BGIA

Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

BGIA-Report 8/2006e

Exposure to quartz at the workplace

Authors:

Ute Bagschik, BG *) in the mechanical engineering and metalworking industry
Margret Böckler, BG in the electrical, textile and precision engineering industry
Walter Chromy, BG in the building trade
Dirk Dahmann, BG in the mining industry/IGF
Stefan Gabriel, BGIA – Institute for Occupational Safety and Health of the German Social Accident Insurance
Heiner Gese, BG in the metalworking industry in northern and southern Germany
Karlheinz Guldner, BG in the ceramics and glass industry
Dirk Fendler, BG in the electrical, textile and precision engineering industry
Kurt Kolmsee, BG in the quarrying industry
Peter Kredel, BG in the chemical industry
Josef Kraus, BG in the building trade
Markus Mattenklott, BGIA – Institute for Occupational Safety and Health of the German Social Accident Insurance
Angela Möller, BGIA – Institute for Occupational Safety and Health of the German Social Accident Insurance
Joachim Münch, BG in the metalworking industry in northern and southern Germany
Günter Sonnenschein, BG in the mechanical engineering and metalworking industry
Othmar Steinig, BG in the ceramics and glass industry
Adolf Tigler, BG in the metalworking industry in northern and southern Germany
Rainer Van Gelder, BGIA – Institute for Occupational Safety and Health of the German Social Accident Insurance

*) BG = German Berufsgenossenschaft (Institution for Statutory Accident Insurance and Prevention)

Editorial office: Central Division of the BGIA – Institute for Occupational Safety and Health

Published by: German Social Accident Insurance (DGUV)
Mittelstr. 51
10117 Berlin
Germany
Tel.: +49 30 288763-800
Fax: +49 30 288763-808
Internet www.dguv.de

– December 2008 –

ISBN: 978-3-88383-767-3

ISSN: 1869-3491

Exposure to quartz at the workplace

Abstract

The aim of this report from the BGIA – Institute for Occupational Safety and Health of the German Social Accident Insurance is to present summarised information on respirable quartz dust at the workplace. The statistical evaluation concentrates on 100 000 measurements recorded by the German Berufsgenossenschaften (Institutions for Statutory Accident Insurance and Prevention) and stored in the BGIA's MEGA exposure database (Measuring data on exposure to hazardous substances at the workplace). Information is covered from 1972 onwards, when the VC 25F system was introduced as a standard measuring equipment for dust. For the purposes of this report, the readings have been broken down into sectors and further into areas of work. When there are sufficient data available, they are also presented in separate time periods up to 2004. They are supplemented by explanatory notes on activities subject to quartz exposure, work processes, exposure trends, how to implement protective measures and on the latest state of the art. Hence they provide a register for prevention in each area of work, as well as a retrospective overview of exposure to dust.

Quarzexpositionen am Arbeitsplatz

Zusammenfassung

Mit diesem BGIA-Report wird eine Synopse zur Exposition gegenüber alveolengängigem Quarzstaub in Arbeitsbereichen vorgelegt. Als Schwerpunkt enthält die statistische Auswertung ca. 100 000 Messergebnisse der Unfallversicherungsträger aus der Expositionsdatenbank MEGA (Messdaten zur Exposition gegenüber Gefahrstoffen am Arbeitsplatz) des BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, beginnend mit dem Jahr 1972, in dem das Probenahmegerät VC 25F als Standardmessgerät für Staubmessungen eingeführt wurde. Die Messergebnisse werden nach Branchen und innerhalb dieser nach Arbeitsbereichen getrennt dargestellt. Sofern eine ausreichende Zahl von Messergebnissen vorliegt, werden die Ergebnisse bis einschließlich 2004 auch in verschiedene Zeiträume eingeteilt. Die Daten werden durch Erläuterungen zu exponierten Tätigkeiten, Arbeitsverfahren, Zeittrends der Exposition, zur Umsetzung von Schutzmaßnahmen und zum Stand der Technik ergänzt. Sie bieten ein Arbeitsbereichskataster für die Prävention und eine retrospektive Expositionsübersicht.

Les expositions au quartz sur les lieux de travail

Résumé

Ce rapport de BGIA – institut pour la sécurité du travail des organismes d'assurance et de prévention des risques professionnels présente une vue d'ensemble sur l'exposition aux poussières alvéolaires de quartz sur les lieux de travail. Cette valuation statistique met l'accent sur env. 100 000 résultats expérimentaux des organismes d'assurance et de prevention des risques professionnels provenant de la banque de données sur l'exposition MEGA (donnés de mesure sur exposition aux substances dangereuses sur le lieu de travail du BGIA. Ces mesures commencent en 1972 quand l'appareil de prélèvement VC 25F a été introduit comme appareil standard de mesures pour les mesurages de poussières. Les résultats expérimentaux sont présentés par branches et pour chaque branche séparés par secteur professionnels Dès qu'il ya un nombre suffisant ces résultats sont répartis par périodes jusqu'à 2004 inclus. Ces donnés sont complétées par des explications concernant les activités exposées, les modes opératoires, les tendances de l'exposition, concernant la réalisation des mesures de protection et l'état de la technique. Elles représentent un cadastre des secteurs professionnels pour la prévention et une vue d'ensemble rétrospective sur les expositions.

Exposiciones al cuarzo en el puesto de trabajo

Resumen

Con este informe del BGIA (Instituto para la Seguridad del trabajo de organismo de securos y prevención de riesgos profesionales) se presenta un sinóptico sobre la exposición al polvo de silíceo que penetra en los alvéolos pulmonares en la zonas de trabajo. Como punto central, la evaluacion estadística contine aprox. 100 000 resultados de medición de los organismos de seguros y prevenciòn de riesgos profesionales a partir del banco de datos de exposoción MEGA (datos medidos relativos a la exposición a substancias peligrosas en el puesto de trabajo) del BGIA – Instituto para la Protección Laboral de los organismos de seguros y prevenciòn de riesgos profesionales, comenzando por el ano 1972, en que se introdujo el aparato de toma de muestras VC 25F como equipo medidor estándar para las mediciones de polvo. Los resultados de las mediciones se presentan separados según los ramos de actividad y dentro de èstos, según las zonas de trabajo. Siempre cuando se dispone de un número suficiente de resultados de medición, se dividen los resultados hasta 2004, inclusive, también en diversos períodos. Los datos se completan con explicaciones sobre lasactividas expuestas, los procedimientos de trabajo, tendencias de la exposición en finción del tiempo, la implantación de medidas de protección y el estado actual de la tecnología. Ofrecen un catastro de zonas de trabajo para la prevención y una vistra retrospectiva de la exposición.

Inhaltsverzeichnis

1 Introduction ... 11

2 Health hazards and occupational diseases ... 13
2.1 Health hazards ... 13
2.2 Occupational diseases ... 15

3 Measurement procedures ... 19
3.1 Sampling procedures ... 19
3.1.1 Respirable dust, definition and sampling systems ... 19
3.1.2 Personal and stationary measurements ... 21
3.2 Analysis methods ... 22
3.2.1 X-ray diffraction method ... 22
3.2.2 Infrared spectroscopy ... 23
3.2.3 Phase-contrast microscopy ... 23
3.2.4 Phosphoric acid method ... 24
3.2.5 Occurence of amorphous silica ... 24
3.2.6 Detection limits and influence of the dust concentration ... 25

4 Uses and occurence ... 29
4.1 Quartz ... 29
4.1.1 Extraction of gravels and sands containing quartz ... 29
4.1.2 Foundries (foundry sands) ... 29
4.1.3 Chemical industry ... 29
4.1.4 Ceramics industry ... 31
4.1.5 Glass industry (glass sands) ... 31
4.1.6 Filter sands and gravels ... 32
4.1.7 Electrical engineering (piezoelectric quartz) ... 32
4.1.8 Quartz-sand-filled fuses ... 32
4.1.9 Electrical installation work ... 33
4.1.10 Precision mechanics – dental technology ... 33
4.1.11 Construction materials industry, construction industry ... 33
4.1.12 Working on decorative stones ... 34
4.1.13 Grinding, polishing and abrasive agents ... 34
4.1.14 Blasting agents ... 34

4.1.15	Further applications	35
4.1.16	Other forms of occurrence and unintended use	35
4.2	Cristobalite	36
4.2.1	Cristobalite from fibres	36
4.3	Tridymite	36
5	**Exposure data**	**39**
5.1	Body of data and principles of evaluation	39
5.2	Statistics and presentation of exposure	39
5.3	Exposure data	41
5.3.1	Extraction of quartz sand	41
5.3.2	Extraction and processing of minerals and earths	44
5.3.2.1	Natural hewn stone industry – manufacture, treatment and working of natural hewn stone, stone masonry	44
5.3.2.2	Natural stone industry – extraction and preparation of natural stone	51
5.3.2.3	Extraction and preparation of gravel and sand	57
5.3.2.4	Extraction and preparation of limestone and dolomite	60
5.3.2.5	Manufacture of cement and lime	61
5.3.2.6	Recycling and sorting of construction materials	63
5.3.2.7	Concrete industry (stationary operation)	66
5.3.2.8	Asphalt mixing plants	73
5.3.2.9	Manufacture of drywall construction materials (premix dry mortar, premix plaster)	75
5.3.2.10	Mineral milling works (mineral pigments)	77
5.3.3	Ceramics and glass industry	78
5.3.3.1	Clay, kaolin, extraction	78
5.3.3.2	Brickwork products, manufacture	79
5.3.3.3	Large stoneware products and split tiles, manufacture	82
5.3.3.4	Refractory products, manufacture	84
5.3.3.5	Abrasive devices, manufacture	87
5.3.3.6	Porcelain and fine ceramic bodies, manufacture	89
5.3.3.7	Utility stoneware and fine stoneware, manufacture; clay and pottery ware, manufacture	94
5.3.3.8	Wall/floor tiles, stove tiles and heavy ceramics, manufacture	97
5.3.3.9	Sanitary, technical, and chemical/technical electrical ceramics, manufacture	100

5.3.3.10 Hollow glassware, manufacture and working 104
5.3.3.11 Sand-lime brick, manufacture 106
5.3.4 Foundries..107
5.3.5 Metals manufacture 118
5.3.6 Metalworking, machine and vehicle manufacture 118
5.3.7 Electrical engineering 120
5.3.8 Precision mechanics...123
5.3.8.1 Dental laboratories...124
5.3.8.2 Musical instruments and metal products, manufacture...........................124
5.3.8.3 Jewellery, manufacture and working..125
5.3.9 Chemical industry 125
5.3.9.1 Coatings and adhesives, jointing and filler compounds, manufacture 127
5.3.9.2 Roofing felt and bitumen webs, manufacture..129
5.3.9.3 Auxiliary materials for foundries, manufacture..129
5.3.9.4 Rubberware, manufacture and processing 130
5.3.9.5 Plastics, manufacture and processing 132
5.3.9.6 Pharmaceutical and cosmetic products, manufacture 133
5.3.9.7 Cleaning and care products, manufacture 134
5.3.9.8 Grinding and polishing agents, manufacture 134
5.3.9.9 Silicon compounds, electrothermal manufacture 135
5.3.10 Construction industry 135
5.3.10.1 Masonry work and clinker construction..136
5.3.10.2 Drywall construction..137
5.3.10.3 Plasterwork..138
5.3.10.4 Demolition work 139
5.3.10.5 Earthmoving, levelling, compaction and paving work 140
5.3.10.6 Construction of stoves, chimneys, furnaces and industrial ovens 141
5.3.10.7 Roofing work..142
5.3.10.8 Concrete work (mobile)...142
5.3.10.9 Construction site cleaning...143
5.3.10.10 Blasting work 144
5.3.10.11 Road works...145
5.3.10.12 Further activities in the construction industry 146

5.3.11 Tunnel driving, galley driving, augering 147
5.3.12 Special civil engineering works 148

6 Literature 151

1 Introduction

Quartz is employed as an agent or is released, in the form of quartz dust, in a range of working processes. The main areas in which quartz is used are as a filler in the rubber, plastics and paints industries, as glass sand in the glass industry, as foundry sand in foundries, and as a constituent of various raw materials and products in the construction industry. Quartz is also used as a raw material in the chemical and ceramics industries, and as filter sand in effluent purification and in the chemical industry. In the electrical industry, quartz is exploited for its piezoelectric property. Various varieties of quartz are worked as decorative and semi-precious stones. Quartz is also used in some cases as a grinding, polishing and abrasive agent.

Exposure to respirable quartz dust at workplaces remains significant, despite technical progress and the concerted efforts undertaken to reduce the dust exposure. Since the 1950s, comprehensive series of measurements have been taken by the German Institutions for Statutory Accident Insurance and Prevention (Berufsgenossenschaften, BGs) in order to ascertain the exposure to quartz in various sectors. This exposure is also documented by the number of quartz dust measurements conducted within the Measurement system for exposure assessment of the German Social Accident Insurance institutions – BGMG, currently amounting to approximately 2,500 measurements per year in 600 different working areas. This figure makes quartz dust the discrete substance for which the greatest number of measurements is performed. The analysis methods for quartz measurement which are currently recognized were established in the early 1970s.

Against this background, a need exists for a general survey of quartz: to serve as a basis for the management of preventive measures and monitoring of exposure, and for quantifying past exposure to quartz in the context of cases of suspected occupational disease.

The number of cases of silicosis caused by exposure to quartz dust and formally recognized as occupational disease has fallen steadily in recent decades owing to the success of prevention measures.

2 Health hazards and occupational diseases

2.1 Health hazards

Changes to the lungs caused by the inhalation of dust are described generically as pneumoconiosis. The response of the human organism to dust which is absorbed through the respiratory tract varies according to the size, geometry and chemical composition of the particles.

Inhaled particles which are not deposited directly in the nasal cavity may be carried on the respiratory air through the larynx and trachea to the branches of the bronchi and bronchioles. The interior of this tubular system is ciliated (the ciliated epithelium) and lined with a mucous membrane. The cilia continually transport the mucus together with the foreign objects carried in it in the direction of the throat, where it is generally swallowed. This cleaning mechanism ensures that particles with a diameter exceeding 4 or 5 µm (the density of the quartz is the relevant parameter) do not generally reach the alveoli located lower down, in which gas exchange takes place.

The inner surface of the alveoli is coated by a secretion which lowers the surface tension and prevents the alveoli from collapsing. Particles which have penetrated as far as the alveoli are encased in this secretion and absorbed by special phagocytes (macrophages) which move actively to the ciliated epithelium, from where in turn they are transported out of the system.

One consequence of quartz dust penetrating the alveoli is that it produces fibroses, i.e. scarring of the lung. Tridymite, cristobalite and coesite (but not stishovite) also possess this silicosis-inducing property [1]. The mechanism by which fibrotic changes to lung tissue take place is still not completely understood. Probable factors are however considered to be the interference of quartz particles in the mucous membrane, damage to cells in the region of the alveoli, and certain reactions by the macrophages.

Quartz particles have a toxic effect upon macrophages, and shorten their life. Macrophages respond to the intake of quartz particles by emitting a range of messenger substances which trigger inflammatory processes. Heightened, abnormal crosslinking of collagen fibres is observed, which causes a progressive stiffening of the lung. Node-like collections of macrophages are formed in which dust particles are stored; these macrophages become enlarged and grow together to form calluses. Once a certain stage has been reached, the disease progresses even in the absence of further dust intake. Changes in the lung leading to impairment of the pulmonary function generally occur only after many years of dust exposure.

The specific form of pneumoconiosis caused by the inhalation of quartz dust is described as grinder's disease or silicosis. The sufferer experiences a dry cough and sputum, and later increasingly dyspnea (breathlessness) and chest pain. Chronic bronchitis may develop, and in some cases pulmonary emphysema. Owing to the increased pressure in the pulmonary circulation in the advanced stage of the disease, the right ventricle is overloaded, potentially leading to chronic right heart failure (cor pulmonale).

Persons exposed to quartz dust are approximately one hundred times more likely to contract tuberculosis than the wider population. When combined with silicosis, pulmonary tuberculosis is described as silicotuberculosis.

The fibrosis caused by the deposition of dust is incurable. Certain symptoms and complications (e.g. breathing difficulties, tuberculosis) can now be combated highly effectively. Silicotics and non-silicotics now enjoy virtually the same life expectancy.

Silicosis resulting from workplace exposure is caused not only by pure quartz dust, but also, and in particular, by dust mixtures containing quartz. Accompanying substances may either inhibit or promote the action of the free crystalline silicic acid. An example which will be mentioned in this context is anthracosis, which can be caused in coal-miners by a mixture of coal and quartz dust.

The International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) concluded in a scientific assessment in 1997 that a correlation between the inhalation of respirable quartz and cristobalite dust and an increased risk of lung cancer in persons subject to occupational exposure did not exist under all occupational conditions. The risk of lung cancer may be caused by the properties of quartz itself, or by other factors which influence its biological action. Based upon adequate evidence gained from tests on animals and human subjects, crystalline silicon dioxide, inhaled in the form of quartz or cristobalite encountered at the workplace, has been classified as a human carcinogen (Group 1) [2].

2.2 Occupational diseases

Diseases caused by inorganic dusts are listed as formally recognized occupational disease (BK, Berufskrankheit) No. 41 in the Annex of the German Ordinance governing occupational diseases (BKV, Berufskrankheiten-Verordnung). Pulmonary diseases caused by quartz are classified as follows:

- No. 4101 Silicosis
- No. 4102 Silicosis in conjunction with active pulmonary tuberculosis (silicotuberculosis)
- No. 4112 Lung cancer caused by the action of crystalline silicon dioxide (SiO_2) with proof of a form of silicosis or silicotuberculosis

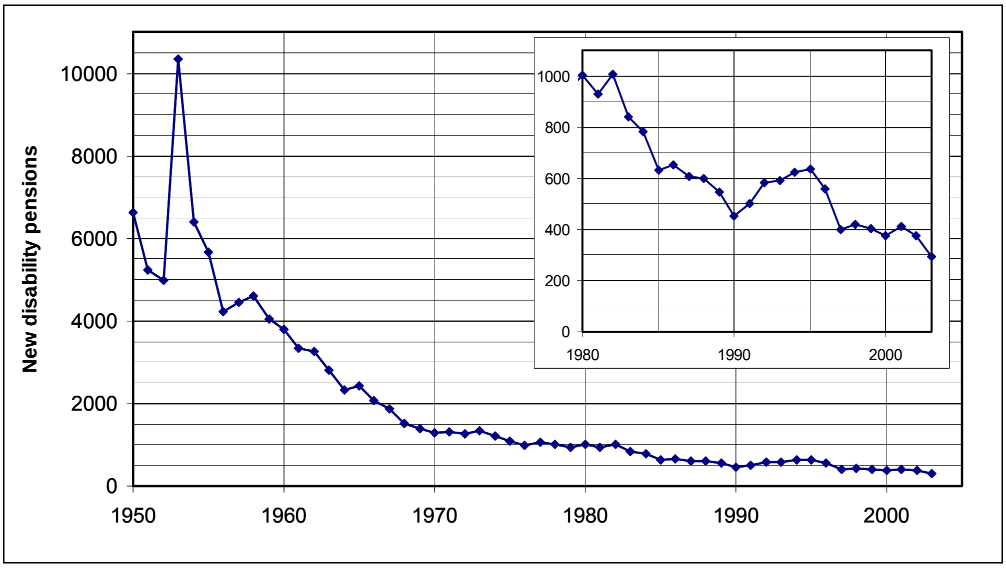
The annex to the Ordinance of the German Democratic Republic governing formally recognized occupational diseases contained the occupational disease (BK) No. 40, "Quartz", under Point II, Diseases caused by dusts. Compensation for occupational diseases listed under this heading remained possible after 1991, provided the disease first became apparent prior to 1 January 1992, and the suspicion of occupational disease was reported before the end of 1993.

As already mentioned in Section 2.1, silicosis may worsen even after the occupational exposure to quartz dust has ceased. Should a considerable worsening of the complaints be demonstrated, the level of the pension must be adjusted accordingly [3]. No strict correlation exists between the damage to the lung caused by quartz and visible on the X-ray, and the clinical symptoms. The health complaints may worsen even though the findings of the X-ray examination remain unchanged.

Besides reducing the quality of life for those affected, silicoses continue to have a major negative economic impact, and are a substantial reason for diseases of the respiratory tract being numerically amongst the occupational diseases most frequently recognized, together with skin diseases and occupational deafness.

Overall, however, the incidence of the disease is thankfully on the decline in Germany (see Figure 1).

Figure 1:
New disability pensions granted in respect of silicosis (BK No. 4101) [4]. The figures are for the most part from the areas of mining, minerals and earths, metals, and the construction industry (see also Figure 2)



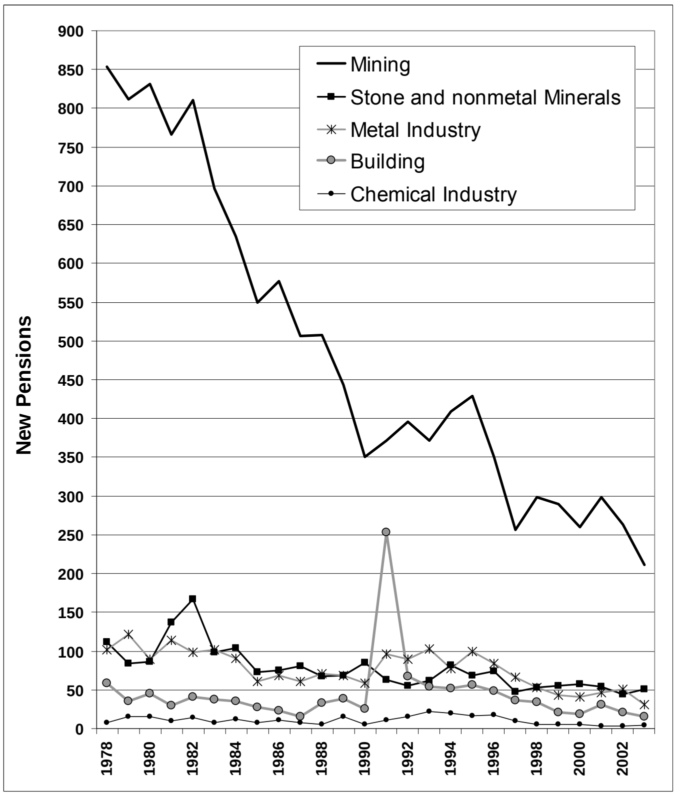


Figure 2:
New disability pensions awarded in respect of silicosis or silicotuberculosis (BK Nos. 4101 and 4102) for the areas of mining, minerals and earths, metals, and the chemical industry [4]. The significantly high value for 2001 for the construction sector is due to the assumption of responsibility for the cases of occupational disease in the former GDR (German Democratic Republic)

This positive development can be attributed to improved technical and medical OSH measures (OSH, occupational safety and health). In 1970, 1,295 new disability pensions were awarded for disease No. 4101 in Annex 1 of the BKV; in 1980, the figure was 1,001, and in 1990 and 2000, 453 and 367 respectively [5]. A slight rise, to 546 new disability pensions, was noted in 1994 as a consequence of German reunification. Since then, the figures have fallen again (2003: 286 new disability pensions). Silicotuberculosis (BK No. 4102) has shown a strong decline (new disability pensions in 1970: 227; 1980: 129; 1990: 66; 2000: 24; 2003: 27).

