted into tridymite through reconstructive transformation. This process only works at very high temperatures and requires a high level of activation energy [4]. The synthetic production of tridymite is of no industrial significance. Tridymite can also be found in silica bricks produced by Siemens-Martin furnaces, in coke oven bricks and as a devitrification product of quartz glasses.

6 Use and appearance

6.1 Quartz

6.1.1 Extraction of quartz-containing gravels and sands

Quartz gravels and sands which occur naturally in the form of detritus of crystalline minerals, are important raw materials for industry. They are extracted from sedimentary deposits, and preparation comprises washing, screening, crushing, grinding, sorting and, where appropriate, use of a dryer.

Gravels are usually sold with particle sizes between 2 and 48 mm.

Sands are used in a moist or dry state, with defined degrees of purity and fineness and in various particle sizes. They are used as raw materials and also as moulding, auxiliary and abrasive materials. By chemically modifying their surface, it is possible to achieve improved cross-linking and bonding with other substances.

Quartz powders are obtained from high-purity quartz sand through iron-free grinding and separation processes. This can produce fractions with particle diameters of a few µm.

6.1.2 Foundry industry (foundry sands)

Thanks to its physical and chemical properties as well as its fire resistance, quartz is suitable as a mould base material for the foundry industry [29]. The onset of sintering of quartz sands consisting of over 99% SiO_2 is above 1,500 °C [4]. The particle content of less than 20 µm in diameter should be as small as possible. Preference is given to sands with rounded edges (natural particles) and monomineralic particles.

6.1.3 Chemical industry

Quartz sand is a raw material for the production of a number of chemicals, which in turn are the starting points for synthesising a wide range of compounds.

Waterglass (sodium and potassium silicates) is obtained by heating mixtures of quartz sand (particle size: 0.1 to 0.5 mm) and alkali carbonates at 1,600 °C. A large proportion of alkali silicates are used in the production of detergents and cleaning agents. Furthermore, it is used to produce, for example, fillers, catalysts, silica sols and gels or waterglass paints.

Silicon carbide is produced in an electric resistance furnace during the chemical conversion of silica sand and petroleum coke. It is an important abrasive as well as a material for refractory goods and electrically conductive heating elements and is also used, for example, to increase the resistance of floor coverings to both wear-and-tear and slipping.

Silicon tetrachloride is produced from quartz sand, silicon carbide and coke through chlorine treatment in a fluidised bed reactor. Ultrapure silicon can be obtained from silicon tetrachloride through thermal decomposition. Highly dispersed silica is produced through combustion.

Organosilanes, organic silicon compounds are synthesised from pure silicon, silicon tetrachloride and other halogen silanes. Diorganodichlorosilanes are the starting materials for the technically very important silicones.

Silicon as an element is initially obtained as raw silicon through a carbothermic reduction of quartz with the aid of coke (or aluminium), whereupon it is processed into high-purity silicon for use in solar cells and computer chips. The transition via a silicon stage is also used in the synthesis of high-purity silicon halides [4].

Quartz powder and sand are extremely suitable as fillers for casting resins, moulding compounds and casting compounds. The benefit of quartz as a filler in casting resin is that it does not compromise the properties of the casting resin, e.g. pot life.

Another field is the use of quartz sand and powder in coatings such as varnishes, paints and fillers, as well as in adhesives, cleaning agents and care products. Large quantities are also used in technical rubber goods, tyres and plastics.

In many cases, amorphous silica, which is produced from quartz sand, is also used as a filler for the applications described here.

Quartz particles treated with Pigmosol dyes or oxide colours (so-called colour fractions) can be used, for example, as aggregates in decorative renderings and in casting resins for a decorative surface finish.

6.1.4 Ceramics industry

Clayey raw materials, but also various silicate and non-silicate minerals, serve as basic raw materials for both fine and coarse ceramics. Clay(kaolin) is a fine sediment formed by the weathering of feldspathic rocks. As a natural impurity, clay always involves free quartz. Mineral analysis shows that the quartz content ranges from 5% for highly plastic clays to 70% for loam sands.

However, quartz sand and powder are also used as aggregates and tempering agents in ceramic masses.

During glazing – the last stage in the finishing of most ceramic products – quartz serves as a crosslinker and acts as an aggressive flux at high temperatures. Depending on the particle size and the accompanying impurities, it is possible for cristobalite to form from the quartz melt.

Some typical products in course ceramics are bricks, limestone products and ceramic building products such as large stoneware (vitrified clay pipes). In refractory ceramic products, cristobalite is also contained in the fireclay that is used as a raw material as well as in silica bricks. The most important products in the fine ceramics industry are tiles, pottery products, sanitary ceramics, porcelain and technical ceramics.

6.1.5 Glass industry (glass sands)

Quartz sand makes up the majority of starting materials for industrially produced glass, accounting for 50 to 80% of the total. This includes products made from sheet glass (window and car panes), hollow glass (bottles, drinking glasses, light bulbs, screens) and other products such as laboratory glassware and glass fibres.

Ultra-pure quartz such as rock crystal and gangue quartz is suitable for the production of quartz glass and optical glasses. Other raw materials for glass production are soda, limestone, marble and calcareous clay as well as special oxides, such as lead oxides for the production of lead crystal glass. The particle size of the raw materials is between 0.05 and 0.5 mm.

Quartz exposure can occur while mixing the raw materials, weighing out the mixture into the melting furnace and during the actual melting process. After melting, SiO_2 is available in amorphous form (glass).

6.1.6 Filter sands and gravels

Quartz sand filters are used for the filtration of process water and turbid solutions. Depending on the application, quartz filters are sold with different particle sizes, specific pore widths and with different filter bed heights. One important area of application is, for example, the filter stages in deferrisation, demanganisation and decarbonation facilities.

6.1.7 Electrical engineering

Quartz and quartz-containing materials are used in various manufacturing processes in electrical engineering, e.g. as an aggregate in the production of cables and insulators as well as in electrical and electronic components. The assembly of such components usually involves mechanical finishing, when quartz dusts can be released.

6.1.8 Electrical installations

During electrical installation work, quartz-bearing dusts are produced from building materials, while cutting chases for electrical cables, producing recesses for switches and distribution boxes, drilling holes for expandable plugs and performing impact drilling work. Depending on the types of stone that were treated, different proportions of quartz were identified.

6.1.9 Precision mechanics and dental engineering

In dental laboratories, casting materials are processed that contain up to 50% quartz and cristobalite. Quartz and cristobalite dusts can therefore occur during casting and cast removal and also curing decanting, refilling, portioning and when blasting a model.

6.1.10 Construction industry and building material industry

Natural mineral raw materials are used technically on a large scale, both in loose and hard form.

Sands and gravels are used, among other things, in the construction of roads and footpaths and also as aggregates in the production of concrete. Moreover, sand is an important component in the production of mortar compounds and synthetic mineral building materials such as bricks, slabs/panels, moulded elements and refractory materials. In addition, they are used as raw materials for the extraction of the ultra-pure quartz fractions, including quartz powders.

Hard rock is mainly used in the building materials industry [30] to make gravel, chippings, including high-grade chippings, crushed sand and rock powder. The materials are used in the construction of roads and footpaths and also as aggregates in the concrete industry and for the production of bituminous mixtures (e.g. asphalt).

Natural stone is used to make façade cladding, ashlars, stairs, slabs/panels, paving, kerbstones and gravestones, among other things. The quartz contents of the most important rock types are listed in *Heidermanns* [25] (see Table 8).

Quartz sands are used for special concretes, mortars, screeds and plasters. Mixtures of sand and lime are used in the manufacture of sand-lime bricks. Lightweight sand-lime brick and aerated concrete are made from sand ground to a fine powder. Deep drilling in the oil and gas industries involves the use of containing cement slurries.

In addition to the use of mineral raw materials in products, a major role is also played by the removal and movement of rocks and earth materials. Both in tunnel construction and in earthworks, large quantities of mineral material are removed, transported and then placed in other locations. Furthermore, quartz dusts are released during the dismantling and redevelopment of buildings containing mineral construction products.

6.1.11 Work on precious stones

In the jewellery industry, several varieties of quartz and cryptocrystalline quartz are used as precious and semi-precious stones. These include, for instance, amethyst, smoky quartz, citrine, rose quartz, chrysopa, agate and onyx [2]. The level of crystallisation can vary for precious stones. Therefore, grinding must be expected to produce not only crystalline fractions but also amorphous silicon compounds (amorphous silica).

6.1.12 Grinding, polishing and abrasive agents

Quartz is particularly suitable for coarse grinding due to its great hardness and sharp edges (mechanically crushed quartz), although it is hardly ever used for this purpose [27]. Today, other substances dominate as abrasives, such as silicon carbide and corundum. Quartz powders are used, for example, in tumble polishing and for wet pumicing [27] as well as in liquid and pasty scouring and cleaning agents. Quartz is used for the production of silicon carbide.

6.1.13 Blasting agents

Until the Second World War, nearly all the blasting agents that were used were quartz sands [31]. Due to the high risk of silicosis for blasting workers, silicogenic blasting agents were increasingly replaced with various substitutes [32]. Today, with a few exceptions, the use of silicogenic blasting agents is prohibited. According to section 4.2.1(3) of TRGS 559 “Quartz-Bearing Dust”, silicogen-free media are defined as media with a quartz content of no more than 2% (by mass), including cristobalite and tridymite.

6.1.14 Other applications

Quartz sands are also used as inert materials in circulating fluidised beds (waste incineration), in bird sand, as roofing gritting material, in hand wash pastes, in golf course construction, in children’s sandpits, in beach volleyball courts, for sandpaper, in drinking water filters and as braking sand for railway rolling stock.

6.1.15 Other occurrences and unintended use

Farming and gardening
Soils that are used for agriculture may contain varying amounts of quartz. Some of it may also occur within the respirable fraction. Soil tests have shown that their respirable fractions (about 0.01 to 0.2 mass % of the soil) contain quartz fractions of 1.6 to 3.4 % in clayey soils and 10.5 to 44.5 % in sandy soils [33].

Apart from agricultural tillage and other soil operations, exposure to quartz may occur when sorting potatoes, onions and other products that have soil attached to them.

Road and construction site traffic
Depending on its origin, quartz may be present in the dust that collects on roads and sealed ground surfaces in cities. This dust is swirled up by vehicle traffic, but also when streets are cleaned, e.g. by sweeping vehicles. Especially on unpaved roads, like those sometimes encountered on construction sites, high levels of dust turbulence can be caused by vehicle traffic on dry surfaces.

Power stations and waste incinerators
Dross and skimmings from power stations and sometimes also from waste incinerators and their fly ashes (filter dusts) may contain quartz. Cristobalite was occasionally found in slags. This mineral waste is recycled e.g. in road construction and in mines (backfill).

Use of building materials and mineral raw materials
Natural mineral raw materials that are used for technical purposes can contain quartz to varying degrees. They include fillers in general, talcum powder, lime powders, clay powders, bentonite and kaolins. For example soils of less than 1 and up to 25% were found in various kaolins.

6.2 Cristobalite

Cristobalite is obtained from quartz through thermal treatment and is used as a filler in road marking paints, compounds and façade paints, coatings and synthetic renders, silicone rubber, mould printing materials, synthetic resin varnishes, adhesives and casting resins. Other special applications for cristobalite are its use in abrasives (scouring and cleaning agents on a liquid or pasty basis), for the production of bird sand, as an additive to light-coloured building materials to obtain light clear colours, and the use of mixtures of cristobalite and quartz and quartzware in casting compounds (dental, jewellery and other precision casting).

If diatomaceous earth is calcined, a more or less large proportion of the amorphous silica is turned into crystalline form during calcination, mainly into cristobalite. Depending on the manufacturing process, cristobalite may also be found in bentonite.

Diatomaceous earths are used as filtration agents, especially in the beverage industry. In 2014, for example, approx. 70,000 tonnes of diatomaceous earth was used in Germany.

6.2.1 Cristobalite from fibres

In furnaces, aluminium silicate and high temperature glass fibres are used for insulation purposes. Both fibres form cristobalite during thermal treatment above 900 °C due to recrystallisation when cooling. In aluminium silicate fibres, approx. 10% cristobalite is formed, and in high-temperature glass fibres up to 40%. Exposure occurs when the insulation is removed [34]. As high-temperature wool is used not only in furnace construction but also, for example, on kiln cars in the ceramics industry, exposures also occur when these facilities are operated or repaired.

6.2.2 Other occurrences and unintended uses

The formation of cristobalite from quartz and other Si-containing materials during thermal processes also leads to cristobalite exposure in other areas.

One example is the occurrence of cristobalite in foundries, where the multiple use of sands leads to the occurrence of cristobalite in rendering. Cristobalite can also be released through the use of diatomaceous earth as an auxiliary material. Cracking of casting lLODes leads to the release of cristobalite from fireclay.

In the manufacture of ceramic products such as grinding discs, quartz sand is occasionally used to sprinkle kiln cars to prevent workpieces from sticking. The repeated use of such sands leads to the formation of cristobalite. Furthermore, cristobalite also occurs as a component of fireclay. It is used, for example, in ceramic mixes for the production of fire-resistant ceramic products.

6.3 Tridymite

Tridymite is of no commercial significance. This crystalline SiO_2 modification can, however, be contained or formed in refractory building materials (e.g. In silica bricks produced by Siemens-Martin furnaces and in coke oven bricks) and may occur as a devitrification product of quartz glasses.

7 Data situation and evaluation strategy

For quartz (crystalline silicon dioxide) in the respirable dust fraction, TRGS 559 specifies an assessment standard (AS) of 0.05 mg/m³ for Germany.

7.1 Selection criteria for statistical evaluations

- Hazardous substance: Quartz (crystalline silicon dioxide)
- AS: 0.05 mg/m³
- Period in which the data were collected: January 2005 to December 2016
- Air samples with exposure relevance
- Workplace measurements
- Sampling systems for the respirable dust fraction (standard MGU method)
- Sampling representative of the exposure period
- Usual operational situations (normal operation, setup, dismantling, start-up work, preparations, set-up work) and unfavourable but realistic conditions.

7.2 Data situation

During the data capture period from January 2005 to December 2016, the selection criteria presented in section 7.1 resulted in the data situation for quartz measurements presented in Table 9.

Table 9:
Data situation of the quartz measurements analysed for the report

General description	Number of measured values and (%)
Total	15,104
Sampling method	
Personal	6,832 (45.2%)
Stationary	
Old code	6,397 (42.3%)
Person-specific for exposure assessment	1,001 (6.6%)
Background exposure for exposure assessment	853 (5.6%)
Limit value reference	
Number of data items › AS	3,387 (22.4%)
Number of data items AS not assessable	183 (1.2%)
Sampling duration	
≥ 2 hrs	12,492 (82.7%)
‹ 2 hrs	2,612 (17.3%)
Local exhaust ventilation	
Without LEV	4,799 (31.8%)
With LEV	7,311 (48.4%)
No details	2,994 (19.8%)

7.3 Evaluation strategy

- Differentiation by sampling procedures:
  - Personal
  - Stationary

- Differentiation by sampling durations:
  - ≥ 2 hrs
  - ‹ 2 hrs

- If data collectives with more than 40 person-based measurements show limit values being exceeded in the 95th percentile, measurements were differentiated by:
  - LEV = yes
  - LEV = no

- The statistical analyses were carried out for:
  - Groups of work areas in different groups of sectors
  - Cross-sector groups of work areas

- If analysis results were below the relevant limit of detection (LOD), then the value of half the LOD was included in the statistics.

- Data sets with less than five measured values were not analysed and are not shown.

- If a data set had five to nine measured values and there were measured values exceeding the limit, the minimum and maximum = values (measured values above the relevant LOD) are shown.

- Data sets from the work area group of other work processes that could not be assigned to a different group (Other Work Areas) are not shown.

7.4 Tables of results, abbreviations and footnotes

General comment: In data sets with very few measured values (number of measured values less than 40), even single extreme values may have a strong impact on the 90% and 95% values.

7.4.1 Abbreviations and footnotes in the results tables

The following abbreviations and footnote comments are used in the results tables (Table 10).

Table 10:
Abbreviations and footnote comments in the results tables in the following chapters

Abbreviation	Explanation
LOD	Limit of detection
Values ‹ LOD*	Number and percentage of measured values below the detection limit in the data set
Highest LOD	Highest detection limit in the data set: The LOD is higher with a lower sample air volume than the LOD of the standard procedure mentioned in the introduction. The sample air volume is calculated as the product of the sampling duration and the volume flow.
No details	No details are possible
*	If analysis results are below the relevant analytical detection limit, then the value of half the LOD is included in the statistics.
**	Data from less than five companies may not be suitable to represent an entire industry or part of it.
***	The data set contains between five and ten measured values. If limits are exceeded, the minimum and maximum measured values are shown.
+	The distribution value is below the highest LOD in the data set.
!	The number of measured values below the LOD is greater than the number of measured values represented by this percentile. Hence, no concentration is specified for this percentile.

7.4.2 Standardised table of results

Table 11:
Standardised table for the presentation of quartz exposure data in the following chapters

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	Column 11	Column 12
Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n.a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
Sampling duration											

Column 1: Sampling procedure
The way in which sampling took place, i.e. either Personal or stationary

Column 2: Number of measured values
Number of measured values

Column 3: Number of companies
Number of companies

Column 4: Number of values ‹ LOD*
Number of values below the detection limit of the relevant measurement procedure

Column 5: Values ‹ LOD* in %
Percentage of values below the detection limit of the relevant measurement procedure

Column 6: Highest LOD* in mg/m³

Highest detection limit in the data set

Columns 7 and 8: ≤ AS in % and › AS in %

Percentage of measured values below and above the AS

Column 9: AS n.a. in %

Percentage of measured values not assessable (n.a.) in relation to the AS

Column 10: 50th percentile* in mg/m³

For this value, 50% of the available concentration values are below this value, and the other 50% are above it. If the distribution value is below the highest LOD in the data set, the value is marked with a +.

Column 11: 90th percentile* in mg/m³

For this value, 90% of the available concentration values are below, and the remaining 10% are above this value. If the distribution value is below the highest LOD in the data set, the value is marked with a +.

Column 12: 95th percentile* in mg/m³

For this value, 95% of the available concentration values are below, and the remaining 5% are above this value. If the distribution value is below the highest LOD in the data set, the value is marked with a +.

Sampling duration:
sampling duration of the measurements (≥ 2 h, ‹ 2 h) in relation to the statistical results shown below.

7.5 Quartz and cristobalite in the same working area

In some work areas within certain industries, cristobalite can also occur and be detected in the respirable dust fraction, in addition to quartz.

7.5.1 Statistical evaluations

The following statistics were calculated for the evaluation of measured values from work areas where cristobalite was detected in addition to quartz.

Quartz
Statistics on all measured quartz values in the relevant work area that meet the selection criteria

Cristobalite
Statistics on all measured cristobalite values in the relevant work area that meet the selection criteria

Quartz and cristobalite – pairs combined

Statistics on the total of measured quartz and cristobalite values in relevant work areas where cristobalite was detected in addition to quartz. In the case of measured quartz values for which there was also a cristobalite value from the same sample (pairs), the two values were added together for statistical evaluation. The measured values were added up using the following rules (Table 12).

In the results tables, due different LODs for quartz and cristobalite, no details of the numbers and percentages of measured values below LOD or the highest LOD can be given in the data set for these statistical analyses.

This data is the sums of the silicogenic components and can therefore be compared with the AS for quartz, as the assessment is not carried out separately for quartz and cristobalite.

Quartz with cristobalite values
Statistics of the quartz measured values in the relevant work area for which there is also a measured value for cristobalite from the same sample.

This data is helpful in determining the exposure to silicogenic components (quartz + cristobalite) that can be expected if both components are detectable in the dust.

Table 12:
Rules for adding up measured quartz and cristobalite values in the same work area

Signs qualifying the individual MVs	Total of the individual MVs	Signs qualifying the total of the individual MVs
Both MVs are "=" values:	$MW_{Quartz} + MW_{Cristobalite}$	"=" sign
A MV is a "<" value	"=" value + ½ "<" value	"=" sign
Both MVs are "<" values	$MW_{Quartz} + MW_{Cristobalite}$	"<" sign

8 Extraction and processing of stones, earths and raw materials

8.1 Extraction and processing of limestone and dolomite

Sector
Limestone, extraction and processing
Limestone, extraction
Gypsum, chalk, extraction
Dolomite, extraction

The extraction and preparation of limestone, gypsum, chalk and dolomite involves working methods with separate activities described in section 8.4. The conclusions reached there are equally applicable here. Preparation is dominated by dry methods. In addition to the degree of comminution, the significantly lower quartz content of these processed minerals must also be borne in mind. In a few occurrences of limestone, quartz content was found in the respirable dust in excess of 10% compared with usually less than 5%. This affected the result of the evaluations accordingly. The chronological progression of the measured values for the periods since 1972 (cf. BGIA Report 08/2006 [10]) shows a considerable reduction of dust loads for the entire industry, which has been achieved through the application and improvement of dust removal measures.

The following workplaces with dust exposure can be found:

- in mining operations during drilling work to produce the blasting system and on conveyors and loading equipment (excavators, wheel loaders, heavy-duty trucks) with cabs without pressure ventilation systems,
- in material preparation within open and enclosed facilities,
- in the loading of the finished products.

The measured values for the period from 2005 to 2016 show dust loads for the entire industry that are below the AS for quartz for specific persons(equipment operators, plant fitters, test lab activities). High exposures can occur when vehicles are operated with their windows open. Stationary measurements, on the other hand, which are often taken in work areas not permanently occupied by mechanical material stress (crushers, screening equipment), occasionally show higher concentrations at the level of the AS.

Table 13:
No differentiation by work areas – extraction and processing of limestone and dolomite

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n.a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	19	13	16	84.2	0.021	94.7	5.3	0	LOD !	0.0148 +	0.0245
Stationary	14	11	6	42.9	0.047	85.7	14.3	0	0.017 +	0.0518	0.0599

8.2 Mining

Sector
Lignite extraction and processing
Hard coal extraction and processing
Ore extraction and processing
Mineral extraction and processing, other

The data set comprises the extraction, manufacture and preparation of raw materials in underground and surface mining operations. This evaluation also includes ancillary work in control rooms, quality control and, where applicable, packaging of the products, which are usually bulk products piled up.

In both surface and underground mining operations, the extraction and preparation methods are those listed in section 8.4. Civil engineering operations predominantly involves processing equipment operated in enclosed spaces – often underground because of noise and dust emissions and under special ventilation conditions. Progressive extraction also requires robust mobile technology for dust capture. While mostly dry methods are used underground (except for drilling operations which involves controlled addition of water) and in the extraction of unconsolidated rock, dry and wet methods are used in the preparation of solid rock above ground. Especially underground, higher dust exposure can therefore occur during extraction and preparation activities, e.g. during comminution. This often affects plant operators, for example of drilling and milling equipment, as well as fitters, whereas pressurised and air-conditioned cabins in transport vehicles are state of the art. Stationary equipment, too, is usually operated from air-conditioned monitoring consoles.

Although the GDLV are mostly not exceeded (cf. IFA Report 6/2020 [35]), due to the typically high quartz contents of certain raw materials in deposits, especially in mineral mining where the quartz content of the surrounding rock may be high, the AS can be significantly exceeded during the dry processing stages.

Table 14:
No differentiation by work areas – mining

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n.a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	37	12	8	21.6	0.029	70.3	29.7	0	0.0215 +	0.13	0.191
Stationary	28	11	6	21.4	0.009	82.1	17.9	0	0.0045 +	0.0668	0.111

8.3 Extraction and processing of gravel and sand

Sector
Grit and gravel mills
Sand, extraction and processing
Gravel and sand (except pumice and silica sand), extraction
Quartz sand, extraction
Gravel and sand, processing
Gravel and sand, extraction

The gravel and sand extracted through dry and wet extraction processes are turned into products of different particle fractions in screening, washing, crushing, sorting, classification and, where appropriate, grinding and drying facilities and are stored in silos or open-air heaps. After drying, special sands are also packed in sacks or big bags (flexible bulk containers). In addition to the automated operations in today's gravel and sand mills, workers essentially carry out control and monitoring activities as well as maintenance work in the facilities, so that operations can continue to run smoothly. In raw material preparation, it is rarely possible to differentiate technically between the sections of a plant in terms of dust, as all the facilities are connected and are not geographically separated. The measurements were carried out in both open-air and enclosed facilities.

Quartz sands also undergo further processing, as they are turned into quartz powders. Exposures to quartz-containing respirable dust occur in all workplaces during both the extraction and preparation of quartz sands. Essential key factors for the level of exposure are in particular by the content of free crystalline silica in the mineral raw material and the potential for dust release at the relevant stage of processing. Thus, for example, the bagging of materials with a high content is a major challenge in technical dust control, because only the combination of several different measures can lead to success. In particular, we should mention the selection of dust-proof packaging materials, the conveying of materials in enclosed transport systems, extraction at material transfer points, e.g. at filling points for packaging machines, the routing and dedusting of displacement air and the implementation of suitable procedures for keeping workplaces clean (vacuum cleaning).

Compared with the periods documented since 1972 (cf. BGIA Report 08/2006 [10]), quartz exposure has mostly fallen considerably but is still well above the AS for various processing stages, despite the frequent automation of operations, the minimisation of dust in vehicle cabins and the use of improved and less dust-intensive manufacturing processes.

The current data sets show that comminution (crushing, grinding), in particular, still entails the highest levels of exposure. It should also be noted that there is no need to stay within the vicinity of a crusher for any length of time while it is running, as such machines operate entirely automatically. Moreover, staying near a crusher is prohibited for reasons of noise protection. The actual duration of stay, e.g. during inspections, must be taken into account for the exposure. Massive dust problems arise when crushers or mills are operated in enclosed processing facilities, without being separately contained. However, dust extraction systems with the necessary efficiency are rarely feasible.

Relatively high concentrations of quartz also occur during two further preparation stages: screening and mixing/drying. The measurements were mainly carried out at dry screening facilities which release more dust than plants under wet operation. Nowadays, whenever sand is dried and different particle fractions are mixed, measures are taken to achieve adequate dust removal.

Although workplaces at filling and packaging machines for sand are usually vacuumed using state-of-the-art technology, the data shows that high exposures can often occur in shift operations – especially with high content e.g. due to lack of maintenance, dust-reducing adjustments and servicing. Also, compliance with the GDLV for the respirable dust fraction (cf. IFA Report 6/2020 [35]) cannot always be ensured if manual or semi a defined filling activities involve equipment with, for example, displacement air being released into the worker's breathing zone and where regular cleaning work is required (to change products).

8.3.1 Extraction: moving, transporting

Table 15:
Extraction: moving, transporting – extraction and processing of gravel and sand

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n.a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	43	28	19	44.2	0.026	83.7	16.3	0	0.008 +	0.059	0.0639
Stationary	33	10	17	51.5	0.024	84.8	15.2	0	LOD !	0.0678	0.0929

Table 15a:
Dust capture – extraction: moving, transporting – extraction and processing of gravel and sand

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n.a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs (personal)											
LEV = no	28	20	15	53.6	0.011	85.7	14.3	0	LOD !	0.0528	0.0618

8.3.2 Preparation: Classification (screening)

Table 16:
Preparation: screening – extraction and processing of gravel and sand

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	22	18	6	27.3	0.011	40.9	59.1	0	0.057	0.108	0.146
Stationary	22	15	0		No details	59.1	40.9	0	0.038	0.586	0.872

8.3.3 Preparation: mixing, drying

Table 17:
Preparation: mixing, drying – extraction and processing of gravel and sand

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	34	22	6	17.6	0.0125	52.9	47.1	0	0.042	0.196	0.333
Stationary	23	14	0		No details	73.9	26.1	0	0.03	0.161	0.238
< 2 hrs											
Stationary	7 ***	2 **	1	14.3	0.003	28.6	71.4	0	“=” values: 0.01 to 0.58		

8.3.4 Preparation: comminution (crushing/grinding)

Table 18:
Preparation: comminution (crushing/grinding) – extraction and processing of gravel and sand

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	21	15	6	28.6	0.011	47.6	52.4	0	0.053	0.235	0.335
Stationary	28	21	3	10.7	0.008	39.3	60.7	0	0.089	0.78	1.491
< 2 hrs											
Stationary	12	3 **	0		No details	0	100	0	0.25	0.558	0.896

8.3.5 Filling and packaging

Table 19:
Filling and packaging – extraction and processing of gravel and sand

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	29	16	2	6.9	0.009	48.3	51.7	0	0.058	0.185	0.29
Stationary	29	16	4	13.8	0.009	69	31	0	0.0285	0.111	0.164

8.4 Extraction and processing of natural stone and other raw materials

Sector
Stones and earths, extraction (e.g. natural stone, raw clay)
Natural stone (except limestone, gypsum, chalk, slate), extraction
Slate, extraction
Stones and earths (other), extraction
Fluorspar, feldspar, barite, silica, extraction
Natural stone, general processing
Minerals (other), processing
Natural stone, extraction

The stones extracted from rocks through blasting or excavation are processed in crushing and screening facilities in several stages to produce the end products: crushed stone, chippings and rock powder. First, the material is pre-crushed in a primary crusher, where any coarse fractions are separated. The various particle fractions are produced during the subsequent shredding and screening stages, whereupon they are either stored in open heaps or silos or filled into either sacks or big bags. As a rule, the greater the degree of comminution of the mineral raw material, the higher the amount of dust. Preparation at quarries predominantly involves the dry To protect the environment, many plants are therefore completely enclosed and equipped with wall-mounted dust extractors, e.g. at belt transfer points and discharge points, and also at crushers and screeners. Water can often only be used for dust control to a limited extent, e.g. to spray a crusher inlet or to sprinkle piles of material, driveways or transfer points in loading areas. Grit is only washed at a small number of facilities.

The following workplaces with dust exposure can be found:

- in mining operations during drilling work to produce the blasting system and on conveyors and loading equipment (excavators, wheel loaders, heavy-duty trucks) with cabs without pressure ventilation systems,
- in material preparation within open and enclosed facilities,
- in stone treatment with the work procedures for natural stone products,
- in the loading of the finished products (bulk goods).

The development of measured values over time for the periods since 1972 (cf. BGIA Report 08/2006 [10]) shows that a significant reduction in dust loads has been achieved through the application and improvement of dust removal measures at workplaces. Nevertheless, high dust and quartz concentrations can occur, especially during activities inside enclosed preparation plants, despite dust removal measures. In the absence of effective LEV equipment **Table 21a**), the quartz concentrations in the respirable dust are even higher. However, these are usually workplaces that are not permanently occupied.

When evaluating the measured data, it is important to look at the influence of the quartz content of the processed mineral raw material and the work method on the level containing concentration of respirable dust. Thus, fine crushing processes, e.g. cone crushers and impact crushers, tend to lead to higher quartz-containing respirable dust concentrations than coarse crushing processes, e.g. using jaw crushers. The higher the quartz content in the material, the higher the amount of quartz-containing respirable dust released into the ambient air when using the same processes.

8.4.1 Extraction

Activities in a quarry can cause high dust loads if they involve extraction, e.g. making blast holes for extraction blasting with the help of large mobile drills, drilling boulders and the operation of extraction and haulage equipment such as excavators, wheel loaders and heavy-duty trucks. The use of hand-held pneumatic tools for drilling, cracking and splitting can cause problems, as dust removal equipment at mobile workplaces – e.g. on site in a quarry – can only be tracked with difficulty. Mobile hydraulic drills for the production of blast holes are subject to state-of-the-art dust removal, so that they usually comply with the GDLV and the AS. The conveying equipment usually also requires pressure ventilation systems in the cabins, which are only effective when all doors and windows are closed. Today, apart from extraction, the operations in a quarry are largely automated.

Table 20:
Extraction – Extraction and processing of natural stone and other raw materials

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	84	49	41	48.8	0.012	82.1	17.9	0	0.009 +	0.18	0.392
Stationary	19	11	7	36.8	0.009	68.4	31.6	0	0.0155	0.141	0.15
< 2 hrs											
Personal	7 ***	5	4	57.1	0.028	85.7	14.3	0	“=” values: 0.019 to 0.24		

8.4.2 Preparation

The use of hand-held pneumatic tools for drilling, cracking and splitting can cause problems, as dust removal equipment at mobile workplaces – e.g. on site in a quarry – can only be tracked with difficulty. Comminution (crushing, grinding) is usually associated with the development of massive amounts of respirable and inhalable dust, and unless suitable protective measures are taken, this can lead to unacceptable dust loads for workers during such operations. As a result, the GDLV are frequently exceeded, so that if a higher quartz content occurs in an respirable dust fraction, the AS is also exceeded.

Essentially, within preparation plants, inspection, monitoring and maintenance are carried out to maintain ongoing operations. High levels of exposure occur, in particular, when staff spend long periods of time in enclosed preparation facilities, inspecting equipment or repairing faults. It is virtually impossible to keep within the AS when processing material with a high quartz content. Workers are only permitted to stay within such facilities if they have suitable respiratory masks and if they restrict themselves to the minimum specified in DGUV Rule 112-190 [36]. Crusher attendants in a control room or cabin can also be exposed to high quartz concentrations in respirable dust if those facilities have inadequate ventilation.

Table 21:
Preparation – extraction and processing of natural stone and other raw materials

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	73	46	26	35.6	0.052	64.4	34.2	1.4	0.0235 +	0.284	0.657
Stationary	65	42	22	33.8	0.19	77	21.5	1.5	0.0105 +	0.11 +	0.198
< 2 hrs											
Stationary	13	5	1	7.7	0.011	30.8	69.2	0	0.14	0.24	0.352

Table 21a:
Dust capture – preparation – extraction and processing of natural stone and other raw materials

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (Personal)											
LEV = yes	29	22	10	34.5	0.022	65.5	34.5	0	0.02 +	0.204	0.245
LEV = no	25	17	8	32	0.052	52	44	4	0.043 +	0.43	0.825

8.4.3 Filling, storing, packaging and weighing

These work areas include storing the finished products in a silo or in an outdoor heap, as well as weighing and loading them onto transport vehicles. During the preparation of natural stone, rock powder accumulates from fine screening and filter systems, which – unless it is loaded directly from the silo into silo vehicles – is filled into sacks or big bags. The filling and packaging equipment is similar to equipment in the cement and lime industries and can cause similar dust emissions typical of such equipment. The loading facilities are designed in a variety of ways (loading belt, loading chute, free-fall loading, with or without dust extraction or water wetting) and can release dust.

Operators who work at silo loading facilities – which are often part of preparation plants and driven under by road trucks – are exposed to dust when controlling and monitoring the loading process outside their enclosed control cabins, e.g. inside the facility for inspection rounds, near a loading point or when driving through a silo. Most of the measured results refer to such facilities. Low readings are obtained on effectively vacuumed or moistened loads. On the other hand, the loading of products placed outside, using a wheel loader, produces considerably lower dust loads for the loading operator if they stay inside the enclosed, pressure-ventilated cabin of the loader and keeps the doors and windows properly closed.

Table 22:
Filling, storing, packaging and weighing – extraction and processing of natural stone and other raw materials

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	23	16	11	47.8	0.052	87	8.7	4.3	0.0105 +	0.0316 +	0.0485 +
Stationary	28	22	13	46.4	0.014	92.9	7.1	0	0.0045 +	0.0344	0.0588
< 2 hrs											
Personal	5 ***	5	2	40	0.019	80	20	0	“=” values: 0.017 to 0.22		
Stationary	10	5	5	50	0.05	80	20	0	0.016 +	0.054	0.076

8.5 Natural stone industry – production, treatment and processing of natural stone, masonry work

Sector
Stones and earths (except heavy ceramics or abrasive production), processing
Natural stone, processing
Natural stone (ashlar) (excluding stone sculpting and masonry), processing
Ashlar, production
Stone sculpting and masonry
Slates, stones and earths, processing
Natural stone, treatment and processing

Raw blocks of stone extracted from quarries are broken down into smaller units in the quarry or at the natural stone plant into bricks and paving stones or cut into slabs/panels or cuboid semi-finished products on stone cutters. Additional shaping and surface treatment to produce the final products is usually carried out by specialised stone treatment companies. Both wet and dry methods are used in stone treatment.

Wet treatment is mainly carried out on stone treatment machines such as stone cutters, grinders and mills, where the tools – which are usually diamond-tipped – are cooled with water. This also reduces the release of dust.

On the other hand, machining operations such as chiselling, embossing, scratch-finishing and splitting are carried out dry, using hand-held pneumatic hammers or cut-off grinders, and the grinding of surfaces is carried out dry with hand-held electric tools such as angle grinders. Both the quartz content of the processed material and the type of processing method have an impact on the concentration of quartz-containing respirable dust. High concentrations in or near certain work areas and operations can often be explained by the high quartz content of the materials (e.g. window sills and natural stone coverings made of granite that contain up to 35% quartz). It should also be noted that fine-grinding processes using high-speed tools, e.g. cut-off grinding, polishing and bush hammering, involve a high degree of fragmentation of quartz particles and therefore produce higher concentrations of quartz dust than coarse-grinding manual processes such as chiselling by hand.

8.5.1 Embossing, scratch-finishing and bush hammering

These are surface and edge treatment processes and carried out dry. Both air-powered manual machines and stationary treatment machines are commonly in use. In surface treatment, bush hammering and scratch-finishing cause major particle fragmentation and therefore release large amounts of dust. Embossing is less dust-intensive, as only parts of the workpiece are cut off, e.g. the edges. The machines used today are mostly vacuumed using state-of-the-art technology. Local exhaust ventilation is subject to extremely high wear and tear, so that the vacuum suction effect is reduced if maintenance is inadequate.

According to Table 23, compliance with the permissible AS at 90% (even when evaluating the GDLV) cannot be guaranteed in the case of bush hammering and scratch-finishing. Since neither significantly improved equipment nor optimised dust extraction technology was used in the period under assessment, from 2005 to 2016, compared with the first evaluations from 1974 to 2004 (cf. BGIA Report 08/2006 [10]), the high 90% values can be explained by the fact that measurements are currently primarily taken at workplaces where dust conditions are noticeably unfavourable.

Table 23:
Embossing, scratch-finishing and bush hammering – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	16	12	3	18.8	0.023	31.2	68.8	0	0.062	1.05	1.6
Stationary	6 ***	6	0		No details	50	50	0	“=” values: 0.007 to 0.26		

8.5.2 Sawing, milling and cutting

During sawing and milling operations, water is supplied to the place of treatment to cool the blades. The water also reduces dust emissions by binding and precipitating the dust. The high-speed tools produce spray water and aerosol containing respirable quartz dust particles that can be inhaled by the machine operator. The quartz concentration in the respirable dust depends partly on the quartz content of the stone and partly on the treatment quality of the recycled water and on the extent to which aerosol and spray water are formed. Devices on the machines to capture and precipitate the spray water and aerosols as well as water purification up to fresh water quality are state of the art today. Like the evaluations of the measured values of the last decades (cf. BGIA Report 08/2006 [10]), the current data also shows unchanged high quartz concentrations in respirable dust during activities involving quartz-bearing natural stone, despite compliance with GDLV (cf. IFA Report 6/2020 [35]).

8.5.3 Treatment at the quarry: cracking, fracturing and the production of lewis holes

High concentrations of dust occur during manual cracking using pneumatic hammers, even if a dust extraction system is usually installed on the tool. The rubber grommets on the chisel for making the lewis holes are subject to considerable wear and tear, so that the vacuum suction effect is reduced if maintenance is inadequate. Effective dust removal from stationary stone-cracking machines is less difficult. Here, the dust is extracted via sensor elements on the upper blade or through suction openings in the machine stand.

The measurement results for cracking carried out in outdoor enclosures due to weather conditions, usually with no dust minimisation, are significantly higher than those carried out either indoors or in the open air.

Table 24:
Sawing, milling and cutting – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	89	48	25	28.1	0.023	75.3	24.7	0	0.019 +	0.163	0.404
Stationary	60	43	5	8.3	0.009	63.3	36.7	0	0.023	0.23	0.28

Table 25:
Treatment at the quarry: Cracking, fracturing and production of lewis holes – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	125	37	16	12.8	0.052	48.8	50.4	0.8	0.0505 +	0.5	0.627
Stationary	37	24	3	8.1	0.01	67.6	32.4	0	0.019	0.0986	0.166

8.5.4 Engraving and chiselling

Both pneumatically and electrically operated handheld machines are used for such work. The dust produced during manual operations is collected via workplace extraction systems of various designs (adjustable extraction funnels, extraction walls). Often, however, the design and servicing of such machines leave room for improvement. At high content the effectiveness of waterwalls has proved to be inadequate, as has the effectiveness of extraction walls without suitable filter media for clean air recirculation. This is because, despite workplace extraction, quartz concentrations in respirable dust occur with 90% values that are significantly higher than the AS (similar to GDLV – see IFA Report 6/2020 [35]). Suitable particle-filtering respirators are therefore required, as specified in DGUV Rule 112-190 [36]. Over the last few decades, there have been no significant improvements in technical equipment or in dust extraction technology, and measurements are therefore mostly taken in work areas with clearly unfavourable dust conditions.

8.5.5 Blasting

The blasting of quartz-containing natural stone surfaces with the help of vacuumed blasting machines, e.g. in the surface treatment of natural stone slabs, leads to significantly lower dust concentrations than the conventional dry process and the free blasting method. Nevertheless, respirable and inhalable dust loads frequently exceed the AS for quartz-containing respirable dust and the GDLV (cf. IFA Report 6/2020 [35]) to such an extent that, in addition to state-of-the-art dust detectors, workers may need particle-filtering respirators. The big differences between the 90% and 50% values confirm the differences between the above-mentioned procedures, which were combined in the data sets (Table 27).

Table 26:
Engraving and chiselling – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	86	47	14	16.3	0.046	41.9	58.1	0	0.065	0.902	2.07
Stationary	41	29	8	19.5	0.02	65.9	34.1	0	0.0145 +	0.213	0.24
< 2 hrs											
Personal	12	7	3	25	0.16	25	66.7	8.3	0.15 +	0.54	1.702

Table 26a:
Dust capture – engraving and chiselling – natural stone industry – production, treatment and processing of natural stone, masonry work

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	61	33	11	18	0.046	41	59	0	0.0675	0.499	0.676
LEV = no	22	14	3	13.6	0.009	45.5	54.5	0	0.056	1.8	2.08

Table 27:
Blasting – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	16	11	4	25	0.009	62.5	37.5	0	0.014	0.692	0.768
Stationary	11	8	0		No details	63.6	36.4	0	0.0325	0.0998	0.397

8.5.6 Grinding, manual

In the three data sets, a distinction is made between manual grinding, machine grinding and mixed operations. Manual grinding is usually carried out with portable, electrically or pneumatically driven high-speed angle grinders. Machine grinding is carried out with stationary grinders or machining centres. The Surface treatment of board-shaped materials is predominantly carried out using a wet process, which results in less exposure to quartz dust compared with the dry method. However, due to the formation of aerosols, high dust concentrations can also occur with wet grinding. The treatment of the recycled water is subject to the same criteria as for sawing and milling (section 8.5.2).

Dry work with angle grinders leads to extremely high dust loads. The development of dust concentrations over time shows a steady decrease in dust exposure while working with these tools (cf. BGIA Report 08/2006 [10]). This is due to the increased use of dust extraction equipment in the form of machine and workplace extraction systems of various designs. However, extractors on such equipment are rarely found in non-stationary work. Consequently, the dust loads identified for workers usually exceed the AS and the GDLV to such an extent that it is necessary to use both LEV equipment (state-of-the-art technology) and particle-filtering respirators, as specified in DGUV Rule 112-190 [36].

Table 28:
Grinding, manual – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	50	30	18	36	0.12	62	34	4	0.028 +	0.17	0.83
Stationary	23	19	3	13	0.016	87	13	0	0.016 +	0.0675	0.0907
< 2 hrs											
Personal	7 ***	5	4	57.1	0.036	71.4	28.6	0	“=” values: 0.026 to 1.2		
Stationary	6 ***	4 **	1	16.7	0.014	66.7	33.3	0	“=” values: 0.02 to 0.11		

8.5.7 Grinding, mechanical

Table 29:
Grinding, mechanical – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	28	20	4	14.3	0.016	60.7	39.3	0	0.038	0.17	0.344
Stationary	22	20	3	13.6	0.015	59.1	40.9	0	0.03	0.156	0.169
< 2 hrs											
Stationary	6 ***	2 **	0		No details	16.7	83.3	0	“=” values: from 0.014 to 0.59		

8.5.8 Grinding, other methods

In addition, we have included both mixed activities involving the use of several treatment methods – the kind that occur, for instance, in a stonemasonry workshop – as well as various activities that cannot be assigned to the work areas or activities listed above, e.g. filling and polishing, and also records of undifferentiated grinding operations. **Table 30** illustrates a very high dust loads during such activities, due to the fact that working conditions do not permit the dust removal measures that are often effective.

Table 30:
Grinding, other methods – natural stone industry – production, treatment and processing of natural stone, masonry work

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	28	17	2	7.1	0.009	25	75	0	0.1	0.608	1.32
Stationary	10	9	0		No details	60	40	0	0.041	0.22	0.38
< 2 hrs											
Personal	5 ***	2 **	1	20	0.017	20	80	0	“=” values: 0.092 to 2.3		

8.6 Mineral grinding mills (coloured earths)

Sector
Mineral grinding mills (coloured earths)
Enamel, production

Natural minerals such as bauxites, chrome ores, iron ores, magnesites and feldspars are prepared in crushing, screening, drying and grinding facilities to form products with a particle size below 10 µm. They are used, among other things, in the production of refractory materials, as well as in the iron and steel industries, in foundries, in the glass industry and in the chemical industry. If quartz-containing fractions are present in the raw material, quartz concentrations may occur, especially around crushers and grinders, as well as during the bagging process. For the preparation of such mineral raw methods are used involving various activities described in section 3.4. The conclusions reached there are equally applicable here. Mixing, filling and packaging are work processes that are similar to those in the cement and lime industries concerning equipment technology and work areas. The chronological progression of the measured values for the periods since 1972 (cf. BGIA Report 08/2006 [10]) shows a considerable decrease in dust loads throughout the industry, thanks to the application and improvement of dust removal measures. However, the trend did not continue for the period of this evaluation (2005 to 2016), and there were isolated cases of the AS being exceeded.

Table 31:
No differentiation by work areas – mineral grinding mills (coloured earths)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	31	13	16	51.6	0.032	87.1	12.9	0	LOD !	0.0625	0.1
Stationary	19	7	4	21.1	0.006	73.7	26.3	0	0.0035 +	0.0894	0.12

8.7 Production of gypsum products, insulation panels and lightweight panels

Sector
Gypsum products (e.g. gypsum plasterboards), production
Insulating and lightweight boards (mineral-bonded), production

Gypsum as a raw material is mainly mined as gypsum rock (natural gypsum) above and below ground, although it also occurs as a by-product in flue gas desulphurisation (flue gas gypsum) and in the production of hydrofluoric acid. Gypsum products are used, among other things, in the construction industry as plasters and dry screeds, primers, fire protection, fillers and plasterboard. The data sets exclude the mining of gypsum itself (see chapter 8.2).

After being crushed with impact or hammer mills to specific particle sizes and grading curve distributions, the gypsum stone is fired in rotary furnaces, carrier gas furnaces, belt grate furnaces, gypsum cookers and grinding furnaces to produce various building material gypsums (calcination) and is refined to suit the desired product. Also, autoclaves are used for the production of specific gypsum products. Products with chemical additives (gypsum dry mortar) are usually filled into containers as bagged goods or into transportable construction site silos as loose goods using fully automated dispensing and packaging equipment, depending on the desired quantity.

Gypsum (cardboard) panels, gypsum fibre boards and gypsum wallboards are used as building elements in interior construction. Gypsum boards are made on continuous conveyor belts, where they are also dried, and consist of a gypsum core and a cardboard cover that is tightly bonded to the board. Gypsum fibreboards consist of gypsum and paper fibres, which are evenly distributed within the structure and are obtained from paper through recycling. Solid gypsum wallboards are produced in moulded stainless steel boxes. They are homogeneously made of plaster, without a plasterboard substrate.