In 2002, BK No. 4112 was added to the list of formally recognized occupational diseases: a case of lung cancer caused by exposure to crystalline silicon dioxide (SiO_2) may now be recognized as an occupational disease if silicosis or silicotuberculosis is already present and the insured condition occurred after 30 November 1997. In 2002, nine new disability pensions resulting from occupational disease (BK) No. 4112 were awarded. The figure for 2003 was 45.

The following formally recognized occupational disease caused by quartz dust has in addition been listed in accordance with Annex 1 of the BKV since 1993:

- No. 2111 Increased dental abrasion caused by several years' activity involving exposure to quartz dust (dental abrasion)

Seven such cases were recognized in 2003.

3 Measurement procedures

3.1 Sampling procedures

3.1.1 Respirable dust, definition and sampling systems

Under the TRGS[1] 900 [6] the limit value for respirable quartz dust was valid up until 2005. Up to 1993, the respirable dust fraction was defined as fine dust in accordance with the 1959 Johannesburg Convention. In theory, this particle spectrum is that of a dust collective which is obtained downstream of a filtration system with the separation function of a sedimentation pre-separator. The sampling efficiency in accordance with the Johannesburg Convention is summarized for certain aerodynamic diameters in Table 1 and shown in Figure 3 (see page 20).

Table 1:
Conventions for respirable particle size fraction: Johannesburg Convention and DIN EN 481 [7; 8]

Johannesburg Convention (1959)		DIN EN 481 (1993)	
Aerodynamic diameter of dust particles in µm	Permeability in %	Aerodynamic diameter of dust particles 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

Since 1994, TRGS 900 has cited the European standard DIN EN 481 [6; 8] as the basis for definition of the respirable fraction. The two conventions are not identical; the differences are however relatively minor with regard to the dust particle distributions occurring in practice.

[1] TRGS = Technische Regeln für Gefahrstoffe, Technical Rules for Hazardous Substances

The sampling devices employed to date for measurement of the fine dust may continue to be used, as their pre-selectors have a separation function which differs only slightly from the intended function defined in DIN EN 481 [9].

The definitions of the inhalable and respirable fractions set out in DIN EN 481 were also reproduced in identical form with regard to their content in DIN ISO 7708, which was adopted as a German standard in 1996 [10].

The sampling devices with pre-separator employed to date for measurement of the respirable fraction are listed in Table 2.

Figure 3:
Deposition efficiency for the respirable dust fraction in accordance with the Johannesburg Convention ("fine dust") and DIN EN 481 ("respirable dust") [7; 8]

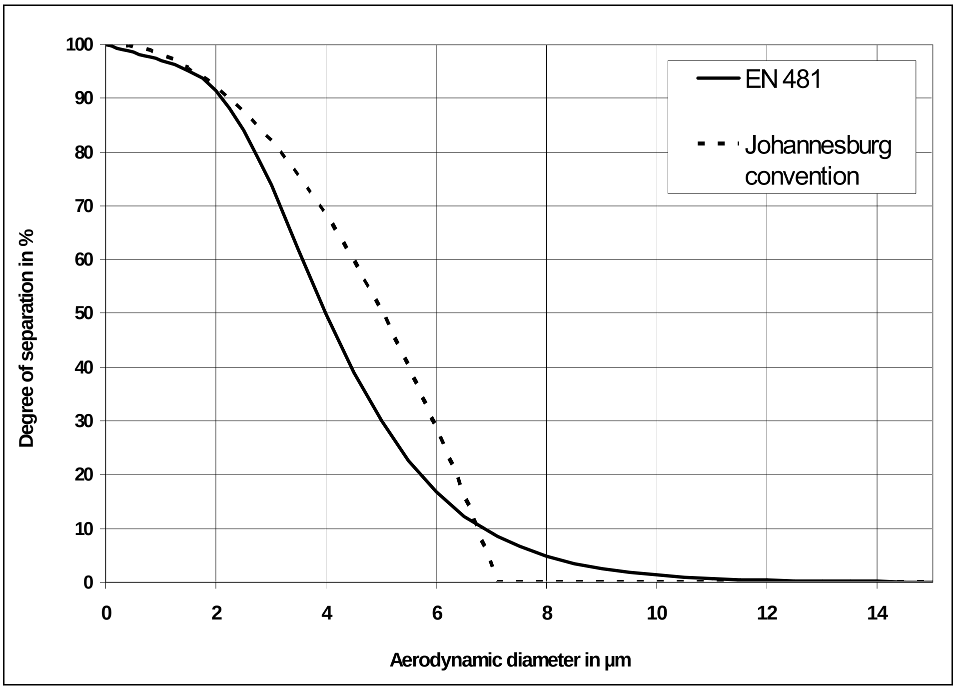


Table 2:
Sampling systems for the respirable dust fraction with indication of the flow rate

Sampling system		Flow rate in m^3/h
Personal [a]		
FSP-BIA	With use of the Casella cyclone	0.12
FSP-10	With 10 l cyclone and SG 10 pump	0.60
Stationary		
MPG II	With sedimentation pre-selector in accordance with the Johannesburg Convention	2.8
PM 4F	Cyclone pre-selector	4.0
VC 25F	Pre-selection by impaction	22.5
VC 25I	As VC 25F, with additional impactor; particularly suitable for measurements in wet areas	22.5

[a] In addition to the sampling systems for measurement of a specific dust fraction, sampling devices have also been developed in recent years for simultaneous measurement of the inhalable and respirable fractions. Examples of the systems available are the PGP-EA (3.5 l/min) and Respicon TM (3.11 l/min)

3.1.2 Personal and stationary measurements

Measurements conducted on the person and stationary measurements generally deliver different results for the dust concentrations. The concentrations determined by personal sampling are generally higher than those obtained by stationary sampling (for examples, see the BGIA Folder, No. 0412/3[2]).

Whether stationary sampling is suitable for measurement of the employees' exposure in certain working areas can be determined for example by comparative measurements.

[2] *Stamm, R.:* Der Einfluß des Probenahmeortes (personengetragen bzw. stationär). In: BGIA-Arbeitsmappe Messung von Gefahrstoffen. 20. Lfg. IV/1998. Hrsg: BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Sankt Augustin. Erich Schmidt, Berlin 1989 – Losebl.-Ausg. www.bgia-arbeitsmappedigital.de

3.2 Analysis methods

All sampling systems listed in Table 2 filter off the respirable dusts on membrane filters. Besides the fine-dust concentration, the concentration of respirable quartz dust must be determined from the dust collected on these filters. The analysis methods available for this purpose are in principle the X-ray diffraction, infrared spectroscopy, and to a lesser degree phase-contrast microscopy (estimation of the mass fraction of the quartz in the respirable dust).

In X-ray diffraction analysis, detectable cristobalite components are identified directly in the dust in addition to the quartz, since the peak of the main interference of the cristobalite lies close to one of the interferences evaluated for quartz analysis. The analysis method for the cristobalite respirable dust concentration is similar to the X-ray diffraction method described for quartz. Analysis of cristobalite by infrared spectroscopy is more difficult, since the relevant extinction band of cristobalite overlaps one of the extinction bands of quartz. An X-ray diffraction method based upon that for quartz analysis can be used to analyze tridymite. Since tridymite is a polytypic substance, a calibration sample from the working area concerned should be used.

3.2.1 X-ray diffraction method

Based upon a known mass of fine dust on the membrane filters, a portion of the filter coated with approximately 4 mg of substance is used for the quartz analysis. Baking of the membrane filter substance in porcelain crucibles at a maximum of 650 °C and subsequent treatment of the baking residue with hydrochloric acid in an ultrasonic bath causes the components soluble in hydrochloric acid, such as carbonates and iron oxides, to be dissolved. The residual suspension is transferred by vacuum filtration to silver membrane filters: a thin, homogeneous dust layer is produced on these filters, which is then subjected to X-ray analysis.

For quantitative quartz analysis, the strongest interference at d = 0.334 nm initially appears the most suitable. This may, however, be subject to considerable disturbance, for example if micas are present. The second- and third-strongest interferences, those at d = 0.426 nm and d = 0.182 nm respectively, are also analyzed. The third-strongest interference has proved to be largely free of disturbance. Provided the loading on the silver membrane filter are sufficiently thin, which is the case at ≤ 4 mg of substance, the mass of the fine quartz dust can be determined directly from the intensity of interference on the silver filter, without consideration of the mass attenuation coefficients in the mineral mixture present. This aspect can no longer be disregarded in the case of thick dust layers. A comprehensive description of the analysis method can be found in the literature [11]. The authors emphasize that the documented respirable quartz dust concentrations were analyzed for the most part by the X-ray analysis method as described. Only in the case of personal sampling systems and low filter loadings (approx. < 2 mg) does infrared spectroscopy offer a more favourable detection limit.

3.2.2 Infrared spectroscopy

The dust loaded filter or a defined portion of it and a known quantity of potassium chloride (KCl) are homogenized by milling, and incinerated at 620 °C following the addition of a few drops of isopropanol. A defined portion of this is used to produce a KCl pellet. A ratio of 1 mg substance to 250 mg KCl must not be exceeded.

The integral extinction of the two infrared bands at 779/798 cm^{-1} is employed for the quantitative analysis of quartz. If the quartz component is high, the weaker band at 695 cm^{-1} can also be used [12].

3.2.3 Phase-contrast microscopy

For phase-contrast microscopy analysis of quartz, the dusts are placed on an object slide, an embedding medium the refractive index of which is very close to those of quartz (e.g. eugenol: n_D = 1.542) is added, and the mixture is covered with a slide cover glass and studied. When suspended in the embedding medium, dusts on membrane filters can easily be transferred to the cover glass by means of a lancet. Special optical staining then causes the quartz to stand out from all other particles in positive phase contrast (white light), since the latter have different refraction indices and appear colourless. The quartz content can be estimated by examination of approximately 100 visual fields. Observation under crossed polarization further permits differentiation between isotropic and birefractive mineral components [13]. This method is suitable when assessment for the magnitude of the quartz content is required at short notice.

3.2.4 Phosphoric acid method

The use of phosphoric acid digestion for the analysis of quartz became established in the OSH sphere in the early 1950s, and was the method primarily used in this area until the end of the 1960s. At that time, the respirable dust fraction was not measured directly. Sampling measured the total dust, equivalent to the present inhalable dust fraction. The fine component of the dust was then separated off by sedimentation analysis, after which it could be studied separately.

The principle of the phosphoric acid digestion method is that phosphoric acid dissolves most silicates whilst attacking quartz only weakly. Following pretreatment of the sample with HCl for the removal of interfering components, it is exposed to phosphoric acid dehydrated prior to use in a crucible at 250 °C. After a reaction time, the content of the crucible is diluted with water, tetrafluoroboric acid HBF_4 is added – in order to prevent the precipitation of SiO_2 – and the content then filtered. The residue is incinerated and then fumed off with hydrofluoric acid (HF). The quartz component is estimated from the difference between the residue insoluble in phosphoric acid and the residue following fuming-off [14; 15].

3.2.5 Occurrence of amorphous silica

An infrared spectroscopic method is employed for analysis of the amorphous silica fraction in dusts. The analysis method does not identify the type of amorphous silica in the sample, however. Nor does it distinguish between an amorphous silica and another amorphous material with a high SiO_2 content (e.g. window glass). Knowledge of the materials used/present is therefore crucial for measurement of the concentration of amorphous silica in the working area. Whether amorphous silica is used in a given working process, and if so, the type of amorphous silica involved, must be determined in advance. Information from safety data sheets may be referred to for this purpose. Only with this information can sampling be performed and the result compared properly to a limit value. At the same time, it must be remembered that amorphous silica may be produced by certain processes, such as the fusion of quartz sand (quartz glass/silica glass) or the manufacture of silicon (silica fumes).

Amorphous silica may also contain components of crystalline SiO_2 modifications. Diatomaceous earths are particularly relevant here. These are natural raw materials, consisting of deposits of diatom skeletons. Depending upon the location of the deposits, unfired diatomaceous earths may contain a quartz component. If diatomaceous earths are fired (calcined), cristobalite is produced, its mass fraction generally being around 50 to 80%. In such cases, amorphous and crystalline SiO_2 modifications must be analyzed and evaluated separately.

3.2.6 Detection limits and influence of the dust concentration

Under the most favourable conditions – in the absence of high dust concentrations and of interference by cross-sensitivity caused by other dust components – the various sampling systems yield the detection limits shown in Table 3.

Table 3:
Relative detection limits for analysis of the respirable quartz dust concentration, by sampling system and sampling duration, under best-case conditions

Duration of sampling in hours	Relative detection limit in mg/m³				
	VC 25F or VC 25I	PM 4F	MPG II	FSP-BIA	FSP-10
0.25	0.014	0.040	0.057	0.33	0.067
0.5	0.007	0.020	0.029	0.17	0.033
1	0.004	0.010	0.014	0.083	0.017
2	0.002	0.005	0.007	0.042	0.008
4	0.0009	0.003	0.004	0.021	0.004
6	0.0006	0.002	0.002	0.014	0.003
8	0.0004	0.001	0.002	0.010	0.002

Sampling with VC 25F/I, PM 4F, MPG II: in this case with X-ray diffraction as the analysis method; sampling with FSP-BIA, FSP 10: in this case with infrared spectroscopy as the analysis method

Since, for quartz analysis, the dust loading of the filter has a decisive influence upon the attainable relative detection limit, attention must particularly be paid in this case to the influence of the respirable dust concentration in the working area under evaluation. Only a limited quantity of the dust from the filter can be employed for analysis (a maximum of 4 mg for X-ray diffraction or 1 mg for infrared spectroscopy). The detection limit thus rises with increasing respirable dust concentration. The influence of the respirable dust concentration upon the relative detection limit for quartz is shown in Table 4 for stationary sampling by means of the VC 25F and for personal sampling by means of the FSP-10. The table shows a comparison of the relative detection limits for the analysis of respirable quartz dust in air samples, at various respirable dust concentrations.

Table 4:
Relative detection limits for respirable quartz dust with stationary (VC 25F) and personal (FSP-10) sampling as a function of the respirable dust concentration and the duration of sampling

<table>
<tr><th rowspan="3">Duration of sampling in hours</th><th colspan="10">Relative detection limit for respirable quartz dust in mg/m³</th></tr>
<tr><th colspan="5">Sampling with VC 25F
Respirable dust concentration in mg/m³</th><th colspan="5">Sampling with FSP-10
Respirable dust concentration in mg/m³</th></tr>
<tr><th>Quartz only</th><th>0.3</th><th>1.5</th><th>3.0</th><th>6.0</th><th>Quartz only</th><th>0.3</th><th>1.5</th><th>3.0</th><th>6.0</th></tr>
<tr><td>0.25</td><td>0.014</td><td>0.014</td><td rowspan="7">0.015</td><td rowspan="7">0.030</td><td rowspan="7">0.060</td><td>0.067</td><td>0.067</td><td>0.067</td><td>0.067</td><td>0.067</td></tr>
<tr><td>0.5</td><td>0.0071</td><td>0.0071</td><td>0.033</td><td>0.033</td><td>0.033</td><td>0.033</td><td rowspan="6">0.060</td></tr>
<tr><td>1</td><td>0.0036</td><td>0.0036</td><td>0.017</td><td>0.017</td><td>0.017</td><td rowspan="5">0.030</td></tr>
<tr><td>2</td><td>0.0018</td><td rowspan="4">0.0030</td><td>0.0083</td><td>0.0083</td><td rowspan="4">0.015</td></tr>
<tr><td>4</td><td>0.0009</td><td>0.0042</td><td>0.0042</td></tr>
<tr><td>6</td><td>0.0006</td><td>0.0028</td><td rowspan="2">0.0030</td></tr>
<tr><td>8</td><td>0.0004</td><td>0.0021</td></tr>
</table>

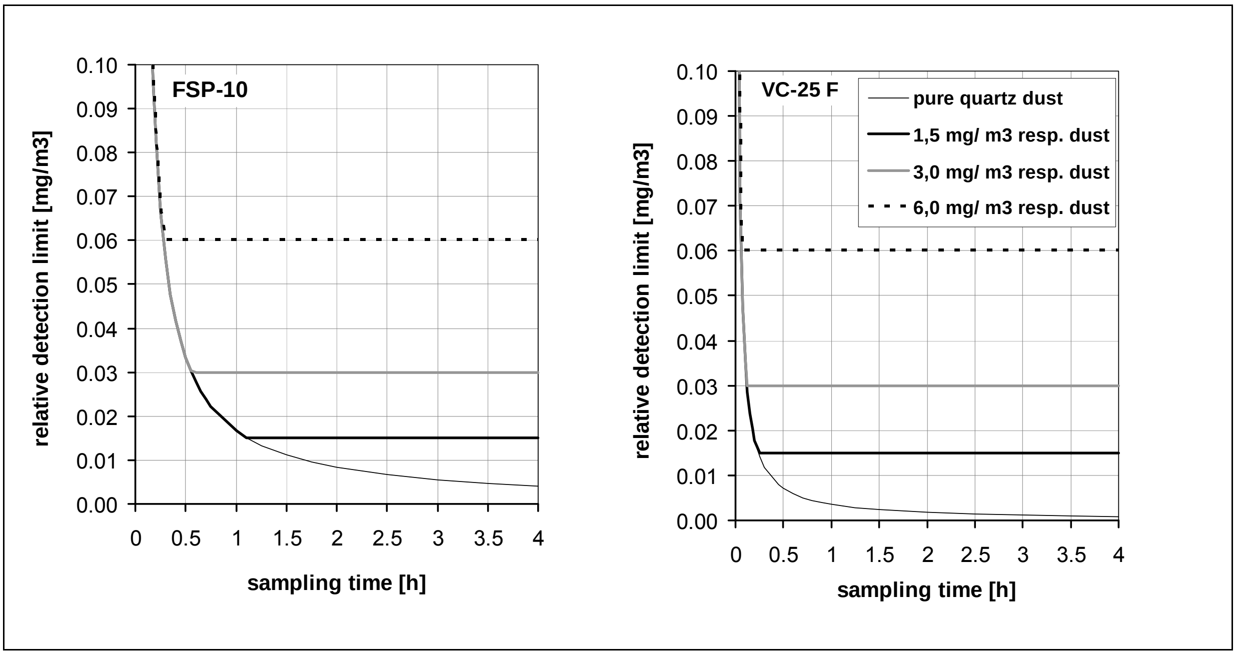
Quartz only: Respirable dust consists of 100% quartz
Sampling with VC 25F: X-ray diffraction is used in this case for analysis
Sampling with FSP-10: infrared spectrometry is used in this case for analysis

As can clearly be seen, once a certain dust concentration is reached in the working area, the detection limit can no longer be improved by extension of the sampling duration. The following serves as a rule of thumb:

The relative detection limit for the respirable quartz dust concentration in air measurements cannot be lower than one-hundredth of the respirable dust concentration in the working area under evaluation.

In other words, should for example the respirable dust concentration in the working area be 2.5 mg/m^3, the detection limit for quartz analysis cannot be lower than 0.025 mg/m^3, regardless of the sampler used, the sampling duration and the analysis method. This relationship is also shown in Figure 4.

Figure 4:
Relative detection limits for analysis of the respirable quartz dust concentration of air samples as a function of the respirable dust concentration and the duration of sampling, with the sampling systems VC 25F and FSP-10 serving as examples



4 Uses and occurence

4.1 Quartz

4.1.1 Extraction of gravels and sands containing quartz (see also Section 5.3.1)

Quartz gravels and quartz sands occurring naturally in the form of the detritus of crystalline minerals constitute important raw materials for industry. They are extracted from the sedimentary deposits, and worked by washing, screening and milling processes.

Gravels are sold as a product with a screen size of 2 to 48 mm.

Sands are used wet or dry, with defined purity and fineness grades and in a range of different particle sizes. They are employed as raw materials, mould materials, auxiliary materials and abrasives. By chemical modification to their surface, their crosslinking and bonding with other substances can be improved.

Quartz powders are obtained from high-purity quartz sand by iron-free milling. This enables fractions with particle diameters of just a few µm to be obtained.

4.1.2 Foundries (foundry sands) (see also Section 5.3.4)

Its physical, chemical and refractory properties make quartz suitable for use as a basic material for moulds in foundries [16]. The onset of sintering of quartz sands comprising over 99% SiO_2 lies above 1,500 °C [17]. The proportion of particles with a diameter of < 20 µm should be as low as possible. Sands comprising monomineralic particles with rounded edges are preferred.

4.1.3 Chemical industry (see also Section 5.3.9)

Quartz sand serves as the raw material in the manufacture of a range of chemicals which in turn form the basis for the synthesis of a large number of compounds.

Waterglass (sodium and potassium silicates) is obtained by the heating of mixtures of quartz sand (particle size: 0.1 to 0.5 mm) and alkali carbonates at 1,600 °C. A large part of the alkali silicates are employed for the manufacture of detergents and cleaning agents. They are also used in the manufacture of products such as fillers, catalysts, silica sols and silica gels, and waterglass paints.

Silicon carbide is produced in an electric resistance furnace during the conversion of quartz sand and petroleum coke. It is an important abrasive, a material for refractory goods and electrically conductive heating elements, and is used for example for increasing the resistance of floor surfacings to wear and slipping.

Silicon tetrachloride is manufactured from quartz sand, silicon carbide and coke by treatment with chlorine in a fluidized-bed reactor. Ultrapure silicon can be obtained from silicon tetrachloride by thermal decomposition. Combustion produces highly disperse silicic acid.

Organic silanes, i.e. organic silicon compounds, are synthesized from pure silicon (see below), silicon tetrachloride, or other halogenosilanes. Diorganodichlorosilanes constitute the raw materials for the silicones, which are of major technical importance.

The element **silicon** is first obtained in the form of raw silicon by the carbothermic reduction of quartz sand with the aid of coke (or aluminium), and is processed to highly pure silicon for use in solar cells or computer chips. The transition through the interim silicon stage is also used for the synthesis of high-purity silicon halides (see above) [18].

Quartz as a filler (see also Section 5.3.9)

Quartz powder and quartz sand are highly suited to use as fillers for casting resins, moulding compounds and casting compounds. The advantage of quartz as a filler in casting resin is that it does not impair the latter's properties, such as its pot life.

A further application of quartz sand or powder is in coatings, such as varnishes, paints or stoppers; in adhesives; and in cleaning and care products. Large quantities are also used in industrial rubber products, tyres, and plastics.

In many of these applications, amorphous silicon dioxide manufactured from quartz sand may be employed as a filler.

Quartz particles stained by Pigmosol® preparations or oxide pigments (colour fractions) can for example be used as loading in decorative plasters or casting resins for a decorative surface finish [19].

4.1.4 **Ceramics industry** (see also Section 5.3.3)

Argillaceous (clayey) raw materials are employed as basic components for both fine and heavy ceramics. Clay/kaoline is a fine-grain sediment which is produced by the weathering of feldspathic rocks. Free quartz is always present as a natural impurity in clay. Mineral analyses show the quartz component to be between 5% in highly plastic clays and 70% in loam sands.

However, quartz powder is also used as a loading or nonplastic material in ceramic compounds.

During glazing, the finishing process for the majority of ceramic products, quartz serves as a crosslinker, and it acts as an aggressive flux at high temperatures. Depending upon the particle size and the accompanying impurities, cristobalite may be formed from the quartz melt.

Typical heavy ceramic products are roof tiles, stone pipes and split tiles. Refractory ceramic products, particularly silica bricks, may also contain cristobalite. The most significant fine ceramic products are floor and wall tiles, pottery, sanitary ceramics, porcelain, and industrial ceramics.