Dust loads occur during comminution, cleaning and bagging, especially with semi-automated valve bagging involving one or more nozzles, and also during batch changes. While activities at bagging lines tend to be stationary, workers in the manufacture of gypsum products usually move around the various production sections, e.g. inspections and mechanical servicing, so that their exposure is of a mixed kind. The data sets for personal exposure are below the GDLV for shifts and usually involve mixed exposure. Higher quartz dust loads can occur at operating points that are not permanently occupied, as documented by the data sets for stationary measurements. Individual activities such as manual feeds without vacuum devices exhibit noticeably unfavourable levels of dust release.

Table 32:
No differentiation by work areas – production of gypsum products, insulation and lightweight panels

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	18	9	13	72.2	0.01	88.9	11.1	0	LOD !	0.0396	0.131
Stationary	28	9	18	64.3	0.047	85.7	14.3	0	LOD !	0.0588	0.117

8.8 Asphalt mixing plants

Sector
Asphalt mixing plant
Bituminous mixtures, production (at asphalt mixing facilities)

Asphalt is made by mixing pre-dried mineral mixtures with bitumen as a binder and other additives (including asphalt recyclate) in a mixer. The components are added and the mixing process takes place in a largely enclosed system and is automated. The mixing process is controlled from a console located at a physical distance from the machine. During the manufacturing process, there is no need for staff to be present with the equipment. The exceptions are:

- manual addition of additives,
- inspection rounds,
- the removal of sudden malfunctions.

Staying inside the closed mixing tower during production leads to a high level of dust exposure. Sources of dust include screening machines and transfers of mineral doses. The length of stay for an inspection round is usually less than one hour per shift, which reduces exposure to one eighth of the reported values. By contrast, transportation and the loading of materials into batchers using wheel loaders are carried out on factory premises throughout the shift. With the exception of the fine-grained fillers, the mineral materials are stored on factory premises in heaps. The length of stay for an inspection round is usually less than one hour per shift, which reduces exposure to one eighth of the reported values.

Enclosed mixing plants with a completely enclosed mixing tower and a central dust extractor to eliminate dust deposits are state-of-the-art. Until the 1980s, entire factory sites still predominantly contains open facilities with high levels of dust emissions. Today, compliance with the AS during production is documented through person-based readings.

Table 33:
No differentiation by work areas – asphalt mixing plants

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	29	17	23	79.3	0.044	93.1	6.9	0	LOD !	0.0319 +	0.051
Stationary	19	13	8	42.1	0.017	89.5	10.5	0	0.0043 +	0.0345	0.123

8.9 Production of cement and lime

Sector
Cement and cementitious binders, production
Cement, production
Cement factory
Cement mill
Lime, production
Fertiliser lime, production

Limestone extracted from a quarry is crushed at crushing plants and, after intermediate storage, enters a raw processing plant where it is then dried, ground into raw powder at ball mills and sometimes granulated. In rotary furnaces, the raw material – either raw powder or raw powder granulate – is heated and burned to form cement clinker. Once cooled, the clinker is ground into different types of cement in a further grinding process in ball mills with the addition of certain additives and is then stored in silos. A large part of the finished cement is loaded loose into silo trains, while the remainder is packed into paper bags and big bags by bagging machines. Compared with cement production, limestone is usually burnt in ring shaft furnaces, where the coarsely crushed limestone is only heated to the point where the heat expels the carbon dioxide contained within it. All further stages of production are similar to those in the production of cement.

Certain limestone deposits can have quartz contents as high as 5% or more in the respirable dust. Substances containing quartz, such as sand, which are added both during raw powder production and when grinding the cement clinker, to influence the cement properties, can also have an effect on the quartz concentrations in the respirable dust.

Operations in today's cement and limestone plants are largely automated, so that the only work that needs to be carried out is monitoring, maintenance and repair work to remove malfunctions. Raw material preparation, firing and grinding are controlled from an air-conditioned control room. Workers exposed to dust include inspectors, maintenance staff and equipment operators in certain parts of the plant that are not controlled from the control room, e.g. in the cement bagging and loading areas. Cement and limestone plants usually have efficient dust extractors (see **Table 34a**). Dust-intensive parts of a plant (e.g. cement mills) are mainly located in enclosed buildings or are fitted with effective, state-of-the-art dust extractors at the various transfer and extraction points. Rotary and ring shaft furnaces are usually dedusted via electrostatic precipitators. Dust extraction on cement bagging machines is also improved by vacuumed filling nozzles. The exposure data shows compliance with the AS for quartz-containing respirable dust, provided that the equipment is state-of-the-art, whereas the GDLV are often exceeded (cf. IFA Report 6/2020 [35]).

Table 34:
No differentiation by work areas – production of cement and lime

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	103	36	73	70.9	0.05	88.3	11.7	0	LOD !	0.0534	0.123
Stationary	88	30	58	65.9	0.046	97.7	2.3	0	LOD !	0.023 +	0.0276 +
< 2 hrs											
Personal	10	8	5	50	0.036	90	10	0	0.018 +	0.046	0.051

Table 34a:
Dust capture – no differentiation by work areas – production of cement and lime

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	16	14	13	81.3	0.024	93.7	6.3	0	LOD !	0.0266	0.0516
LEV = no	25	12	15	60	0.05	80	20	0	LOD !	0.0705	0.155

8.10 Production of dry building materials

Sector
Mortar, production
Finishing plaster, production
Ready-mixed mortar, production
Special mortar, production
Gypsum, calcined, production
Perlite (expanded), production

Dry mortars and finishing plasters, e.g. grouting mortars, concrete fillers, and interior and exterior renderings, are manufactured on the basis of cement, lime, gypsum, sand, plus additives such as organic polymers, swelling agents, and fibres, which provide specific product properties. Due to the quartz content of the minerals that are used, quartz-containing dust forms during the drying of sand, during the dry mixing process – especially when filling and emptying mixers – and during the manual addition of mixture components. Dust exposure also occurs at workplaces where finished products are filled into bags and other types of packaging, and when cleaning work is performed (change of product).

The development of measured values for respirable dust and quartz exposure over time (cf. BIA Report 08/2006 [10] and IFA Report 6/2020 [35]) shows that a significant reduction in the dust load has been achieved through the application and improvement of dust removal measures at the plants. For years, however, this figure has remained constant, at a high level, even though production plants are dedusted using state-of-the-art central extractors, and additional industrial vacuum cleaners are available to clean local workplaces and facilities.

8.10.1 Dosing, mixing, drying

Dust may be released through frequent product changes (dry mixing processes) requiring appropriate cleaning – especially when filling and emptying the mixers – and the manual addition of mixing components, as this involves interference with the material flow. Another frequent source of dust loads is the drying of sand. Vacuum-ventilated dedusting technology for manual feeding and partially enclosed conveyor systems are state-of-the-art. Nevertheless, quartz dust exposures clearly exceed the AS during such operations, although it must be borne in mind that measurements were primarily carried out in plant sections that required optimisation in terms of dust technology.

Table 35:
Dosing, mixing, drying – production of dry building materials

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	34	23	18	52.9	0.037	70.6	29.4	0	LOD !	0.126	0.221
Stationary	21	13	5	23.8	0.009	71.4	28.6	0	0.0135	0.067	0.108

8.10.2 Filling, packaging

The finished products are filled and packaged using rotor packaging machines as well as manually operated and automated bagging machines. Dust exposure occurs during the production of dry mortar and decorative plaster at workplaces where finished products are filled into bags or where other packaging takes place either manually or semi-automatically, as well as during cleaning operations. Despite continuous improvements in previous years, the person-based exposure data from the IFA Report 6/2020 [35], in particular, still show significant exceedances of the GDLV for the respirable dust fraction, especially in relation to semi-automated bagging. Data sets for quartz exposures may occur at the level of the AS for quartz.

8.10.3 Storing, transporting, loading

Looking at picking and packing, palletising, transporting (on forklift trucks) and loading, the activities that were recorded in warehouses were primarily of a mixed kind, as all these production processes are closely linked. Bulk loading into silo trains does not produce any dust under normal operating conditions. Such mixed activities, which involve both loose and packaged products, show significant exceedances of the AS and the GDLV for the respirable dust fraction in certain workplaces (cf. IFA Report 6/2020 [35]).

Table 36:
Filling, packaging – production of dry building materials

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	99	54	66	66.7	0.055	85.9	11.1	3	LOD !	0.0519 +	0.0714
Stationary	69	44	26	37.7	0.04	95.7	4.3	0	0.0055 +	0.027 +	0.0406

Table 36a:
Dust capture – filling, packaging – production of dry building materials

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	96	51	65	67.7	0.055	87.5	9.4	3.1	LOD !	0.039 +	0.0686

Table 37:
Storing, transporting, loading – production of dry building materials

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	29	21	17	58.6	0.033	86.2	13.8	0	LOD !	0.0725	0.334
Stationary	12	11	4	33.3	0.009	66.7	33.3	0	0.009 +	0.222	0.344
< 2 hrs											
Personal	10	7	8	80	0.036	80	20	0	LOD !	0.086	0.543

8.11 Concrete industry (stationary operation)

Sector
Concrete products (excluding prefabricated buildings), production
Concrete products, production and treatment
Cast stone, production
Concrete slabs/panels, production
Concrete blocks, production
Concrete pipes and manholes, production
Roof tiles, production
Precast concrete parts, production
Lightweight panels (cement-bonded), production
Aerated concrete blocks, production
Prefabricated concrete structural elements (large-format), production
Ceiling and wall panels, production
Prefabricated garages and similar, production
Ready-mixed concrete and mortar, production
Concrete blocks, treatment and processing

Concrete is produced in mixers using gravel, sand, cement, water, certain additives to affect the flow and setting behaviour, and sometimes colouring agents. Depending on the type of further processing, its consistency ranges from earth-moist to liquid. The concrete is shaped into end products in concrete block machines or into concrete products on vibrating tables. Some examples are paving stones, kerbstones, slabs/panels, pipes, manhole rings and slatted floors. Also, using wooden or steel moulds, it is shaped into large-format concrete elements such as columns, trusses, wall elements and filigree ceilings. The concrete is compacted by vibrating, pressing or tamping. To increase the tensile strength and stability of certain concrete products, they are given steel reinforcements which are inserted into the formwork mould before concreting.

Especially when vibrating and tamping the earth-moist concrete mix, quartz dust can be released by crushing the quartz-bearing minerals. Sometimes high levels of exposure to quartz-bearing respirable dust also occur during the finishing of hardened concrete products, when burrs and imperfections are sanded off or removed in a dry state, when surfaces are levelled or when notches, gaps, recesses etc are created through drilling, sawing, milling or chiselling. The dust load at a concrete plant depends to a large extent on the regular cleaning of the production areas, i.e. the removal of scattered debris and dust deposits. Unless they are removed, dust is continually stirred up in such areas.

What we said for mixing plants in concrete factories also applies to ready technology concrete plants, as they have the same technology. Operations during the cleaning of a mixer, such as the removal of concrete and cement deposits and the prising of set concrete residues with a pneumatic or electric hammer, are part of the mixing activities of the plant operator (MRP), although such activities are usually only performed occasionally and only continue for brief periods of time. This may involve high dust concentrations, so that workers need to wear particle-filtering respirators as specified in DGUV Rule 112-190 [36]. For stationary work areas in the concrete industry, you will find a breakdown of data sets by specific activities and work processes below.

8.11.1 Mixing of concrete

Stationary mixers are designed as enclosed units and are fully automated, so that there is no permanent workstation in their immediate vicinity. They are either vacuumed or connected to dust filters of various designs, removing displaced air during the filling process. The data sets contain readings ranging from partially to fully automated mixers. The measurements were mainly taken during dust removal from mixers and activities involving the production of the concrete mix, e.g. the manual addition of concrete admixtures, as well as during inspection rounds at mixing plants, sometimes including cleaning operations. The percentile values of the measurement data in IFA Report 6/2020 [35] show significant isolated exceedances of the GDLV for the respirable dust fraction, although similarly significant exceedances of the AS for quartz can also occur in measurements on persons. It must be borne in mind that, for the sake of preventive care, measurements are primarily taken in work areas with noticeably unfavourable dust exposure.

Table 38:
Mixing of concrete – concrete industry (stationary operation)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	16	13	6	37.5	0.009	87.5	12.5	0	0.012	0.103	0.248
Stationary	42	24	16	38.1	0.059	85.7	11.9	2.4	0.005 +	0.0562 +	0.0677

8.11.2 Production of concrete products and prefabricated concrete elements

Increased dust loads, potentially exceeding the AS for quartz in the respirable dust fraction, can be expected in the production of

- concrete slabs/panels that have older rotary table presses fitted with tamping units (usually encapsulated and vacuumed),
- concrete products on vibrating tables or trestles where the mould rests loosely.

Extraction systems are state-of-the-art on panel presses with tamping units, but not on any other type of machinery. To reduce noise, the majority of panel making machines are enclosed, which also helps to prevent dust from spreading. Vibrating tables in the production process have the effect of reducing the particle size, which causes respirable dust to develop. Dust removal through vacuuming is virtually impossible. Production – the placement and/or distribution of concrete mix in moulds – is essentially manual. Dust exposures is lower in the production of manholes and rings, pipes with pipe makers, concrete products with sliding table makers, concrete products with panel makers, concrete products with floor makers and precast concrete elements such as floor and wall elements, columns and girders. Concrete roof tiles are made in ring systems on support moulds, so-called pellets. The concrete mix is produced by conventional concrete mixers. Dust exposures may occur during mixing operations

- near the mixer,
- when removing the moulds from the hardened roof tiles and
- when cleaning the support moulds (pellet cleaner).

A decrease in the dust load in the relevant workplaces has been observed since the mid-1980s, when sanding of roof tiles was discontinued, when improved, state-of-the-art dust removal techniques were introduced (e.g. vacuuming at the concrete mixer) and when the surface coating agent was applied without the use of pneumatic pressure. Nevertheless, extreme dust concentrations frequently occur for short periods of time during activities involving high-speed tools. The more intensive the crushing of the gravel and sand particles during “concrete cosmetics” and concrete compaction, the higher the measured respirable dust concentrations. If reference is made to specific shifts, it can be confirmed that various dust protection measures are effective at a plant, and so is the automation of manufacturing processes, as most of the values are below the AS. The small differences between the presence and absence of local exhaust ventilation indicates that some plants are not very efficient at capturing the dust capture of some of their equipment.

Table 39:
Production of concrete products and prefabricated concrete elements – concrete industry (stationary operation)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	130	75	63	48.5	0.033	86.9	13.1	0	0.009 +	0.056	0.0985
Stationary	106	64	35	33	0.015	93.4	6.6	0	0.007 +	0.034	0.0656
< 2 hrs											
Personal	12	8	8	66.7	0.052	83.4	8.3	8.3	LOD !	0.0436 +	0.173

Table 39a:
Dust capture – production of concrete products and prefabricated concrete elements – concrete industry (stationary operation)

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	34	17	13	38.2	0.015	82.4	17.6	0	0.013 +	0.0622	0.0989
LEV = no	78	49	38	48.7	0.023	87.2	12.8	0	0.009 +	0.0692	0.11

8.11.3 Treatment and finishing of concrete products: Blasting

Blasting of concrete surfaces is the surface treatment of concrete products, e.g. slabs/panels and paving stones. State of the art means that enclosed automated machinery is used, where the dust is vacuumed and where a non-silicogenic blasting agent is continually recycled. Despite enclosure, measured values on the persons indicate isolated exceedances of the AS, although exceedances of the GDLV (cf. IFA Report 6/2020 [35]) were also detected.

Table 40:
Treatment and finishing of concrete products: Blasting – concrete industry (stationary operation)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	16	10	7	43.8	0.009	81.2	18.8	0	0.008 +	0.092	0.24
Stationary	19	16	4	21.1	0.009	84.2	15.8	0	0.012	0.15	0.171

8.11.4 Treatment and finishing of concrete products: mechanical

High dust concentrations can be expected when drilling, sawing, milling, cutting and grinding – especially in dry-cutting operations. Dry grinding using angle grinders and cup grinders in “concrete cosmetics” has the purpose of repairing damaged corners and edges, smoothing concrete surfaces and removing burrs, and subsequently in creating connections with concrete shafts, concrete pipes and recesses. Mobile and stationary dust extraction systems are state-of-the-art, and their effectiveness essentially depends on their performance (e.g. stationary extraction systems with wet separators can only be used to a limited extent for quartz-containing respirable dust) and maintenance. In many cases, suitable particle-filtering respirators are also used in compliance with DGUV Rule 112-190 [36].

Mechanical “concrete cosmetics” is characterised by short-term, often mobile activities involving high levels of exposure. Effective dust capture techniques and wet work practices can help to reduce dust exposure. However, if the activities are not carried out separately using efficient dust extraction equipment, considerable dust loads can also occur in neighbouring work areas within enclosed spaces. As well as exceeding the GDLV (cf. IFA Report 6/2020 [35]), the AS for quartz can be expected to be exceeded for the respirable dust fraction:

- sawing – both dry and wet (however, compared with wet sawing, dry sawing produces more than 50% lower respirable dust concentrations in combination with dust extraction),
- dry sanding without dust extraction,
- bush hammering of concrete surfaces without dust extraction
- lining of manholes, especially when cutting hard-fired clinker bricks.

For the finishing of concrete surfaces, wet grinding and bush-hammering in vacuumed, automated bush-hammering systems have proven to be state-of-the-art. However, working in a moistened environment can only partially suppress the release of dust, because the dust concentration during wet sawing is significantly affected by the formation of aerosol and by the properties of the water (circulating water or fresh water).

Table 41:
Treatment and finishing of concrete products: mechanical – concrete industry (stationary operation)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	58	44	20	34.5	0.015	72.4	27.6	0	0.016	0.102	0.175
Stationary	60	45	7	11.7	0.008	83.3	16.7	0	0.014	0.11	0.17
< 2 hrs											
Personal	9 ***	3 **	3	33.3	0.05	33.3	66.7	0	“=” values: 0.06 to 0.75		
Stationary	14	7	3	21.4	0.018	50	50	0	0.039	0.22	1.26

Table 41a:
Dust capture – Treatment and finishing of concrete products: mechanical – concrete industry (stationary operation)

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	21	15	7	33.3	0.01	85.7	14.3	0	0.013	0.0553	0.0836
LEV = no	31	29	11	35.5	0.015	61.3	38.7	0	0.026	0.119	0.193

8.11.5 Treatment and finishing of concrete products: general, coating, hardening, quality control

The data sets that have been compiled show mixed exposures of various operations in the treatment and finishing of concrete products that cannot be assigned under the listed classifications and which can cause high dust exposures among the workforce. Some operations can lead to significant exceedances of the AS. Supplementary **Table 42a** suggests that in such cases the efficiency of the LEV is compromised.

Table 42:
Treatment and finishing of concrete products: general, coating, hardening, quality control – concrete industry (stationary operation)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	63	40	24	38.1	0.016	68.3	31.7	0	0.013 +	0.363	0.674
Stationary	70	40	23	32.9	0.011	88.6	11.4	0	0.006 +	0.052	0.09
< 2 hrs											
Personal	8 ***	5	3	37.5	0.037	37.5	62.5	0	“=” values: 0.077 to 2.1		

Table 42a:
Dust capture – treatment and finishing of concrete products: general, coating, hardening, quality control – concrete industry (stationary operation)

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	15	10	1	6.7	0.009	46.7	53.3	0	0.052	0.32	0.565
LEV = no	36	25	17	47.2	0.016	77.8	22.2	0	0.008 +	0.276	0.936

8.11.6 Transporting, loading and packaging of concrete products

Measurements were mainly carried out during the consolidation and packaging of concrete paving stones, during the removal of the products from the manufacturing halls and their storage in an external warehouse, and when they were being loaded into trucks for removal. Workplaces and packaging facilities are often located near or within dust-emitting production areas, so that dust is spread from there. Increased exposure to quartz-containing dust can be avoided if the storage and handling areas are cleaned on a regular basis. This also includes the low-dust disposal of ripped containers. The exposure readings show that the AS can be met most of the time.

Table 43:
Transporting, loading and packaging of concrete products – concrete industry (stationary operation)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	35	22	16	45.7	0.014	91.4	8.6	0	0.01 +	0.0485	0.0722
Stationary	26	20	7	26.9	0.01	92.3	7.7	0	0.006 +	0.0488	0.0521

9 Ceramic and glass industries

9.1 Glass, production and processing

Sector
Sheet glass, production and processing
Hollow glass, production and processing
Container/moulded glass, production and processing
Technical glass (incl. laboratory and optical glass), production and processing
Speciality glass, production and processing
Perlite (expanded), production

The manufacture of glass involves dosing mineral raw materials – mainly quartz sand, soda, alkali carbonates, alkaline earth oxides and special additives – according to a formulation and then homogenising them in mixers. This mixture is usually melted in continuously operating furnaces (Figure 10) at temperatures of about 1,400 °C into a hot molten mass that solidifies into an amorphous, glassy mass after the moulding process. Depending on the product, the target object is shaped by pressing, blowing, spinning, rolling and stretching the glass.

Examples of hollow glass products made primarily by blowing or pressing include commercial glassware such as drinking glasses and dishes as well as containers such as bottles and jam jars. However, this group also includes special products such as building bricks, television screens, Christmas baubles and tube glass for vials.

Sheet glass is mainly produced in a float process where the molten glass floats on a bath of liquid tin and can thus be stretched to the desired thickness. However, it can also be stretched, rolled or cast using a variety of older processes.

In addition, there are numerous other types of products for special applications, such as optical glass, technical glass, glass for lighting technology and glass ceramics.

The relevant dust formation in the glass industry occurs while creating the relevant mixture (preparation), when a mixture is placed in a tub or pot furnace and during the mechanical treatment and finishing of the final product through grinding, sawing, drilling, cutting and blasting.

In most areas, the 90% values for quartz-containing respirable dust are below the AS. Higher exposures still occur around the area where the mixture is produced, especially at older plants. However, workers spend part of their shifts in externally ventilated control rooms. The values shown in Tables 44 to 46 should therefore generally be given a factor for reduced exposure. During the mechanical treatment and finishing of the completed glass, the measurement results for quartz-containing respirable dust are below the AS by approximately one unit, as the silicon dioxide is present in an amorphous state once the glass has solidified. The energy input during mechanical treatment of the glass leads to local heating at the treatment point and in the glass dust that has been removed. Here, depending on the energy input and provided that the temperature is high enough, there may be partial recrystallisation in the glass dust, so that quartz-bearing respirable dust becomes detectable. Quartz may also be present in the respirable dust if quartz-containing materials are used for polishing, grinding or blasting.

Figure 10: Placing the mixture in a tub. Source: IFA

9.1.1 Production of mixtures

Table 44:
Production of mixtures – glass, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	90	48	56	62.2	0.026	92.2	7.8	0	LOD !	0.034	0.0625
Stationary	211	73	81	38.4	0.023	98.1	1.9	0	0.003 +	0.0178 +	0.0333
< 2 hrs											
Personal	19	15	12	63.2	0.11	73.6	21.1	5.3	LOD !	0.11	0.716
Stationary	78	31	55	70.5	0.049	97.4	2.6	0	LOD !	0.0226 +	0.0286 +

9.1.2 Melting, furnace

Table 45:
Melting, furnace – glass, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	19	13	14	73.7	0.015	100	0	0	LOD !	0.0194	0.0323
Stationary	30	13	15	50	0.015	100	0	0	0.002 +	0.0075 +	0.008 +

9.1.3 Shaping: blowing, pressing

Table 46:
Shaping: blowing, pressing – glass, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	13	8	13	100	0.009	100	0	0	LOD !	LOD !	LOD !
Stationary	47	23	34	72.3	0.014	100	0	0	LOD !	0.0042 +	0.0135 +

9.1.4 Mould workshop

Table 47:
Mould workshop – glass, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	6	8	80	0.009	100	0	0	LOD !	0.007 +	0.0095
Stationary	20	12	8	40	0.005	100	0	0	0.001 +	0.004 +	0.009

9.1. 5 Glass processing, storage, packaging

Table 48:
Glass processing, storage, packaging – glass, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	22	16	14	63.6	0.006	100	0	0	LOD !	0.002 +	0.0029 +

9.1.6 Surface treatment, surface coating

Table 49:
Surface treatment, surface coating – glass, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	10	8	5	50	0.002	100	0	0	0.001 +	0.003	0.005

9.1.7 Mechanical treatment and finishing: Polishing, grinding, blasting, cutting

Table 50:
Mechanical treatment and finishing: polishing, grinding, blasting, cutting – glass, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	32	20	27	84.4	0.015	100	0	0	LOD !	0.0073 +	0.0132 +
Stationary	62	34	33	53.2	0.021	100	0	0	LOD !	0.0058 +	0.01 +

Figure 11:
Fire-polishing of hollow glassware Source: VBG

9.1.8 Cristobalite in glass production and processing

There are no indications of cristobalite exposure during glass production. Cristobalite only occurs during the further processing of special glass with a high content of SiO_2, e.g. blasting beads. During filling and transfers of blasting beads, it is possible to observe cristobalite loads with multiple exceedances of the AS for quartz.