4.1.5 **Glass industry (glass sands)** (see also Section 5.3.3.10)

At 50 to 80%, quartz sand constitutes the largest component of the raw materials for glasses in industrial manufacture. These include products manufactured from flat glass (building and automotive glazing), hollow glass (bottles, drinking glasses, light bulbs, VDT and TV screens), and other products, such as laboratory glassware or glass fibre.

Very pure quartz, such as rock crystal or gangue quartz, is suitable for the manufacture of quartz glass or optical glasses. Further raw materials used in glass manufacture are sodium carbonate, limestone, marble and calcareous clay, and special oxides, such as lead oxide for the manufacture of lead crystal glass. The particle size of the raw materials ranges from 0.05 to 0.5 mm.

Exposure to quartz may occur when the raw materials are mixed; when the mixture is weighed out into the melting furnace; and during the melting process itself. The product of the melting process is SiO_2 in amorphous form (glass).

4.1.6 Filter sands and gravels

Filters manufactured from quartz sand are employed for the filtration of process water and turbid solutions. Quartz filters are employed with a range of particle sizes and specific pore sizes and in different filter bed heights, according to the area of application. Among the important areas of application are the filter stages in installations for deferrization, demanganization and decarbonization [19].

4.1.7 Electrical engineering (piezoelectric quartz) (see also Section 5.3.7)

A particular property of quartz is that when mechanical pressure is applied to the surfaces of a quartz wafer cut with preferred orientation, opposing electrical charges are generated on the surfaces (piezoelectricity). Conversely, application of an alternating voltage to the faces of the wafer causes it to vibrate. The resonance of this vibration stabilizes the frequency of the alternating voltage. The uses of piezoquartz include installations for calibration of the frequency of radio transmitters, in microphones and loudspeakers, for the generation of ultrasound, and in clocks [20; 21]. Both, natural and synthetically manufactured quartzes are used.

4.1.8 Quartz-sand-filled fuses

Quartz sand is employed as an insulating material in low-voltage fuses. The quartz sand is supplied by a machine and the amount depends on the fuse dimension.

4.1.9 Electrical installation work (see also Section 5.3.7)

During electrical installation work, dusts containing quartz are produced from the construction materials used, during the cutting of chases for electrical wiring, the production of recesses for switches and distribution boxes, the drilling of holes for expandable plugs, and impact drilling work. The quartz component measured varied according to the mineral type being worked. The highest fine quartz dust concentrations are observed during the use of high-speed rotating tools (wall-chasers).

4.1.10 Precision mechanics – dental technology (see also Section 5.3.8)

Embedding compounds with a quartz and cristobalite component of up to 50% are employed in dental laboratories. Quartz and cristobalite dusts may therefore be produced during embedding and deflasking, during decantation and portioning, and during blasting of the models.

4.1.11 Construction materials industry, construction industry (see also Section 5.3.10)

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

Sands and gravels are used for example in road-building and as loading agents in the manufacture of concrete. Sands are also an important component in the manufacture of mortar compounds and artificial mineral construction materials such as bricks, panels, moulded elements, fireproof materials, etc. They are also used as raw materials for the production of ultrapure quartz fractions up to and including quartz powders.

Hard rock is employed primarily in the construction materials industry [22] for the manufacture of crushed rock, chippings, screened chippings, crushed sand and ground rock. The materials are used not only in road-building, but also as loading agents in the concrete industry and for the manufacture of bituminous compounds (such as asphalt).

Uses of natural hewn stones include the manufacture of façade surfacings, hewn stone, steps, slabs, paving and kerbing, not to mention gravestones. The quartz contents of the main mineral types are listed in [23].

Quartz sands are employed for special concretes, mortars, screeds and plasters. Mixtures of sand and lime are employed in the manufacture of sand-lime brick (see Section 5.3.3.11). Sand milled to a powder is used in the manufacture of light calcareous sandstone and porous concrete (see Section 5.3.10.1). Cement slurries containing quartz are employed in deep drilling in the oil and natural gas industry.

4.1.12 Working on decorative stones (see also Section 5.3.8.3)

In the decorative stone industry, a number of varieties of quartz and cryptocrystalline quartz are employed as decorative and semi-precious stones. These include amethyst, smokey quartz, citrine, rose quartz, chrysoprase, agate and onyx [20]. The decorative stones exhibit different levels of crystallization. In addition to crystalline fractions, amorphous silicon compounds (amorphous silicic acids) must therefore also be anticipated during grinding.

4.1.13 Grinding, polishing and abrasive agents (see also Section 5.3.9.8)

Owing to its high hardness and sharp-edgedness (when grounded mechanically), quartz is suitable for use as a coarse grinding agent. It is however rarely used as such [24]. Other substances are now preferred for this purpose, such as silicon carbide or corundum. The uses of quartz powders include tumble polishing and wet pumicing [24]. Quartz is employed in the manufacture of silicon carbide. Quartz powders are also used in scouring and cleaning liquids and pastes.

4.1.14 Blasting agents (see also Section 5.3.10.10)

Up to the Second World War, the material used almost exclusively as a blasting agent was quartz sand [25]. Owing to the high risk of silicosis to which blasting workers were exposed, the silicosis-inducing blasting agents were then progressively replaced by substitutes [26]. With a small number of exceptions, the use of silicosis-inducing blasting agent is now prohibited. Under Section 2.24 of BG Rule 500 (formerly VBG 48/BGV D26[3)]) [27; 28], blasting agents are defined as being silicosis-inducing when they contain more than 2% quartz – including cristobalite and tridymite – by mass.

4.1.15 Further applications

Quartz sands are also used as inert materials for circulating fluidized beds, as bird sand, as roofing gritting material, in handwash pastes, in the construction of golf courses, in children's sand pits and beach volleyball courts [29], for sandpaper, in drinking water filters, and as braking sand for railbound vehicles.

4.1.16 Other forms of occurrence and unintended use

Agriculture and gardens

Soils used for agricultural purposes may contain varying proportions of quartz. A part of this quartz may occur within the respirable fraction. Soil studies have shown their inhalable fraction (approximately 0.01 to 0.2% of the soil by mass) to contain quartz components of 1.6 to 3.4% in clayey soils and of 10.5 to 44.5% in sandy soils [30].

Road and construction site transport

Dust collects in urban areas on roads and other sealed ground surfaces. Depending upon its origin, this dust may have a quartz component. The dust is raised by traffic, and also by road-cleaning measures, such as the operation of road-sweeping vehicles [31]. On unmetalled roads in particular, such as those found on many construction sites, the traffic may raise considerable quantities of dust during dry weather.

Power stations

Ash from power stations and fly ash may contain a quartz component. Cristobalite components have been detected in slag in isolated cases.

---

3) In the course of rationalization of the BG body of regulations, accident prevention regulation BGV D26 governing blasting work has been transferred to Chapter 2.24 of BG rule 500 governing the use of tools. The provisions are therefore re-used in the form of a recognized code of practice.

The use of construction materials and mineral raw materials

Natural mineral raw materials used for industrial purposes may contain varying degrees of quartz. Examples are filler materials in general, talcum powder, lime powders, clay powders, bentonite and kaolines. Quartz has been detected for example in proportions of between < 1 and 25% in various kaolins.

4.2 Cristobalite

Cristobalite is produced from quartz by thermal treatment. It is used as a filler material in road-marking paints and compounds and in façade paints, in coatings and plastic plasters, and in silicone rubber model impression compounds, artificial resin coatings, adhesives and casting resins.

Special applications for cristobalite further include its use in abrasive materials (liquid- or paste-based scouring and cleaning agents), for the manufacture of bird sand, as an additive to light-coloured construction materials for the retention of clear bright colours, and in mixtures of cristobalite and quartz/fused silica in embedding compounds (for dental, jewellery and other precision moulds) [17; 32].

If diatomaceous earths are calcined, a greater or lesser proportion of the amorphous silica is converted during firing to the crystalline form, particularly cristobalite. Depending upon the manufacturing process, cristobalite may also be found in bentonite.

4.2.1 Cristobalite from fibres

Ceramic and high-temperature glass fibres are employed for insulation purposes in furnaces. Both fibre types form cristobalite during thermal treatment above 900 °C, by recrystallization during recooling. Approximately 10% cristobalite is created in the case of ceramic fibres, up to 40% in that of high-temperature glass fibres. Exposure occurs when the insulation is removed [33; 34].

4.3 Tridymite

Tridymite has no commercial relevance. This crystalline SiO_2 modification may however be contained or produced in refractory construction materials (such as silica bricks in open-hearth furnaces, bricks from coke-ovens), and may occur as a devitrification product of quartz glasses.

5 Exposure data

5.1 Body of data and principles of evaluation

The measured values listed in this chapter for quartz and the respirable dust fraction (fine dust) were recorded over three decades from 1972 to 2004 in the Measurement system for exposure assessment of the German Social Accident Insurance institutions – BGMG, and were entered in the MEGA database of measured data relating to exposure to hazardous substances at the workplace. The measurements were conducted in accordance with BGMG standard procedures in around 8,900 companies. The standard BGMG procedure was likewise employed for analysis. For quartz analysis, X-ray diffraction was primarily used, and also to a small degree infrared spectroscopy. The measured values for respirable dust were obtained by weighing and β radiation absorption.

All measured values were recorded in the BGMG system, subject to the quality management procedures, with reference to the sector and working area, and documented in the MEGA exposure database. Data from some 104,000 measurements comprising both a respirable dust and a quartz measurement value were available for this report. The quartz component was calculated for each pair of measured values.

5.2 Statistics and presentation of exposure

The data were analyzed statistically by means of the MEGA analysis software developed at the BGIA – Institute for Occupational Safety and Health of the German Social Accident Insurance. The data collectives were differentiated by sector and working area. The OMEGA code lists of plant types and working areas were employed for this purpose. These lists are based upon the classification of industrial sectors, including designations for plants etc., which is issued by the Federal Office of Statistics in Wiesbaden. This enabled average shift values to be summarized for comparable sectors and working areas.

For observation of trends in the concentration values over time, the overall time for the sectors and working areas under consideration was divided into uniform periods of time, where permitted by the number of value measurements taken per period of time. In order to permit comparison of the statistical parameters, they are presented in standardized form in tables.

Tables 5 to 93 contain the following information:

Column 1: Period of time

Period of time for which data were analyzed. Up to six periods of time were analyzed, depending upon the number of cases.

Column 2: Measured data/plants

The number of measured data items and the number of plants per period of time for the substance indicated.

Column 3: Substance/dimension

Description of the three selected parameters – respirable dust fraction, quartz, quartz content – with the associated dimension.

The quartz content of a sample was calculated as the percentage from the concentrations of quartz (in mg/m^3) and of the respirable dust fraction (in mg/m^3) in the workplace atmosphere.

If the concentration of the quartz and that of the respirable dust fraction in the workplace atmosphere both lay below the detection limit for the method employed, the quartz content was not calculated. The quartz content calculated was assigned the < sign if the concentration of quartz in the workplace atmosphere was below the detection limit of the method employed.

The quartz content calculated was assigned the > sign if the concentration of the respirable dust fraction in the workplace atmosphere was below the detection limit of the method employed.

Column 4: Arithmetic mean value

Arithmetic mean value for the respirable dust fraction, quartz and quartz content, per period of time.

Column 5: 10th percentile value

This value (the 10th percentile) is the value above 10% of the concentration values measured and below the remaining 90% of the concentration values.

Column 5: 50th percentile value

This value (the 50th percentile) is the value above 50% of the concentration values measured and below the remaining 50% of the concentration values.

Column 5: 90th percentile value

This value (the 90th percentile) is the value above 90% of the concentration values measured and below the remaining 10% of the concentration values.

The development of the dust exposure over time is shown for selected sectors in box plots. The box plots were created by means of the SPSS 14.0 software application. The box encompasses the mid 50% of the measured values, from the 25th percentile to the 75th percentile. The median value is entered in the box in the form of a black line. The whiskers extend to the highest and lowest measured values located no more than 1.5 times the box length from the upper and lower extremities of the box respectively. Values outside the whiskers are classified as extreme values, and are marked by circles or stars. Values marked with a star are located more than three times the box length from the upper or lower extremity of the box.

5.3 Exposure data

5.3.1 Extraction of quartz sand

Quartz sand is extracted for use as a raw material, for example for the chemical and glass industries, by dry or wet quarrying from particularly homogeneous deposits. It is then processed to the desired particle fraction, up to and including quartz powder. The raw material is washed, sorted, fractionated, dried and milled in discrete stages. The finished product is then packed in sacks or loaded onto tanker trailers.

Exposure to respirable quartz dust exists at all workplaces involving direct access to the raw material and to the finished product, during both extraction and preparation of quartz sand and the production of quartz powder. The essential factors which particularly influence the level of exposure are the proportion of free crystalline silicic acid in the mineral raw material, and the scope for the emission of dust in the processing stage concerned. The individual working areas and the corresponding exposure are shown in Table 5.

Table 5:
Exposure data for the extraction of quartz sand

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Open-cast pit, mine, extraction/transport within the plant						
1973 to 2003	58/7 58/7 54/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.62 0.19 36.75	0.19 0.02 8.1	0.45 0.15 40.7	1.17 0.41 62.0
Wet preparation						
1974 to 1984	42/5 42/5 42/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.49 0.3 28.66	0.12 0.03 10.7	0.62 0.14 20.0	4.11 0.81 55.5
1985 to 1994	41/10 41/10 41/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.78 0.19 25.08	0.1 0.01 5.0	0.27 0.05 22.0	1.19 0.33 47.4
1995 to 2002	29/5 29/5 27/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.37 0.11 26.8	0.11 0.003 1.6	0.26 0.05 26.6	0.56 0.3 45.4
Dry preparation						
1974 to 1984	85/13 85/13 85/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.74 0.24 32.92	0.09 0.02 8.4	0.45 0.12 25.0	1.96 0.51 65.9
1985 to 1994	114/13 114/13 113/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.61 0.22 35.7	0.11 0.01 6.0	0.31 0.09 28.4	1.23 0.48 67.8
1995 to 2003	58/13 58/13 51/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.34 0.1 29.74	0.05 0.003 3.6	0.18 0.03 26.0	0.85 0.18 58.1
Milling						
1979 to 1984	55/5 55/5 55/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.61 0.15 30.19	0.06 0.01 12.1	0.22 0.06 27.5	1.0 0.31 53.8
1985 to 1994	92/8 92/8 91/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.71 0.2 30.99	0.1 0.01 7.0	0.24 0.08 28.9	1.28 0.39 56.8
1995 to 2003	26/7 26/7 26/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.39 0.17 50.38	0.05 0.01 4.8	0.21 0.1 48.9	0.9 0.33 83.3

Table 5: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
		Sacking				
1974 to 1984	109/12 109/12 109/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.97 0.24 30.08	0.16 0.03 11.4	0.42 0.11 24.4	1.46 0.42 56.4
1985 to 1994	93/12 93/12 93/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.63 0.21 31.56	0.19 0.02 5.4	0.38 0.11 24.8	1.16 0.4 61.6
1995 to 2004	75/19 75/19 72/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.48 0.18 26.61	0.09 0.005 3.3	0.26 0.06 24.4	0.93 0.37 51.4
		Transport, loading (product)				
1973 to 2003	86/16 86/16 84/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.17 0.41 27.5	0.08 0.01 4.4	0.56 0.08 25.0	3.64 1.35 57.7
		Laboratory				
1979 to 1999	23/7 23/7 22/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.24 0.06 22.74	0.09 0.003 1.6	0.18 0.03 19.0	0.42 0.12 57.3

For some of the working areas listed, sufficient data were available for an exposure characteristic to be plotted over time. The success of traditional dust control measures is particularly well-documented in the area of preparation (wet and dry).

The area of milling, but also that of sacking, particularly involves installations in which the sand is processed further to smaller particle sizes (powders). In this area, observance of the workplace concentration of 0.15 mg/m³ respirable quartz dust still cannot be documented at the 90th percentile value, probably owing to the relatively high quartz content in the product. This suggests that this statistical value is highly sensitive to isolated abnormal occurrences during certain processes within the technically complex methods, since the arithmetical mean values indicate that the value concerned can generally be observed. In this context, it must however be pointed out that, for example, during the sacking of material with a 50% quartz content, the observance of 0.3 mg/m³ respirable quartz dust presents a particularly challenging task for engineered dust control.

This can be achieved only by way of a number of individual dust control measures, which are now state of the art. Measures particularly worthy of mention are the selection of dust-tight packaging materials, the handling of material within closed transport systems, the exhausting of material transfer points such as filler systems on packing machines, routing and dedusting of the displacement air, and the implementation of suitable methods for the maintenance of clean workplaces (vacuum cleaners).

5.3.2 Extraction and processing of minerals and earths

5.3.2.1 Natural hewn stone industry – manufacture, treatment and working of natural hewn stone, stone masonry

Quarried raw stone blocks are split into smaller units, down to bricks and paving stones, before they leave the quarry, or are cut on stone-cutting machines to form semifinished products in the form of slabs or ashlars. Further shaping and surface work for production of the end products is generally carried out by specialist stone-working companies.

Both, wet and dry processes are employed in stoneworking. Wet processes are performed primarily on stoneworking machines such as cutting-off, surfacing and milling machines (see Figure 5). The bits of these tools, which are generally diamond-tipped, are water-cooled. This has the effect at the same time of reducing the quantity of dust raised.

Figure 5:
Mechanized wet surfacing of natural hewn stone

Conversely, methods such as chiselling, scabbling (see Figure 6), charring, splitting with hand-held pneumatic hammers, abrasive cutting-off, and the grinding of surfaces with hand-held electric tools such as angle grinders, are performed dry.

Figure 6:
Manual working of natural hewn stone: scabbling

The level of the respirable quartz dust concentration (see Table 6) is influenced on the one hand by the quartz content of the material being processed or worked, and on the other by the method employed. High concentrations in certain working areas and during certain tasks are often attributable to a high quartz content of the materials. Whereas as recently as 20 years ago, virtually quartz-free marble was the material in demand for window ledges and natural stone facings, natural stone containing quartz, such as granite, is now used for the same purpose. It should also be noted that fine crushing processes, such as abrasive cutting-off, polishing or kernelling, cause the quartz grain to be shattered, and thus produce higher quartz dust concentrations than do manual coarse crushing processes, such as manual chiselling.

Table 6:
Exposure data for the manufacture, processing and working of natural hewn stone, stonemasonry (total)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	3,834/460	Respirable fraction in mg/m³	1.72	0.34	0.96	3.31
	3,834/460	Quartz in mg/m³	0.2	0.01	0.06	0.4
	3,797/453	Quartz content in %	10.17	1.0	6.5	24.1
1985 to 1994	2,161/433	Respirable fraction in mg/m³	1.31	0.22	0.74	2.5
	2,161/433	Quartz in mg/m³	0.21	0.01	0.08	0.44
	2,101/428	Quartz content in %	15.28	1.8	12.0	33.4
1995 to 2004	892/271	Respirable fraction in mg/m³	1.01	0.11	0.6	1.91
	892/271	Quartz in mg/m³	0.19	0.01	0.05	0.34
	778/259	Quartz content in %	14.27	1.4	9.9	30.0

Sawing and milling

Water applied at the cutting point for cooling of the cutting segments during sawing and milling also has the effect of reducing dust emissions, since it binds and precipitates the dust. High-speed tools cause spray and aerosols to be formed. These contain respirable quartz dust particles which may be inhaled by the machine operator. The level of the respirable quartz dust concentration (Table 7) is dependent upon the quality of conditioning of the recirculated water and the level of aerosol and spray formation. Facilities on machines for capturing and precipitating the spray and the aerosols and for purifying the water to drinking water quality are now state of the art.

Table 7:
Exposure data for sawing and milling

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	775/167	Respirable fraction in mg/m³	1.05	0.25	0.66	1.6
	775/167	Quartz in mg/m³	0.12	0.01	0.04	0.16
	756/162	Quartz content in %	8.5	1.0	6.6	19.1
1985 to 1994	409/142	Respirable fraction in mg/m³	0.75	0.14	0.56	1.38
	409/142	Quartz in mg/m³	0.09	0.01	0.04	0.18
	392/140	Quartz content in %	10.49	2.0	9.4	20.0
1995 to 2004	182/88	Respirable fraction in mg/m³	0.65	0.09	0.44	1.43
	182/88	Quartz in mg/m³	0.07	0.005	0.03	0.18
	171/85	Quartz content in %	9.84	1.1	8.2	22.5

Kernelling, charring and scabbling

These techniques are used to prepare the surfaces and edges of workpieces by dry methods. Both, pneumatic hand-held machines and stationary machines are used. Kernelling (see Figure 7) and charring cause heavy shattering of the grain on the surfaces being worked, with large quantities of respirable quartz dust being produced. Scabbling is less dust-intensive, as only smaller areas, such as the edges, are removed from the workpiece. State-of-the-art exhaust facilities are fitted to the majority of machines currently in use. The dust collection facilities are subject to heavy wear, with the result that the exhaust efficiency drops if maintenance is inadequate.

Since, during the period surveyed from 1974 to 2004, neither the machine nor the dust collection technology changed significantly, the variations in the 90th percentile values for the three periods shown separately in Table 8 can be explained by the fact that following a fall in the dust concentration from the period 1974 to 1984 to the period 1985 to 1994, measurements were performed in the period from 1995 to 2004 only at workplaces at which the dust conditions were clearly unfavourable.

Figure 7:
Kernelling at a natural hewn stone

Table 8:
Exposure data for kernelling, charring and scabbling

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	113/58	Respirable fraction in mg/m³	1.73	0.18	1.2	3.63
	113/58	Quartz in mg/m³	0.38	0.01	0.13	1.11
	112/58	Quartz content in %	18.8	2.0	16.2	36.4
1985 to 1994	173/70	Respirable fraction in mg/m³	1.36	0.24	0.8	2.62
	173/70	Quartz in mg/m³	0.27	0.02	0.14	0.62
	172/70	Quartz content in %	21.49	2.5	16.0	47.7
1995 to 2004	26/17	Respirable fraction in mg/m³	1.34	0.26	0.61	3.04
	26/17	Quartz in mg/m³	0.26	0.01	0.15	0.83
	23/16	Quartz content in %	23.19	1.4	22.2	48.3

Impact drilling and chiselling

Both, pneumatic and electric hand-held machines are used for these working methods (see Table 9, page 48). The dust generated during work is collected by workplace dust collection facilities of various types (positionable exhaust funnels, suction walls).

Table 9:
Exposure data for impact drilling and chiselling

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	121/60	Respirable fraction in mg/m³	1.92	0.25	1.0	4.65
	121/60	Quartz in mg/m³	0.38	0.01	0.1	1.02
	118/58	Quartz content in %	15.65	2.0	13.8	33.1
1985 to 1994	256/89	Respirable fraction in mg/m³	1.13	0.21	0.66	2.4
	256/89	Quartz in mg/m³	0.23	0.01	0.08	0.63
	232/87	Quartz content in %	18.4	1.0	16.0	41.2
1995 to 2004	203/35	Respirable fraction in mg/m³	0.82	0.09	0.62	1.41
	203/35	Quartz in mg/m³	0.21	0.01	0.05	0.29
	148/32	Quartz content in %	15.1	1.7	8.6	41.2

Stone splitting

High dust concentrations arise during the use of pneumatic hammers for manual stone-splitting, despite the dust exhaust facilities with which the tools are generally equipped (see Table 10). The rubber noses on the chisel for production of the lewis holes are subject to a very high degree of wear, with the result that the exhaust effect is reduced if maintenance is inadequate. Exhausting dust effectively from stationary stone-splitting machines is less difficult (see Figure 8). In this case, the dust is exhausted through collection elements on the upper blade, or through intakes in the machine's stand.

Table 10:
Exposure data for stone-splitting

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	44/12	Respirable fraction in mg/m³	1.52	0.35	0.85	2.1
	44/12	Quartz in mg/m³	0.24	0.06	0.11	0.31
	44/12	Quartz content in %	16.43	9.0	13.0	27.2
1985 to 1994	97/38	Respirable fraction in mg/m³	1.2	0.34	0.7	2.15
	97/38	Quartz in mg/m³	0.19	0.03	0.1	0.47
	96/38	Quartz content in %	16.46	6.6	16.0	27.4
1995 to 2004	77/33	Respirable fraction in mg/m³	0.7	0.15	0.57	1.43
	77/33	Quartz in mg/m³	0.12	0.005	0.07	0.28
	68/29	Quartz content in %	17.06	2.0	16.2	30.0

Figure 8:
Mechanized splitting of stone blocks

Surface treatment by grinding

In the two data collectives shown below, a distinction is drawn between manual and mechanized grinding. Manual grinding is generally performed using hand-held electric or pneumatic machines (angle grinders). Mechanized grinding is performed on stationary grinding machines or machining centres.

The surface of materials in slab form is generally worked by means of the wet method; this results in lower quartz dust exposure compared to the dry method. Owing to the formation of aerosols, high dust concentrations may, however, also occur during wet grinding (see Table 11). The criteria for conditioning of the recirculated water during sawing and milling (see above) also apply to grinding.

The use in the 1970s of polishing agents containing high quartz levels (e.g. Neuburg siliceous earth) during machine grinding had a major influence upon the respirable quartz dust concentration in the data recording period from 1972 to 1984.

Dry work performed with angle grinders leads to extremely high dust exposure. The characteristic for the dust concentration over time shows a steady drop in the dust exposure during tasks involving these tools. This is attributable to the increased use of dust collection facilities in the form of various types of machine and workplace dust exhaust systems. Dust exhaust facilities on this equipment are, however, rare, particularly in mobile use.

Table 11:
Exposure data for grinding

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Machine grinding						
1972 to 1984	1,545/200 1,545/200 1,538/196	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.82 0.12 5.94	0.45 0.01 1.0	1.2 0.04 3.0	3.47 0.22 14.1
1985 to 1994	318/88 318/88 315/88	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.15 0.1 8.03	0.28 0.01 1.4	0.95 0.05 6.7	2.2 0.23 16.6
1995 to 2004	54/33 54/33 51/31	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.62 0.23 8.56	0.2 0.004 0.9	0.65 0.03 7.1	3.56 0.49 19.3
Manual grinding						
1972 to 1984	37/21 37/21 37/21	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	6.98 1.14 9.2	0.92 0.01 0.3	4.99 0.09 3.1	12.07 1.68 24.4
1985 to 1994	152/57 152/57 147/56	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.57 0.36 9.95	0.41 0.01 0.54	1.57 0.06 6.8	4.83 0.75 24.5
1995 to 2004	102/49 102/49 100/48	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.82 0.25 10.44	0.21 0.005 0.6	0.89 0.04 6.2	3.27 0.49 21.1

Blasting

The results of a research project show that free-jet blasting of surfaces containing quartz still leads to dust concentrations of 0.6 mg/m³ and higher, even if the slurry blasting method – which generates considerably less dust than the conventional dry blasting method – and quartz-free blasting agents are used. Where blasting machines with exhaust facilities are employed, for example for the surface treatment of quarry stone tiles, the respirable quartz dust concentration can be kept below 0.075 mg/m³ (see Table 12).

The major differences between the 90th and the 50th percentile values confirm the differences between the two methods, which are summarized in the data collectives.

Table 12:
Exposure data for blasting

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	106/9	Respirable fraction in mg/m³	3.02	0.25	0.51	7.25
	106/9	Quartz in mg/m³	0.49	0.01	0.08	1.44
	106/9	Quartz content in %	16.12	2.4	10.6	38.1
1985 to 2004	15/11	Respirable fraction in mg/m³	0.72	0.16	0.56	1.48
	15/11	Quartz in mg/m³	0.09	0.01	0.05	0.19
	14/10	Quartz content in %	9.74	3.2	8.7	14.7

Mixed tasks

Mixed tasks involving several processing methods which may for instance be encountered in a stone-cutting company are summarized here, as are discrete tasks which cannot be categorized clearly according to the working areas and tasks indicated above. Such tasks include the flame-cleaning of surfaces, the breaking-up and splitting of blocks in the open air, unspecific sizing work, drilling work, general coarse work, etc. Table 13 shows the high dust exposure arising during these tasks, which is due to the fact that the working conditions prevent the implementation of effective dust collection measures.

Table 13:
Exposure data for mixed tasks

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	772/190	Respirable fraction in mg/m³	1.97	0.38	1.1	3.83
	772/190	Quartz in mg/m³	0.32	0.03	0.12	0.71
	768/189	Quartz content in %	15.99	2.0	14.1	30.2
1985 to 1994	583/149	Respirable fraction in mg/m³	1.39	0.21	0.75	2.56
	583/149	Quartz in mg/m³	0.31	0.02	0.12	0.59
	580/147	Quartz content in %	20.23	3.3	17.7	40.4
1995 to 2004	139/65	Respirable fraction in mg/m³	1.23	0.11	0.63	2.57
	139/65	Quartz in mg/m³	0.38	0.01	0.09	0.66
	124/59	Quartz content in %	23.24	2.8	16.1	60.2

5.3.2.2 Natural stone industry – extraction and preparation of natural stone

The rock freed from the rock mass by blasting or excavation is prepared in several stages in crushing and sizing plant to form the end products crushed rock, chippings and ground rock. The material is initially precrushed in a primary crusher, in which the coarse fractions are separated off. In the subsequent recrushing and screening stages, the various particle fractions are created, which are then stored either on open stockpiles or in silos. The level of dust produced generally increases with progressive size reduction of the mineral raw material.

Dry methods are generally employed for preparation in quarrying componies. In order to prevent pollution, many installations are therefore fully enclosed, and equipped with complex dust exhaust facilities, for example at transfer points between conveyors and at conveyor discharge points, and on crushers and screening machines. Scope for the use of water for dust control is often limited, for example for jetting at the crusher intake, sprinkling of stockpiles, and at transfer points during loading for transport.

Workplaces involving dust exposure may be encountered:

- at extraction, during drilling work for production of the blast charge, and on handling and loading equipment (excavators, wheel loaders, heavy goods vehicles)
- in material processing within open and enclosed installations
- during loading of the finished products

Where used, methods for the working of natural stone (see Section 5.3.2.1) also involve dust exposure at the associated workplaces.

Pneumatic hand tools used during drilling, secondary blasting and splitting operations (see Figure 9) present problems, since dust collection facilities at mobile workplaces, such as on site in the quarry, can track the work only with difficulty.

Figure 9:
Use of a pneumatic hammer to split natural stone

Dust collection facilities are the state of the art on mobile hydraulic drills for the production of blastholes; a respirable quartz dust concentration of 0.15 mg/m³ can therefore generally be observed.

With the exception of the extraction process, work performed in quarries is now virtually completely automated. Within the preparation installations, working tasks essentially involve checks and observation, and maintenance tasks. High exposures occur in particular when personnel enter enclosed preparation installations for longer periods for the purpose of monitoring and the clearing of faults. Observance of a respirable quartz dust concentration of 0.15 mg/m³ is virtually impossible in this case when material with a higher quartz content is being processed. Persons may enter such installations only with respiratory protection, and the time spent within the installations should be kept to an absolute minimum. Crusher operators at the control station or in a cabin may also be exposed to high respirable quartz dust concentrations if the ventilation at these points is inadequate.

Personnel responsible for operating silo loading installations, which often form part of the preparation installations and beneath which roadgoing goods vehicles pass, are exposed to dust during control and observation of the loading process when conducting these tasks outside the enclosed control cabin, for example during inspection patrols within the installation, in the vicinity of the loading point and in the silo portal (see Figure 10). Measurement results primarily refer to these installations. Conversely, the use of a wheel loader for the loading of stockpiles involves considerably lower dust exposure for its operator, who remains within the enclosed cab of the loader.

Figure 10:
Inspection control

The substantial difference between the 50th and 90th percentile values is due to the wide variation in the technical design of loading facilities (loading conveyor, loading nozzle, free-fall loading, with or without dust collection or spraying with water). Low measured values are associated with loading methods featuring effective dust collection or water spraying; high values are encountered with loading methods featuring less effective dust control.

Evaluation of the measurement data must take into account what influence the quartz content of the processed mineral raw material and the working methods have upon the measured respirable quartz dust concentration. The higher the quartz content of the material, the higher the quantity of respirable quartz dust released by a given process. Fine crushing processes, such as cone and baffle crushers, generally lead to higher respirable quartz dust concentrations than do coarse crushing processes, such as jaw crushers.

Natural stone industry (total)

The characteristic over time for the measured values for the periods from 1972 to 1984 and from 1995 to 2004 shows (see Table 14) that the use and improvement of dust collection measures at the workplaces enabled the dust exposure to be reduced significantly. Only for the area of preparation are the measured data for the period from 1995 to 2004 not consistent with the trend. This is attributable to the fact that for environmental reasons, preparation plants are now increasingly encapsulated. Despite the dust collection measures taken, high dust concentrations therefore arise within the installations.

Table 14:
Exposure data for the extraction and preparation of natural stone (total)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	411/115	Respirable fraction in mg/m³	5.75	0.51	2.23	11.89
	411/115	Quartz in mg/m³	0.62	0.03	0.2	1.39
	411/115	Quartz content in %	13.25	2.0	10.0	28.0
1985 to 1994	399/156	Respirable fraction in mg/m³	1.1	0.2	0.74	2.25
	399/156	Quartz in mg/m³	0.15	0.01	0.08	0.38
	385/152	Quartz content in %	14.9	1.5	13.0	29.2
1995 to 2004	294/100	Respirable fraction in mg/m³	0.85	0.13	0.54	1.87
	294/100	Quartz in mg/m³	0.13	0.005	0.06	0.33
	251/100	Quartz content in %	13.33	1.2	10.8	26.7

Extraction, loading out and handling

These are tasks in the quarry which are associated with extraction, such as the use of drilling gear for producing the blastholes for extraction blasting, secondary drilling, and operation of the extraction and handling plant, such as excavators, wheel loaders and heavy trucks (see Table 15).

Table 15:
Exposure data for extraction, loading out and handling

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	58/29	Respirable fraction in mg/m³	5.81	0.54	1.65	17.33
	58/29	Quartz in mg/m³	0.62	0.02	0.15	1.09
	58/29	Quartz content in %	14.39	0.9	9.0	34.2
1985 to 1994	107/58	Respirable fraction in mg/m³	1.22	0.19	0.66	2.75
	107/58	Quartz in mg/m³	0.15	0.01	0.06	0.41
	97/54	Quartz content in %	13.16	1.2	11.1	27.8
1995 to 2004	65/34	Respirable fraction in mg/m³	0.49	0.09	0.26	0.96
	65/34	Quartz in mg/m³	0.06	0.003	0.02	0.14
	41/27	Quartz content in %	10.49	0.8	7.5	22.8

Preparation

This includes crushing of the mineral raw materials in crushing and milling plant, fractionating to the desired particle fractions, and if applicable washing and drying of the material (see Table 16).

Table 16:
Exposure data for preparation

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	248/79	Respirable fraction in mg/m³	5.66	0.65	2.5	10.62
	248/79	Quartz in mg/m³	0.47	0.03	0.22	1.24
	248/79	Quartz content in %	13.13	2.0	10.0	26.8
1985 to 1994	164/66	Respirable fraction in mg/m³	1.22	0.31	0.84	2.62
	164/66	Quartz in mg/m³	0.16	0.01	0.08	0.44
	162/66	Quartz content in %	15.3	1.0	13.0	30.5
1995 to 2004	114/49	Respirable fraction in mg/m³	1.25	0.22	0.8	2.87
	114/49	Quartz in mg/m³	0.2	0.01	0.09	0.65
	107/49	Quartz content in %	14.01	1.2	12.4	24.9

Loading for transport

This area of activity encompasses placing of the finished products in storage in silos or on stockpiles, and weighing out and loading onto vehicles. Installations for loading into silos are frequently integrated into the preparation installations (see Table 17).

Table 17:
Exposure data for loading for transport

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 2004	76/32 76/32 71/31	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.28 0.14 10.4	0.21 0.005 1.7	0.81 0.07 7.7	3.02 0.32 18.8

Stone splitting and stone working

Natural stone businesses frequently process a part of their rock resources to paving and wall stones, or to raw blocks from which in turn construction elements are manufactured. The results of measurements are summarized here which were taken during manual stone-splitting with pneumatic chisels, during mechanized stone-splitting, and during other work such as sawing, drilling, milling, chiselling or grinding (see Table 18).

Table 18:
Exposure data for stone-splitting and stone working

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	69/22 69/22 69/22	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	7.69 1.39 14.16	0.3 0.02 3.0	1.56 0.21 15.8	22.84 4.71 22.0
1985 to 1994	82/40 82/40 81/39	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.84 0.14 16.5	0.2 0.01 2.5	0.7 0.1 14.1	1.7 0.37 31.8
1995 to 2004	52/27 52/27 45/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.53 0.09 16.85	0.17 0.01 4.0	0.45 0.06 12.6	0.96 0.2 34.8

Filling and sacking of fine material

During the preparation of natural stone, ground rock is produced as a by-product of fine screening and filtration which, if it is not loaded directly from the silo into silo wagons, is filled into sacks or big bags. The filling and packaging installations are comparable to similar installations in the cement and lime industry (see Table 19).

Table 19:
Exposure data for the filling and sacking of fine material

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 2004	68/23	Respirable fraction in mg/m³	1.94	0.2	1.0	4.87
	68/23	Quartz in mg/m³	0.3	0.02	0.09	0.76
	68/23	Quartz content in %	15.32	2.0	9.0	33.1

5.3.2.3 Extraction and preparation of gravel and sand

Gravels and sands extracted from the deposits by either wet or dry processes are prepared to form products differing in their particle size fraction in screening, washing, crushing, sorting, fractionating and possibly drying installations, and stored in silos or on open stockpiles (see Figure 11). Special sands are also packed in sacks or big bags after drying (see also Section 5.3.1).

Figure 11:
Crusher in a gravel works

Compared to the past, the processes in modern gravel and sand works are largely automated. Working tasks essentially involve checks and observation, and maintenance tasks. Dust can very rarely be prevented from migrating between the discrete plant areas during raw material preparation, since the installations are interlinked and are not spatially separated. The measurements were performed in both, open and encapsulated installations. The individual working areas and the corresponding exposure to respirable quartz dust can be seen in Table 20 (see page 58).

Table 20:
Exposure data for the extraction and preparation of gravel and sand

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Extraction and preparation of gravel and sand (total)						
1972 to 1984	589/117 589/117 587/117	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	9.35 1.39 15.23	0.5 0.03 2.0	1.85 0.19 12.0	11.43 1.54 30.0
1985 to 1994	468/125 468/125 436/123	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.36 0.2 18.24	0.2 0.01 1.5	0.8 0.09 13.2	2.75 0.51 40.0
1995 to 2004	434/143 434/143 358/138	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.92 0.09 11.74	0.09 0.004 0.8	0.41 0.02 6.4	1.48 0.26 28.4
Extraction: transport, handling						
1985 to 1994	35/13 35/13 32/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.1 0.1 15.2	0.33 0.01 1.2	0.87 0.05 6.8	1.99 0.22 56.5
1995 to 2004	89/41 89/41 56/33	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.83 0.04 4.46	0.19 0.003 0.7	0.41 0.01 1.8	1.42 0.08 10.0
Preparation: particle size reduction (crushing, milling)						
1972 to 1984	350/89 350/89 349/89	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	13.74 2.09 15.92	0.6 0.05 2.0	2.5 0.27 13.0	13.55 2.09 33.0
1985 to 1994	177/77 177/77 173/77	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.95 0.28 19.21	0.28 0.02 1.3	1.25 0.13 16.0	3.17 0.73 44.0
1995 to 2004	102/59 102/59 90/57	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.09 0.14 16.8	0.09 0.01 1.1	0.56 0.05 13.0	2.26 0.4 35.7
Preparation: fractionating (screening)						
1972 to 1984	84/39 84/39 83/39	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.78 0.5 14.82	0.52 0.05 2.3	1.5 0.17 13.0	8.72 0.98 29.9
1985 to 1994	47/25 47/25 47/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.42 0.33 24.75	0.34 0.03 6.3	0.93 0.22 19.2	2.95 0.6 53.2
1995 to 2004	28/18 28/18 26/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.75 0.14 18.48	0.18 0.003 1.3	0.49 0.04 15.0	1.52 0.35 52.4
Preparation: drying, mixing						
1972 to 1984	42/17 42/17 42/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.41 0.38 10.22	0.25 0.01 2.0	1.05 0.09 7.0	9.55 0.46 20.0
1985 to 1994	89/15 89/15 75/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.72 0.14 20.05	0.12 0.01 1.6	0.38 0.04 18.3	1.99 0.34 41.5
1995 to 2004	65/12 65/12 54/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.65 0.06 10.63	0.14 0.005 0.9	0.53 0.04 8.6	1.27 0.13 24.4
Filling, packing						
1972 to 1984	58/22 58/22 58/22	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.86 0.28 17.2	0.4 0.02 2.0	1.3 0.19 14.0	2.9 0.64 38.4

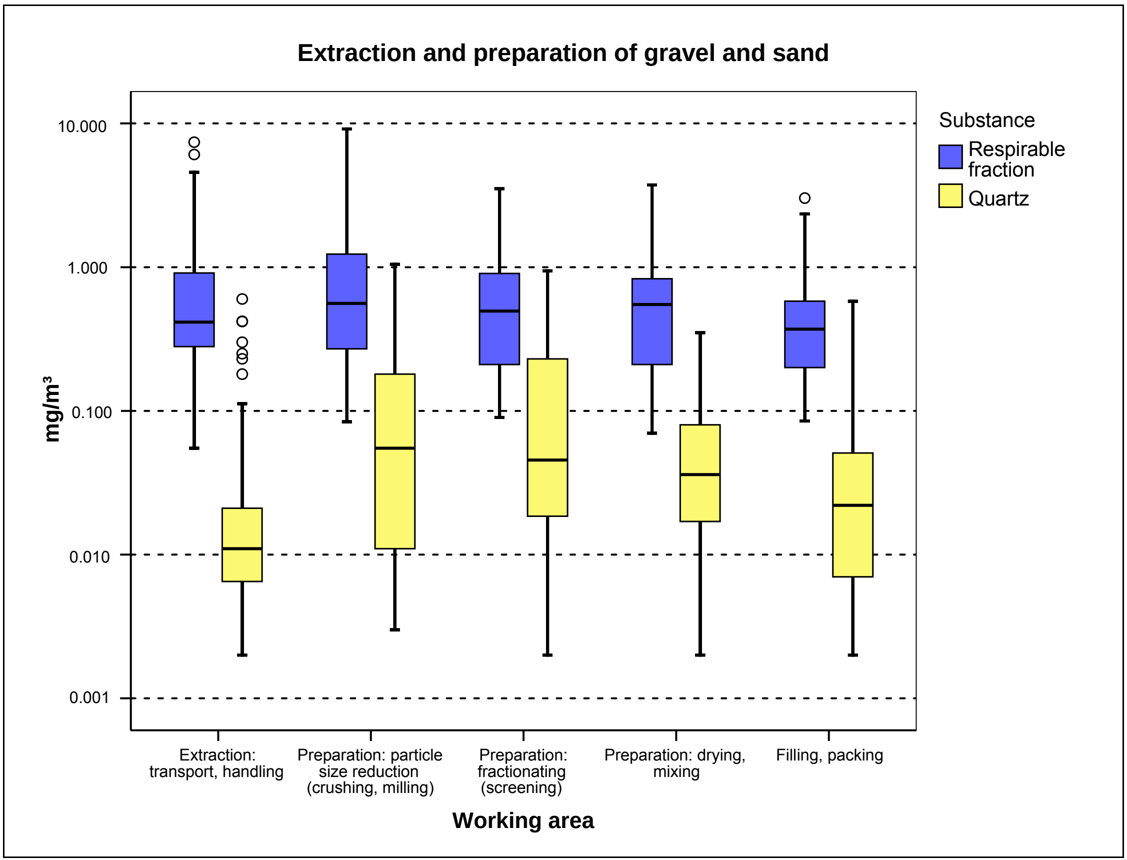
Table 20: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Filling, packing (continued)						
1985 to 1994	30/18 30/18 28/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.95 0.16 18.13	0.18 0.02 3.8	0.6 0.07 13.4	2.55 0.38 30.9
1995 to 2004	85/33 85/33 80/33	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.48 0.06 12.25	0.09 0.005 1.1	0.37 0.02 7.4	1.01 0.15 32.9
Control panel						
1972 to 2004	46/33 46/33 42/30	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.6 0.22 9.29	0.09 0.003 1.0	0.41 0.03 8.8	3.13 0.26 16.9
Laboratory and quality control						
1972 to 2004	17/12 17/12 16/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.63 0.08 9.36	0.18 0.003 1.0	0.38 0.02 5.7	0.75 0.17 20.5

The data collectives show that crushing and milling in particular are associated with the highest exposures (see Figure 12, page 60). A large proportion of the measurements concern the production of crushed gravel, for example by means of cone crushers. Longer periods need not be spent in the vicinity of crusher installations, since they are operated fully automatically; a longer presence in these areas is also prohibited owing to the noise exposure. The mean shift values in the table must therefore be converted if appropriate to the actual time spent in the vicinity of these installations, for example during inspection patrols.

Dust problems arise on a considerable scale when crushers or milling installations are operated within encapsulated preparation plants rather than being housed separately. Dust collection facilities with the required efficacy are very rarely possible. Relatively high values were obtained for the fractionation stage. Measurements were taken in this case primarily in dry screening installations; the generation of dust in such installations is higher than in those for the corresponding wet processes. Measures are now taken by which adequate dust collection is attained during sand drying and the mixing of different particle fractions. Workplaces on sand filling and packaging machines feature state-of-the-art dust collection. A workplace concentration of 0.15 mg/m³ at the 90th percentile is now observed.

Figure 12:
Mean shift values for the concentration of the respirable dust fraction and for the quartz concentration in different working areas during the extraction and preparation of gravel and sand, during the period from 1995 to 2004



The trend in the measured values for the periods from 1972 to 1984 and from 1995 to 2004 (see Table 20) shows that dust exposure in the gravel and sand industry has fallen considerably, due in great measure to the automation of processes, and also to the use of improved production methods which have the effect of generating less dust.

5.3.2.4 Extraction and preparation of limestone and dolomite

The extraction and preparation of these mineral raw materials involves the methods and discrete tasks described in Section 5.3.2.2 (extraction and preparation of natural stone). The comments made there apply here by extension. The substantially lower quartz content of the mineral raw materials which are processed must be taken into account. In a small number of limestone deposits, a quartz component of over 10% was measured in the respirable dust, compared to the usual value of < 5%. This value had a corresponding influence upon the results of evaluation. This explains why, for the 90th percentile value, relatively high quartz exposure was also observed for the areas of preparation and loading for transport.

The trend in the measured values for the periods from 1972 to 1984 and from 1995 to 2004 (see Table 21) shows that the use and improvement of dust collection measures enabled the dust exposure to be reduced considerably for the sector as a whole.