9.2 Glass fibres, mineral fibres, production and processing

Sector
Artificial mineral fibres, processing
Natural and artificial mineral fibres, processing
Ceramic fibres, production
Ceramic fibres, processing
Rock wool, production
Rock wool, processing
Glass fibres, production and processing

The production of synthetic mineral fibres (glass wool, slag wool and rock wool) involves the mechanical crushing, mixing and dosing of mineral raw such as limestone, feldspar, dolomite, basalt, sand and cement or even waste glass. This mixture is usually melted in a continuously operating smelter, e.g. a tank or shaft furnace, at temperatures of 1,300 to 1,500 °C , to form a molten mass (molten glass). Depending on the process, this molten mass is used to form synthetic mineral fibres (fine threads) through centrifuging, spinning, blowing or tuyere injection (moulding). During defibration, a mixture of synthetic resin prepolymers (phenol, urea and formaldehyde), dust binders (oil) and other additives is sprayed onto the fibres. The fibres soon cool down, solidify to a glassy consistency and are condensed into a non-woven fabric. The prepolymer is then cured in a tunnel furnace at approx. 250 °C, which gives the fibre products their structural stability. The final stage involves cutting ready-to-use pieces of fabric from a continuous strip.

The first stage in the production of high-temperature fibres usually requires very pure raw materials of silicon, aluminium, boron and zirconium oxide which are then crushed, mixed and proportioned. Spinning can take the form of melt-spinning or dry spinning with the use of sol-gel polymer solutions. under high Using high pressure, the suspension is forced through ultra-delicate nozzles, causing the formation of threads. The fibres dry as a result of their free fall through a heated spinning duct. In the next step, the green fibres are pyrolysed in a tunnel furnace at approx. 1,000 to 1,200 °C and are thus converted into polycrystalline or amorphous ceramic fibres. In the subsequent finishing process, the fibre mats are cut to size, as required.

Quartz-containing dusts are generated around the preparation facilities. In most areas, the 90% values for quartz-containing respirable dust are below the AS. Higher exposures still occur in the preparation and dosing of raw materials, especially at older plants. The facilities are highly automated, so workers spend part of their shifts in externally ventilated control rooms.

Figure 12:
Products made from high-temperature fibres.
Source: VBG

Figure 13:
Products made from mineral wool insulation materials.
Source: VBG

Table 51:
No differentiation by work areas – glass fibres, mineral fibres, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	21	9	18	85.7	0.041	100	0	0	LOD !	0.0158 +	0.0203 +
Stationary	48	16	25	52.1	0.029	100	0	0	LOD !	0.0086 +	0.0136 +
< 2 hrs											
Stationary	12	6	5	41.7	0.035	75	25	0	0.0175 +	0.0848	0.147

9.3 Quartz glass (including growing of crystal), production and processing

Sector
Quartz glass (incl. growing of crystal), production and processing

Quartz glass consists of pure SiO_2 and, unlike the usual types of glass, does not contain any other components such as lime or soda. So-called natural quartz glass is produced by melting high-purity quartz or other minerals containing SiO_2. Alternatively, the starting material – SiO_2 – can also be obtained by oxidising volatile silicon compounds such as $SiCl_4$. Due to its amorphous structure, unlike crystalline quartz, quartz glass is also known as fused silica. Its special material properties such as optical permeability, chemical resistance and high thermal shock resistance make quartz glass an important raw material for a wide range of technical applications.

The relevant manufacturing processes are usually high art and state-of-the-art. Therefore, despite the high-purity quartz materials that are used in manufacturing, the 95% value is significantly lower than the AS for quartz-containing respirable dust.

Table 52:
No differentiation by work areas – quartz glass (including growing of crystal), production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	15	9	8	53.3	0.017	100	0	0	LOD !	0.0295	0.037
Stationary	28	11	14	50	0.01	100	0	0	0.001 +	0.0052 +	0.0066 +
< 2 hrs											
Stationary	10	5	9	90	0.018	100	0	0	LOD !	0.006 +	0.0075 +

9.4 Clay and kaolin, extraction

Sector
Slate, clay and kaolin, extraction
Clay and kaolin, extraction

Clay and kaolin are mainly extracted selectively in opencast mines using excavators. The raw material is taken into intermediate storage via belt conveyors, trucks or dumpers, and may then also be crushed and coarsely pre-mixed in crushers. As kaolin is usually contaminated with quartz, mica and feldspar, it must be removed in a separation process. Fine kaolin is an important raw material for the porcelain and paper industries. Sands and feldspars are screened and sometimes ground. The quartz sands produced in this process are used, among other things, as raw in the production of glass and high-quality building products such as high-grade plasters.

The main issue of exposure to quartz-containing respirable dust in the extraction of clay and kaolin is the preparation processes, where the materials, which are mostly extracted in opencast mining, are crushed, ground, screened, mixed and bagged. The resulting dusts often have an above-average proportion of quartz-containing respirable dust. These operations are not shown separately in **Table 53**.

Figure 14:
Extraction of kaolin in opencast mining. Source: VBG

Table 53:
No differentiation by work areas – clay and kaolin, extraction

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	17	7	6	35.3	0.01	76.5	23.5	0	0.0185	0.198	0.313
Stationary	13	4 **	2	15.4	0.002	84.6	15.4	0	0.009	0.0531	0.0795

9.5 Refractory products, production

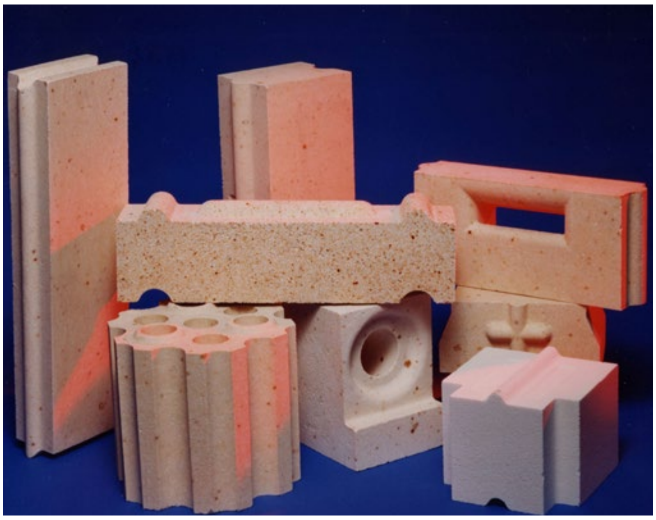
Sector
Refractory products, production

Refractory products consist of ceramic materials that soften at temperatures above 1,500 °C. Depending on their application and use, refractory products can withstand temperatures of up to 2,500 °C. Besides refractory clay and fireclay, both oxide and non-oxide ceramic materials are used as raw materials. Examples include silicon carbide (SiC), steatite ($MgSiO_3$), aluminium oxide (Al_2O_3) and various metal oxides (Zr, Ti, Ni, Cr and others). The addition of graphite dust boosts heat conversion. During the production of these materials, preparation involves screening, dosing and mixing the raw materials.

Chemical binders such as resins, tar, cement, magnesium salts and phosphates are often added before moulding. Depending on the requirements, products are manufactured from powdery masses in a process of (semi-) plastic moulding, dry pressing or tamping. The subsequent firing leads to a material transformation that gives the refractory materials their different physical, chemical and thermal properties. Refractory materials are primarily used for high-temperature applications in the metal, ceramics and glass industries.

Dust mainly develops at the material preparation stage, when the ceramic raw materials are crushed, ground, weighed, mixed and conveyed, often in a dry state. The 90% values in these areas are clearly above the AS for quartz-containing respirable dust. However, workers spend part of their shifts in externally ventilated control rooms. The values shown in Tables 54 to 59, especially the stationary ones, should therefore generally be given a factor for reduced exposure. During moulding, firing and finishing of the refractory products, increased exposures occur especially in any dry treatment and processing and also in the handling of the dried and fired products. The capture of the released dust and waste still leaves room for improvement in these processes.

Figure 15:
Refractory products. Source: VBG



9.5.1 Preparation: Mixing, screening, transporting

Table 54:
Preparation: Mixing, screening, transporting – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	109	38	48	44	0.11	61.5	27.5	11	0.0238 +	0.21	0.37
Stationary	203	40	37	18.2	0.057	86.2	13.3	0.5	0.013 +	0.0594	0.1
< 2 hrs											
Stationary	89	21	4	4.5	0.023	42.7	57.3	0	0.0695	1.22	2.2

Table 54a:
Dust capture – preparation: Mixing, screening, transporting – refractory products, production

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
personal											
LEV = yes	84	35	39	46.4	0.11	63.1	26.2	10.7	0.023 +	0.176	0.312
LEV = no	10	7	5	50	0.051	70	20	10	0.012 +	0.16	0.29

Table 55:
Cristobalite – preparation: Mixing, screening, transporting – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	33	11	26	78.8	0.06	69.7	9.1	21.2	LOD !	0.0349 +	0.134
Stationary	89	13	62	69.7	0.057	93.3	5.6	1.1	LOD !	0.0371 +	0.0524 +
< 2 hrs											
Stationary	34	11	16	47.1	0.022	70.6	29.4	0	+0.011	0.0936	0.266

Quartz and cristobalite – pairs combined

Cristobalite occurs at the preparation stage, as a component of fireclay, which is added to certain raw material mixtures. During preparation (mixing, screening, transporting), personal measurement only showed detectable cristobalite exposure in about 10% of all cases, and stationary measurements in no more than about 15% of all cases. In all, however, when we look at the quartz and cristobalite total, it is noticeable that the 90% exposure values are about one third higher than for quartz on its own (see Table 56). The level of cristobalite exposures is shown in Table 55. Although in the data set for cristobalite a significant proportion of measured values is below the LOD, the increase in exposure to silicogenic components caused by cristobalite is nevertheless significant.

The conspicuously high 90% values of the stationary measurements with durations below 2 hours are due to measurement situations predominantly related to emissions and specific activities.

Table 56:
Quartz and cristobalite (pairs combined) – preparation: Mixing, screening, transporting – refractory products, production

Sampling procedure	Number of measured values #	Number of companies	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs								
Personal	109	38	57.8	28.4	13.8	0.027 +	0.284	0.4065
Stationary	203	40	81.3	18.2	0.5	0.014 +	0.0865 +	0.1385
< 2 hrs								
Stationary	89	21	36.0	64.0	0	0.0755	1.438	2.2

Values included in the statistics as totals of a quartz value and a cristobalite value combined and coming from the same sampling medium were counted as single measured values

Table 57:
Quartz with cristobalite values – preparation: mixing, screening, transporting – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	33	11	18	54.5	0.11	39.4	33.3	27.3	LOD !	0.107 +	0.177
Stationary	89	13	16	18.0	0.057	86.5	1.1	12.4	0.013 +	0.0525 +	0.0837
< 2 hrs											
Stationary	34	11	1	2.9	0.02	47.1	52.9	0	0.051	0.268	0.671

9.5.2 Preparation: Crushing and grinding

Table 58:
Preparation: Crushing and grinding – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	25	8	14	56	0.14	52	32	16	LOD !	0.23	0.278
Stationary	14	8	5	35.7	0.01	92.9	7.1	0	0.005 +	0.0312	0.445
< 2 hrs											
Stationary	15	6	1	6.7	0.038	40	60	0	0.175	0.8	0.95

Quartz and cristobalite – pairs combined

Here, too, higher exposures are recorded when quartz and cristobalite are combined. However, the difference is not as big as in the previous area Preparation: Mixing, screening, transporting.

Table 59:
Quartz and cristobalite (pairs combined) – preparation: crushing and grinding – refractory products, production

Sampling method	Number of measured values #	Number of companies	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs								
Personal	25	8	52	32	16	LOD !	0.2433	0.3083
Stationary	13	8	92.9	7.1	0	0.005 +	0.0336	0.4452
< 2 hrs								
Stationary	15	6	33.3	66.7	0	0.2685	0.86	0.9553

Values included in the statistics as totals of a quartz value and a cristobalite value combined and coming from the same sampling medium were counted as single measured values

9.5.3 Shaping

Table 60:
Shaping – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	29	18	17	58.6	0.046	89.7	10.3	0	LOD !	0.0508	0.104
Stationary	217	30	46	21.2	0.01	98.6	1.4	0	0.005 +	0.0183	0.024
‹ 2 hrs											
Stationary	10	3 **	4	40	0.015	90	10	0	0.006 +	0.034	0.0635

Cristobalite

There is no relevant increase in exposure to silicogenic components due to cristobalite. Of the 98 cristobalite readings (stationary measurements), only 20% is detectable exposures, which is also less than one tenth of the AS.

Table 61:
Cristobalite – shaping – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	98	12	76	77.6	0.008	100	0	0	LOD !	0.0036 +	0.005 +

9.5.4 Preparation for firing

Figure 16:
Placing refractory bricks on kiln cars. Source: VBG

Table 62:
Preparation for firing – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	14	6	3	21.4	0.001	100	0	0	0.002	0.01	0.0181

9.5.5 Firing

Table 63:
Firing – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	24	11	13	54.2	0.021	91.7	8.3	0	LOD !	0.0374	0.0558
Stationary	44	15	2	4.5	0.01	95.5	4.5	0	0.009 +	0.0298	0.0454

9.5.6 Finishing

Table 64:
Finishing – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	31	16	19	61.3	0.015	93.5	6.5	0	LOD !	0.0377	0.0552
Stationary	59	25	14	23.7	0.019	98.3	1.7	0	0.005 +	0.018 +	0.0255

Table 65:
Cristobalite – finishing – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Stationary	21	14	5	23.8	0.007	95.2	4.8	0	0.012	0.0389	0.0428

Quartz and cristobalite – pairs combined

In the data set of stationary measurements, we can see that cristobalite exposure leads to an increase in silicogenic exposures (factor 2). However, there is no such effect for personal measurements (Table 66). If the exposure were to increase and cristobalite were included to the same extent, the result would be a clear exceedance of the AS for the 90% value. Whether this is actually the case is a question that will need to be checked through personal measurements in the future.

Table 66:
Quartz and cristobalite (pairs combined) – finishing – refractory products, production

Sampling method	Number of measured values #	Number of companies	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs								
Personal	31	16	93.5	6.5	0	LOD !	0.0377	0.0552
Stationary	59	25	96.6	3.4	0	0.006 +	0.035	0.0441

Values included in the statistics as totals of a quartz value and a cristobalite value combined and coming from the same sampling medium were counted as single measured values

9.5.7 Packaging, quality control

Table 67:
Packaging, quality control – refractory products, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	14	7	0		No details	100	0	0	0.004	0.0146	0.0168

9.6 Sand-lime brick, production

Sector
Sand-lime brick, production

Sand and quicklime are mixed together and fed into a reactor via conveyors where the quicklime is exothermically slaked to hydrated lime ($Ca(OH)_2$) with the addition of water. Further moistening ensures that the optimum pressing moisture is reached, and the stones are formed using hydraulic presses. The blanks are then hardened under saturated steam pressure in stone hardening boilers, at temperatures of approx. 200 °C. In the production process, silicate-lime hydrate phases are formed, giving the stone blank its strength.

Exceedances of the AS for quartz-containing respirable dust are mainly found in the finishing of the completed find lime bricks and partly during preparation. During the finishing process, the stones are machined or cut to size. In recent years, there has been a sharp increase in such treatment operations, in which, for example, the stones are smoothed for laying in thin-bed mortar, the edges are bevelled or visible surfaces are embossed or cracked.

Figure 17:
Exit area of hardening boilers for sand-lime bricks.
Source: VBG

9.6.1 Preparation

Table 68:
Preparation – sand-lime brick, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	5 ***	5	1	20	0.01	80	20	0	“=” values: 0.003 to 0.063		
< 2 hrs											
Stationary	15	7	1	6.7	0.034	20	80	0	0.11	3.35	3.475

9.6.2 Shaping

Table 69:
Shaping – sand-lime brick, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	35	25	17	48.6	0.017	97.1	2.9	0	0.0085 +	0.0305	0.0335
Stationary	41	25	6	14.6	0.011	95.1	4.9	0	0.0125	0.0399	0.0467
< 2 hrs											
Stationary	32	11	2	6.3	0.036	43.7	56.3	0	0.052	0.108	0.152

9.6.3 Finishing

Table 70:
Finishing – sand-lime brick, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	17	15	9	52.9	0.011	82.4	17.6	0	LOD !	0.0771	0.112
Stationary	23	15	0		No details	87	13	0	0.008	0.054	0.0838

9.7 Porcelain and ceramics (industrial), production

Sector
Porcelain and fine ceramic materials, production
Porcelain and tableware ceramics, production
Utility, ornamental and artistic ceramics (industrial), production

A mixture of 50% kaolin, 25% quartz and 25% feldspar can be regarded as a standard ratio for porcelain material. Quartz and feldspar of them hard materials, are pulverised in drum mills and added to the kaolin slurry. The kaolin is dissolved in water in vats using whisks. The resulting slurry is either processed directly, or it is drained in filter presses. Another process is the production of granules by injecting the slurry into a spray tower. Since the mid-1970s, porcelain factories have increasingly switched to sourcing the finished mass from raw material manufacturers rather than preparing it themselves. This has significantly reduced the load porcelain plants. In the shaping process, rotationally symmetrical products are turned (in) or rolled over on machines. Casting involves pouring slurry into gypsum moulds, resulting in cullet on the boundary layer due to the water-absorbing property of the gypsum. The excess slurry is poured out and the blank is removed from the mould. Since the late 1980s, large series have been manufactured through the isostatic pressing of spray particles. Seams and burrs on the dried blanks are scraped off and then smoothed down with damp sponges. Biscuit firing gives the blank the necessary strength so that it can then be glazed. This is followed by glost firing and sometimes also decorative firing. In a final step, the finishing, the surfaces of the porcelain articles are polished until smooth.

Exceedances of the AS for quartz-containing respirable dust, some of which are still significant, are mainly found during preparation, although they also occur during firing and cleaning. At the firing stage, the strong thermal conditions keep the dust in a state of suspension for a long time, and cleaning (removal of burrs and irregularities) is mainly carried out manually. At the finishing stage, the AS for quartz-containing respirable dust can usually be maintained with the help of well-adapted stationary extraction systems. The porcelain industry is an example of how over the years the dust situation has been significantly improved through the modernisation of manufacturing equipment and the resulting optimisation, above all, of technical dust abatement measures. Moreover, most of the material preparation is now outsourced to external contractors. Such operations are also included in the evaluation in sections 9.4 and 9.7.1.

Figure 18:
Removal of kaolin from a material box using a suction hose. Source: VBG

9.7.1 Preparation

Table 71:
Preparation – porcelain and ceramics (industrial), production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	23	13	5	21.7	0.009	69.6	30.4	0	0.028	0.0931	0.1
Stationary	36	16	1	2.8	0.001	69.4	30.6	0	0.007	0.104	0.134
‹ 2 hrs											
Stationary	25	11	4	16	0.038	52	48	0	0.041	0.39	0.838

9.7.2 Moulding

Figure 19:
Low-dust moulding of porcelain tableware using the pressure casting method. Source: VBG

Table 72:
Shaping – porcelain and ceramics (industrial), production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	28	18	12	42.9	0.01	89.3	10.7	0	0.009 +	0.0388	0.0594
Stationary	57	29	4	7	0.009	100	0	0	0.007 +	0.0223	0.0243

9.7.3 Decorating, printing, firing

Figure 20:
Tunnel kiln exit
after firing. Source: VBG

Table 73:
Decorating, printing, firing – porcelain and ceramics (industrial), production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	24	13	11	45.8	0.012	75	25	0	0.006 +	0.0952	0.118
Stationary	57	26	7	12.3	0.006	96.5	3.5	0	0.003 +	0.0159	0.0221

9.7.4 Fettling

Figure 21:
Manual white fettling of porcelain. Source: VBG

Table 74:
Fettling – porcelain and ceramics (industrial), production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	21	13	9	42.9	0.009	85.7	14.3	0	0.0095	0.103	0.119
Stationary	42	18	0		No details	97.6	2.4	0	0.004	0.0198	0.0288

9.7.5 Finishing

Table 75:
Finishing – porcelain and ceramics (industrial), production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	20	11	15	75	0.017	95	5	0	LOD !	0.028	0.029
Stationary	30	14	5	16.7	0.015	93.3	6.7	0	0.002 +	0.014 +	0.0495

9.8 Sanitary ceramics, production

Sector
Sanitary ceramics, production

Sanitary ceramics are a particularly dense type of porcelain (vitreous china) with a high level of mechanical strength. Some typical products are washbasins, washstands, sinks, toilets and urinals. Their production involves grinding the raw materials – quartz, feldspar, kaolin and clay – in drum mills. The resulting slurry is poured into plaster moulds, creating a so-called cullet at the boundary layer due to the water-absorbing properties of the gypsum. The excess slurry is poured out and the blank is removed from the mould. For some years now, shaping has increasingly been carried out using a die-casting process based on plastic moulds.

After shaping and drying, the ceramic parts are manually finished in white plaster. Using sandpaper or abrasive cloth, the sanitary ceramics is cleaned of any shaping seams from the multi-part moulds and other surface defects resulting from sanding activities. Finally, the surfaces are polished with damp sponges. The subsequent glazing with a ceramic glaze requires a dust-free surface. The sanitary ceramics is therefore cleaned in extractor cabins where such dust is blown off with compressed air. The glaze coat is usually sprayed onto the surface. Next, the mould is fired. High-quality sanitary ceramics have been refined since the mid-1980s by grinding and sawing to size.

The exposure situation is similar to the one described in section 9.7. Dust capture is particularly problematic in the dry, predominantly manual treatment of large-format products (finishing for firing) such as washbasins and toilets. Due to their size and very different shapes and contours, direct and complete dust capture at the rendering point is only possible with extraction are equipped with specially designed extractor elements.

9.8.1 Preparation

Table 76:
Preparation – sanitary ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	12	7	4	33.3	0.009	83.3	16.7	0	0.029	0.106	0.124
Stationary	8 ***	5	1	12.5	0.001	62.5	37.5	0	"=" values: 0.01 to 0.12		

9.8.2 Shaping

Figure 22:
Toilet bowl after moulding. Source: VBG

Table 77:
Shaping – sanitary ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	11	5	3	27.3	0.009	54.5	45.5	0	0.0425	0.167	0.242
Stationary	28	7	1	3.6	0.011	89.3	10.7	0	0.019	0.0508	0.063
< 2 hrs											
Stationary	9 ***	5	0		No details	55.6	44.4	0	"=" values: 0.004 to 0.2		

9.8.3 Preparation for firing

Table 78:
Preparation for firing – sanitary ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	66	11	13	19.7	0.026	50	50	0	0.046	0.294	0.338
Stationary	45	12	1	2.2	0.011	93.3	6.7	0	0.008 +	0.022	0.0522
< 2 hrs											
Personal	15	6	2	13.3	0.017	20	80	0	0.15	0.535	0.92
Stationary	13	7	0		No details	46.2	53.8	0	0.044	0.714	0.738

Table 78a:
Dust capture – preparation for firing – sanitary ceramics, production

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	65	11	12	18.5	0.026	49.2	50.8	0	0.0495	0.295	0.34

9.8.4 Finishing

Figure 23:
White rendering on WC basins in a white rendering cabin. Source: VBG

Table 79:
Finishing – sanitary ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	11	6	2	18.2	0.009	63.6	36.4	0	0.017	0.0958	0.343
Stationary	9 ***	5	0		No details	77.8	22.2	0	“=” values: 0.004 to 0.14		

9.9 Technical ceramics, production

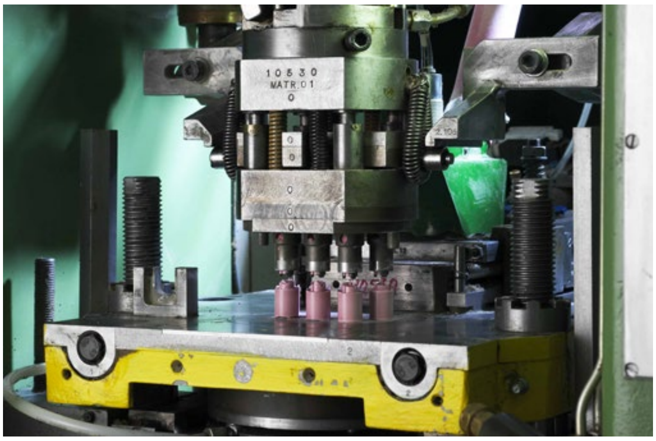
Sector
Technical ceramics, production
Special ceramics, production

Technical ceramics is a collective term that describes products used in a wide range of applications in technical fields (e.g. electronics and electrical engineering, chemistry, laboratories, medical engineering and mechanical and automotive engineering). Its properties are specifically optimised for certain technical applications. In addition to normal raw porcelain materials, manufacture mainly involves materials such as steatite, cordierite, aluminium oxide, zirconium oxide and silicate ceramics, but also non-oxide materials such as carbides and nitrides. The preparation, shaping and firing are tailored to suit each raw material. Special shaping and firing processes are often used in production, e.g. hot isostatic pressing and firing under a reducing atmosphere.