Table 21:
Exposure data for the extraction and preparation of limestone and dolomite

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Extraction and preparation of limestone and dolomite (total)						
1972 to 1984	71/16 71/16 71/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	6.28 0.1 2.0	0.47 0.01 1.0	2.69 0.04 2.0	16.75 0.29 3.9
1985 to 1994	10/6 10/6 10/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.78 0.02 1.02	0.21 0.002 0.4	1.78 0.01 0.5	3.6 0.02 1.9
1995 to 2004	45/20 45/20 39/20	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.96 0.03 3.35	0.169 0.002 0.5	0.77 0.02 2.0	1.81 0.09 7.6
Extraction, loading out, handling						
1972 to 2004	39/15 39/15 38/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.78 0.02 1.53	0.24 0.004 0.7	1.21 0.01 1.0	3.65 0.05 3.2
Preparation						
1972 to 2004	95/34 95/34 91/34	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	5.54 0.11 2.76	0.36 0.01 0.5	2.5 0.03 2.0	15.0 0.3 7.2
Loading for transport						
1972 to 2004	17/8 17/8 17/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	5.59 0.11 3.21	0.23 0.003 0.4	2.86 0.04 1.3	15.79 0.33 9.8

5.3.2.5 Manufacture of cement and lime

Limestone extracted in quarries is crushed in crushers, then placed in intermediate storage, after which it undergoes raw preparation in the form of drying, milling to raw meal in cone mills, and possibly also granulation. The raw material – raw meal or raw-meal granulate – is heated to approximately 1,400 °C in rotary kilns and fired in the sintering zone to form cement clinker. Once it has cooled, the clinker is milled in cone mills in a further milling process with the addition of certain additives to produce various cement types. It is then stored in silos. A large part of the final cement is loaded into tanker trailers. The remainder is packed in paper sacks on sacking machines and filled into big bags.

In contrast to cement manufacture, limestone is generally fired in annular shaft kilns, in which the coarsely crushed limestone is heated only sufficiently for the carbon dioxide bound within it to be expelled. The further production steps are comparable to those for cement manufacture.

Some limestone deposits may have quartz components of 5% or more in the respirable dust fraction. Substances containing quartz, such as sand, which are added both during the manufacture of raw meal, and during the milling of the cement clinker in order to improve the cement properties, also have an effect upon the quartz content in the dust.

Processes in modern cement and lime works are largely automated; only monitoring tasks, maintenance and repair work for the clearing of faults need therefore be performed. Raw preparation, firing and milling are controlled from an air-conditioned control panel. Workers performing inspection patrols, maintenance personnel, and plant operators in certain parts of plants which are not controlled from the control panel, such as in cement sacking and loading for transport, are considered to be subject to dust exposure.

Modern cement and lime works feature effective dust collection facilities in the relevant plant areas, not least for environmental reasons. Parts of plants with high dust generation (e.g. cement mills) are generally found in closed buildings, or are equipped with effective state-of-the-art dust collection facilities at the intake, transfer and discharge points. Electrofilters are generally used for dust collection in rotary kilns and annular shaft kilns. Filler necks with dust exhaust in addition to the usual dust collection measures on cement sacking machines also now set the standard. The exposure data are compiled in Table 22.

Table 22:
Exposure data for the production of cement and lime

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th per-centile value	50th percentile value	90th percentile value
Manufacture of cement and lime (total)						
1972 to 1984	84/19 84/19 81/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.78 0.09 4.43	0.35 0.003 0.5	1.17 0.02 2.0	5.99 0.16 11.1
1985 to 1994	162/36 162/36 155/35	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.17 0.02 2.32	0.09 0.002 0.5	0.82 0.01 1.3	2.96 0.05 4.6
1995 to 2004	49/27 49/27 41/24	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.04 0.02 1.45	0.19 0.002 0.4	0.56 0.01 0.9	2.09 0.03 2.8
Crushing						
1972 to 1984	13/8 13/8 13/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.98 0.19 5.27	0.35 0.01 1.0	1.28 0.02 2.0	5.32 0.29 11.0
1985 to 2004	36/17 36/17 35/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.17 0.04 4.18	0.18 0.003 0.6	0.67 0.02 2.4	3.26 0.11 7.6
Raw-meal manufacture						
1972 to 1984	20/7 20/7 19/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.15 0.03 2.41	0.35 0.001 0.5	0.79 0.01 1.3	2.35 0.11 4.2
1985 to 2004	22/7 22/7 20/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.77 0.02 1.98	0.11 0.001 0.7	0.44 0.01 1.9	2.06 0.03 3.3
Firing, milling						
1972 to 2004	25/15 25/15 22/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.24 0.02 1.58	0.16 0.002 0.5	0.63 0.01 0.9	2.1 0.03 3.0
Filling, weighing out, packing						
1972 to 1984	31/7 31/7 31/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.36 0.11 6.85	0.35 0.003 0.4	1.36 0.04 3.5	5.26 0.15 13.1
1985 to 1994	57/20 57/20 57/20	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.52 0.03 2.21	0.34 0.01 0.5	1.08 0.01 1.4	3.24 0.05 4.6
1995 to 2004	22/14 22/14 20/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.99 0.01 1.05	0.18 0.002 0.5	0.59 0.01 0.8	1.68 0.02 1.7

5.3.2.6 Recycling and sorting of construction materials

Legacy mineral construction materials, such as building and civil engineering waste, road breakage product and construction site waste, are prepared for re-use in either stationary or mobile/semi-mobile recycling and sorting plants. In their essential design, these plants largely correspond to those for conventional raw materials extraction and processing in the natural stone industry. They comprise discrete stages for the removal of unwanted substances (such as construction timber, plastic film, reinforcing steel, paper), for crushing and for fractionation. The stockpiled and possibly presorted material is transported by wheel loader or excavator to the intake funnel, from where it passes through preliminary screening to the crusher. Baffle or jaw crushers are generally employed. Finally, the crushed material is fractionated in a downstream screening installation, and stockpiled separately according to particle size.

Workplaces with a risk of dust exposure can be found

- in material charging (manual presorting on picking belts, wheel loader/excavator drivers)
- throughout the plant, during plant operation and monitoring (inspection patrols)
- in particular, at the crusher intake on mobile installations during monitoring of material feed and manual removal of unwanted materials (see Figure 13); this is not generally a permanent workplace, however
- during relocation of the recycling material, and loading from stockpiles onto trucks by means of wheel loaders

Figure 13:
Manual removal during recycling of construction materials

Stationary installations are generally operated and monitored from within a cabin.

The measured values shown in Table 23 indicate that the highest dust exposures occur during preparation of the material by crushing and fractionating. The creation of dust is considerably higher on impact crushers than on jaw crushers. Substantially lower values were measured in the working areas for sorting, transport and loading for transport. The excavators and wheel loaders employed feature enclosed driver's cabs which provide protection against dust exposure (see Figure 14).

Table 23:
Exposure data for construction material recycling and sorting installations

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Recycling and sorting of construction materials (total)						
1985 to 1994	148/56 148/56 145/55	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.99 0.08 7.32	0.17 0.01 1.3	0.65 0.04 5.2	2.27 0.24 14.2
1995 to 2004	266/105 266/105 232/103	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.73 0.05 6.02	0.13 0.004 0.6	0.49 0.02 3.9	1.49 0.13 14.4
Handling, transport, storage, loading for transport						
1985 to 1994	31/14 31/14 31/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.8 0.03 5.25	0.17 0.01 1.0	0.52 0.02 4.4	1.84 0.08 11.9
1995 to 2004	60/36 60/36 45/31	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.69 0.03 3.71	0.13 0.003 0.8	0.43 0.01 1.9	1.47 0.09 8.2
Sorting						
1995 to 2004	78/39 78/39 75/38	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.75 0.04 5.48	0.19 0.004 1.0	0.49 0.02 3.6	1.41 0.09 12.6
Crusher, mill, fractionating, screening						
1985 to 1994	80/39 80/39 79/39	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.11 0.1 8.0	0.17 0.01 2.0	0.72 0.05 5.8	2.94 0.25 15.2
1995 to 2004	84/46 84/46 73/42	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.77 0.07 8.55	0.14 0.004 1.2	0.56 0.04 7.4	1.53 0.17 17.2

Figure 14:
Crusher feed in construction material recycling

Dust exposure in the areas of crushing and fractionating has been reduced by a third in recent years by dust control measures, even though the throughput rose during the same period.

Whereas comprehensive dust collection facilities are the state of the art on stationary recycling and sorting installations, this is not the case for mobile installations, the compact design of which limits the scope for such facilities. Dust control measures include:

- water sprinkling, by which dust is prevented from drifting from stockpiles
- water-jetting, in order to promote precipitation on the crusher and at transfer points on conveyor equipment
- adjustment of drop heights to the alluvial cone of stockpiles
- regular spraying and cleaning of traffic areas

5.3.2.7 Concrete industry (stationary operation)

Concrete is produced in mixing plant from gravel, sand, cement, water, certain additives for modification of the flow and setting properties, and in some cases pigments. Depending upon the intended subsequent processing, its consistency ranges from earth-moist to liquid. The concrete is formed on concrete block machines or on vibrating tables on which the final product is produced, such as paving stones, kerbstones, panels, pipes, tubing rings, slatted floors; or in wooden or steel shell forms for the production of large concrete elements such as stays, girders, wall elements and filigree floors. The concrete is compacted by vibration, compression or tamping.
In order for the tensile strength and stability of certain concrete products to be increased, they are armoured with steel which is laid into the shell form prior to the concrete.

Respirable quartz dust may be released during crushing of the mineral substances containing quartz, in particular during vibration and tamping of the earth-moist concrete mixture. Further exposure to respirable quartz dust exists during finishing of the cured concrete products, when burrs or faults are dry-ground off or out, surfaces smoothed, or recesses produced by drilling, sawing, milling or chiselling. The dust exposure in a concrete works is dependent essentially upon regular cleaning of the production areas, i.e. the removal of loose residue and dust deposits. Should these not be removed, dust is raised again.

Measurements on mobile concrete plant were performed only sporadically; the data for mixing installations in concrete plants also apply here by extension, as the same technology is employed. Work processes during cleaning of the mixer, such as removal of the concrete or cement deposits or the removal of adhering concrete residue by means of pneumatic or electric hammers, were also analyzed in only a few cases, as these are generally only occasional tasks of brief duration. High dust concentrations may occur here which necessitate the wearing of breathing masks.

Table 24 contains a summary of the measured data collectives for stationary areas within the entire concrete industry, without differentiation by task or working area. A more detailed breakdown of the results obtained in the overall evaluation, according to discrete tasks and working areas, is shown in Tables 25 to 31 (see pages 68 ff.)

Table 24:
Exposure data for the concrete industry (stationary operation, total)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	538/83	Respirable fraction in mg/m³	2.55	0.44	1.2	5.38
	538/83	Quartz in mg/m³	0.17	0.01	0.03	0.2
	532/83	Quartz content in %	4.96	0.5	3.0	12.0
1985 to 1994	417/121	Respirable fraction in mg/m³	1.1	0.18	0.65	2.05
	417/121	Quartz in mg/m³	0.06	0.003	0.02	0.18
	398/121	Quartz content in %	6.15	0.9	3.0	15.0
1995 to 2004	572/164	Respirable fraction in mg/m³	0.79	0.11	0.55	1.44
	572/164	Quartz in mg/m³	0.09	0.003	0.02	0.12
	513/153	Quartz content in %	5.46	0.8	3.1	12.4

Concrete mixing

The data collectives contain measurement results for hand-fed, partly automated to fully automated mixers. Measurements were performed on mixers both with and without dust collection facilities, during manual feeding, and during tasks associated with production of the concrete mix, such as the manual addition of additives, and also during inspection patrols on mixing installations.

Modern stationary mixing machines are generally of encapsulated design and are controlled automatically; no permanent workplace therefore exists in the area in which they are housed. They are dedusted or connected to a dust filter for ventilation of the displacement air occurring during the filling process.

The percentile values in the measurement data in Table 25 from the three periods of time under consideration document the improvements achieved by automation of the mixing process and the dedusting measures taken.

Table 25:
Exposure data for the mixing of concrete

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	116/30	Respirable fraction in mg/m³	2.04	0.44	1.05	3.09
	116/30	Quartz in mg/m³	0.07	0.01	0.04	0.13
	115/30	Quartz content in %	5.79	1.0	4.0	11.1
1985 to 1994	56/26	Respirable fraction in mg/m³	1.02	0.18	0.63	2.04
	56/26	Quartz in mg/m³	0.03	0.002	0.02	0.06
	53/26	Quartz content in %	4.06	0.5	1.8	8.7
1995 to 2004	44/32	Respirable fraction in mg/m³	0.73	0.18	0.37	1.64
	44/32	Quartz in mg/m³	0.02	0.003	0.01	0.05
	33/26	Quartz content in %	3.01	0.7	1.9	6.3

Manufacture of concrete products and precast concrete components

The measured quartz dust concentration rises with finer crushing of the gravel and sand particles during compaction of the concrete (e.g. of surplus concrete, residual concrete). Particle crushing with the generation of respirable quartz dust occurs for example during the manufacture of slabs on rotary table presses with a tamper facility and of concrete products on vibrating tables with an unrestrained mould.

Dust extraction facilities are the state of the art on slab presses with a tamper facility, but not on the other machine types. For reasons of noise exposure, the majority of block-making machines are encapsulated, which also has the effect of preventing dust from spreading.

The vibrating table installation causes a reduction in particle size accompanied by the production of quartz dust. Virtually no scope exists for the exhaust of dust. Production – the insertion and/or distribution of the concrete mix into the moulds – is generally performed manually.

Despite the fact that the performance of the installations has increased whilst the manufacturing technologies have remained largely unchanged during the same time, a reduction has been observed in the 90th percentile value from 0.26 to 0.17 mg/m³ (see Table 26). This confirms the efficacy both of a whole series of general dust prevention measures in the plants, and the automation of the production processes.

Table 26:
Exposure data for the manufacture of concrete products and precast concrete components (total)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	209/27 209/27 204/27	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.53 0.08 4.45	0.32 0.005 1.0	0.8 0.03 3.0	3.37 0.16 8.6
1985 to 1994	152/50 152/50 151/50	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.92 0.06 6.39	0.2 0.004 1.0	0.63 0.02 3.0	1.75 0.15 17.9
1995 to 2004	205/76 205/76 187/72	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.77 0.05 5.93	0.09 0.003 1.1	0.55 0.02 3.1	1.56 0.13 15.5

Manufacture of concrete products

The results of measurements of the respirable quartz dust concentration in the period from 1997 to 2001 show the following trends for this particular area, broken down by manufacturing method: A respirable quartz dust concentration in excess of 0.15 mg/m³ can be anticipated during the manufacture of

- cement slabs by means of an older rotating table press with tamper facility. Modern tampers are generally encapsulated and feature dust exhaust, resulting in substantially lower concentrations.
- concrete items on vibrating tables or stands on which the mould rests without restraint.

Respirable quartz dust concentrations in some cases substantially below 0.15 mg/m³ (see Table 27) were measured for the manufacture of

- manholes and rings
- pipes, by means of a pipe-making machine (see Figure 15)

- concrete products, by means of transfer-table systems
- concrete products, by means of block-making machines (< 0.10 mg/m³)
- concrete products, by means of egglayers (< 0.05 mg/m³)

Table 27:
Exposure data for the manufacture of concrete products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 2004	183/63	Respirable fraction in mg/m³	2.2	0.31	0.92	5.47
	183/63	Quartz in mg/m³	0.14	0.01	0.05	0.3
	181/62	Quartz content in %	7.32	1.0	4.3	19.3

Figure 15:
Pipe manufacture in the concrete industry

Manufacture of large precast concrete components

During use of the compaction process for the manufacture of precast concrete components such as ceiling and wall elements, stays or girders, the mineral substances contained within the concrete do not undergo any reduction in particle size. Measured concentrations of respirable quartz dust are around 0.05 mg/m³ (see Table 28).

Table 28:
Exposure data for the manufacture of large precast concrete components

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 2004	77/31	Respirable fraction in mg/m³	0.66	0.14	0.51	1.38
	77/31	Quartz in mg/m³	0.03	0.003	0.01	0.1
	72/29	Quartz content in %	3.5	1.0	2.6	7.4

Manufacture of roof tiles

Concrete roof tiles are produced on pallets in production cycle machines. The concrete mix is produced in conventional concrete mixers. Respirable quartz dust may be released

- in the region of the mixer (see detailed description in the section on concrete mixing)
- during de-forming of the cured tiles
- during cleaning of the pallets
- during sealing of the tile surfaces by spraying with a liquid coating, which generally contains quartz components (e.g. colour dispersion).

The trend in the measured values for the periods from 1972 to 1984 and from 1995 to 2004 is shown in Table 29, and reveals a considerable drop in the dust exposure at the workplaces concerned. The reasons for this are the discontinuation of the sand-surfacing of roof tiles around the mid-1980s, and the progressive improvement in dust collection measures which are now the state of the art, such as dust collection on concrete mixers, the increased use of dust collection at the point of dust creation, and application of the surface coating agent without the use of compressed air.

Table 29:
Exposure data for the manufacture of roof tiles

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	121/2	Respirable fraction in mg/m³	1.54	0.46	0.83	3.09
	121/2	Quartz in mg/m³	0.05	0.01	0.03	0.11
	121/2	Quartz content in %	3.89	1.0	3.0	8.0
1985 to 1994	35/3	Respirable fraction in mg/m³	0.9	0.2	0.55	1.75
	35/3	Quartz in mg/m³	0.04	0.004	0.01	0.07
	35/3	Quartz content in %	3.69	1.0	2.0	7.0
1995 to 2004	31/7	Respirable fraction in mg/m³	0.35	0.13	0.32	0.66
	31/7	Quartz in mg/m³	0.01	0.003	0.01	0.01
	23/7	Quartz content in %	2.39	1.3	2.2	4.1

Treatment and finishing

High concentrations of respirable quartz dust must be anticipated during drilling, sawing, milling, cutting and grinding, in particular where dry processes are used. Such processes are employed during the treatment and finishing of concrete surfaces, and the retrospective production of junctions in concrete shafts and concrete pipes and of recesses in other precast concrete parts. In particular, dry grinding using angle grinders and cup wheel grinding machines for cosmetic repairs to damaged corners and edges, for the smoothing of concrete surfaces, and for the removal of burrs, is accompanied by the generation of large quantities of dust.

The release of dust can be suppressed only in part by the spraying of water during the work. The level of the dust concentration (see Table 30) arising during wet sawing is substantially influenced by the formation of aerosols and the quality of the water (recirculated/fresh water). The comments found in Section 5.3.2.1 (natural hewn stone industry) apply.

The surfaces of concrete products, such as slabs and paving stones, can be treated by blasting. Blasting is performed in encapsulated installations with dust collection and with conditioning of the non-silicosis-inducing blasting agent employed in the recirculating system.

Table 30:
Exposure data for the treating and finishing of concrete products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	186/39	Respirable fraction in mg/m³	4.12	0.65	1.9	9.73
	186/39	Quartz in mg/m³	0.32	0.01	0.03	0.31
	186/39	Quartz content in %	4.68	0.5	1.0	18.8
1985 to 1994	167/67	Respirable fraction in mg/m³	1.34	0.12	0.77	2.07
	167/67	Quartz in mg/m³	0.07	0.003	0.02	0.2
	155/67	Quartz content in %	6.45	0.9	2.9	14.2
1995 to 2004	232/86	Respirable fraction in mg/m³	0.9	0.21	0.61	1.44
	232/86	Quartz in mg/m³	0.17	0.004	0.02	0.12
	215/83	Quartz content in %	6.33	0.8	4.4	12.3

The results of measurements of the respirable quartz dust concentration in the period from 1997 to 2001 show the following trends for the individual processing methods: A respirable quartz dust concentration in excess of 0.15 mg/m³ can be anticipated during

- sawing, whether dry or wet; during dry sawing with dust collection, the respirable quartz dust concentrations were over 50% below those during wet sawing

- sining of manholes, particularly during cutting of special-quality clinker to size

Respirable quartz dust concentrations in some cases substantially < 0.15 mg/m³ were measured for

- wet grinding
- dry grinding with dust collection: around 0.05 mg/m³
- blasting of concrete surfaces in blasting systems with dust collection and with conditioning of the blasting agent (< 0.1 mg/m³)
- kernelling of concrete surfaces in kernelling installations with dust collection (< 0.1 mg/m³)

Packing, transport, loading for transport

Measurements were taken here essentially during the making-up of packages of concrete paving stones, transfer of the products from the production shops to the external store, and loading onto goods vehicles for dispatch. The workplaces and packing installations are frequently located within or in the vicinity of production areas in which dust is emitted and from which it is transported. Increased exposure to respirable quartz dust is avoidable if the storage and transfer areas are cleaned regularly (see Table 31).

Table 31:
Exposure data for the packing, transport and loading of concrete products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1994	28/13 28/13 28/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.46 0.17 7.14	0.15 0.01 1.0	0.52 0.03 7.0	3.23 0.17 16.0
1995 to 2004	57/33 57/33 45/30	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.47 0.02 2.6	0.09 0.003 0.9	0.33 0.01 2.1	1.08 0.03 4.6

5.3.2.8 Asphalt mixing plants

Asphalt is manufactured by the mixing of a predried mineral mixture, employing bitumen as the binder and further additives, in a mixer (see Figure 16, page 74). The mix components are fed in and mixed within a largely enclosed and automated system. The mixing process is controlled from a control panel located at a distance from the installation. Personnel need not be present in the installation during the manufacturing process. Exceptions are

- manual addition of additives
- inspection patrols
- clearing of unanticipated faults

Figure 16:
Dry drum of an asphalt mixing plant

Workers present in the closed mixing tower during production are exposed to high levels of dust. Dust sources include screening machines and the transfer points for the metering in of minerals. Inspection patrols generally involve less than one hour's presence in the installation per shift. Exposure is thus one-eighth of the values indicated. Conversely, the wheel loader is used on the site throughout the shift for transport to and charging of the metering funnels. With the exception of the fine filler materials, the minerals are stored on the site in stockpiles. The driver remains within the closed cab of the wheel loader throughout the transport and charging processes.

Encapsulation of the mixers began in the second half of the 1970s as a direct consequence of the German legislation governing pollution (Bundes-Immissionsschutzgesetz). Data measured during the period from 1972 to 1984 (see Table 32) reflect the previous situation with open installations, in which the dust was raised and distributed over a large area of the plant site. Enclosed mixing plants with fully encapsulated mixer tower and central dust extraction facilities for the removal of dust deposits are now the state of the art.

Sector-wide arrangements for this aspect can be found in the BG/BGIA Recommendations [35] governing the manufacture and transport of asphalt.

Table 32:
Exposition data in asphalt mixing plants

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Asphalt mixing plants (total)						
1972 to 1984	138/36 138/36 138/36	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	6.88 0.4 6.14	0.3 0.01 1.0	1.29 0.05 5.0	10.62 0.81 11.0
1985 to 1994	96/25 96/25 96/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.32 0.09 6.94	0.24 0.01 2.0	0.75 0.03 5.0	2.96 0.22 15.9
1995 to 2004	56/27 56/27 42/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.7 0.03 5.22	0.1 0.003 1.1	0.42 0.02 3.4	1.57 0.08 13.5
Within the mixing plant						
1972 to 1984	91/29 91/29 91/29	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.71 0.27 6.33	0.36 0.01 1.0	1.0 0.06 5.0	9.51 0.59 11.0
1985 to 1994	53/21 53/21 53/21	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.27 0.09 6.41	0.24 0.01 2.0	0.78 0.04 5.0	2.99 0.24 12.3
1995 to 2004	20/9 20/9 18/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.08 0.03 3.42	0.17 0.004 1.1	0.83 0.03 3.4	2.16 0.07 4.9
Transport, external						
1972 to 2004	39/26 39/26 29/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.68 0.04 7.13	0.16 0.004 0.9	0.44 0.02 2.6	1.32 0.1 19.0

5.3.2.9 Manufacture of drywall construction materials (premix dry mortar, premix plaster)

Premix dry mortars and premix plasters, such as grouting compounds, concrete fillers, and interior and exterior plasters, are manufactured from cement, lime, gypsum, sand, and additives such as organic polymers, swelling agents and fibres which lend them particular product properties.

Owing to the quartz content of the mineral materials employed, dusts containing quartz are formed during the sand-drying and dry mixing processes, particularly during filling and emptying of the mixer and the manual addition of mix components. Workplaces at which final products are filled into sacks or other packaging also involve dust exposure, as does cleaning work.

Rotary packing machines and manually operated sacking machines are employed for filling and packing of the final products (see Figure 17). In the area of loading and transport, measurements were primarily performed on mixed tasks involving combined sacking and palletizing, and fork-lift truck handling in storage areas, since these production areas are closely connected. Bulk loading of tanker trailers was not considered, since dust is not released in this case except in the event of a fault.

Figure 17:
Sacking of premix plaster

The trend in the measured values for the periods from 1985 to 1994 and from 1995 to 2004 shows (see Table 33) that the use and improvement of dust collection measures in the plants enabled the dust exposure to be reduced significantly.

Table 33:
Exposure data for the manufacture of drywall construction materials (premix dry mortar, premix plaster)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Manufacture of drywall construction materials (premix dry mortar, premix plaster) (total)						
1972 to 1984	252/46	Respirable fraction in mg/m³	2.97	0.7	2.02	5.65
	252/46	Quartz in mg/m³	0.07	0.005	0.03	0.13
	251/45	Quartz content in %	2.21	0.5	1.0	4.0
1985 to 1994	219/62	Respirable fraction in mg/m³	1.49	0.4	1.25	3.07
	219/62	Quartz in mg/m³	0.06	0.01	0.02	0.13
	217/62	Quartz content in %	4.71	0.5	2.2	9.4
1995 to 2004	192/76	Respirable fraction in mg/m³	1.39	0.22	0.88	3.03
	192/76	Quartz in mg/m³	0.05	0.003	0.01	0.08
	182/75	Quartz content in %	3.23	0.5	1.6	6.7

Table 33: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
		Mixing				
1972 to 1984	71/28 71/28 71/28	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.4 0.05 1.98	0.49 0.003 0.4	1.4 0.02 1.0	4.73 0.1 4.0
1985 to 1994	61/24 61/24 61/24	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.39 0.04 4.01	0.36 0.01 0.5	1.2 0.03 2.3	2.49 0.12 8.5
1995 to 2004	34/20 34/20 33/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.54 0.03 2.0	0.24 0.003 0.7	1.37 0.02 1.5	3.34 0.08 4.2
		Drying and metering-in				
1972 to 1984	17/10 17/10 17/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.11 0.37 5.33	0.6 0.004 0.3	1.4 0.07 4.0	10.71 1.1 14.0
1985 to 2004	17/13 17/13 17/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.16 0.06 4.31	0.44 0.01 0.7	0.91 0.02 3.0	1.68 0.17 9.4
		Filling and packing				
1972 to 1984	148/43 148/43 147/42	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.07 0.05 2.02	0.86 0.01 0.5	2.15 0.03 1.0	5.53 0.11 3.3
1985 to 1994	123/48 123/48 121/48	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.57 0.07 5.15	0.41 0.01 0.5	1.29 0.02 2.0	3.23 0.12 11.6
1995 to 2004	92/57 92/57 91/57	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.4 0.04 3.01	0.24 0.003 0.6	0.84 0.02 1.7	2.99 0.09 7.0
		Loading and transport				
1972 to 1994	10/9 10/9 10/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.09 0.05 2.13	0.7 0.01 0.8	1.4 0.02 1.0	4.65 0.08 5.0
1995 to 2004	37/18 37/18 31/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.98 0.04 4.35	0.16 0.004 0.5	0.3 0.01 1.7	2.34 0.06 10.0

Central dust exhaust installations are the state of the art on the production plants. Frequent product changeovers with the resulting need for cleaning and the manual feeding of certain additives into the material flow may cause dust to be released which then leads to higher concentrations. Industrial vacuum cleaners are therefore available for localized cleaning of workplaces and installations.

5.3.2.10 Mineral milling works (mineral pigments)

Natural minerals such as bauxite, chrome ores, iron ores, magnesites and feldspars are processed in crushing, screening, drying and milling installations to form products with a particle size of < 10 µm. These products are used for example in the iron and steel industry, in foundries, and in the glass and chemical industries, for the manufacture of refractory materials. Should the raw material contain quartz components, respirable quartz dust may be produced, particularly on crushing and milling installations and during sacking.

The preparation of these mineral raw materials involves the methods and discrete tasks described in Section 5.3.2.2 (extraction and preparation of natural stone). The comments made there apply here by extension. The areas of mixing, filling and packing are comparable to those in the cement and lime industry with regard to the installations and processes employed.

The trend in the measured values for the periods from 1972 to 1984 and from 1995 to 2004 shows (see Table 34) that the use and improvement of dust collection measures enabled the dust exposure to be reduced considerably for the sector as a whole.

Table 34:
Exposure data in mineral milling plants (mineral pigments)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	126/28 126/28 125/28	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.74 0.26 4.97	0.48 0.01 0.5	2.0 0.05 3.0	14.16 0.53 12.8
1985 to 1994	107/19 107/19 106/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.66 0.04 3.22	0.32 0.004 0.5	1.19 0.01 1.2	3.26 0.09 10.2
1995 to 2004	35/10 35/10 34/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.54 0.02 2.11	0.18 0.003 0.7	0.97 0.01 0.7	3.27 0.04 3.6

5.3.3 Ceramics and glass industry

5.3.3.1 Clay, kaolin: extraction

Clays and kaolins are extracted for the most part selectively by excavators in open-pit mines. The raw materials are transported by means of conveyors, trucks or dumpers to intermediate storage points, and may be crushed in crushers and coarsely premixed. Since kaolin generally contains contaminants in the form of quartz, mica (undecomposed feldspar) and feldspar, the kaolin must be separated. Fine kaolin is an important raw material for the porcelain and paper industries. Sands and feldspars are fractionated and in some cases milled. Although the situation has been progressively improved over time by engineered measures, a respirable quartz dust concentration in the atmosphere of 0.15 mg/m³ continues to be exceeded in some cases (see Table 35).

Table 35:
Exposure data for the extraction of clay and kaolin

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Extraction, general						
1972 to 2004	16/5 16/5 16/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.0 0.2 14.59	0.14 0.01 4.2	0.39 0.06 10.0	2.54 0.47 29.1
Wet preparation, general						
1972 to 2004	14/4 14/4 14/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.9 0.09 5.66	0.23 0.01 1.9	0.96 0.06 5.5	2.84 0.18 8.0
Dry preparation, general						
1972 to 1984	42/5 42/5 42/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.82 0.32 17.56	0.45 0.02 3.0	1.4 0.14 11.4	3.36 0.7 40.0
1985 to 1994	19/6 19/6 19/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.92 0.23 27.22	0.31 0.03 6.7	0.81 0.14 14.6	1.73 0.47 60.0
1995 to 2004	19/6 19/6 19/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.86 0.08 11.79	0.18 0.005 0.8	0.57 0.04 8.9	1.42 0.15 25.9

5.3.3.2 Brickwork products, manufacture

The most common products in the brickwork group are back-up bricks, clinker and roof tiles. The argillaceous raw materials are metered out in charging boxes, crushed in crushers and pan mills, and mixed. The final preparation stage are fine rolling mills, the gap widths of which have fallen progressively since the 1980s and are now < 1 mm. The body is aged in the sump house to ensure good homogenization. Pore-forming agents are mixed into the body used for back-up bricks. The body, which is plasticized by water or steam, is drawn into bricks in vacuum extrusion presses or pressed into roof tiles on revolving presses. The products are then dried. Roof tiles are engobed or glazed. Since the 1990s, back-up bricks have increasingly been surface-ground after firing. Table 36 shows the trend towards lower values which has been attained by improved dust collection measures. Overall, the quartz content in the clays is seen to vary strongly according to the deposit, and this in turn to have an influence upon the respirable quartz dust concentration in the atmosphere.

Table 36:
Exposure data for the manufacture of brickwork products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation, general						
1972 to 1984	79/22	Respirable fraction in mg/m³	4.47	0.6	2.13	12.14
	79/22	Quartz in mg/m³	0.45	0.05	0.16	0.93
	79/22	Quartz content in %	10.53	4.9	8.0	13.6
1985 to 1994	201/79	Respirable fraction in mg/m³	0.97	0.14	0.64	2.02
	201/79	Quartz in mg/m³	0.09	0.01	0.06	0.2
	198/79	Quartz content in %	9.4	2.5	8.7	16.4
1995 to 2004	339/132	Respirable fraction in mg/m³	0.65	0.09	0.56	1.27
	339/132	Quartz in mg/m³	0.06	0.01	0.04	0.15
	329/130	Quartz content in %	9.06	2.4	7.7	16.5
Preparation, coarse						
1972 to 1984	24/12	Respirable fraction in mg/m³	6.51	0.92	1.7	12.82
	24/12	Quartz in mg/m³	0.67	0.08	0.13	1.64
	24/12	Quartz content in %	10.4	4.8	11.0	13.8
1985 to 1994	47/30	Respirable fraction in mg/m³	0.93	0.18	0.52	2.04
	47/30	Quartz in mg/m³	0.07	0.01	0.052	0.18
	47/30	Quartz content in %	9.42	2.0	9.1	14.7
1995 to 2004	53/36	Respirable fraction in mg/m³	0.59	0.17	0.54	1.07
	53/36	Quartz in mg/m³	0.06	0.01	0.04	0.09
	53/36	Quartz content in %	9.66	3.9	8.3	14.7
Preparation, fine; glazing						
1972 to 1984	16/7	Respirable fraction in mg/m³	6.26	0.55	2.57	14.92
	16/7	Quartz in mg/m³	0.54	0.05	0.17	1.38
	16/7	Quartz content in %	8.19	3.9	7.0	12.8
1985 to 1994	21/14	Respirable fraction in mg/m³	0.92	0.17	0.54	1.99
	21/14	Quartz in mg/m³	0.1	0.01	0.05	0.2
	21/14	Quartz content in %	9.53	1.8	9.4	18.1
1995 to 2004	50/31	Respirable fraction in mg/m³	0.67	0.09	0.6	1.25
	50/31	Quartz in mg/m³	0.05	0.003	0.03	0.09
	49/31	Quartz content in %	6.87	1.1	6.4	11.2
Moulding shop: general						
1972 to 1984	22/13	Respirable fraction in mg/m³	2.17	0.48	1.85	3.29
	22/13	Quartz in mg/m³	0.16	0.04	0.14	0.23
	22/13	Quartz content in %	7.21	5.0	7.1	9.7
1985 to 1994	217/98	Respirable fraction in mg/m³	0.59	0.15	0.44	1.25
	217/98	Quartz in mg/m³	0.06	0.01	0.03	0.11
	215/98	Quartz content in %	8.27	2.4	6.6	14.3
1995 to 2004	392/171	Respirable fraction in mg/m³	0.34	0.12	0.24	0.8
	392/171	Quartz in mg/m³	0.03	0.003	0.01	0.06
	376/170	Quartz content in %	5.94	1.7	5.0	10.3
Moulding shop: pressing						
1972 to 1984	21/12	Respirable fraction in mg/m³	2.25	0.7	1.88	3.34
	21/12	Quartz in mg/m³	0.17	0.04	0.14	0.23
	21/12	Quartz content in %	7.09	5.0	7.1	9.3

Table 36: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Moulding shop: pressing (continued)						
1985 to 1994	205/96 205/96 203/96	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.6 0.06 8.34	0.15 0.01 3.0	0.45 0.03 6.5	1.25 0.11 14.1
1995 to 2004	379/170 379/170 364/169	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.34 0.03 5.93	0.12 0.003 1.7	0.23 0.01 5.0	0.77 0.06 10.5
Drying, general						
1972 to 1984	-/- -/- -/-	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1985 to 1994	15/10 15/10 12/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.63 0.06 8.08	0.14 0.005 1.8	0.31 0.02 6.0	1.43 0.15 16.9
1995 to 2004	32/23 32/23 31/23	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.45 0.04 7.22	0.18 0.004 1.8	0.33 0.02 5.0	0.87 0.07 13.4
Preparation for firing, general: glazing						
1972 to 1984	14/6 14/6 14/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.17 0.07 5.96	0.19 0.01 2.5	1.0 0.04 5.4	2.38 0.14 8.0
1985 to 1994	30/18 30/18 30/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.61 0.05 7.13	0.13 0.003 1.7	0.31 0.03 6.2	1.59 0.07 14.2
1995 to 2004	80/49 80/49 78/49	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.3 0.02 5.83	0.15 0.003 2.1	0.2 0.01 4.6	0.64 0.04 11.1
Kiln, general						
1972 to 1984	20/10 20/10 20/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.11 0.11 4.35	0.23 0.002 1.0	1.2 0.08 3.0	11.2 0.24 7.7
1985 to 1994	126/69 126/69 123/69	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.39 0.04 6.96	0.1 0.002 1.2	0.25 0.02 5.7	0.86 0.08 12.8
1995 to 2004	304/143 304/143 300/143	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.3 0.03 7.48	0.09 0.003 1.7	0.09 0.01 6.0	0.73 0.08 15.6
Kilns: loading of intermittent firing and tunnel kilns						
1972 to 1984	4/3 4/3 4/3	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	-- -- --	-- -- --	-- -- --	-- -- --
1985 to 1994	66/49 66/49 66/49	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.43 0.04 6.88	0.14 0.003 1.4	0.26 0.02 5.5	0.89 0.09 11.4
1995 to 2004	183/122 183/122 181/122	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.33 0.03 7.3	0.14 0.003 1.7	0.18 0.01 6.2	0.75 0.08 13.9
Kilns: unloading of intermittent firing and tunnel kilns						
1972 to 1984	2/2 2/2 2/2	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	-- -- --	-- -- --	-- -- --	-- -- --

Table 36: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Kilns: unloading of intermittent firing and tunnel kilns (continued)						
1985 to 1994	31/26 31/26 30/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.27 0.02 5.89	0.16 0.002 1.0	0.22 0.01 4.6	0.48 0.03 12.4
1995 to 2004	103/75 103/75 103/75	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.28 0.03 8.32	0.14 0.003 1.7	0.14 0.01 6.2	0.7 0.07 16.9
Finishing work, general						
1972 to 1984	34/12 34/12 34/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.18 0.09 7.16	0.41 0.02 2.9	1.0 0.06 7.1	2.02 0.24 11.6
1985 to 1994	95/57 95/57 93/57	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.5 0.07 9.55	0.09 0.01 2.8	0.31 0.02 8.3	1.16 0.15 14.9
1995 to 2004	254/109 254/109 237/107	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.25 0.02 6.46	0.12 0.002 1.1	0.12 0.01 4.5	0.62 0.05 13.3
Finishing: grinding, sawing						
1972 to 1984	12/4 12/4 12/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.2 0.12 8.64	0.28 0.02 3.0	1.05 0.06 7.5	2.06 0.29 13.8
1985 to 1994	9/6 9/6 9/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	-- -- --	-- -- --	-- -- --	-- -- --
1995 to 2004	55/32 55/32 54/32	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.28 0.02 5.51	0.12 0.003 1.5	0.18 0.01 4.4	0.53 0.04 10.1
Finishing: sorting, storage						
1972 to 1984	11/5 11/5 11/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.01 0.07 7.52	0.22 0.02 3.1	1.0 0.06 7.1	1.57 0.13 11.4
1985 to 1994	67/47 67/47 65/47	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.4 0.05 8.47	0.09 0.01 2.9	0.26 0.02 7.8	0.76 0.08 14.2
1995 to 2004	188/85 188/85 174/84	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.23 0.02 6.51	0.13 0.002 1.1	0.13 0.01 4.5	0.53 0.05 13.3

5.3.3.3 Large stoneware products and split tiles, manufacture

Large stoneware products include sewage pipes, troughs, acid-proof elements and slabs, generally for flooring. The argillaceous raw materials are crushed and metered. The crushed, milled and fractionated chamotte – fired clay or recycling product – is added to the clay and mixed with water to form a plastic body. Vacuum extrusion presses are used as moulding units. The "white" product is generally glazed after drying, and then fired. In order for a tight seal to be assured on stone pipes, a ring of hard polyurethane or (up to the end of the 1990s) polyester shortened with quartz powder is cast into the socket ends. Since the end of the 1990s, the socket ends have also been ground out. The measured data are shown in Table 37.

Table 37:
Exposure data for the production of large stoneware products and split tiles

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation, general						
1972 to 1984	24/5	Respirable fraction in mg/m³	3.14	0.38	0.9	6.68
	24/5	Quartz in mg/m³	0.38	0.02	0.08	0.84
	24/5	Quartz content in %	13.97	2.4	8.0	14.0
1985 to 1994	46/7	Respirable fraction in mg/m³	1.35	0.36	1.22	2.21
	46/7	Quartz in mg/m³	0.13	0.02	0.12	0.25
	45/7	Quartz content in %	9.35	4.5	9.5	12.8
1995 to 2004	16/4	Respirable fraction in mg/m³	0.81	0.37	0.62	1.04
	16/4	Quartz in mg/m³	0.08	0.01	0.07	0.11
	16/4	Quartz content in %	8.26	2.7	8.3	11.8
Shaping: general						
1972 to 1984	19/6	Respirable fraction in mg/m³	2.42	0.44	0.83	7.94
	19/6	Quartz in mg/m³	0.23	0.02	0.07	0.72
	19/6	Quartz content in %	7.16	2.8	6.4	13.9
1985 to 1994	32/6	Respirable fraction in mg/m³	0.6	0.15	0.41	1.23
	32/6	Quartz in mg/m³	0.05	0.01	0.03	0.09
	32/6	Quartz content in %	7.59	5.1	7.5	8.8
1995 to 2004	29/6	Respirable fraction in mg/m³	0.64	0.25	0.58	1.09
	29/6	Quartz in mg/m³	0.05	0.02	0.04	0.1
	29/6	Quartz content in %	7.9	5.8	7.4	10.4
Shaping: pressing						
1972 to 1984	12/5	Respirable fraction in mg/m³	3.38	0.51	1.2	9.27
	12/5	Quartz in mg/m³	0.38	0.03	0.08	1.0
	12/5	Quartz content in %	8.49	3.4	7.0	14.0
1985 to 1994	28/6	Respirable fraction in mg/m³	0.64	0.15	0.44	1.24
	28/6	Quartz in mg/m³	0.05	0.01	0.03	0.1
	28/6	Quartz content in %	7.48	5.4	7.4	8.8
1995 to 2004	25/6	Respirable fraction in mg/m³	0.67	0.3	0.6	1.1
	25/6	Quartz in mg/m³	0.06	0.02	0.05	0.1
	25/6	Quartz content in %	8.02	5.2	7.5	10.9
Drying, general						
1972 to 2004	13/4	Respirable fraction in mg/m³	0.53	0.18	0.23	1.32
	13/4	Quartz in mg/m³	0.04	0.005	0.01	0.12
	13/4	Quartz content in %	5.95	2.5	5.5	8.8
Preparation for firing, general						
1972 to 2004	38/14	Respirable fraction in mg/m³	0.88	0.21	0.67	1.82
	38/14	Quartz in mg/m³	0.07	0.01	0.03	0.18
	38/14	Quartz content in %	6.73	2.9	5.7	11.2
Kiln, general						
1972 to 1984	23/6	Respirable fraction in mg/m³	1.0	0.4	0.73	2.19
	23/6	Quartz in mg/m³	0.05	0.01	0.04	0.1
	23/6	Quartz content in %	5.1	1.8	5.3	7.2
1985 to 1994	33/6	Respirable fraction in mg/m³	0.39	0.15	0.23	0.96
	33/6	Quartz in mg/m³	0.03	0.01	0.02	0.09
	33/6	Quartz content in %	7.22	3.9	6.8	11.7

Table 37: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Kiln, general (continued)						
1995 to 2004	22/5 22/5 22/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.56 0.06 9.66	0.16 0.01 3.3	0.41 0.03 8.4	1.21 0.14 16.6
Finishing work, general						
1972 to 1984	42/8 42/8 42/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.45 0.06 6.1	0.4 0.01 1.0	0.8 0.05 6.0	1.99 0.12 10.9
1985 to 1994	12/6 12/6 12/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.48 0.03 6.89	0.18 0.01 4.3	0.32 0.02 6.9	1.04 0.06 8.3
1995 to 2004	19/5 19/5 19/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.55 0.05 9.8	0.19 0.01 4.1	0.42 0.04 8.4	1.07 0.09 16.0

5.3.3.4 Refractory products, manufacture

Refractory materials (see Figure 18) are primarily employed in the metals, ceramics and glass industries. Raw materials are fractionated, metered and mixed in the course of preparation. Depending upon the requirements, the products are manufactured by (semi-)plastic moulding, dry pressing, or by punching from powder bodies. The subsequent firing lends the refractory materials their various physical, chemical and thermal properties. Table 38 shows the exposure data.