After shaping and drying, the moulded parts are finished manually. Sandpaper and abrasive cloth are used to clean the parts from shaping seams and other surface defects. Finally, the surfaces are polished with damp sponges.

As the materials that are in use – especially raw materials – are largely quartz-free, the AS for quartz-containing respirable dust is mostly adhered to. When preparing the mixture, the 90% values measured for quartz-containing respirable dust on persons, in particular, are somewhat above the AS. At the downstream manufacturing stages, dust protection measures are usually at a high technical level, which is reflected in this evaluation. Preparation for firing also has higher personal readings for quartz-bearing respirable dust. This is caused by manual treatment operations during the cleaning of the parts and by the occasional use of quartz-containing firing additives.

Figure 24:
Pressing of ceramic articles for technical applications.
Source: VBG



9.9.1 Preparation: Mixing, screening, transporting

Table 80:
Preparation: Mixing, screening, transporting – technical ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	45	21	22	48.9	0.022	84.4	15.6	0	0.0075 +	0.066	0.0783
Stationary	58	19	6	10.3	0.018	96.6	3.4	0	0.007 +	0.0232	0.0329
< 2 hrs											
Stationary	19	8	6	31.6	0.023	63.2	36.8	0	0.0138 +	0.189	0.271

Table 80a:
Dust capture – preparation: Mixing, screening, transporting – technical ceramics, production

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	32	15	14	43.8	0.019	84.4	15.6	0	0.008 +	0.0642	0.0758

9.9.2 Preparation: Comminution, grinding

Table 81:
Preparation: Comminution, grinding – technical ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	18	15	8	44.4	0.019	88.9	11.1	0	0.01 +	0.0558	0.0965
Stationary	19	12	3	15.8	0.004	94.7	5.3	0	0.007	0.0441	0.0454
< 2 hrs											
Stationary	9 ***	6	4	44.4	0.052	55.6	33.3	11.1	"=" values: 0.006 to 0.37		

9.9.3 Shaping

Table 82:
Shaping – technical ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	38	21	24	63.2	0.01	92.1	7.9	0	LOD !	0.0384	0.0593
Stationary	94	33	16	17	0.01	92.6	7.4	0	0.004 +	0.035	0.0612

9.9.4 Preparation for firing

Table 83:
Preparation for firing – technical ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	33	17	14	42.4	0.013	84.8	15.2	0	0.0065 +	0.071	0.389
Stationary	42	20	15	35.7	0.006	90.5	9.5	0	0.002 +	0.0376	0.0866

9.9.5 Firing

Table 84:
Firing – technical ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	11	8	8	72.7	0.034	90.9	9.1	0	LOD !	0.035	0.0491
Stationary	29	16	13	44.8	0.009	100	0	0	0.003 +	0.0147	0.0271

9.9.6 Finishing

Table 85:
Finishing – technical ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	29	14	24	82.8	0.022	96.6	3.4	0	LOD !	0.0243	0.0286
Stationary	65	26	15	23.1	0.005	96.9	3.1	0	0.0025 +	0.0155	0.0215
‹ 2 hrs											
Stationary	11	7	3	27.3	0.062	81.8	9.1	9.1	0.003 +	0.0288 +	0.0512 +

9.9.7 Packaging, quality control

Table 86:
Packaging, quality control – technical ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	12	5	10	83.3	0.009	91.7	8.3	0	LOD !	0.0081 +	0.113
Stationary	12	5	2	16.7	0.002	91.7	8.3	0	0.001 +	0.0038	0.0332

9.10 Wall and floor tiles, production

Sector
Wall and floor tiles, production

Materials for the production of tiles include clay, kaolin and mineral aggregates such feldspar dolomite and fireclay. The raw materials are ground in drum mills and then suspended in water. The resulting slurry is injected into a heated spray tower and dried into a spray granulate. This dry shaping material is formed into tiles under high pressure using hydraulic presses. The tiles are either fired in a single-firing process, or the glaze can be melted separately in a second firing process. Furnace and stove tiles are pressed from plastic clay that has been tempered with fireclay, and complex shapes can also be cast. The glaze is applied by dipping, dousing, spraying or painting.

Significant exceedances of the AS for quartz-containing respirable dust are mainly found during preparation and shaping. When a mixture is prepared through grinding, screening and mixing and also in spray-drying – a typical process in the tile industry – the 90% values are clearly above the AS. Particularly at modern facilities, workers handling the preparation of the material spend part of their shifts in externally ventilated control rooms. The values shown in Table 87 should therefore generally be given a factor for reduced exposure. Room for improvement also exists in shaping and pressing. Dust emissions occur when pressing takes place at high pressure, when the granulate is crushed by the pressure of the press and when the displaced air takes the finely crushed raw material with it. The capture of dust and waste at the presses and during the work and transport processes directly downstream is still problematic and requires improvement. Another source of dust is the frequent replacement of moulds.

Figure 25:
Drum mills for the crushing of raw material in the tile industry. Source: VBG

Figure 26:
Low-dust feeding of raw materials using big bags. Source: VBG

9.10.1 Preparation: Grinding, mixing, screening, transporting and comminution

Table 87:
Preparation: Grinding, mixing, screening, transporting and comminution – wall and floor tiles, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	35	15	5	14.3	0.009	65.7	34.3	0	0.0265	0.14	0.215
Stationary	53	18	0		No details	67.9	32.1	0	0.0345	0.0948	0.1235
< 2 hrs											
Stationary	20	8	2	10	0.023	25	75	0	0.13	0.52	0.52

9.10.2 Shaping

Figure 27:
Hydraulic tile press
Source: VBG

Table 88:
Shaping – wall and floor tiles, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	24	14	2	8.3	0.009	66.7	33.3	0	0.041	0.126	0.138
Stationary	35	18	0		No details	54.3	45.7	0	0.04535	0.091	0.1325
< 2 hrs											
Stationary	13	8	0		No details	15.4	84.6	0	0.14	0.405	0.462

9.10.3 Preparation for firing, firing

Figure 28:
Tile removal behind
a fast-fire tunnel kiln.
Source: VBG

Table 89: Preparation for firing, firing – wall and floor tiles, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	53	19	0		No details	84.9	15.1	0	0.019	0.0632	0.0999

9.10.4 Finishing, quality control, packaging

Figure 29:
Spray glazing of tiles.
Source: VBG

Table 90:
Finishing, quality control, packaging – wall and floor tiles, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	22	12	1	4.5	0.003	100	0	0	0.01	0.027	0.0433

9.11 Structural ceramics, production

Sector
Structural ceramics, production

The highly heterogeneous group of structural ceramics comprises ceramic products manufactured for special applications in the construction industry. These are mainly large stoneware (vitrified clay pipes), ceramic façade elements in various formats and shapes (slabs, brick slips) as well as chimney pipes and split tiles. When manufacturing large stoneware, the raw material is also mixed with fireclay containing cristobalite. A common feature of the production process is that moist, clay-like materials are used in the shaping process. The different shapes are made using extruders, followed by cutting or punching, and then dried and fired. During the shaping process, the AS for quartz-containing respirable dust is therefore mostly observed. However there are significant exceedances of the AS in the preparation of the raw materials and in the finishing process. for the BM matrix method. Wet and dry processes are often used in parallel for the finishing of the fired articles, which involves sawing or grinding. Care should be taken to apply wet processes at all times and/or to use extraction systems with effective dust capture.

Measured values in the structural ceramics sub-sector also include a significant number of cristobalite values. In some cases, ceramic materials are processed which then have fireclay added to them, and the fireclay may contain more or less high proportions of cristobalite. Particularly with stationary measurements and sampling durations of less than 2 hours, this leads to increased values for quartz and cristobalite as silicogenic components (pairs combined).

This is mainly relevant for companies that produce large stoneware (vitrified clay pipes). In such cases, the mean shift values (sampling duration more than 2 hours) in the treatment and preparation of the fired articles, e.g. through sawing or grinding, are also significantly increased by the cristobalite content.

9.11.1 Preparation: Grinding, mixing, screening, transporting and comminution

Table 91:
Preparation: Grinding, mixing, screening, transporting and comminution – structural ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	22	9	6	27.3	0.009	45.5	54.5	0	0.064	0.302	0.401
Stationary	24	10	2	8.3	0.002	75	25	0	0.02	0.0858	0.1066
< 2 hrs											
Stationary	20	7	0	0	No details	5	95	0	0.21	0.5	0.51

Quartz and cristobalite – pairs combined

Table 92:
Quartz and cristobalite (pairs combined) – preparation: Grinding, mixing, screening, transporting and comminution – structural ceramics, production

Sampling method	Number of measured values #	Number of companies	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs								
Personal	22	9	45.5	54.5	0	0.064	0.374	0.4145
Stationary	24	10	75	25	0	0.02	0.0858	0.1066
< 2 hrs								
Stationary	20	7	5	95	0	0.213	0.81	0.84

Values included in the statistics as totals of a quartz value and a cristobalite value combined and coming from the same sampling medium were counted as single measured values

9.11.2 Shaping

Table 93:
Shaping – structural ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	15	9	0		No details	0.085	93.3	6.7	0	0.015	0.033

9.11.3 Preparation for firing, firing

Table 94:
Preparation for firing, firing – structural ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	7	5	50	0.009	90	10	0	0.008 +	0.045	0.0665
Stationary	27	11	1	3.7	0.001	92.6	7.4	0	0.0125	0.0379	0.0764

9.11.4 Finishing, packaging, quality control

Figure 30:
Wet grinding of vitrified clay pipes. Source: VBG

Table 95:
Finishing, packaging, quality control – structural ceramics, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	15	5	0		No details	93.3	6.7	0	0.007	0.032	0.056

9.12 Furnace and stove tiles, production

Sector
Furnace and stove tiles, production

There is no differentiation by work areas.

Table 96:
No differentiation by work areas – furnace and stove tiles, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	12	7	4	33.3	0.017	83.3	16.7	0	0.009 +	0.0774	0.11
Stationary	29	14	0		No details	93.1	6.9	0	0.016	0.0409	0.0826

9.13 Abrasive tools, production

Sector
Abrasive tools and agents, production

Grinding, cutting and roughing discs, honing stones, scythe stones and other abrasive products are used for the chip removal on different materials. They consist of an abrasive product (abrasive grit) such as corundum, silicon carbide or diamond, which is embedded in a matrix as a composite material. This is done either through ceramic or organic bonding, e.g. through mineral materials or glass or through synthetic resin or bakelite. The abrasive grit and the bonding agent are mixed and pressed. The mixtures of abrasive grit and bonding agent are usually created manually. Abrasive grits with a ceramic bond are fired, and abrasive grits with an organic bond are cured.

Significant exceedances of the AS for quartz in respirable dust are found in raw material preparation, but also elsewhere. For the shaping, firing and finishing stages, the 90% values are mostly below the AS for quartz in respirable dust. Problematic work areas are due to the specific structure of the industry, i.e. in some cases there is no implementation of state-of-the-art technology or of the industry standard in the relevant operations and procedures. Moreover, quartz sand is sometimes sprinkled on the kiln cars as a firing additive prior to firing in order to prevent the products from sticking to the kiln cars. This produces a significant amount of dust which contains quartz and cristobalite. The latter is formed from the sprinkled quartz sand repeated cycles. The replacement of quartz sand with quartz-free grit brings a significant improvement.

9.13.1 Preparation

Table 97:
Preparation – abrasive tools, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	43	24	16	37.2	0.015	79.1	20.9	0	0.014 +	0.12	0.182
Stationary	44	18	8	18.2	0.007	97.7	2.3	0	0.004 +	0.0302	0.0398
< 2 hrs											
Stationary	12	6	4	33.3	0.021	91.7	8.3	0	0.003 +	0.0208 +	0.182

9.13.2 Shaping

Table 98:
Shaping – abrasive tools, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	15	8	11	73.3	0.045	93.3	6.7	0	LOD !	0.0302 +	0.139
Stationary	43	15	4	9.3	0.009	97.7	2.3	0	0.0043 +	0.0237	0.0307

9.13.3 Firing

Table 99:
Firing – abrasive tools, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	23	9	6	26.1	0.015	60.9	39.1	0	0.03	0.131	0.242
Stationary	17	9	1	5.9	0.011	88.2	11.8	0	0.021	0.0577	0.0917

9.13.4 Finishing

Table 100:
Finishing – abrasive tools, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	18	11	12	66.7	0.015	88.9	11.1	0	LOD !	0.0494	0.0589
Stationary	15	8	1	6.7	0.006	100	0	0	0.0035 +	0.0065	0.00775

9.14 Brickwork and tilework, production

Sector
Brickwork and tilework, production

The most common representatives in the group of bricks are backing bricks, facing bricks (clinker bricks) and roof tiles (beaver tiles or pantiles). For the production process, the clayey raw materials are fed into box feeders and are then crushed and mixed in crushers and in the pan grinder. The final during two further preparation stages involves the use of fine rolling mills, which have been working with smaller and smaller gap widths of less than 0.5 mm since the 1980s. For good homogenisation, the material is mashed in a marsh house (where it is stored in a damp place to achieve the right moisture content). To make backing bricks, aeration agents such as polystyrene and papermaking sludge are added to the clay. The mass, plasticised with water or steam, is pulled in de-airing pugmills to form a continuous strand from which the separate wall or roof tiles are cut. Roof tiles with seams and more complex shapes are pressed on turret or form. Next, the products are dried. Roof tiles are usually engobed or glazed before firing. Since the 1990s, back bricks have increasingly been planed on the front sides after firing.

In preparation (comminution, grinding, mixing, screening and transporting), the AS for quartz-containing respirable dust is clearly exceeded. However, exposure may be shorter, which must be taken into account when making an assessment. For the operations involved in the preparations for firing (setting and unloading of brick products onto kiln cars at the kiln and in production before and after firing) and also for the firing itself, the evaluation shows 90% values above the AS for quartz-containing respirable dust. What is problematic here is of dried and fired brick products during various handling processes. The resulting dust and any material that drops off is often only captured at certain points. Moreover, in the production of clinker, quartz sand is often used to sprinkle the kiln cars, which causes additional quartz-containing respirable dust emissions. In the finishing of fired products (sawing, grinding), the state of the art (including closed systems, optimal dust capture) has not yet been fully implemented. Furthermore, the existing plants are subject to a high degree of wear and tear due to their heavy-duty operation.

9.14.1 Preparation: Comminution, grinding

Table 101:
Preparation: comminution, grinding – brickwork and tilework, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	37	29	4	10.8	0.009	45.9	54.1	0	0.051	0.223	0.383
Stationary	74	47	0		No details	44.6	55.4	0	0.056	0.126	0.156
< 2 hrs											
Stationary	65	27	0		No details	15.4	84.6	0	0.145	0.615	0.775

9.14.2 Preparation: mixing, screening, transporting

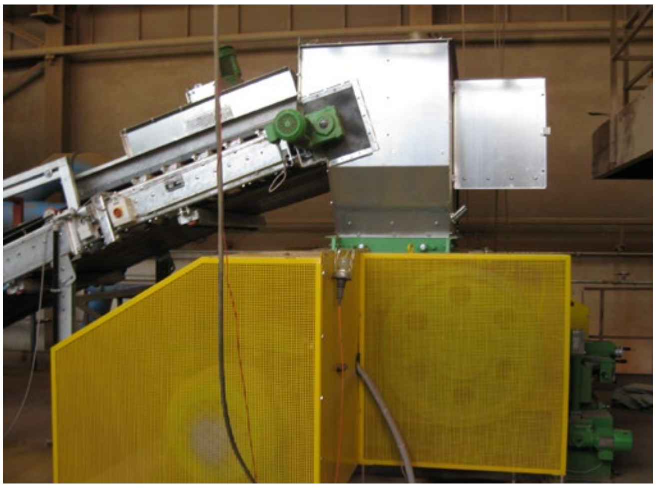


Figure 31:
Low-dust material feed thanks to enclosure. Source: VBG

Table 102:
Preparation: Mixing, screening, transporting – brickwork and tilework, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	85	71	17	20	0.01	76.5	23.5	0	0.0275	0.165	0.25
Stationary	76	48	1	1.3	0.017	76.3	23.7	0	0.029	0.0858	0.13
< 2 hrs											
Stationary	35	13	0		No details	11.4	88.6	0	0.13	0.63	0.745

Table 102a:
Dust capture – preparation: Mixing, screening, transporting – brickwork and tilework, production

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	40	34	7	17.5	0.01	72.5	27.5	0	0.029	0.19	0.27
LEV = no	17	16	5	29.4	0.009	64.7	35.3	0	0.0255	0.176	0.201

9.14.3 Shaping

Figure 32:
Roof tile after the pressing process on a turret. Source: VBG

Table 103:
Shaping – brickwork and tilework, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	33	29	18	54.5	0.01	87.9	12.1	0	LOD !	0.0609	0.09
Stationary	149	85	4	2.7	0.009	92.6	7.4	0	0.007 +	0.0311	0.0762
< 2 hrs											
Stationary	15	5	0		No details	13.3	86.7	0	0.115	0.805	1.075

9.14.4 Preparation for firing

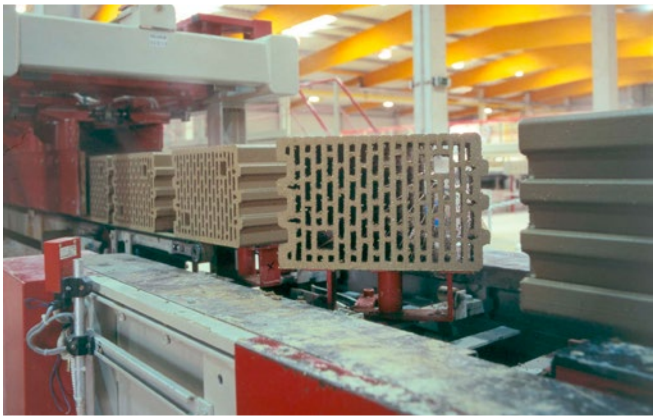


Figure 33:
Backing bricks on an automatic conveyor. Source: VBG

Table 104:
Preparation for firing – brickwork and tilework, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	16	13	12	75	0.01	87.5	12.5	0	LOD !	0.0412	0.0874
Stationary	64	34	2	3.1	0.011	93.7	6.3	0	0.007 +	0.0366	0.0558
‹ 2 hrs											
Stationary	10	4 **	1	10	0.13	50	40	10	0.047 +	0.17	0.195

9.14.5 Firing

Table 105:
Firing – brickwork and tilework, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	32	23	10	31.3	0.012	78.1	21.9	0	0.018	0.138	0.232
Stationary	153	86	6	3.9	0.03	86.3	13.7	0	0.0085 +	0.0787	0.134
‹ 2 hrs											
Stationary	17	8	1	5.9	0.018	58.8	41.2	0	0.0135 +	0.273	0.429

9.14.6 Finishing

Table 106:
Finishing – brickwork and tilework, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	22	19	9	40.9	0.009	59.1	40.9	0	0.022	0.226	0.385
Stationary	81	54	3	3.7	0.001	84	16	0	0.009	0.0689	0.148
‹ 2 hrs											
Stationary	10	4 **	1	10	0.002	60	40	0	0.003	1	1.15

9.14.7 Packaging, quality control

Table 107:
Packaging, quality control – brickwork and tilework, production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	9	8	80	0.01	90	10	0	LOD !	0.016	0.043
Stationary	40	30	1	2.5	0.001	92.5	7.5	0	0.007	0.026	0.11

10 Chemical, pharmaceutical, rubber and plastics industries

10.1 Chemical and pharmaceutical industries, paints

Sector
Chemical industry
Abrasives and polishes (dry), production
Paints, adhesives and joint fillers, production/processing
Pharmaceutical products, production
Cosmetic products, production
Cleaning and sanitary products
Putties, production
Paints, production (solvent-based)
Paints, production (emulsion paints and renderings)
Paints, production and processing (powder coatings)

In the chemical industry, quartz-containing substances are added to a variety of products and articles to achieve or improve certain properties. Quartz-containing substances are usually added in the form of fillers or thickeners. However, they can also be used to create certain properties, e.g. abrasion. Furthermore, higher-grade compounds such as pure silicon and silicon carbide can be made from quartz through chemical processes. Quartz is also often present as an impurity in a variety of compounds, e.g. talc. Quartz can sometimes be replaced by amorphous silica. Together with technical improvements to facilities and workplaces, this has led to a significantly pollution in recent decades.

10.1.1 Weighing in

Weighing-in operations can be fully automatic or manual. In manual weigh-in, quartz or quartz-containing solids are removed, e.g. from drums, buckets or bags, using a scoop, and are then weighed openly on scales. Weighing stations are often equipped with dust extractors.

10.1.2 Preparation of liquid mixtures

In the production of paints, varnishes and adhesives, quartz and quartz-containing solids are poured fully automatically from silos or big bags or manually from drums, buckets or sacks into storage containers or mixing vessels. This leads to different quartz dust loads, depending on the material properties, quantities and extraction equipment.

Table 108:
Weighing-in – chemical and pharmaceutical industries, paints

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	14	13	11	78.6	0.071	92.9	0	7.1	LOD !	0.0258 +	0.0295 +
< 2 hrs											
Personal	11	5	7	63.6	0.11	63.6	18.2	18.2	LOD !	0.0546 +	0.0798 +

Table 109:
Preparation of liquid mixtures – chemical and pharmaceutical industries, paints

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	14	10	10	71.4	0.012	78.6	21.4	0	LOD !	0.128	0.246
‹ 2 hrs											
Personal	11	7	9	81.8	0.072	63.6	18.2	18.2	LOD !	0.0693 +	1.345
Stationary	5 ***	3 **	1	20	0.023	20	80	0	"=" values: 0.07 to 1.1		

10.1.3 Preparation of dry mixtures

Filling compounds, adhesives and paints are made by mixing various solids and other additives. When quartz, cristobalite and other quartz-containing aggregates are added to the feeders and mixers, quartz dust loads may occur.

The sporadically high cristobalite readings are due to the manual addition of cristobalite to open mixers.

Table 110:
Preparation of dry mixtures – chemical and pharmaceutical industries, paints

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	74	42	45	60.8	0.047	82.4	17.6	0	LOD !	0.073	0.129
Stationary	15	12	10	66.7	0.046	86.7	13.3	0	LOD !	0.0395 +	0.057
‹ 2 hrs											
Personal	28	19	18	64.3	0.042	82.1	17.9	0	LOD !	0.232	0.706
Stationary	11	6	6	54.5	0.076	45.4	36.4	18.2	LOD !	0.276	0.341

Table 111:
Cristobalite – preparation of dry mixtures – chemical and pharmaceutical industries, paints

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
No differentiation											
Personal	14	6	3	21.4	0.014	57.1	42.9	0	0.047	0.706	1.021

10.1.4 Filling and packaging

After products have been manufactured, usually in mixing processes, they are filled into different types of packaging, e.g. big bags, sacks, drums, buckets and boxes. Depending on the type of product, quantity and filling technology, different amounts of silica dust may develop.

10.1.5 Production, reaction plants

Many production facilities are largely enclosed, so that quartz dust loads tend to be lower. In open production plants, e.g. open mixers and screening units, higher loads can also occur.

Table 112:
Filling and packaging – chemical and pharmaceutical industries, paints

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	48	23	39	81.3	0.046	95.8	4.2	0	LOD !	0.0222 +	0.047
Stationary	19	13	13	68.4	0.009	89.5	10.5	0	LOD !	0.0425	0.204

Table 113:
Production, reaction plants – chemical and pharmaceutical industries, paints

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	23	14	21	91.3	0.078	91.4	4.3	4.3	LOD !	LOD !	0.035 +
Stationary	5 ***	5	3	60	0.012	80	20	0	“=” values: 0.01 to 0.13		
< 2 hrs											
Personal	16	11	12	75	5.1	62.5	12.5	25	LOD !	1.122 +	10.44

10.2 Roofing felt and bitumen sheeting, production

Sector
Roofing felt and bitumen roof sheeting, production

Roofing felt and bitumen roof sheeting are made from different materials. It is possible to use paper, plastic sheeting, rubber sheeting, glass-fibre fabric, polyester and jute sheeting. For certain purposes, the roofing felt and bitumen sheets are sprinkled with gravel, flakes of slate or quartz sand. The highest levels of exposure to containing dusts occur around the sprinkler units. However, there are usually no regular workstations there.

10.3 Foundry auxiliaries, production

Sector
Foundry auxiliaries, production

Sand and other minerals such as aluminosilicates, fireclay and magnesite are used for the production of foundry sand for the foundry industry. Furthermore, bonding agents such as clays, waterglass and cement are also needed. Quartz dust is generated, for example, when pouring, mixing, drying and filling the products, and also when cleaning the equipment.

Table 114:
No differentiation by work areas – roofing felt and bitumen sheeting, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	9 ***	6	0		No details	44.4	55.6	0	“=” values: 0.014 to 1		
Stationary	11	7	2	18.2	0.026	63.6	36.4	0	0.031	0.887	0.989

Table 115:
No differentiation by work areas – foundry auxiliaries, production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	28	10	7	25	0.016	60.7	39.3	0	0.02	0.216	0.352

10.4 Rubber goods, production and processing

Sector
Rubber goods, production and processing
Tyres, manufacturing and retreading
Rubber goods (technical), production
Fine rubber products (latex products etc.)

A wide range of raw materials and additives are processed to produce rubber compounds. Examples are rubber, soot, anti-ageing agents, vulcanisation aids, release agents and other additives, which may also contain quartz. The processes in the manufacture of Glass are mixing, kneading, finishing and vulcanising, as well as – in some instances – subsequent and further processing. The highest quartz dust loads occur while weighing in and mixing.

10.5 Plastics, production and processing

Sector
Plastic roofing and welded sheets, production
Plastic and plastic foam, processing
Moulded plastic parts, production
Plastic injection moulding
Plastic films, production
Semi-finished plastics, production
Plastic and plastic foam, production
Glass-fibre reinforced plastics, production
Seals, production
Vehicle interior, production
Acid-resistant construction, construction of plastics and containers
Acid-resistant construction

Quartz-containing minerals are used for a wide variety of purposes in the manufacture and treatment of plastic and synthetic products. Such substances can be found, for example, in dental materials and mineral casting. Quartz sand and powder are used, for example, in the manufacturing of façade panels, flooring and glass-fibre-reinforced plastic pipes and fittings. Quartz dust loads can occur, for example, in mixing and extruding as well as in finishing processes, such as drilling, sawing and sanding.

Table 116:
No differentiation by work areas – rubber goods, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	7	6	60	0.047	90	10	0	LOD !	0.034 +	0.0655
Stationary	18	10	13	72.2	0.016	94.4	5.6	0	LOD !	0.0174	0.0307

10.5.1 Manufacturing of plastic parts: extruding, casting, calendering, laminating (GRP), prepreg, foaming

Table 117:
Manufacturing of plastic parts: extruding, casting, calendering, laminating (GRP), prepreg, foaming – plastics, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	19	15	14	73.7	0.014	84.2	15.8	0	LOD !	0.0543	0.0702
Stationary	12	11	7	58.3	0.015	91.7	8.3	0	LOD !	0.0143 +	0.0324
< 2 hrs											
Personal	8 ***	4 **	3	37.5	0.062	50	37.5	14.5	"=" values: 0.024 to 8.9		

10.5.2 Processing: Conveying, filling, mixing, weighing, comminution

Table 118:
processing: Conveying, filling, mixing, weighing, comminution – plastics, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	19	12	15	78.9	0.047	94.7	5.3	0	LOD !	0.0255 +	0.0748

10.5.3 Processing and finishing of plastic products

Table 119:
Processing and finishing of plastic products – plastics, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	31	14	20	64.5	0.019	87.1	12.9	0	LOD !	0.0532	0.109

11 Wood and paper industries

11.1 Wood processing

Sector
Office furniture, production
Wood fibre and chipboard manufacturing
Woodworking and wood processing
Production of writing and drawing utensils
Carpentry, timber construction

The measured values listed here include quartz-containing dusts released during the treatment and processing of wood substitutes and composite materials that have a low wood content and which could not be clearly classified as wood dust as defined in TRGS 553, “Wood Dust” where samples were taken on site.

There is no differentiation by work areas.

11.2 Paper and board, production and processing

Sector
Paper and board, production and processing
Printshop

There is no differentiation by work areas.

Table 120:
No differentiation by work areas – wood processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	6	5	50	0.045	100	0	0	0.012 +	0.028 +	0.0295 +
Stationary	8 ***	3 **	5	62.5	0.014	62.5	37.5	0	“=” values: 0.051 to 0.84		

Table 121:
No differentiation by work areas – paper and board, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	22	8	7	31.8	0.005	100	0	0	0.002 +	0.0156	0.016

12 Foundries, metal manufacturing

12.1 Foundries

Sector
Iron and steel foundries, mixed
Iron foundries
Steel foundries
Non-ferrous metal foundries, mixed
Light metal foundries
Heavy metal foundries
Iron, steel and non-ferrous metal foundries, mixed
Suppliers to the foundry industry
Services for the foundry industry

The work of a foundry is a manufacturing process in which liquid metal is poured into moulds. Depending on the casting process, a distinction is made between sand moulding, shell moulding, chill moulding, die casting and centrifugal/continuous casting as well as art foundry and investment casting. Depending on the material group, a distinction is made between iron and steel foundries, on the one hand, and non-ferrous (NF) metal foundries, on the other. Foundries provide the shortest and most direct way of casting metal products for a wide range of products.

12.1.1 Core making shop

To produce recesses or branched cavities in a cast piece, so-called cores are required. A distinction is made between destructible cores such as sand cores, which are only used for a single cast and are removed from the mould when the cast is emptied, and so-called permanent cores which are made Metal materials and can be used repeatedly. Since 1990, most machines used for core production have been either enclosed or vacuumed. The connected sand mixers are now also encapsulated.

The 90% value for quartz is clearly above the AS, regardless of the Sampling method and duration.

Table 122:
Core making shop – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	175	91	75	42.9	0.05	73.7	26.3	0	0.02 +	0.13	0.175
Stationary	126	69	23	18.3	0.046	72.2	27.8	0	0.0215 +	0.154	0.217
< 2 hrs											
Stationary	11	5	1	9.1	0.078	9.1	81.8	9.1	0.18	0.259	0.548

Table 122a:
Dust capture – core making shop – foundries

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	116	61	58	50	0.047	78.4	21.6	0	0.0145 +	0.114	0.152
LEV = no	52	36	15	28.8	0.05	65.4	34.6	0	0.025 +	0.138	0.164

12.1.2 Moulding shop

In the production of casting moulds, especially sand moulds, a distinction is made between manual and mechanical moulding. Manual moulding involves filling moulding boxes with moulding sand. Next, the sand is compacted either by hand or with a pneumatic tamper. Mechanical moulding means that some or all manual moulding steps are carried out by a machine. This involves the use of moulding machines with pattern plates. The 90% value for quartz is clearly above the AS, regardless of the sampling procedure and duration.

Table 123:
Moulding shop – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	285	130	74	26	0.047	68.4	31.6	0	0.03 +	0.11	0.16
Stationary	177	93	37	20.9	0.048	75.1	24.9	0	0.026 +	0.103	0.14
‹ 2 hrs											
Personal	15	12	3	20	0.046	60	40	0	0.0365 +	0.11	0.117
Stationary	51	19	11	21.6	0.08	74.5	23.5	2	0.024 +	0.109	0.138

Table 123a:
Dust capture – moulding shop – foundries

Dust capture	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	84	58	25	29.8	0.046	71.4	28.6	0	0.024 +	0.0964	0.158
LEV = no	176	90	40	22.7	0.045	66.5	33.5	0	0.031 +	0.128	0.162

12.1.3 Smelters

Metals and their alloys are melted to a liquid state. The high temperatures during the melting phase cause a large number of reactions that can lead to considerable amounts of smoke rising up. The smoke mostly carries particles within the respirable dust fraction. No sand used in the smelter itself, i.e. any quartz dust that is present there has been carried in the air from adjacent parts of the foundry and moulding shop.

The 90% value for quartz is just below the AS for personal measurements and just above the AS for stationary measurements.

Table 124:
Smelters – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	81	52	34	42	0.05	90.1	9.9	0	0.0205 +	0.0489 +	0.0609
Stationary	73	38	21	28.8	0.034	86.3	13.7	0	0.0143 +	0.0551	0.0754
‹ 2 hrs											
Stationary	44	13	2	4.5	0.024	59.1	40.9	0	0.041	0.14	0.168

Table 124a:
Dust capture – smelters – foundries

Dust capture	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	59	42	24	40.7	0.047	91.5	8.5	0	0.02 +	0.0481	0.06
LEV = no	16	9	10	62.5	0.05	87.5	12.5	0	LOD !	0.0402 +	0.106

12.1.4 Casting shop, general operation

In the casting shop, preparatory activities are carried out, such as the production of casting moulds and the melting of materials. Next, the same place also accommodates the actual casting, i.e. the filling of moulds and the solidification of the melt. Furthermore, this is where casts may undergo further processing, such as demoulding (removal from the mould) and fettling (cleaning of casts). In addition, the casting blanks are usually also placed into and take out of storage in this hall.

The 90% value for quartz is clearly above the AS, regardless of the sampling procedure and duration.

Table 125:
Casting shop, general operation – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	155	98	35	22.6	0.062	60	38.7	1.3	0.033 +	0.215	0.297
Stationary	123	68	22	17.9	0.045	61	39	0	0.031 +	0.168	0.229
< 2 hrs											
Personal	21	11	6	28.6	0.077	42.9	47.6	9.5	0.0423 +	0.279	0.289
Stationary	61	19	2	3.3	0.031	16.4	83.6	0	0.12	0.33	0.558

Table 125a:
Dust capture – casting shop, general operation – foundries

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	82	60	14	17.1	0.038	57.3	42.7	0	0.038 +	0.198	0.276
LEV = no	59	42	19	32.2	0.062	66.1	30.5	3.4	0.0253 +	0.158	0.326

12.1.5 Casting operations

Casting means pouring a liquid material into a mould. The mould is filled under the influence of gravity, centrifugal force or pressure. The liquid material solidifies, resulting in the desired finished product. When the molten mass is poured into the mould, this results in a cast. The breakdown of the bonding agents and the burning of casting gases can produce large quantities of smoky hazardous substances (including quartz particles) during casting and cooling. Such substances then escape into the higher parts of the hall.

The 90% value for quartz is clearly above the AS, regardless of the sampling procedure.

Table 126:
Casting operations – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	123	69	52	42.3	0.27	86.2	13	0.8	0.0177 +	0.0657 +	0.165 +
Stationary	169	85	66	39.1	0.057	86.4	13	0.6	0.013 +	0.0651	0.111
< 2 hrs											
Personal	11	8	6	54.5	0.18	54.5	18.2	27.3	LOD !	0.117 +	0.183
Stationary	20	9	6	30	0.013	85	15	0	0.017	0.055	0.12

Table 126a:
Dust capture – casting operations – foundries

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	67	37	26	38.8	0.046	83.6	16.4	0	0.0185 +	0.079	0.156
LEV = no	44	31	21	47.7	0.27	86.3	11.4	2.3	0.017 +	0.0628 +	0.163 +

12.1.6 Fettling, mechanical

Post-treatment of the cast means that the gating system and the risers are cut off, burrs are removed and the cut-off points are smoothed down. Fettling is mainly carried out with the help of an angle grinder. The particles that are released during fettling have a high level of kinetic energy. An extractor can only detect them if the particle beam can be directed as far as possible towards the LEV.

The 90% value for quartz is clearly above the AS, regardless of the sampling procedure and duration.

Table 127:
Fettling, mechanical – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	306	140	62	20.3	0.12	50	49.3	0.7	0.047 +	0.244	0.37
Stationary	162	75	36	22.2	0.054	66.7	32.1	1.2	0.0225 +	0.16	0.289
< 2 hrs											
Personal	26	14	7	26.9	0.14	23.1	61.5	15.4	0.072 +	0.644	0.895
Stationary	45	16	3	6.7	0.038	35.6	64.4	0	0.0665	0.475	0.833

Table 127a:
Dust capture – fettling, mechanical – foundries

Dust capture	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	217	112	40	18.4	0.12	48.9	50.2	0.9	0.051 +	0.24	0.349
LEV = no	77	48	18	23.4	0.031	51.9	48.1	0	0.0435	0.303	0.382

12.1.7 Fettling, blasting

The surfaces of the casts are blasted to remove any remaining residues of the mould and core sand. Casts can be blasted either manually or with blasting machines. In manual blasting, the casts are cleaned in a blasting cabin. This involves the use of blasting media made of metal, non-ferrous metal, corundum or plastic which are either blasted or centrifuged onto the casts. Quartz-containing fine dust can be produced through the destruction of residual mould sand and through the formation of quartz-containing layers.

The 90% value for quartz is clearly above the AS, especially in personal measurements.

Table 128:
Fettling, blasting – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	65	37	15	23.1	0.033	47.7	52.3	0	0.054	0.255	0.357
Stationary	47	28	9	19.1	0.019	59.6	40.4	0	0.0375	0.106	0.133
‹ 2 hrs											
Stationary	15	6	2	13.3	0.028	53.3	46.7	0	0.042	0.165	0.25

Table 128a:
Dust capture – fettling, blasting – foundries

Dust capture	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	50	29	12	24	0.033	50	50	0	0.043	0.22	0.32
LEV = no	14	10	2	14.3	0.009	35.7	64.3	0	0.078	0.348	0.372

12.1.8 Sand preparation

Sand preparation is the production of a moulding sand for sand or mask moulding and core making. In sand foundries, the used sand that accumulates when emptying the casts generally serves as the basis for the finished sand. The used sand is processed accordingly (with unwanted components being separated) and recycled. The used sand fraction, which is either separated by screening and extraction facilities or removed along with the casts, must be replenished by adding an appropriate amount of new sand. Sand preparation involves the use of various devices such as crushers, mixers, metal separators and screens.

The 90% value for quartz is clearly above the AS, regardless of the sampling procedure and duration.

Table 129:
Sand preparation – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	54	35	11	20.4	0.046	61.1	38.9	0	0.043 +	0.172	0.288
Stationary	30	21	5	16.7	0.044	73.3	26.7	0	0.032 +	0.11	0.13

Table 129a:
Dust capture – sand preparation – foundries

Dust capture	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs (personal)											
LEV = yes	31	22	5	16.1	0.031	74.2	25.8	0	0.032	0.0804	0.109
LEV = no	15	11	6	40	0.046	60	40	0	0.0375 +	0.6	0.76

12.1.9 Drilling, turning, planing

Table 130:
Drilling, turning, planing – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	7 ***	5	4	57.1	0.046	71.4	28.6	0	"=" values: 0.05 to 0.11		
Stationary	7 ***	3 **	2	28.6	0.037	71.4	28.6	0	"=" values: 0.014 to 0.075		

12.1.10 Floor conveyors, transportation, warehouse work

Table 131:
Floor conveyors, transportation, warehouse work – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	11	7	6	54.5	0.019	100	0	0	LOD !	0.0262	0.0355
Stationary	9 ***	9	3	33.3	0.009	66.7	33.3	0	"=" values: 0.001 to 0.21		

12.1.11 Inspections, test benches

Table 132:
Inspections, test benches – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	7 ***	6	3	42.9	0.011	57.1	42.9	0	"=" values: 0.037 to 0.11		
Stationary	15	12	6	40	0.044	80	20	0	0.0105 +	0.067	0.085

12.1.12 Investment casting

Table 133:
Investment casting – foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Stationary	13	9	4	30.8	0.013	84.6	15.4	0	0.0245	0.0533	0.0588

12.1.13 Cristobalite in foundries

There is no differentiation by work areas.

Table 134:
Cristobalite in foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	27	15	7	25.9	0.012	77.8	22.2	0	0.014	0.102	0.189

Table 135:
Quartz with cristobalite values – cristobalite in foundries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	27	15	3	11.1	0.024	55.6	44.4	0	0.0435	0.219	0.375

12.2 Metal production

Sector
Blast furnaces, steel mills and hot rolling mills
Electric steel plants
Blow moulding steel works (AOD, OBM)
Rolling mills, general
Wire rolling mill
Sheet metal rolling mill
Pipe rolling mill
Section rolling mill
Hot rolling mill
Non-ferrous metal production (except lead)

The iron ore is processed and converted into crude iron in a blast furnace. Steel is produced by adding scrap metal and alloys. The processes are similar in the production of non-ferrous alloys. Exposure to dust must be expected in the furnace and casting hall, at the moulds and in the fettling shop. Further exposures can occur when handling slag, during maintenance work on crucibles and furnaces, and when cutting out and bricking with refractory materials.

The 90% value for quartz is clearly below the AS, regardless of the sampling procedure.

Table 136:
No differentiation by work areas – metal production

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	18	10	13	72.2	0.066	88.8	5.6	5.6	LOD !	0.0274 +	0.0367 +
Stationary	70	15	58	82.9	0.052	97.2	1.4	1.4	LOD !	0.011 +	0.02 +
< 2 hrs											
Stationary	24	5	15	62.5	0.074	79.2	8.3	12.5	LOD !	0.0418 +	0.0806

13 Metalworking and processing, mechanical and vehicle engineering, workshops, paint shops

13.1 Metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Using numerous treatment processes, metals are formed, separated and joined or material properties are modified to create workpieces. Cutting includes machining using geometrically defined cutting edges, e.g. turning, drilling, planing, sawing, milling and filing, as well as using geometrically undefined cutting edges, e.g. grinding, honing, lapping, polishing and blasting. Joining techniques include the various welding, soldering and bonding processes. The material properties of a metal are modified, among other things, through hardening and tempering. Extensive improvements to extraction equipment and ventilation technology, as well as the modernisation of treatment methods and machines, have led to an overall reduction in dust exposure.

Sector
Hard metals, iron powder, production and processing
Surface finishing and hardening
Powder coating, laminating, flocking
Electroplating
Powder coating
Processing of liquid coating materials(Liquid paint coating)
Electroplating, automatic rack/drum system
Electroplating, semi-automatic, manually controlled rack/drum system
Metal working and processing, general
Drop forge
Moulding processes, other
Pipe production, general
Grinding (of metal goods)
Metalworking shop
Steel and light metal construction
Steel construction
Production of windows, doors, façade elements (metal)
mechanical and vehicle engineering, general
Mechanical engineering
Toolmaking

Sector
Vehicle construction
Agricultural machinery
Apparatus engineering
Fittings, production
Plant engineering, production of plants
Environmental engineering, production
Production of parts for motor vehicles and engines (Automotive supplies)
Production of vehicle bodies
Aircraft construction
Repair workshop, motor vehicles
Repair workshop, machinery
Repair workshop, railways
Electromechanical engineering
Repair workshop, electrical appliances
Container production
Plant and equipment construction (metal)
Painting and varnishing
Car paint shop
Wholesale of motor vehicles, machinery, mechanical equipment and related technical supplies (except tyres and rubber products)

13.1.1 Machining processes (incl. CNC, without grinding)

CNC (Computerized Numerical Control) machining centres are stationary machines that are enclosed and vacuumed. Machining is largely carried out in a wet process using a cooling lubricant. Workers' activities are limited to loading and unloading workpieces and operating and monitoring the system.

The 90% value for quartz is clearly below the AS, especially in personal measurements.

13.1.2 Dry grinding

Dry grinding can be applied to all types of workpieces, ranging from small to large, and most of the grinding tools are hand-held. Dry grinding is always very dusty. However, the grinding discs do not contain any quartz. Only ceramically bonded grinding discs may contain quartz, but it is only released briefly while the grinding discs are being dressed.

The high 90% value for quartz cannot be interpreted in any direct way, as a large number of industries are involved.

Table 137:
Machining processes (incl. CNC, without grinding) – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	28	17	20	71.4	0.036	96.4	3.6	0	LOD !	0.0274 +	0.0372
Stationary	22	12	8	36.4	0.068	86.4	9.1	4.5	0.0045 +	0.0452 +	0.0561 +

Table 138:
Dry grinding – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	30	24	19	63.3	0.11	63.3	30	6.7	LOD !	0.13	0.21
Stationary	21	15	13	61.9	0.045	85.7	14.3	0	LOD !	0.362	0.675
< 2 hrs											
Personal	17	6	7	41.2	0.19	41.2	41.2	17.6	0.052 +	0.503	1.06

13.1.3 Wet grinding, deburring, filing, polishing, general grinding work

Wet grinding involves the use of a cooling lubricant to reduce the frictional heat generated during the grinding process and to cool the workpiece. The particles released in the grinding process are also bound in the coolant. This usually results in lower exposures in a workplace.

The 90% value for quartz is clearly below the AS, regardless of the sampling procedure.

Table 139:
Wet grinding, deburring, filing, polishing, general grinding work – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	7	7	70	0.01	90	10	0	LOD !	0.04	0.0685
Stationary	13	9	11	84.6	0.044	100	0	0	LOD !	0.0176 +	0.022 +

13.1.4 Blasting, surface treatment

Table 140:
Blasting, surface treatment – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	66	49	62	93.9	0.06	95.5	3	1.5	LOD !	LOD !	0.0213 +
Stationary	36	24	29	80.6	0.026	91.7	8.3	0	LOD !	0.0194 +	0.336

13.1.5 Surface coating, paint spraying, flame spraying

Table 141:
Surface coating, paint spraying, flame spraying – mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	20	11	7	35	0.029	50	50	0	0.041	0.38	0.43
Stationary	13	6	11	84.6	0.066	84.6	0	15.4	LOD !	0.0327 +	0.0365 +

13.1.6 Powder coating, surface coating, other

Table 142:
Powder coating, surface coating, other – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n.a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	16	13	13	81.3	0.017	100	0	0	LOD !	0.0308	0.0396
Stationary	25	16	20	80	0.03	100	0	0	LOD !	0.0118 +	0.0165 +

13.1.7 Conveying, filling, mixing, screening, weighing solids

Experience has shown that weighing, mixing and filling solids can be very dust-intensive; dust turbulence should be avoided. If it is not possible to enclose or encapsulate, at least a local extractor should be used. If possible, it should be adjustable so that it can be positioned effectively at the point of occurrence.

When quartz-containing substances are stirred up, the 90% value for quartz is clearly above the AS, especially in personal measurements.