Figure 18:
Placing of refractory products on intermittent kiln cars

Table 38:
Exposure data for the manufacture of refractory products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
		Preparation, general				
1972 to 1979	105/21 105/21 104/21	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	5.26 0.52 8.96	0.65 0.02 0.8	2.45 0.1 5.2	11.0 0.55 11.0
1980 to 1984	173/34 173/34 172/34	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.55 0.13 6.43	0.5 0.01 1.0	1.38 0.06 4.6	4.15 0.24 12.0
1985 to 1994	86/23 86/23 82/23	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.2 0.08 7.93	0.2 0.004 0.8	1.09 0.03 4.2	2.34 0.17 14.3
1995 to 2004	208/44 208/44 197/44	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.25 0.08 8.66	0.23 0.005 0.5	0.88 0.03 3.1	2.1 0.15 22.8
		Preparation, coarse				
1972 to 1979	22/10 22/10 22/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.14 1.26 17.41	0.36 0.02 2.1	1.45 0.1 7.6	10.17 0.36 53.4
1980 to 1984	26/12 26/12 26/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.79 0.29 10.26	0.5 0.03 2.6	1.1 0.11 6.5	6.91 0.52 24.8
1985 to 2004	21/10 21/10 21/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.48 0.08 6.04	0.25 0.01 1.4	1.4 0.07 5.7	2.34 0.15 11.0
		Preparation, fine; glazing				
1972 to 1979	15/10 15/10 15/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	5.36 0.28 4.92	0.57 0.01 0.8	2.08 0.07 5.0	1.,75 0.42 9.5
1980 to 1984	14/8 14/8 14/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.37 0.13 5.11	0.36 0.003 0.5	1.25 0.05 5.1	3.04 0.15 8.2
1985 to 2004	25/12 25/12 24/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.98 0.07 3.48	0.41 0.01 0.9	1.96 0.03 2.2	3.7 0.17 7.0
		Preparation, other working areas				
1972 to 1979	68/18 68/18 67/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	5.93 0.34 7.09	0.7 0.02 0.9	2.9 0.14 4.4	10.14 0.62 10.6
1980 to 1984	133/29 133/29 132/29	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.03 0.1 5.81	0.5 0.01 1.0	1.48 0.06 4.0	3.56 0.2 12.0
1985 to 1994	69/21 69/21 65/21	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.1 0.08 8.93	0.16 0.004 0.58	0.91 0.03 4.5	2.14 0.17 21.7
1995 to 2004	186/43 186/43 176/43	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.22 0.08 9.07	0.23 0.005 0.5	0.88 0.02 3.0	2.07 0.15 25.4
		Moulding shop: general				
1972 to 1984	151/31 151/31 150/31	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.17 0.05 5.66	0.35 0.01 1.0	0.72 0.04 5.0	2.05 0.12 10.0
1985 to 1994	83/25 83/25 80/24	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.6 0.03 6.03	0.13 0.003 1.1	0.37 0.02 4.1	1.38 0.08 10.0

Table 38: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Moulding shop: general (continued)						
1995 to 2004	222/34 222/34 210/34	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.39 0.02 5.81	0.14 0.002 0.6	0.28 0.01 2.8	0.82 0.05 15.3
Moulding shop: pressing						
1972 to 1984	97/27 97/27 97/27	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.97 0.06 6.79	0.35 0.01 2.0	0.74 0.04 5.5	2.0 0.13 15.6
1985 to 1994	59/20 59/20 56/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.51 0.04 6.94	0.17 0.003 1.0	0.35 0.01 4.3	1.03 0.1 14.5
1995 to 2004	191/31 191/31 179/31	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.37 0.02 6.32	0.14 0.002 0.6	0.25 0.01 2.9	0.77 0.05 16.6
Drying, general						
1972 to 2004	17/8 17/8 17/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.91 0.04 2.99	0.17 0.001 0.6	0.42 0.01 2.1	2.53 0.15 6.1
Preparation for firing, general						
1972 to 1984	37/11 37/11 37/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.46 0.08 5.65	0.4 0.01 1.2	1.13 0.06 5.5	2.11 0.16 10.2
1985 to 1994	11/7 11/7 10/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.79 0.06 5.28	0.17 0.001 0.5	0.6 0.01 3.1	1.44 0.05 7.8
1995 to 2004	33/9 33/9 33/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.58 0.02 3.11	0.16 0.002 0.5	0.52 0.01 1.9	1.06 0.04 6.9
Kiln, general						
1972 to 1984	83/22 83/22 83/22	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.83 0.05 7.32	0.29 0.003 0.8	0.61 0.03 4.4	1.6 0.14 8.7
1985 to 1994	35/16 35/16 32/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.35 0.02 5.51	0.16 0.001 1.5	0.26 0.01 4.2	0.74 0.03 9.7
1995 to 2004	96/24 96/24 92/24	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.31 0.02 6.71	0.12 0.003 1.1	0.2 0.01 4.2	0.67 0.05 13.3
Kilns: loading of intermittent firing and tunnel kilns						
1972 to 1984	20/9 20/9 20/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.97 0.05 5.4	0.23 0.02 2.6	0.6 0.03 4.6	1.6 0.12 8.5
1985 to 1994	15/9 15/9 14/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.36 0.02 6.57	0.17 0.002 2.5	0.3 0.02 4.2	0.7 0.04 15.0
1995 to 2004	37/16 37/16 36/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.43 0.03 7.88	0.17 0.003 1.0	0.29 0.02 5.8	1.09 0.08 15.3
Kilns: unloading of intermittent firing and tunnel kilns						
1972 to 1984	30/11 30/11 30/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.72 0.03 4.47	0.3 0.003 0.8	0.6 0.02 3.1	1.3 0.08 7.8

Table 38: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Kilns: unloading of intermittent firing and tunnel kilns (continued)						
1985 to 1994	16/8	Respirable fraction in mg/m³	0.27	0.16	0.24	0.44
	16/8	Quartz in mg/m³	0.02	0.001	0.01	0.03
	15/7	Quartz content in %	5.27	1.2	5.0	9.1
1995 to 2004	46/14	Respirable fraction in mg/m³	0.21	0.12	0.12	0.45
	46/14	Quartz in mg/m³	0.02	0.002	0.01	0.03
	43/14	Quartz content in %	6.71	1.2	5.2	13.3
Finishing work, general						
1972 to 1984	97/28	Respirable fraction in mg/m³	1.64	0.45	0.78	3.18
	97/28	Quartz in mg/m³	0.08	0.01	0.03	0.18
	96/28	Quartz content in %	8.31	1.0	4.2	25.8
1985 to 1994	41/17	Respirable fraction in mg/m³	0.57	0.16	0.4	1.39
	41/17	Quartz in mg/m³	0.02	0.003	0.01	0.05
	40/17	Quartz content in %	4.95	1.0	2.6	10.0
1995 to 2004	95/29	Respirable fraction in mg/m³	0.48	0.13	0.3	0.89
	95/29	Quartz in mg/m³	0.02	0.002	0.007	0.03
	92/29	Quartz content in %	4.06	0.6	2.5	8.2
Finishing: grinding, sawing						
1972 to 1984	47/12	Respirable fraction in mg/m³	1.67	0.45	0.78	2.58
	47/12	Quartz in mg/m³	0.04	0.01	0.03	0.08
	47/12	Quartz content in %	4.87	0.8	3.9	8.0
1985 to 1994	21/8	Respirable fraction in mg/m³	0.47	0.16	0.43	0.73
	21/8	Quartz in mg/m³	0.02	0.005	0.01	0.03
	21/8	Quartz content in %	4.52	1.2	3.1	9.9
1995 to 2004	44/14	Respirable fraction in mg/m³	0.51	0.18	0.32	0.9
	44/14	Quartz in mg/m³	0.01	0.003	0.01	0.02
	43/13	Quartz content in %	2.27	0.6	2.2	3.9
Finishing: sorting, storage						
1972 to 1984	44/18	Respirable fraction in mg/m³	1.75	0.42	0.8	3.36
	44/18	Quartz in mg/m³	0.13	0.01	0.04	0.34
	44/18	Quartz content in %	11.67	1.0	4.4	27.6
1985 to 1994	13/8	Respirable fraction in mg/m³	0.59	0.16	0.25	1.76
	13/8	Quartz in mg/m³	0.03	0.002	0.01	0.09
	12/7	Quartz content in %	7.54	1.34	2.6	16.9
1995 to 2004	27/14	Respirable fraction in mg/m³	0.54	0.13	0.31	1.54
	27/14	Quartz in mg/m³	0.03	0.002	0.01	0.06
	26/14	Quartz content in %	7.17	0.6	3.8	12.6

5.3.3.5 Abrasive devices, manufacture

Grinding wheels, abrasive cutting wheels, scythe stones, and other abrasive devices are employed for the chip-forming machining of various materials. They consist of an abrasive agent such as corundum, silicon carbide or diamond, and a binder, which is either ceramic or organic, such as artificial resin or Bakelite. The abrasive grain and binder are mixed, and generally pressed hydraulically. Abrasive devices employing ceramic binder are fired and hardened with organic binder. The measured data are compiled in Table 39. The measured values for both, quartz and the quartz content, which arise during preparation are notably high.

Table 39:
Exposure data for the manufacture of abrasive devices

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th per-centile value	90th percentile value
Preparation, general						
1972 to 1984	96/12	Respirable fraction in mg/m³	1.15	0.29	0.71	2.63
	96/12	Quartz in mg/m³	0.06	0.01	0.02	0.18
	95/12	Quartz content in %	3.89	1.0	3.0	6.2
1985 to 1994	19/9	Respirable fraction in mg/m³	1.0	0.18	0.73	1.41
	19/9	Quartz in mg/m³	0.07	0.01	0.03	0.24
	18/8	Quartz content in %	12.7	0.6	4.3	35.4
1995 to 2004	94/19	Respirable fraction in mg/m³	1.33	0.18	0.47	2.23
	94/19	Quartz in mg/m³	0.11	0.002	0.02	0.26
	89/18	Quartz content in %	8.86	0.6	4.7	19.3
Shaping: general						
1972 to 1984	47/9	Respirable fraction in mg/m³	0.69	0.25	0.55	1.13
	47/9	Quartz in mg/m³	0.02	0.005	0.01	0.04
	47/9	Quartz content in %	2.96	1.2	2.5	5.9
1985 to 1994	6/6	Respirable fraction in mg/m³	---	---	---	---
	6/6	Quartz in mg/m³	---	---	---	---
	5/5	Quartz content in %	---	---	---	---
1995 to 2004	43/17	Respirable fraction in mg/m³	0.22	0.16	0.16	0.42
	43/17	Quartz in mg/m³	0.01	0.001	0.004	0.02
	37/15	Quartz content in %	3.04	0.5	2.3	6.2
Shaping: pressing						
1972 to 1984	19/6	Respirable fraction in mg/m³	0.56	0.22	0.4	0.83
	19/6	Quartz in mg/m³	0.01	0.004	0.01	0.02
	19/6	Quartz content in %	2.5	1.0	1.6	4.0
1985 to 1994	4/4	Respirable fraction in mg/m³	---	---	---	---
	4/4	Quartz in mg/m³	---	---	---	---
	3/3	Quartz content in %	---	---	---	---
1995 to 2004	33/14	Respirable fraction in mg/m³	0.18	0.16	0.16	0.39
	33/14	Quartz in mg/m³	0.01	0.001	0.005	0.02
	27/12	Quartz content in %	3.32	0.5	3.4	6.2
Shaping: turning, punching, casting						
1972 to 2004	35/11	Respirable fraction in mg/m³	0.7	0.21	0.54	1.15
	35/11	Quartz in mg/m³	0.03	0.002	0.02	0.05
	35/11	Quartz content in %	3.83	1.1	2.2	6.1
Preparation for firing, general						
1972 to 2004	14/6	Respirable fraction in mg/m³	0.45	0.15	0.22	0.98
	14/6	Quartz in mg/m³	0.03	0.002	0.01	0.07
	14/6	Quartz content in %	4.32	1.5	2.5	9.6
Kiln, general						
1972 to 1984	17/6	Respirable fraction in mg/m³	0.94	0.15	0.4	1.89
	17/6	Quartz in mg/m³	0.04	0.003	0.01	0.1
	17/6	Quartz content in %	3.29	1.0	3.0	5.1
1985 to 1994	6/4	Respirable fraction in mg/m³	---	---	---	---
	6/4	Quartz in mg/m³	---	---	---	---
	6/4	Quartz content in %	---	---	---	---

Table 39: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th per-centile value	90th percentile value
Kiln, general (continued)						
1995 to 2004	27/10 27/10 24/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.21 0.02 8.09	0.16 0.002 2.3	0.17 0.01 6.1	0.38 0.05 14.7
Finishing work, general						
1972 to 1984	10/4 10/4 10/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.56 0.01 3.34	0.25 0.003 1.0	0.45 0.01 1.1	0.8 0.03 3.7
1985 to 1994	10/4 10/4 10/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.56 0.02 3.0	0.18 0.001 0.6	0.27 0.004 1.1	1.46 0.04 6.7
1995 to 2004	54/15 54/15 49/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.34 0.02 4.35	0.15 0.001 1.0	0.2 0.01 2.3	0.71 0.02 9.1
Finishing: grinding, turning						
1972 to 1984	7/3 7/3 7/3	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1985 to 1994	8/4 8/4 8/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1995 to 2004	50/14 50/14 45/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.33 0.01 3.31	0.15 0.001 0.7	0.19 0.01 2.2	0.64 0.02 8.8

5.3.3.6 Porcelain and fine ceramic bodies, manufacture

50% kaolin, 25% quartz and 25% feldspar can be regarded as the standard composition of porcelain. The hard quartz and feldspar materials are milled ultrafine in drum mills and mixed into the kaolin slurry. The kaolin is dissolved in vats with the aid of blungers. The slurry is either processed directly, or is dewatered in filter presses.
A third process is the manufacture of granulate by jetting of the slurry into a spray tower. Since the mid-1970s, porcelain factories have increasingly gone over to obtaining the substance ready-prepared from raw-material manufacturers rather than preparing it themselves. Rotationally symmetrical geometries are turned or rolled on machines. At the casting stage, the slurry is poured into plaster-of-paris moulds. The hygroscopic property of the plaster-of-paris causes a ceramic body to be produced at the boundary layer. The surplus slick is poured out and the blank de-formed. Since the end of the 1980s, large runs have been manufactured by the isostatic pressing of spray-dried powder. Seams and burrs are scraped off the dried blanks (see Figure 19), and the latter fettled and sponged off. Biscuit firing lends the blank the necessary

strength for subsequent glazing. This is followed by glost firing, and possibly also by decoration firing.

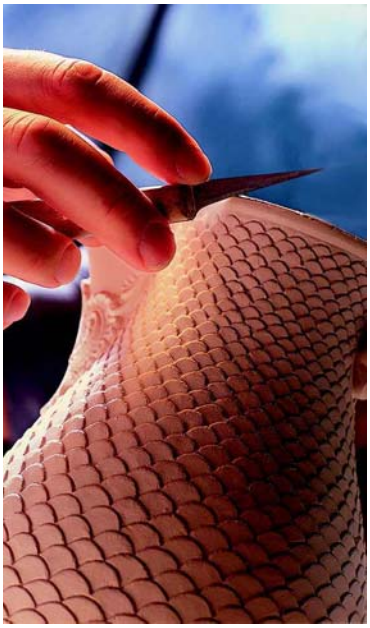


Figure 19:
Manufacture of porcelain whiteware

In order to allow for good stackability, the bases are ground. The quartz dust situation has been improved over time in all areas of the porcelain industry. Table 40 shows the exposure data.

Table 40:
Exposure data for the production of porcelain and fine ceramic bodies

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation, general						
1972 to 1984	135/34	Respirable fraction in mg/m³	1.88	0.4	1.0	3.18
	135/34	Quartz in mg/m³	0.41	0.01	0.12	0.76
	135/34	Quartz content in %	14.17	2.5	9.2	36.0
1985 to 1994	59/20	Respirable fraction in mg/m³	0.73	0.22	0.62	1.33
	59/20	Quartz in mg/m³	0.11	0.01	0.04	0.33
	59/20	Quartz content in %	13.22	2.0	9.7	32.5
1995 to 2004	92/29	Respirable fraction in mg/m³	0.45	0.1	0.34	0.94
	92/29	Quartz in mg/m³	0.03	0.003	0.01	0.07
	88/27	Quartz content in %	6.58	1.0	5.0	15.3
Preparation, dry						
1972 to 1984	43/16	Respirable fraction in mg/m³	2.03	0.27	0.9	3.89
	43/16	Quartz in mg/m³	0.49	0.01	0.11	0.71
	43/16	Quartz content in %	14.65	3.3	10.3	38.9
1985 to 1994	14/9	Respirable fraction in mg/m³	0.74	0.18	0.47	1.62
	14/9	Quartz in mg/m³	0.11	0.005	0.03	0.26
	14/9	Quartz content in %	12.06	1.2	8.2	29.8

Table 40: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation, dry (continued)						
1995 to 2004	12/5 12/5 12/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.6 0.05 5.81	0.18 0.01 1.1	0.62 0.01 4.0	1.1 0.06 8.6
Preparation, wet						
1972 to 1984	37/19 37/19 37/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.72 0.32 15.03	0.39 0.01 1.8	1.23 0.14 8.0	3.22 0.93 40.4
1985 to 1994	17/9 17/9 17/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.57 0.11 15.18	0.17 0.01 2.0	0.43 0.03 7.9	0.99 0.39 38.6
1995 to 2004	39/20 39/20 38/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.36 0.03 6.82	0.14 0.002 1.1	0.28 0.02 5.6	0.77 0.06 15.5
Shaping: general						
1972 to 1984	205/41 205/41 203/41	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.69 0.04 5.36	0.3 0.01 2.0	0.6 0.03 5.0	1.18 0.07 8.9
1985 to 1994	154/44 154/44 151/44	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.36 0.02 6.57	0.13 0.01 2.5	0.25 0.02 5.8	0.81 0.05 10.5
1995 to 2004	363/65 363/65 331/63	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.24 0.01 5.1	0.1 0.002 1.3	0.17 0.01 4.7	0.5 0.03 8.9
Shaping: pressing						
1972 to 1984	24/17 24/17 24/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.98 0.06 5.76	0.47 0.01 1.3	0.85 0.05 4.8	1.58 0.1 9.6
1985 to 1994	27/11 27/11 27/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.41 0.03 7.58	0.13 0.01 3.3	0.28 0.02 5.9	0.96 0.06 10.5
1995 to 2004	32/14 32/14 30/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.27 0.02 5.87	0.16 0.003 1.1	0.2 0.01 5.3	0.52 0.03 11.1
Shaping: turning, rolling						
1972 to 1984	91/29 91/29 91/29	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.62 0.03 4.77	0.3 0.01 2.0	0.55 0.02 4.7	1.0 0.06 7.4
1985 to 1994	37/12 37/12 36/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.39 0.03 7.26	0.14 0.01 3.1	0.34 0.02 6.1	0.78 0.05 11.9
1995 to 2004	66/32 66/32 60/31	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.18 0.01 4.76	0.17 0.002 1.5	0.17 0.01 3.9	0.37 0.02 8.5
Shaping: casting						
1972 to 1984	82/29 82/29 80/28	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.68 0.04 5.88	0.25 0.01 2.5	0.6 0.03 5.7	1.15 0.08 9.0
1985 to 1994	66/25 66/25 64/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.31 0.02 6.65	0.15 0.01 2.7	0.2 0.02 6.3	0.77 0.06 9.8

Table 40: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Shaping: casting (continued)						
1995 to 2004	117/45 117/45 109/44	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.23 0.01 4.37	0.1 0.002 1.34	0.13 0.01 4.2	0.5 0.02 7.6
Shaping: isostatic pressing						
1972 to 1984	-- -- --	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	-- -- --	-- -- --	-- -- --	-- -- --
1985 to 1994	4/3 4/3 4/3	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	-- -- --	-- -- --	-- -- --	-- -- --
1995 to 2004	100/22 100/22 92/22	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.25 0.02 6.14	0.13 0.003 1.3	0.19 0.01 6.3	0.52 0.04 9.9
Drying, general						
1972 to 2004	25/17 25/17 24/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.4 0.02 5.39	0.14 0.003 1.3	0.24 0.01 5.2	0.91 0.05 7.9
Preparation for firing, general						
1972 to 1984	210/40 210/40 208/40	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.75 0.05 5.75	0.25 0.01 2.0	0.6 0.03 5.0	1.4 0.1 9.2
1985 to 1994	209/52 209/52 202/51	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.28 0.02 7.2	0.14 0.01 2.8	0.2 0.02 5.9	0.62 0.06 12.3
1995 to 2004	410/68 410/68 363/67	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.19 0.01 4.79	0.11 0.001 1.1	0.11 0.01 3.9	0.38 0.03 9.0
Preparation for firing: fettling, garnishing						
1972 to 1984	137/35 137/35 136/35	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.86 0.06 5.9	0.29 0.01 2.7	0.65 0.03 5.8	1.53 0.11 9.2
1985 to 1994	135/39 135/39 131/38	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.31 0.03 7.42	0.15 0.01 3.2	0.22 0.02 5.9	0.73 0.06 12.0
1995 to 2004	233/54 233/54 214/52	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.2 0.01 4.66	0.12 0.002 1.1	0.12 0.01 3.9	0.42 0.02 7.7
Preparation for firing: glazing (excluding spray-glazing)						
1972 to 1984	43/19 43/19 42/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.47 0.02 4.38	0.15 0.002 1.0	0.43 0.02 4.2	0.8 0.05 8.0
1985 to 1994	35/18 35/18 34/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.21 0.02 8.26	0.15 0.004 2.4	0.17 0.01 6.1	0.38 0.06 17.7
1995 to 2004	110/35 110/35 94/35	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.16 0.01 4.74	0.11 0.001 1.1	0.11 0.005 2.9	0.26 0.02 10.4
Preparation for firing: spray-glazing						
1972 to 1984	19/10 19/10 19/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.82 0.06 8.61	0.35 0.01 3.2	0.63 0.04 5.2	1.33 0.11 9.4

Table 40: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation for firing: spray-glazing (continued)						
1985 to 1994	28/15	Respirable fraction in mg/m³	0.31	0.18	0.23	0.59
	28/15	Quartz in mg/m³	0.02	0.005	0.02	0.03
	28/15	Quartz content in %	5.4	2.0	4.4	9.5
1995 to 2004	45/22	Respirable fraction in mg/m³	0.24	0.14	0.14	0.5
	45/22	Quartz in mg/m³	0.02	0.001	0.01	0.08
	34/20	Quartz content in %	6.72	0.6	3.9	15.2
Kiln, general						
1972 to 1984	60/28	Respirable fraction in mg/m³	0.53	0.25	0.45	0.9
	60/28	Quartz in mg/m³	0.02	0.01	0.02	0.04
	60/28	Quartz content in %	4.02	1.8	3.6	6.0
1985 to 1994	38/22	Respirable fraction in mg/m³	0.17	0.12	0.12	0.32
	38/22	Quartz in mg/m³	0.01	0.002	0.01	0.03
	37/21	Quartz content in %	4.7	1.3	3.4	9.1
1995 to 2004	66/26	Respirable fraction in mg/m³	0.11	0.09	0.09	0.19
	66/26	Quartz in mg/m³	0.01	0.001	0.005	0.01
	55/24	Quartz content in %	3.83	0.8	2.8	7.8
Finishing work, general						
1972 to 1984	91/31	Respirable fraction in mg/m³	0.71	0.17	0.4	0.95
	91/31	Quartz in mg/m³	0.02	0.002	0.001	0.04
	90/31	Quartz content in %	3.49	0.5	2.0	8.0
1985 to 1994	36/19	Respirable fraction in mg/m³	0.15	0.15	0.15	0.25
	36/19	Quartz in mg/m³	0.008	0.001	0.01	0.02
	35/19	Quartz content in %	3.17	0.6	2.8	6.3
1995 to 2004	153/31	Respirable fraction in mg/m³	0.19	0.11	0.11	0.35
	153/31	Quartz in mg/m³	0.01	0.001	0.004	0.02
	133/31	Quartz content in %	3.21	0.6	2.2	6.2
Finishing: grinding, polishing						
1972 to 1984	61/24	Respirable fraction in mg/m³	0.78	0.15	0.4	1.23
	61/24	Quartz in mg/m³	0.01	0.002	0.01	0.02
	60/24	Quartz content in %	3.06	0.5	2.0	6.7
1985 to 1994	17/13	Respirable fraction in mg/m³	0.13	0.17	0.17	0.25
	17/13	Quartz in mg/m³	0.01	0.001	0.005	0.01
	16/13	Quartz content in %	2.81	0.9	2.8	4.6
1995 to 2004	95/28	Respirable fraction in mg/m³	0.23	0.11	0.11	0.36
	95/28	Quartz in mg/m³	0.01	0.001	0.005	0.02
	82/28	Quartz content in %	3.55	0.6	2.7	7.7
Finishing: storage						
1972 to 1984	23/16	Respirable fraction in mg/m³	0.59	0.2	0.4	0.9
	23/16	Quartz in mg/m³	0.04	0.002	0.01	0.04
	23/16	Quartz content in %	3.41	1.0	2.0	6.9
1985 to 1994	10/6	Respirable fraction in mg/m³	0.1	0.15	0.15	0.15
	10/6	Quartz in mg/m³	0.01	0.001	0.01	0.02
	10/6	Quartz content in %	3.75	0.5	2.8	8.3
1995 to 2004	53/20	Respirable fraction in mg/m³	0.14	0.14	0.14	0.23
	53/20	Quartz in mg/m³	0.01	0.001	0.003	0.01
	46/19	Quartz content in %	2.62	0.7	1.7	5.8

5.3.3.7 Utility stoneware and fine stoneware, manufacture; clay and pottery ware, manufacture

The raw materials for crockery and ornamental ware are clays, in some cases also chamotte (fired clay) with particle sizes of < 0.1 to 0.2 mm. Preparation, shaping and drying are similar to the corresponding processes for porcelain. Following drying, the blanks are painted, dipped, coated or sprayed with glaze, and then fired. The exposure data are compiled in Table 41; Figure 20 shows a typical workplace in a pottery.