Table 143:
Conveying, filling, mixing, screening, weighing solids – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	26	14	13	50	0.039	76.9	23.1	0	0.007 +	0.346	0.579
Stationary	21	12	12	57.1	0.01	100	0	0	LOD !	0.011	0.0233
< 2 hrs											
Personal	7 ***	5	2	28.6	0.12	14.3	57.1	28.6	"=" values: 0.049 to 1.6		

13.1.8 Assembly, insulating, cladding

Table 144:
Assembly, insulating, cladding – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	11	7	10	90.9	0.033	100	0	0	LOD !	LOD !	0.0284 +

13.1.9 Inspections, test benches, laboratories

Table 145:
Inspections, test benches, laboratories – metalworking, mechanical engineering and vehicle construction, workshops (vehicles, machines), paint shops

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	15	9	8	53.3	0.009	86.7	13.3	0	LOD !	0.296	0.657
Stationary	14	6	10	71.4	0.009	100	0	0	LOD !	0.0126	0.021

13.2 Repairs, maintenance, workshop operations in other industries

Sector
Porcelain and tableware ceramics, production
Coal-fired power stations
Sand, extraction and preparation
Refractory goods, production
Natural stone (except limestone, gypsum, chalk, slate), extraction
Electrical engineering, general
Solar engineering, production
Brick and tile products, production
Porcelain and fine ceramic materials, production
Iron foundries
Cement factory
Mortar, production
Ready-mixed mortar, production
Sanitary ceramics, production
Moulded plastic parts, production
Grit and gravel mills
Grinding discs and abrasives, production
Chemical industry
Stones and earths, extraction (e.g. natural stone, raw clay)
Mineral grinding mills (coloured earths)
Cement, production
Special mortar, production
Concrete products, production and treatment
Natural stone, general preparation
Gravel and sand, preparation
Natural stone (ashlar) (excluding stone sculpting and masonry), processing
Utility, ornamental and artistic ceramics (industrial), production
Sheet glass, production and processing
Container/moulded glass, production and processing
Glass fibres, production and processing
Blast furnaces, steel mills and hot rolling mills
Electric steel plants
Light metal foundries
Iron, steel and non-ferrous metal foundries, mixed
mechanical and vehicle engineering, general
Workshops for disabled persons, general

Work areas
General work areas
Workshop activities, general
Repairs and maintenance, general
Repairs and maintenance, at a workshop
Repairs and maintenance, at the plant
Ceramics
Cleaning, repair, miscellaneous work, repairing of tunnel and hearth kiln cars
Repair of furnaces and stoves
Repair of the kiln cars
Blast furnaces
Die casting hall, repairs of die casts
Repairs, maintenance, general
Foundries
Installation, electrical, equipment repairs
Mechanical workshop, metalworking shops (finished products) electrical workshop, space
Production of mortar and high-grade plaster
Maintenance of ancillary equipment, construction site silos
Glass
Repair fitter’s shop

Table 146:
No differentiation by work areas – repair, maintenance, workshop operations in other industries

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	44	32	29	65.9	0.075	86.3	11.4	2.3	LOD !	0.0456 +	0.15
Stationary	58	38	23	39.7	0.01	96.6	3.4	0	0.0045 +	0.0234	0.0416
< 2 hrs											
Personal	15	6	12	80	0.03	86.7	13.3	0	LOD !	0.0595	0.0815
Stationary	18	9	4	22.2	0.019	88.9	11.1	0	0.003 +	0.0462	0.0713

14 Electrical and precision engineering industries and trades

14.1 Electrical engineering

Sector
Electrical engineering, general

A wide range of activities are carried out in electrical engineering where quartz-containing substances are either used or released. The following work areas are affected, in particular:

14.1.1 Filling, mixing, weighing

Quartz and quartz-containing materials are used in various manufacturing processes, e.g. as an additive in the production of rubber, plastics and cables, as well as in potting compounds for the casting of electrical and electronic components. Dust exposure may occur while filling, mixing and weighing quartz-containing substances.

14.1.2 Polishing, grinding, blasting, other treatments

In the past, quartz-containing aggregates were used, for example, in casting compounds for casting electrical and electronic components such as engines and transformers. The assembly of such components usually involves mechanical finishing. In addition, exposure to quartz dust must be expected during the mechanical treatment of ceramic insulators and plastic enclosures of electrical devices as well as in electrical furnace construction. Also, in the past, quartz sand was used as a blasting medium in abrasive blasting as surface treatment.

Quite often, the activities listed here are carried out for short periods of time. When measuring hazardous substances, different strategies are used depending on the issue and the conditions on site (cf. section 4.3).

- Measurements with reference to a specific activity:
  With this measuring strategy, only the briefly performed activity as such is relevant, e.g. polishing, grinding or blasting (with a sampling duration less than 2 hours). The exposure values that are determined are usually above those of a measurement with reference to a shift.

- Measurements with reference to a shift:
  With this measurement strategy, in addition to the polishing, grinding and blasting activities, other activities during a shift are also relevant, e.g. preparations and inspections(sampling duration: at least 2 hours). The exposure values that are determined are usually below those of a measurement with reference to a specific activity.

Table 147:
Filling, mixing, weighing – electrical engineering

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	6	9	90	0.009	100	0	0	LOD !	LOD !	0.0128
Stationary	5 ***	4 **	2	40	0.009	60	40	0	“=” values: 0.022 to 0.17		

Table 148:
Polishing, grinding, blasting, other metal-cutting processes – electrical engineering

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	24	12	20	83.3	0.034	95.8	4.2	0	LOD !	0.0188 +	0.0264 +
< 2 hrs											
Personal	10	6	8	80	0.032	80	20	0	LOD !	0.2	0.255

14.2 Jewellery, production and processing

Sector
Jewellery, production and processing
Jewellery cutting

During the production and processing of jewellery, precious and semi-precious stones as well as metals and metal alloys are treated mechanically. Activities such as cutting, grinding and polishing, especially machining without adequate dust capture, are likely to result in high quartz dust exposures.

Table 149:
No differentiation by work areas – jewellery, production and processing

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	12	6	7	58.3	0.009	66.7	33.3	0	LOD !	0.51	0.886

14.3 Dental laboratory

Sector
Dental laboratory

Dental laboratories use investment materials with a quartz or quartz/cristobalite content of up to 50%. Quartz-containing dusts are mainly generated during investment and divestment as well as during blasting work. During blasting, any investment residue still attached to the workpiece is removed in a blasting box. Glass beads and high-grade corundum media (aluminium oxide) are normally used for this purpose.

Such activities are usually carried out for short periods of time. When measuring hazardous substances, different strategies are used depending on the issue and the conditions on site (cf. section 4.3).

- Measurements with reference to a specific activity:
  With this measuring strategy, only the activity as such, i.e. investing, divesting or blasting is of any relevance. Each activity only occurs for a short period of time (sampling duration: less than 2 hours). The exposure values that are determined are usually above those of a measurement with reference to a shift.
- Measurements with reference to a shift:
  With this measurement strategy, in addition to the polishing, grinding and blasting activities, other activities during a shift are also relevant, e.g. processing and inspection activities (sampling duration: at least 2 hours). The exposure values that are determined are usually below those of a measurement with reference to an activity.

DGUV Informative Publication 213-730 “Mineral dusts during investment, divestment and blasting in dental laboratories” provides process- and substance Mineral criteria according to TRGS 420. If the protective measures specified in this document are applied, the relevant values are within the AS for quartz and cristobalite.

Table 150:
No differentiation by work areas – dental laboratory

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	12	11	10	83.3	0.017	100	0	0	LOD !	0.0137 +	0.0178
< 2 hrs											
Personal	7 ***	6	2	28.6	0.037	42.9	57.1	0	“=” values: 0.045 to 0.73		

14.4 Electrical installation work at construction sites

Sector
Installation, electrical equipment

During electrical installation work at construction sites, quartz-containing rock dust is released while chiselling, cutting bridges for electrical cables and drilling holes for switch boxes and junction boxes. Different quartz dust exposures can be expected, depending on the machinery and the LEV equipment.

14.5 Friction linings

Sector
Friction linings (brake and clutch linings) – production, treatment

The manufacture of friction linings involves mixing a quartz-containing powdery friction material with a bonding agent – usually based on synthetic resins – and pressing it onto a base plate made of steel or grey cast iron. At the next stages, the resulting blanks are mechanically treated (grinding, drilling).

Table 151:
No differentiation by work areas – electrical installation work at construction sites

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
No differentiation											
Personal	14	4 **	2	14.3	0.046	50	50	0	0.033 +	0.47	0.929
Stationary	14	4 **	5	35.7	0.038	64.3	35.7	0	0.016 +	0.338	0.541

Table 152:
No differentiation by work areas – friction linings

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	10	5	7	70	0.02	100	0	0	LOD !	0.019 +	0.02 +
Stationary	24	4 **	23	95.8	0.022	95.8	4.2	0	LOD !	LOD !	LOD !

15 Research institutes, educational facilities, energy production, transport

15.1 Research and test institutions and laboratories, design studios

Sector
Research and test institutions and laboratories
Engineering offices for technical planning
Environmental service, consultancy and testing

Exposure measurements in research and test institutions, laboratories and design studios cover a wide range of processes. Particularly high dust loads were found whenever mechanical crushing or sorting/screening activities were performed as part of the research. This is the case, for example, in building material test laboratories and at geological research institutions. Another source of increased dust exposure is the mechanical treatment of test objects through dry grinding, sawing and similar operations.

High values above the AS for quartz-containing respirable dust mainly occur during the mechanical treatment of test objects through dry grinding and sawing and while laboratory facilities are being swept.

Table 153:
No differentiation by work areas – research and test institutions and laboratories, design studios

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	19	11	7	36.8	0.047	42.1	57.9	0	0.0515	0.253	0.463
Stationary	19	9	6	31.6	0.01	89.5	10.5	0	0.0048 +	0.046	0.0556

15.2 Vocational colleges and training centres for the construction trade

Sector
Vocational education and training colleges
Training centres

During practical training for occupations in the building trade (e.g. bricklaying), trainees carry out characteristic activities such as bricklaying and concreting. The resulting training structures are subsequently dismantled and the training rooms are cleaned. Such activities take place in fairly large enclosed training rooms or halls and are usually carried out by several trainees at the same time. In general, relatively high concentrations of dust were found, especially in personal measurements of trainees and teachers. High values above the AS for quartz-containing respirable dust mainly occur during the short sampling periods when the training rooms are being swept and when the training structures are being demolished.

Table 154:
No differentiation by work areas – vocational colleges and training centres for the construction trade

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	22	10	13	59.1	0.04	90.9	9.1	0	LOD !	0.0314 +	0.237
Stationary	11	6	4	36.4	0.007	100	0	0	0.0048 +	0.0157	0.0169
< 2 hrs											
Personal	11	3 **	8	72.7	0.044	81.8	18.2	0	LOD !	0.0922	0.136
Stationary	13	5	4	30.8	0.025	84.6	15.4	0	0.0123 +	0.146	0.271

15.3 Transport

Sector
Transportation, shipping companies, transport operators et al.
Trams

Table 155:
Transport – vehicle halls and garages

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	11	7	3	27.3	0.008	90.9	9.1	0	0.005 +	0.0206	0.0566
Stationary	20	8	5	25	0.56	35	55	10	0.058 +	0.52 +	0.57
< 2 hrs											
Personal	21	5	3	14.3	0.02	90.5	9.5	0	0.015 +	0.0468	0.0546
Stationary	19	8	4	21.1	0.009	36.8	63.2	0	0.0815	0.329	0.423

15.4 Energy production

Sector
Coal-fired power stations
Combined heat and power stations
Heating plants

Depending on the type of power station, different fuels are fed into the combustion process for the generation of steam. In addition to oil and gas, quartz-containing hard coal is also used as a fuel. Exposure to quartz dust can be expected during the extraction and transportation of hard coal as well as in the ashes produced during combustion. In addition, boiler linings (stone, mortar) are mechanically treated when carrying out inspection work in a boiler, along with quartz-containing combustion residues. In such cases, high levels of quartz dust exposure can be expected.

Table 156:
No differentiation by work areas – energy production

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	126	26	107	84.9	0.026	98.4	1.6	0	LOD !	0.0098 +	0.017 +
Stationary	130	21	92	70.8	0.04	98.5	1.5	0	LOD !	0.017 +	0.026 +
‹ 2 hrs											
Personal	16	5	5	31.3	0.062	18.7	68.8	12.5	0.23	1.84	3.4

High values with sampling durations less than 2 hours occur in a series of measurements for “construction and demolition work” (13 readings).

16 Wholesalers and retailers, beverage production

16.1 Wholesalers and retailers of various building materials

Sector
Building material wholesalers
Home improvement markets and DIY retailers

Home improvement markets are usually very large retail outlets. They can be roughly divided into two areas: the sales (customer) area, sometimes with a drive-in next to it, and the warehouse with goods receipt.

Home improvement markets have various specialist departments such as building products, building materials, wood, paints, wallpapers, carpets, tools, machinery, gardening tools, electrical fittings/appliances and lamps. Particularly in the area of building materials, the product range contains quartz-containing products such as sands and certain natural stones, e.g. granite.

In the building materials trade, the materials delivered by suppliers are temporarily stored on pallets, in pieces or in bulk and are then delivered to or collected by construction companies or private customers.

A wide variety of building materials are put together by the workers in this trade for delivery and collection. In addition to the mechanical loading of bulk goods and the transportation of entire pallets with forklift trucks, these items are also picked and compiled by hand, which involves lifting, carrying and moving.

Quartz dusts can be generated in home improvement markets and DIY stores, e.g. when filling products such as sand. Leaking bags and containers can also be an issue in this context. The treatment of natural stones such as granite can also lead to the formation of quartz-containing dusts.

When filling or treating products containing quartz, care must be taken to ensure effective dust capture. Failure to do so may sometimes lead to considerable exposure to quartz dust. On the whole, quartz dust exposure can be effectively prevented by regularly cleaning the relevant working areas. For cleaning purposes, preference should be given to industrial vacuum cleaners (dust class H) and wet methods. Surfaces must not simply be swept or treated with a blower.

Table 157:
No differentiation by work areas – Wholesalers and retailers of various building materials

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	22	17	7	31.8	0.013	86.4	13.6	0	0.019	0.146	0.17
Stationary	15	11	5	33.3	0.045	80	20	0	0.0115 +	0.0785	0.0985

16.2 Wholesalers in chemical products

Sector
Wholesalers of chemicals
Wholesalers of paints, adhesives and coating materials
Wholesalers of pharmaceutical and cosmetic products and medical supplies

Chemicals and hazardous (dangerous) substances are present in all areas of business and daily life. It is essentially the responsibility of wholesalers and retailers – especially of chemicals – to ensure that such substances are available at the locations where they are intended for use, processing or consumption. Chemicals are filled, packed, stored and transported as solids (e.g. granules, pellets, powders, etc.), pastes, liquids and gases. Particularly in Quartz-containing products such as renderings and undercoats can be found within construction chemicals, in particular.

In addition to general hazards, anyone working with chemicals and construction chemicals is exposed to special additional risks and hazards due to the toxic, physical and chemical properties of such substances. It follows that, whenever dusts occur in a given work area, their specific properties are highly relevant, regardless of whether they contain quartz or not.

Quartz-containing dusts can occur in particular during the manufacture and filling of quartz-containing products in the form of powders, granulates and pellets. During such activities, which can be carried out either manually or (semi-)automatically, care must be taken to ensure effective capture of any dust that may be generated, as well as regular cleaning of the relevant work areas.

Table 158:
No differentiation by work areas – wholesalers of chemical products

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	24	5	6	25	0.057	50	41.7	8.3	0.034 +	0.262	0.618

16.3 Breweries and beverage manufacturers, filtration

Diatomaceous earth is the most common filtration medium in the beverage industry for filtering out impurities from beer, juice, spirits and wine. Diatomaceous earth (also known as kieselguhr and diatomite) consists of microporous fossil sediments of unicellular siliceous algae (diatoms). The raw product, which is extracted from deposits, contains water and is “earthy” in consistency (hence: diatomaceous earth). The main ingredient is pure silicic acid or amorphous silicon dioxide.

When preparing diatomaceous earth for use in food production, it is subjected to a drying, annealing or burning process. Depending on the temperature and duration of impact, different types of diatomite are obtained, which differ in their pore structures and thus also in their filtration properties. At the same time, the process converts a considerable part of the amorphous silicon dioxide into crystalline silicon dioxide (cristobalite).

Three processes can be distinguished here: drying, calcination and flux calcination. The drying of the diatomaceous earth at temperatures of 300 to 400 °C serves to expel the moisture and to anneal organic components. The result is a fine diatomaceous earth. During calcination, the diatomaceous earth is treated at temperatures of 800 to 1,000 °C. This results in the complete breakdown of all organic compounds and oxidation of the iron contained within the diatomaceous earth, while partly closing its porous structure. Diatomite particles begin to melt on the surface and form smaller agglomerates. The result is mostly medium to coarse diatomaceous earth. An extension of this process is flux calcination, where alkaline fluxes are added which reduce the melting temperature of the diatomaceous earth through the formation of alkali silicates. The temperature treatment takes place in rotary kilns at temperatures between 800 and 1,100 °C. The surface structures of the diatomaceous earth are covered by liquefied alkali silicates, the pores are closed and diatomaceous earth particles are sintered into larger agglomerates under the impact of the flux, resulting in coarse diatomaceous earths. Depending on the amount of alkali flux that is added (e.g. sodium carbonate), the proportion of crystalline silica increases from 30% to 60 crystalline under pure calcination. After all the temperature treatments, a specific particle size distribution is achieved through grinding and sifting so as to obtain consistent filtrate properties for the distribution spectrum of the natural products. The flux-calcined diatomaceous earth is registered with REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals, Regulation (EC) 1907/2006) (CAS: 68855-54-9). The usual classification according to filtration properties is based on water permeability, the so-called Darcy value, which correlates with the grain size distribution. Diatomaceous earth is ideally suited for beer filtration due to its incompressibility and its very large specific surface of up to 20m²/g [37].

The filtration principles for beer are precoat filtration and depth filtration. Before filtering the product, it is mixed with coarse diatomaceous earth, to form a support layer. This process is called precoating. To further build up the filter cake, medium to fine diatomaceous earths are added (in a continuing dosage). The filtration depth increases with enlarged porosity of the filter aids. In most cases, a suspension of fine diatomaceous earth is added during the continuing dosage to ensure constant permeability of the filter cake surface and thus filtration efficiency. Filtration is finished when the differential pressure becomes too high due to the filter cake of diatomaceous earths and turbid substances and when there is a risk that the filter cake and supporting layer might tear. On average, beer requires approx. 170g of diatomaceous earth per hectolitre of non-filtered beer.

Filter types include frame filters, horizontal screen filters, cartridge filters and vacuum rotary filters. Frame filters are mainly used by small to medium-sized breweries. Horizontal screen filters are rare, while cartridge filters are occasionally found in factories of all sizes. Vacuum rotary filters are used for the filtering of juice and wine [38].

Figure 34:
Filtration aids are added during beverage production.
Source: BGN

Filtration aids are added by small to medium-sized companies into a dosage vessel using a scoop or directly from a bag (e.g. 20 kg). Workers wear an FFP2 mask in this process.

Exposure to potentially silicogenic dusts occurs mainly when the filtration aids are filled into the dosing vessel and when the paper bags are subsequently emptied. Typically, at small breweries, filtration takes place only once a week. The amount of non-filtered beer in hectolitres gives an approximate indication of the mass of filtration aids that are added.

In very large breweries, the addition of filtration aids is typically automated and carried out dust-free, poured out from big bags within an enclosed system.

In winemaking, the filtration described above is less common and the average amount of filtration aid is only 100g/hl of unfiltered wine.

The following exposure data was recorded between 2014 and 2018 and represent measured values over periods of up to 4 hours. The 29 companies comprised two fruit juice manufacturers and 27 breweries.

In most cases, cristobalite was found in respirable concentrations below the detection limit. In a single record, where the concentration of fine quartz dust was greater than the AS, it was not possible to determine the source [39].

Table 159:
Quartz – breweries and beverage manufacturers, filtration

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	32	29	25	78.1	0.025	96.9	3.1	0	LOD !	0.0145	0.0292
Stationary	31	29	21	67.7	0.014	100	0	0	LOD !	0.0067	0.0085

Table 160:
Cristobalite – breweries and beverage manufacturers, filtration

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	32	29	4	12.5	0.011	78.1	21.9	0	0.027	0.0704	0.0989
Stationary	31	29	7	23	0.005	91	9	0	0.007	0.024	0.0573

Quartz and cristobalite – pairs combined

Table 161:
Quartz and cristobalite – pairs combined – breweries and beverage manufacturers, filtration

Sampling procedure	Number of measured values #	Number of plants	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs								
Personal	32	29	68.8	31.1	0.1	0.0325	0.0988	0.1037
Stationary	31	29	90.3	9.7	0	0.0098	0.0328	0.0612

Values included in the statistics as totals of a quartz value and a cristobalite value combined and coming from the same sampling medium were counted as single measured values

17 Waste disposal, recycling

17.1 Waste collection, disposal, incineration and recycling (excluding glass recycling), wastewater disposal

Sector
Waste and wastewater disposal
Waste disposal
Waste incineration
Landfills
Recycling of packaging material (e.g. take-back recyclables)
Plastic recycling
Waste sorting facilities
Composting facilities
Sewage sludge recycling
Wastewater recycling

17.2 Electronic scrap recycling

Sector
Electronic scrap recycling

In the past, quartz-containing aggregates, among other things, were used in compounds for the casting of electrical and electronic components. Furthermore, old electrical resistors and fuses often have quartz fillings. Exposure to quartz dust may occur during the disassembly of waste electrical and electronic equipment in a recycling operation, especially during the destruction of such components.

There is no differentiation by work areas.

Table 162:
No differentiation by work areas – waste collection, disposal, incineration and recycling (excluding glass recycling); wastewater disposal

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	12	7	9	75	0.009	100	0	0	LOD !	0.0138	0.0192
Stationary	15	10	7	46.7	0.012	100	0	0	0.006 +	0.0215	0.0285

Table 163:
No differentiation by work areas – electronic scrap recycling

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	15	4 **	11	73.3	0.019	100	0	0	LOD !	0.0098 +	0.0105 +

17.3 Glass recycling

Sector
Glass recycling

In glass recycling, the waste glass that is mostly collected in public glass containers is sorted, separated and mechanically prepared. The first stage usually involves manual pre-sorting, i.e. the manual removal of the largest impurities. At the second stage, the material is selectively reduced to a size of approx. 15 mm in a crusher, resulting in fragments that are as uniform as possible; and at the third stage, the material is automatically sorted by material and colour. Minor impurities are screened and airstream-sorted, while metals are removed by metal separators. To avoid defects and unwanted colour changes in the finished glass products, coloured glass admixtures and opaque materials such as stones and ceramics are separated from the broken glass in an electro-optical screening process. The recycled glass obtained in this way is stored openly in boxes and can then be used as a valuable raw material in the glass industry at a proportion of up to 90%.

As all processing stages are mechanical, it is reasonable to expect the formation of dust. The silicon dioxide is available in the glass in an amorphous state. Mechanical treatment of the glass fragments in the crusher can lead to partial recrystallisation in the glass dust that has been removed, so that quartz-containing respirable dust is then detected. The readings obtained in this way are clearly below the AS.

Figure 35:
Storage of recycled glass fragments. Source: VBG

Table 164:
No differentiation by work areas – glass recycling

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	27	14	21	77.8	0.028	96.3	3.7	0	LOD !	0.0133 +	0.0302
Stationary	30	12	9	30	0.01	100	0	0	0.004 +	0.011	0.0195

17.4 Building material recycling and screening facilities

Sector
Slag preparation
Building material recycling
Recycling of mineral building materials

Mineral construction waste mainly includes concrete, bricks and tiles. Road debris containing bitumen also belongs to this category. To break down the waste material – often in a mobile unit directly at the demolition site – crushers, mills and screens are used, in particular. This process can be expected to release containing dusts.

Measures to reduce dust and thus quartz in the ambient air include, in particular, moistening the debris, using water nebulisers, encapsulating and extracting dusty aggregates, reducing drop heights and doing without chutes. Workers at crushers must only stay in specific places designated by the manufacturer. Dust release can also be expected while loading, handling and moving the crushed waste.

The crushed rubble is sorted, e.g. by means of screening stations/sorting belts, classifiers and magnetic separators. When sorting manually in sorting cabins, special attention must be paid to keeping the release of dust to a minimum, as the cabins may be full-shift workplaces with insufficient natural ventilation.

The regulations that must be observed are the Ordinance on Hazardous Substances (Annex I No. 2 “Particulate Hazardous Substances”), TRGS 559 “Silica Dust”, the DGUV Rule 101-603 “Demolition and Deconstruction Sector” and No. 5.2.3 “Dust Emissions from Handling, Storage and Treatment of Solid Materials” of the Technical Instructions on Air Quality Control (TA Luft).

Figure 36:
Measuring dust on a screening belt in the recycling of construction waste. Source: VBG

17.4.1 Crushers, mills

Table 165:
Crushers, mills – building material recycling and screening facilities

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	39	24	16	41	0.042	59	41	0	0.0208 +	0.3	0.349
Stationary	25	16	5	20	0.012	56	44	0	0.0295	0.56	1.145

17.4.2 Conveying, storing, transporting, loading

Table 166:
Conveying, storing, transporting, loading – building material recycling and screening facilities

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	37	23	31	83.8	0.017	94.6	5.4	0	LOD !	0.0226	0.0493
Stationary	12	9	8	66.7	0.015	100	0	0	LOD !	0.014 +	0.0206

17.4.3 Screening and mixing

Table 167:
Classifying, mixing, screening and sorting – building material recycling and screening facilities

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	30	22	11	36.7	0.011	83.3	16.7	0	0.01 +	0.08	0.215
Stationary	17	14	4	23.5	0.014	88.2	11.8	0	0.0125 +	0.0525	0.079
< 2 hrs											
Stationary	10	3 **	0		No details	40	60	0	0.056	0.23	0.24

17.4.4 Inspections, control cabins, test benches

Table 168:
Inspections, control cabins, test benches – building material recycling and screening facilities

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	12	8	7	58.3	0.021	100	0	0	LOD !	0.0246	0.032

18 Construction industry

The exposure data of the construction industry listed below are based on the details given in BGIA Report 08/2006 [10] with regard to the underlying data sets. The general comments on working procedures and working conditions made there are still applicable. In the construction industry, specific solutions have been developed regarding dust exposure in individual sectors. It contains details on further exposures specific to each sector and activity, and these are continually updated (www.staub-war-gestern.de).

18.1 Brickwork and clinker construction

18.1.1 Walls

The exposure values also cover activities in enclosed spaces (training facilities / furnace construction). Outdoors, measured values during construction work are likely to be lower. As part of the drive towards low-dust technologies, solutions are now available such as the use of mortar pads, which prevent the dust-intensive mixing of mortars. However, this was not yet included in the data period. Overall, the amount of mortar has been significantly reduced through the use of facing bricks, which only need to be glued. This applies to all load-bearing brickwork. For face brickwork, on the other hand, there has been no change in this respect. Activities during renovation work must be classified as having a higher dust load, as they are often carried out with limited ventilation and are impacted by a higher base load caused by other activities.

18.1.2 Sawing

The following measured values were obtained indoors, from the dry sawing of stones. The tools were equipped with dust extractors, but their effectiveness was limited. Concerning normal sawing operations at construction sites, in particular the normal use of wet saws, please refer to BGIA Report 08/2006 [10]. There have been no major developments in wet sawing, so these data sets are still relevant.

18.2 Rendering

For rendering work (plastering, smoothing, removal of plaster), there is only limited measurement data from workplace operations under real-life conditions during the period covered by this report. They are within the bandwidth of the measured data listed in BGIA-Report 08/2006 [10] . The working procedures and conditions have largely remained unchanged. However, the measured data can also be applied to the period after 2004.

Table 169:
Walls – brickwork and clinker construction

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	5	4	1	20	0.009	40	60	0	“=” values: 0.032 to 0.11		

Table 170:
Sawing – brickwork and clinker construction

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	6	1	0		No details	16.7	83.3	0	“=” values: 0.025 to 0.61		

18.3 Demolition work

For such activities, there is only limited measurement data from operational practice during the period covered by this report. They are within the bandwidth of the measured data listed in BGIA Report 08/2006 [10]. The working procedures and conditions have largely remained unchanged. However, the measured data can also be applied to the period after 2004. For demolition work, chiselling and caulking, there is no practical measurement data under real-life conditions from the period covered by this report.

18.4 Earthworks, levelling, compaction and paving

18.4.1 Transportation with regular watering or use of dust binders

The measured values result from tests with two dust binders: calcium magnesium acetate and magnesium chloride. Furthermore, water spraying from these trials has been included, with watering being extremely regular.

18.4.2 Transportation without regular watering or use of dust binders

The measured values were mainly obtained from a test section that was significantly exposed to wind, which explains the high proportion of low values despite clearly visible dust emissions.

18.4.3 Levelling

The decisive factor for respirable dust and quartz exposure during levelling work is the humidity of the soil surface, which explains the wide scatter of the measured values. Due to the small number of measured values, it makes sense to use the data of BGIA Report 08/2006 [10].

Table 171:
Transportation with regular watering or use of a dust binder – excavation, levelling, compacting and paving

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	135	3	126	93.3	0.011	100	0	0	0.010 +	0.010 +	0.0155

Table 172:
Transportation without regular watering or use of a dust binder – excavation, levelling, compacting and paving

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	10	6	9	90	0.069	90	10	0	0.008 +	0.077	0.269

Table 173:
Levelling – excavation, levelling, compaction and paving

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	7	5	2	29	0.019	85.7	14.3	0	"=" values: 0.007 to 0.93		

18.5 Construction of tiled stoves, chimneys and furnaces, incl. industrial furnaces

The period covered by this report does not contain measurement data under real-life conditions for the mixing of powdery products, and the measurement data from BGIA Report 08/2006 [10] can be taken over. In the case of low-dust tile adhesives, dry mortars and levelling compounds, the analogous conclusion for respirable dust exposures shows a reduction in exposure to non-low-dust products by a factor of about 10 (www.bgbau.de/filead-min/Gisbau/Anm__starm_Tr_080611.pdf).

18.6 Roofing

18.6.1 Cut-off grinding of roof tiles and concrete roofing tiles

The period covered by this report does not contain any measurement data for roofing work under real-life conditions. However, the measurement data from the BGIA Report 08/2006 [10] can also be applied to the time after 2004.

18.7 Concrete construction

For formwork stripping, only isolated measurement data is available from the period covered by this report, and all the figures are within the range of the earlier data. However, the measurement data from the BGIA Report 08/2006 [10] can also be applied to the time after 2004. Only isolated data is available for the cleaning of formwork, but all the figures are within the range of the data measured earlier, and those figures can therefore be taken over. During the preparation of formwork involving the use of hand-held machines without extraction (needle guns, angle grinders), exposures were measured within the AS range for quartz dust.

18.7.1 Concreting work

Only minor dust formation was observed in the handling of ready-to-use moist compounds delivered to the installation site. The values of the stationary measurements are shown. Personal measurements are only available in small quantities and are below the detection limit.

18.8 Cleaning of construction sites

18.8.1 Cleaning in general and with a broom

Only isolated measurement data is available for cleaning with a broom, and all the figures are within the range of the earlier data. However, the measurement data from the BGIA Report 08/2006 [10] can also be applied to the time after 2004.

Table 174:
Concreting work – concrete construction

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	10	4	5	50	0.005	90	10	0	0.004 +	0.030	0.046

Table 175:
Cleaning in general and with a broom – cleaning of construction sites

Sampling procedure	Number of measured values	Number of companies	Number of Values ‹ LOD*	Values ‹ LOD* in %	Highest LOD* in mg/m³	≤ AS in %	› AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	6	3	4	67	0.18	50	50	0	"=" values: 0.035 to 0.081		

18.8.2 Cleaning with a sweeper, vacuum-cleaning

Only isolated measurement data is available for this process, and all the figures are within the range of the earlier data. So the measurement data from BGIA Report 08/2006 [10] can be taken over. Certain measurements with sweepers after 2016 show that the AS for quartz dust can be exceeded, e.g. in the case of high dust loads on the ground and when using the side brush of a sweeper. Dust stirred up by the side brush is not captured adequately enough. Now, however, solutions are available, and it is also possible to fit small everyday devices with a cover for the side brush or a water spraying system.

18.9 Blasting

18.9.1 Blasting, dry

Only isolated measurement data is available for the area of activity. and all the figures are within the range of the earlier data. However, the measurement data from the BGIA Report 08/2006 [10] can also be applied to the time after 2004.

18.9.2 Blasting, moist, wet, liquid

Only isolated measured values are available for measurements with a sampling duration of at least 2 hours.

Table 176:
Blasting, moist, wet, liquid – blasting

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m^3	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m^3	90th percentile* in mg/m^3	95th percentile* in mg/m^3
≥ 2 hrs											
Personal	8	2	4	50	0.026	87.5	12.5	0	“=” values: 0.022 to 0.18		
Stationary	13	3	10	77	0.024	100	0	0	0.00875	0.0127 +	0.0147 +

18.10 Road works

18.10.1 Milling during road works

Generally, a distinction is made between the use of large and small milling machines during road works. However, the measured values during the assessment period do not show any significant differences with regard to exposure. The majority of exposure data is based on measurements on asphalt roads with water precipitation on the dusts. From 2007 onwards, aerosol extractors were increasingly added to milling chambers. Since 2007, thanks to the use of such extractors on large milling machines, the AS for quartz dust has usually been observed for milling work on asphalt. When milling machines are used on concrete, exceedance must be expected even when using water precipitation, whereas dry milling during marking operations leads to considerable exceedance.

Measurement data from stationary measurements and personal measurements differs significantly for large milling machines. This is because in 2006 measurements were taken to optimise dust capture in the machines, and this provided the measurement data on dust emissions. However, some of these stationary measurements were intended to ensure reproducibility, so as to provide comparable data for the assessment of further developments, rather than to establish a connection with workers' exposure.

Table 177:
Exposure data for small milling machines (up to a working width of approx. 1.6 m)

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	12	7	2	17	0.005	83.3	16.7	0	0.019	0.054	0.182
< 2 hrs											
Stationary	6	3	1	17	0.024	33.3	66.6	0	"=" values: 0.014 to 0.37		

Table 178:
Exposure data for large milling machines

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Personal	21	7	0	0	No details	52.4	47.6	0	0.035	0.18	0.228
Stationary	52	5	4	7.6	0.042	25	75	0	0.18	1.2	2.2
< 2 hrs											
Personal	19	2	3	16	0.037	26.3	73.7		0.098	0.223	0.257
Stationary	39	2	4	10.2	0.09	23.1	76.9	0	0.315	1.44	2.415

18.11 Tunnelling

The measurement data was obtained exclusively during the excavation work, i.e. to excavate and secure the tunnel structures (infrastructure and supply tunnels). A distinction was made between the two tunnelling methods of conventional tunnelling (shotcrete support) and mechanised tunnelling (segmental lining). In most cases, tunnelling is carried out in so-called continuous operation, i.e. working day and night shifts as well as weekends. The average daily working time was 10 hours per shift. For the measured values listed in the following tables, several measurements were combined with the aim of representing the entire stripping work and obtaining a mean value for each shift.

The quartz concentration in the workers' ambient air is directly related to the quartz content of the surrounding rocks. Also, quartz dust exposure is directly affected by the excavation method, the available ventilation capacity and the implementation of dust reduction measures (e.g. a dust extractor, water wetting, wet shotcrete).

This evaluation does not include the measurement data of possible quartz concentrations during the installation of the inner lining or tunnel lining operations (e.g. track construction, installation of rolled asphalt, installation of technical equipment).

18.11.1 Conventional tunnelling

With conventional tunnelling, the tunnel excavation and the securing of the cavities were carried out in stages. Depending on the geology, excavation is carried out using drilling and blasting methods or purely mechanically with an excavator or roadheader. After excavation, the loosened rocks are usually loaded into dump trucks by a wheel loader and then taken out of the tunnel. The highest level of quartz exposure occurs while the rocks are being excavated and loaded. Next, the cavity is secured Medium mesh, lining arches and, above all, shotcrete. At the final stage of the tunnelling work, to complete stabilisation of the cavity, anchors and reinforcing bars are drilled and installed, before the next section can be tunnelled. Depending on the extent of the necessary stabilisation work, each tunnelling stage takes between 3 and 5 hours, so that two to three tunnelling stages can be carried out per shift.

In the measurements, the 90% value for quartz dust is several times higher than the AS.

Table 179:
Conventional tunnelling – tunnelling

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	99	59	6	6.1	0.011	35.4	64.6	0	0.0780	0.2876	0.4421

18.11.2 Mechanised tunnelling

In mechanised tunnelling, the tunnel is excavated using a tunnel boring machine (TBM). The cavity is stabilised by segment lining, which is assembled into a load-bearing ring from prefabricated reinforced concrete parts. As in the excavation work in conventional tunnelling, a TBM drills the entire surface of the tunnel cross-section to the required depth, so that the next segment ring can then be installed. The excavated material is conveyed during the drilling process and depends on the design of the TBM. In the case of so-called hydroshields with fluid-assisted working faces, the excavated material is taken out of the tunnel via an enclosed conveyor pipe using a pump, whereas in the case of earth pressure balance shields it is usually taken out via an open conveyor belt system. When hydroshields are used, quartz dusts cannot therefore be released. In the case of earth pressure balance shields, quartz dust is only released when the machines are operated in so-called open mode, i.e. the excavated material is carried off on the conveyor without being conditioned with water or in any other way that might form an earth slurry. However, even in such cases, dust formation can be described as relatively low compared with conventional tunnelling. Depending on the hardness of the rock, the drilling time required to install the next segment ring can vary, whereas the time spent on installing the ring is consistent. As a result, the number of segment rings installed on each layer can vary a lot.

In the measurements, the 90% value for quartz dust is below the AS.

18.12 Other activities in the construction industry

18.12.1 Drilling, sawing and grinding of concrete

Only isolated measurement data is available for this work area, but all the figures are within the range of the earlier data. So the measurement data from BGIA Report 08/2006 [10] can be taken over. Thanks to the increasing spread of vacuumed machines, it can be assumed that workers’ exposure has also improved in this area. Under test bench conditions, where operations were standardised to ensure comparability between machines, it was possible to make significant progress. However, this has not yet been validated by measurements under real-life conditions.

Table 180:
Conventional tunnelling – tunnelling

Sampling procedure	Number of measured values	Number of companies	Number of Values < LOD*	Values < LOD* in %	Highest LOD* in mg/m³	≤ AS in %	> AS in %	AS n. a. in %	50th percentile* in mg/m³	90th percentile* in mg/m³	95th percentile* in mg/m³
≥ 2 hrs											
Stationary	16	7	5	31.3	0.011	93.8	6.2	0	0.0130	0.0415	0.0533

References

[1] GESTIS-Stoffdatenbank, published by Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA), Berlin 2021. http://www.dguv.de/ifa/stoffdatenbank/

[2] *Okrusch, M. and Matthes, S.*: Mineralogie – Einführung in die spezielle Mineralogie, Petrologie und Lagerstättenkunde – 4Th ed., Springer-Lehrbuch – Springer, Berlin 1996

[3] *Stoffler, D.; Arndt, J.*: Coesit und Stishovit-Hochstdruckmodifikationen des Siliciumdioxids – Naturwissenschaften 56 (1969), pp. 100-109

[4] *Bartholomé, E.*: Ullmanns Encyklopädie technical Chemie: Schwefel bis Sprengstoffe, vol. 21, Wiley-VCH, Weinheim 1982

[5] *Mattenklott, M.*: Differenzierung und Bewertung von amorphen Kieselsäuren (0512), in: IFA-Arbeitsmappe "Messung von Gefahrstoffen", published by Deutsche Gesetzliche Unfallversicherung (DGUV), Erich Schmidt Verlag, Berlin 2021

[6] *Dinger, K.; Jebsen-Marwedel, H.*: Kieselsäure in der Natur, Glastechn. Ber. 30 (1957), p. 320

[7] Begründung zum Allgemeinen Staubgrenzwert in TRGS 900 (2014) http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/Arbeitsplatzgrenzwerte.html

[8] Begründung zum Beurteilungsmaßstab zu Quarz (2015) https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/pdf/900/Quarz.pdf

[9] Technical Rules for Hazardous Substances: Quartz-Bearing Dust (TRGS 559) 4th issue, 2020. Joint Ministerial Gazette (2020) no. 16, pp. 306-319; ber. GMBl. (2020) no. 19, p. 371

[10] *Bagschik, U.; Böckler, M.; Chromy, W.; Dahmann, D.; Gabriel, S.; Gese, H.* et al.: Quarzexposition am Arbeitsplatz (BGIA-Report), published by Hauptverband der gewerblichen Berufsgenossenschaften (HVBG), Ausschuss für Gefahrstoffe, Sankt Augustin 2006

[11] Directive (EU) 2019/130 of the European Parliament and of the Council of 16 January 2019 amending Directive 2004/37/EC on the protection of workers from risks related to exposure to carcinogens and mutagens at work, (2019) OJ EU No. L 30 (2019), pp. 112-120,

[12] Assessment Standard for Quartz (Respirable Dust). Joint Ministerial Gazette (2016), p. 623

[13] German Hazardous Substances Regulation (GefStoffV) No. 59, pp. 1643-1692, last amended German Federal Gazette (*Bundesgesetzblatt*)(2017) p. 626

[14] Technical Rules for Hazardous Substances: Protective Measures (TRGS 500), 2008 issue, Joint Ministerial Gazette (2019) No. 66/ 67, pp. 1330-1366; Joint Ministerial Gazette, amended (2020) no. 4, p. 88

[15] Technical Rules for Hazardous Substances: List of carcinogenic activities or processes according to section 3 para. 2 no. 3 of the German Hazardous Substances Regulation (GefStoffV) (TRGS 906). 7Th issue, 2005. Joint Ministerial Gazette (2005) pp.79-80; last amended Joint Ministerial Gazette (2007) no. 24, p. 514

[16] DGUV Informative Publication 213-730: "Mineralische Stäube beim Ein-, Ausbetten und Strahlen in Dentallaboratorien" (Mineral dusts during investment, divestment and blasting in dental laboratories), published by Deutsche Gesetzliche Unfallversicherung (DGUV), Berlin 2018

[17] DGUV Informative Publication 213-111: "Quarzhaltiger Staub in der Keramischen Industrie" (Quartz-containing dust in the ceramics industry), published by Deutsche Gesetzliche Unfallversicherung (DGUV), Berlin 2021

[18] DIN EN 481: Arbeitsplatzatmosphäre – Festlegung der Teilchengrößenverteilung zur Messung luftgetragener Partikel (Workplace atmospheres – size fraction definitions for measurement of airborne particles), Springer, Berlin 1993

[19] DIN ISO 7708: Luftbeschaffenheit – Festlegung von Partikelgrößenverteilungen für die gesundheitsbezogene Schwebstaubprobenahme (Air quality — particle size fraction definitions for related sampling), Springer, Berlin 1995

[20] DGUV Informative Publication 213-582: “Verfahren zur Bestimmung von Quarz und Cristobalit – Von den Unfallversicherungsträgern anerkannte Analysen- verfahren zur Festlegung der Konzentrationen krebserzeugender, keimzellmutagener und reproduktions- toxischer Stoffe in der Luft in Arbeitsbereichen” (Methods for the determination of quartz and cristobalite - analytical methods recognised by the accident insurance institutions for determining the concentrations of carcinogenic, germ cell mutagenic and reproductively toxic substances in the air in work areas), published by Deutsche Gesetzliche Unfallversicherung (DGUV), Berlin 2020

[21] Deutsche Forschungsgemeinschaft (German Research Foundation): Quarz, Analytische Methoden, Luftanalysen., Vol. 1, Analytische Methoden zur Prüfung gesundheitsschädlicher Arbeitsstoffe (Quartz, Analytical Methods, Air Analyses., Vol. 1, Analytical methods for the testing of harmful working substances), Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe der Deutschen Forschungsgemeinschaft (Senate Commission for the Testing of Substances Hazardous to Health of the German Research Foundation (DFG), 1993

[22] Quarz (8522), in: IFA-Arbeitsmappe “Messung von Gefahrstoffen”, Vol. 14. Lfg. II/95, published by Deutsche Gesetzliche Unfallversicherung (DGUV), Erich Schmidt Verlag, Berlin 1995

[23] *Heidermanns, G.*: Zur phasenkontrastmikroskopischen Quarzanalyse staubförmiger Proben unter besonderer Berücksichtigung schwach doppelbrechender Minerale – Staub – Reinhalt. Luft 27 (1967), pp. 546-550

[24] *Barth, T. W.; Eskola, P.*: Die Entstehung der Gesteine: ein Lehrbuch der Petrogenese, Springer-Verlag 2013

[25] *Heidermanns, G.*: Quarzgehalte in technisch genutzten Gesteinen, Kennzahl 140 210, in: IFA-Handbuch (IFA Manual), published by Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA), Erich Schmidt Verlag, Berlin 1985

[26] *Rösler, H. J.*: Lehrbuch der Mineralogie, Dt. Verlag für Grundstoffindustrie, 1991

[27] *Burkhart, W.*: Handbuch für das Schleifen und Polieren, Saulgau: Leuze Verlag (1985)

[28] *Hofmann, H.*: Ullmanns Encyklopädie Technical Chemie: Korrosion bis Lacke. vol. 15, Wiley Online Library, Weinheim 1979

[29] *Heidermanns, G.; Mattenklott, M.*: Quarzgehalte in Arbeits- und Hilfstoffen, Kennzahl 140 220. in: IFA-Handbuch (IFA Manual), published by Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA), Erich Schmidt Verlag, Berlin 2007

[30] Vogler, H.: Gewinnungsstätten von Festgesteinen für den Verkehrswegebau in der Bundesrepublik Deutschland, Geologisches Landesamt Nordrhein Westfalen, Krefeld 1985

[31] *Horowitz, I.*: Oberflächenbehandlung mittels Strahlmitteln: Handbuch über Strahltechnik und Strahlanlagen, Vulkan-Verlag 1982

[32] *Mattenklott, M.*: Ersatzstoffe für silikogene Blasting agents – Positivliste, Kennzahl 140 250, in: IFA-Handbuch (IFA Manual), published by Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA), Erich Schmidt Verlag, Berlin 2021

[33] *Stopford, C. M.; Stopford, W.*: Respirable quartz content of farm soils – Applied Occupational and Environmental Hygiene 10 (1995) no. 3, pp. 196-199

[34] *Binde, G.; Bolender, T.*: Rekristallisation und Cristobalitbildung in Hochtemperaturglasfasern (AES) nach thermischer Belastung, Gefahrstoffe Reinhalt. Luft 62 (2002) No. 6, pp. 273-278

[35] *Arnone, M.; Mattenklott, M.; Pflaumbaum, W.; Smola, T.; Stamm, R.; Steinhausen, M.; Binde, G.* et al.: Arbeitsbedingte Exposition gegenüber der einatembaren und der alveolengängigen Staubfraktion (Occupational exposure to inhalable and respirable fraction IFA Report 6/2020), published by Deutsche Gesetzliche Unfallversicherung e. V. (DGUV), Berlin 2020

[36] DGUV Regel 112-190 Benutzung von Atemschutzgeräten (Use of Respiratory Protective Equipment), published by Deutsche Gesetzliche Unfallversicherung (DGUV), Berlin 2011

[37] Schmid, N. A.: Verbesserung der filtrationstechnischen Eigenschaften von Filterhilfsmitteln durch ein thermisches Verfahren (Improving the filtration properties of filter aids by means of a thermal process), doctoral thesis, Munich Technical University 2002

[38] *Schandelmaier, B.*: Kieselgurfiltration im Klein- und Mittelbetrieb, ATW Bericht 128 (2004)

[39] Kieselgur bei der Getränkeherstellung – Arbeitssicherheitsinformation der BGN (Diatomaceous earth in beverage production, BGN occupational safety information) ASI 8.02 (2021)

Authors

General information:

Dr. rer. nat. Markus Mattenklott, IFA, Sankt Augustin
Dr. rer. nat. Marco Steinhausen, IFA, Sankt Augustin
Dr. rer. nat. Nadja von Hahn , IFA, Sankt Augustin

Exposure data:

Dr. rer. nat. Mario Arnone, IFA, Sankt Augustin
Dr. phil. nat. Stefan Auras, BGHW, Mannheim
Dipl. Ing. Dirk Fendler, BG ETEM, Köln
Stefan Gabriel, IFA, Sankt Augustin
Dr. rer. nat. Karlheinz Guldner, VBG, Hamburg
Dipl. Ing. Walter Gunreben, BG Bau, Berlin
AdB Michael Koob, BG RCI, Bochum
Dipl. Ing. Marnix Poppe, BGHM, Köln
Dr. rer. nat. Matthias Weigl, BGN, Mannheim
Dipl.-Ing. (FH) Eckart Willer, BG Verkehr, Hamburg

German Social Accident Insurance Association
(DGUV)

Glinkastrasse 40
10117 Berlin, Germany
Tel.: +49 30 13001 0 (head office)
Email: info@dguv.de
Web: www.dguv.de