Figure 20:
Manual work at the potter's wheel

Table 41:
Exposure data for the manufacture of utility stoneware and fine stoneware and of clay and pottery ware

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
		Preparation, general				
1972 to 1984	93/22	Respirable fraction in mg/m³	1.61	0.35	0.9	3.09
	93/22	Quartz in mg/m³	0.16	0.02	0.07	0.29
	93/22	Quartz content in %	8.98	3.6	8.3	12.5
1985 to 1994	7/5	Respirable fraction in mg/m³	---	---	---	---
	7/5	Quartz in mg/m³	---	---	---	---
	7/5	Quartz content in %	---	---	---	---
1995 to 2004	25/9	Respirable fraction in mg/m³	0.47	0.18	0.38	0.87
	25/9	Quartz in mg/m³	0.02	0.004	0.02	0.05
	25/9	Quartz content in %	5.17	1.1	5.3	8.6
		Shaping: general				
1972 to 1984	156/33	Respirable fraction in mg/m³	0.93	0.4	0.7	1.61
	156/33	Quartz in mg/m³	0.06	0.02	0.04	0.1
	156/33	Quartz content in %	6.2	3.3	5.7	9.1
1985 to 1994	57/27	Respirable fraction in mg/m³	0.52	0.13	0.44	0.94
	57/27	Quartz in mg/m³	0.04	0.01	0.02	0.09
	57/27	Quartz content in %	7.01	2.7	6.9	11.4

Table 41: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
		Shaping: general (continued)				
1995 to 2004	107/45	Respirable fraction in mg/m³	0.33	0.14	0.26	0.63
	107/45	Quartz in mg/m³	0.03	0.004	0.02	0.06
	101/45	Quartz content in %	8.3	1.7	8.0	14.5
		Shaping: pressing				
1972 to 1984	44/9	Respirable fraction in mg/m³	1.11	0.5	0.9	1.91
	44/9	Quartz in mg/m³	0.07	0.02	0.06	0.13
	44/9	Quartz content in %	6.38	4.0	5.7	9.3
1985 to 1994	12/8	Respirable fraction in mg/m³	0.51	0.18	0.35	1.07
	12/8	Quartz in mg/m³	0.05	0.002	0.04	0.1
	12/8	Quartz content in %	7.33	1.1	6.5	12.6
1995 to 2004	31/12	Respirable fraction in mg/m³	0.26	0.14	0.14	0.57
	31/12	Quartz in mg/m³	0.02	0.003	0.01	0.03
	27/12	Quartz content in %	4.64	1.3	3.3	8.5
		Shaping: turning, moulding				
1972 to 1984	58/19	Respirable fraction in mg/m³	1.05	0.34	0.71	1.8
	58/19	Quartz in mg/m³	0.06	0.02	0.04	0.1
	58/19	Quartz content in %	6.32	3.1	5.7	9.1
1985 to 1994	17/11	Respirable fraction in mg/m³	0.58	0.18	0.43	1.03
	17/11	Quartz in mg/m³	0.05	0.01	0.02	0.09
	17/11	Quartz content in %	7.68	2.7	7.7	11.5
1995 to 2004	52/26	Respirable fraction in mg/m³	0.37	0.18	0.3	0.65
	52/26	Quartz in mg/m³	0.04	0.01	0.03	0.07
	51/26	Quartz content in %	9.89	4.8	9.2	16.2
		Shaping: casting				
1972 to 1984	50/21	Respirable fraction in mg/m³	0.62	0.4	0.6	0.85
	50/21	Quartz in mg/m³	0.04	0.02	0.03	0.06
	50/21	Quartz content in %	5.86	3.1	5.5	8.0
1985 to 1994	13/8	Respirable fraction in mg/m³	0.6	0.17	0.45	0.98
	13/8	Quartz in mg/m³	0.05	0.01	0.03	0.1
	13/8	Quartz content in %	6.94	2.6	6.9	10.9
1995 to 2004	22/13	Respirable fraction in mg/m³	0.31	0.18	0.22	0.53
	22/13	Quartz in mg/m³	0.03	0.005	0.02	0.06
	21/13	Quartz content in %	9.12	1.8	9.3	14.0
		Preparation for firing, general				
1972 to 1984	170/43	Respirable fraction in mg/m³	1.3	0.18	0.7	1.85
	170/43	Quartz in mg/m³	0.08	0.01	0.04	0.15
	168/43	Quartz content in %	6.47	2.9	5.9	10.0
1985 to 1994	81/35	Respirable fraction in mg/m³	0.53	0.14	0.4	0.89
	81/35	Quartz in mg/m³	0.04	0.01	0.03	0.07
	81/35	Quartz content in %	7.6	2.3	7.4	13.7
1995 to 2004	82/38	Respirable fraction in mg/m³	0.33	0.12	0.24	0.64
	82/38	Quartz in mg/m³	0.02	0.003	0.02	0.05
	77/37	Quartz content in %	7.39	1.1	7.8	13.8
		Preparation for firing: fettling, garnishing				
1972 to 1984	94/28	Respirable fraction in mg/m³	1.74	0.42	0.8	2.49
	94/28	Quartz in mg/m³	0.12	0.02	0.05	0.25
	94/28	Quartz content in %	7.15	3.3	7.0	10.4
1985 to 1994	25/13	Respirable fraction in mg/m³	0.56	0.12	0.41	1.16
	25/13	Quartz in mg/m³	0.05	0.01	0.03	0.1
	25/13	Quartz content in %	9.16	2.6	8.7	14.1

Table 41: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation for firing: fettling, garnishing (continued)						
1995 to 2004	33/19 33/19 33/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.36 0.04 9.92	0.17 0.01 1.6	0.25 0.03 10.3	0.64 0.06 14.9
Preparation for firing: glazing (excluding spray-glazing)						
1972 to 1984	22/16 22/16 22/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.89 0.04 4.75	0.17 0.01 2.0	0.35 0.01 3.3	1.39 0.06 9.4
1985 to 1994	16/11 16/11 16/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.55 0.05 9.03	0.21 0.01 5.0	0.36 0.03 8.7	0.99 0.09 13.4
1995 to 2004	29/20 29/20 29/20	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.35 0.02 5.88	0.12 0.004 1.1	0.22 0.01 5.7	0.63 0.04 10.1
Preparation for firing: spray-glazing						
1972 to 1984	42/17 42/17 40/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.67 0.03 5.24	0.18 0.01 2.6	0.5 0.03 5.4	0.98 0.06 7.8
1985 to 1994	31/17 31/17 31/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.51 0.02 5.4	0.14 0.01 1.1	0.39 0.02 4.8	0.89 0.04 9.9
1995 to 2004	18/11 18/11 14/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.26 0.01 4.7	0.18 0.001 0.9	0.18 0.01 5.0	0.76 0.02 7.6
Kiln, general						
1972 to 1984	47/19 47/19 47/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.55 0.02 4.22	0.24 0.01 1.7	0.53 0.02 4.2	0.92 0.05 6.3
1985 to 1994	13/9 13/9 13/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.47 0.03 6.12	0.12 0.004 1.9	0.21 0.01 4.7	1.19 0.09 8.1
1995 to 2004	22/13 22/13 22/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.17 0.01 4.64	0.12 0.001 0.7	0.12 0.01 3.3	0.33 0.03 10.0
Finishing work, general						
1972 to 1984	43/13 43/13 43/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.86 0.84 8.6	0.22 0.01 1.9	0.55 0.03 5.2	11.0 0.83 11.6
1985 to 1994	6/4 6/4 6/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1995 to 2004	10/8 10/8 10/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.14 0.01 2.98	0.14 0.002 1.1	0.14 0.003 1.6	0.23 0.01 7.0
Finishing: grinding, polishing						
1972 to 2004	22/9 22/9 22/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	6.97 1.62 13.85	0.21 0.02 3.9	1.55 0.08 10.9	18.21 2.6 16.3
Finishing: storage						
1972 to 2004	34/18 34/18 34/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.42 0.02 4.16	0.14 0.002 1.1	0.25 0.01 3.6	0.78 0.04 8.2

5.3.3.8 Wall/floor tiles, stove tiles and heavy ceramics, manufacture

The substance from which tiles are manufactured consists of clay, kaolin, and mineral loading agents such as feldspar, dolomite and chamotte. The raw materials are milled ultrafine in drum mills. The slick is sprayed into a spray tower. The spray granulate or in some cases dry-press body is formed on hydraulic presses to produce tiles. Tiles may be fired by means of the once-fired method (see Figure 21), or the glaze applied in the second firing. Stove tiles are pressed from plastic body; complex geometries are also cast. The glaze is applied by immersion, pouring, spraying or painting. The exposure data are shown in Table 42.

Figure 21:
Tile production in a fast-firing kiln

Table 42:
Exposure data for the manufacture of wall and floor tiles,
stove tiles and heavy ceramics

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation, general						
1972 to 1984	154/31	Respirable fraction in mg/m³	3.0	0.44	1.65	7.76
	154/31	Quartz in mg/m³	0.36	0.03	0.18	0.91
	154/31	Quartz content in %	10.99	5.0	10.0	17.9
1985 to 1994	90/28	Respirable fraction in mg/m³	0.85	0.16	0.55	1.9
	90/28	Quartz in mg/m³	0.07	0.01	0.05	0.15
	90/28	Quartz content in %	8.84	2.8	8.4	14.6
1995 to 2004	141/28	Respirable fraction in mg/m³	0.79	0.18	0.63	1.35
	141/28	Quartz in mg/m³	0.07	0.005	0.04	0.17
	134/28	Quartz content in %	7.98	1.6	8.0	14.8
Preparation, dry						
1972 to 1984	25/11	Respirable fraction in mg/m³	2.82	0.5	1.83	6.43
	25/11	Quartz in mg/m³	0.36	0.04	0.18	0.94
	24/11	Quartz content in %	11.38	4.0	9.6	18.2

Table 42: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th per-centile value
		Preparation, dry (continued)				
1985 to 1994	29/5	Respirable fraction in mg/m³	0.79	0.18	0.39	1.91
	29/5	Quartz in mg/m³	0.08	0.01	0.04	0.2
	29/5	Quartz content in %	10.19	4.15	9.05	16.2
1995 to 2004	20/7	Respirable fraction in mg/m³	1.05	0.29	0.74	1.33
	20/7	Quartz in mg/m³	0.13	0.01	0.06	0.17
	20/7	Quartz content in %	8.69	1.2	8.3	16.8
		Preparation, wet				
1972 to 1984	24/10	Respirable fraction in mg/m³	2.31	0.46	1.0	3.35
	24/10	Quartz in mg/m³	0.26	0.02	0.08	0.31
	24/10	Quartz content in %	8.74	3.4	8.4	13.0
1985 to 2004	32/17	Respirable fraction in mg/m³	1.1	0.28	1.01	1.95
	32/17	Quartz in mg/m³	0.1	0.01	0.07	0.2
	32/17	Quartz content in %	8.86	2.24	8.5	15.0
		Preparation, glazing				
1972 to 1994	38/16	Respirable fraction in mg/m³	1.41	0.27	0.72	3.23
	38/16	Quartz in mg/m³	0.12	0.01	0.05	0.24
	38/16	Quartz content in %	8.59	2.2	7.9	14.7
1995 to 2004	31/10	Respirable fraction in mg/m³	0.67	0.18	0.43	1.32
	31/10	Quartz in mg/m³	0.06	0.005	0.02	0.17
	30/10	Quartz content in %	6.72	1.0	4.7	11.9
		Shaping: general				
1972 to 1984	194/34	Respirable fraction in mg/m³	1.63	0.4	1.0	3.67
	194/34	Quartz in mg/m³	0.14	0.03	0.07	0.35
	194/34	Quartz content in %	8.07	4.9	7.9	10.9
1985 to 1994	122/32	Respirable fraction in mg/m³	0.76	0.21	0.64	1.44
	122/32	Quartz in mg/m³	0.08	0.02	0.05	0.16
	122/32	Quartz content in %	10.27	4.7	9.7	16.5
1995 to 2004	124/40	Respirable fraction in mg/m³	0.58	0.16	0.48	1.09
	124/40	Quartz in mg/m³	0.05	0.01	0.04	0.09
	120/40	Quartz content in %	8.29	3.2	8.3	12.6
		Shaping: pressing				
1972 to 1984	152/29	Respirable fraction in mg/m³	1.85	0.44	1.15	4.17
	152/29	Quartz in mg/m³	0.17	0.03	0.09	0.44
	152/29	Quartz content in %	8.54	5.2	8.0	11.5
1985 to 1994	82/17	Respirable fraction in mg/m³	0.83	0.23	0.69	1.48
	82/17	Quartz in mg/m³	0.1	0.02	0.07	0.21
	82/17	Quartz content in %	10.77	5.0	10.1	16.5
1995 to 2004	94/29	Respirable fraction in mg/m³	0.61	0.16	0.59	1.11
	94/29	Quartz in mg/m³	0.06	0.01	0.05	0.1
	90/29	Quartz content in %	8.29	2.2	8.3	13.2
		Shaping: turning, moulding				
1972 to 2004	30/14	Respirable fraction in mg/m³	0.66	0.2	0.57	1.14
	30/14	Quartz in mg/m³	0.05	0.01	0.04	0.08
	30/14	Quartz content in %	7.95	3.2	7.6	10.5
		Shaping: casting				
1972 to 1984	24/11	Respirable fraction in mg/m³	0.88	0.44	0.8	1.35
	24/11	Quartz in mg/m³	0.06	0.02	0.04	0.11
	24/11	Quartz content in %	6.17	3.1	6.0	8.3
1985 to 1994	18/10	Respirable fraction in mg/m³	0.49	0.17	0.43	0.86
	18/10	Quartz in mg/m³	0.04	0.01	0.03	0.07
	18/10	Quartz content in %	9.37	3.6	8.8	15.4

Table 42: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Shaping: casting (continued)						
1995 to 2004	11/9 11/9 11/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.47 0.04 7.77	0.17 0.01 3.9	0.45 0.03 7.3	0.73 0.08 9.8
Drying, general						
1972 to 2004	39/21 39/21 39/21	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.98 0.11 9.55	0.18 0.004 2.2	0.73 0.06 8.6	2.07 0.22 14.6
Preparation for firing, general						
1972 to 1984	78/26 78/26 77/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.02 0.06 5.82	0.39 0.01 1.9	0.75 0.04 5.6	1.66 0.14 9.1
1985 to 1994	159/30 159/30 159/30	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.83 0.05 6.13	0.18 0.01 1.7	0.66 0.03 5.3	1.65 0.12 10.9
1995 to 2004	140/37 140/37 134/36	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.34 0.02 5.34	0.13 0.002 1.1	0.26 0.01 4.8	0.74 0.05 10.0
Preparation for firing: fettling, garnishing						
1972 to 1984	22/9 22/9 22/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.16 0.07 5.36	0.47 0.01 2.3	0.9 0.04 4.2	2.03 0.16 8.1
1985 to 1994	36/12 36/12 36/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.6 0.05 7.96	0.18 0.01 1.2	0.39 0.03 7.5	1.36 0.11 11.3
1995 to 2004	19/9 19/9 17/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.4 0.03 6.68	0.18 0.001 1.6	0.41 0.02 6.7	0.74 0.06 8.9
Preparation for firing: glazing (excluding spray-glazing)						
1972 to 1984	35/15 35/15 35/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.08 0.06 6.0	0.36 0.01 1.9	0.82 0.04 5.6	1.66 0.14 10.9
1985 to 1994	79/18 79/18 79/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.82 0.04 5.26	0.18 0.01 1.9	0.57 0.03 4.4	1.65 0.12 10.2
1995 to 2004	90/21 90/21 87/20	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.36 0.02 5.22	0.13 0.003 1.1	0.28 0.01 4.2	0.75 0.04 10.6
Preparation for firing: spray-glazing						
1972 to 1984	21/8 21/8 20/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.77 0.06 6.02	0.3 0.01 1.5	0.6 0.03 5.3	1.27 0.11 9.1
1985 to 1994	41/13 41/13 41/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.06 0.06 5.78	0.44 0.01 1.6	0.81 0.05 4.7	1.91 0.16 9.9
1995 to 2004	23/13 23/13 23/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.25 0.01 5.08	0.13 0.003 1.1	0.22 0.01 5.0	0.4 0.02 8.6
Kiln, general						
1972 to 1984	64/24 64/24 64/24	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.01 0.08 7.15	0.27 0.01 1.7	0.65 0.04 6.0	1.89 0.16 13.5

Table 42: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Kiln, general (continued)						
1985 to 1994	40/16	Respirable fraction in mg/m³	0.3	0.16	0.26	0.53
	40/16	Quartz in mg/m³	0.02	0.01	0.02	0.03
	40/16	Quartz content in %	6.19	2.2	6.1	10.0
1995 to 2004	63/25	Respirable fraction in mg/m³	0.28	0.14	0.19	0.64
	63/25	Quartz in mg/m³	0.02	0.002	0.01	0.04
	61/25	Quartz content in %	4.97	1.1	4.6	9.0
Finishing work, general						
1972 to 1984	89/26	Respirable fraction in mg/m³	1.15	0.39	0.8	1.82
	89/26	Quartz in mg/m³	0.08	0.01	0.04	0.13
	88/26	Quartz content in %	6.34	2.9	5.7	11.2
1985 to 1994	75/19	Respirable fraction in mg/m³	0.7	0.14	0.48	1.37
	75/19	Quartz in mg/m³	0.06	0.01	0.03	0.14
	75/19	Quartz content in %	7.91	3.3	7.1	13.3
1995 to 2004	96/32	Respirable fraction in mg/m³	0.33	0.16	0.23	0.62
	96/32	Quartz in mg/m³	0.03	0.004	0.01	0.05
	93/32	Quartz content in %	6.49	1.6	5.5	12.3
Finishing: grinding, polishing						
1972 to 1984	28/12	Respirable fraction in mg/m³	1.53	0.4	0.76	2.08
	28/12	Quartz in mg/m³	0.12	0.02	0.04	0.21
	28/12	Quartz content in %	6.69	2.5	6.6	9.7
1985 to 1994	31/13	Respirable fraction in mg/m³	0.92	0.2	0.79	1.66
	31/13	Quartz in mg/m³	0.08	0.01	0.06	0.18
	31/13	Quartz content in %	8.11	3.4	7.8	2.3
1995 to 2004	33/15	Respirable fraction in mg/m³	0.51	0.17	0.33	1.13
	33/15	Quartz in mg/m³	0.05	0.005	0.03	0.1
	32/15	Quartz content in %	8.94	1.6	7.8	13.2
Finishing: storage						
1972 to 1984	58/19	Respirable fraction in mg/m³	0.99	0.34	0.85	1.55
	58/19	Quartz in mg/m³	0.07	0.01	0.04	0.1
	57/19	Quartz content in %	6.21	2.9	5.6	11.3
1985 to 1994	43/9	Respirable fraction in mg/m³	0.54	0.14	0.28	0.99
	43/9	Quartz in mg/m³	0.04	0.01	0.02	0.12
	43/9	Quartz content in %	7.68	3.2	6.5	13.7
1995 to 2004	58/18	Respirable fraction in mg/m³	0.22	0.16	0.2	0.46
	58/18	Quartz in mg/m³	0.01	0.004	0.01	0.03
	56/18	Quartz content in %	5.48	2.0	4.4	10.3

5.3.3.9 Sanitary, technical, and chemical/technical electrical ceramics: manufacture

Sanitary ceramics encompass washbasins and wash tables, toilet bowls, and urinals. The raw materials are milled in drum mills. The slurry which is produced is cast in plaster-of-paris moulds. The hygroscopic property of the plaster-of-paris causes a ceramic body to be produced at the boundary layer. The surplus slick is poured out and the blank de-formed. Following drying, a glazing layer is generally sprayed on.

The blank is then fired. Since the mid-1980s, high-quality sanitary ceramics have been finished by grinding or by sawing to size.

The area of electroceramics encompasses electrical porcelain for the manufacture of insulators, cordierite for electrical heaters, and steatite for high-frequency insulating components or capacitors. Special oxides are also employed for piezoelectric materials, magnetic materials, NTC and PTC thermistors, and resistors. The preparation, shaping and firing processes reflect the raw material concerned. The exposure data are compiled in Table 43. In the most recent period, from 1995 to 2004, 90th percentile values close to 0.15 mg/m³ are found for quartz, owing to increasingly complex processing steps following drying.

Table 43:
Exposure data for the manufacture of sanitary ceramics and of technical and technical/chemical electroceramics

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
		Preparation				
1972 to 1984	69/16 69/16 69/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.41 0.13 8.58	0.35 0.01 1.1	1.15 0.07 7.0	2.54 0.24 11.2
1985 to 1994	49/16 49/16 47/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.93 0.13 7.78	0.14 0.002 0.9	0.49 0.02 3.4	2.34 0.15 14.6
1995 to 2004	91/21 91/21 84/21	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.45 0.04 6.69	0.11 0.002 1.0	0.34 0.01 4.2	0.75 0.07 17.4
		Preparation, dry				
1972 to 1984	19/7 19/7 19/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.74 0.14 8.25	0.64 0.02 1.1	1.55 0.08 7.6	2.8 0.37 11.2
1985 to 1994	7/4 7/4 7/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1995 to 2004	12/4 12/4 12/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.82 0.1 9.13	0.15 0.001 0.5	0.37 0.01 4.4	2.29 0.29 22.1
		Preparation, wet				
1972 to 2004	30/16 30/16 28/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.99 0.09 7.44	0.14 0.002 0.8	0.4 0.02 2.2	2.32 0.07 17.9
		Shaping: general				
1972 to 1984	161/19 161/19 160/19	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.96 0.04 4.53	0.31 0.01 1.5	0.75 0.03 3.7	1.69 0.09 8.0

Table 43: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Shaping: general (continued)						
1985 to 1994	61/21	Respirable fraction in mg/m³	0.56	0.14	0.39	1.07
	61/21	Quartz in mg/m³	0.04	0.002	0.02	0.09
	60/21	Quartz content in %	5.6	1.2	4.6	9.9
1995 to 2004	240/30	Respirable fraction in mg/m³	0.52	0.15	0.3	0.95
	240/30	Quartz in mg/m³	0.04	0.002	0.01	0.05
	227/29	Quartz content in %	4.76	0.8	4.0	9.5
Shaping: pressing						
1972 to 1984	48/8	Respirable fraction in mg/m³	0.9	0.32	0.7	1.41
	48/8	Quartz in mg/m³	0.02	0.01	0.02	0.04
	47/8	Quartz content in %	2.58	1.2	2.2	3.3
1985 to 1994	22/9	Respirable fraction in mg/m³	0.33	0.14	0.22	0.64
	22/9	Quartz in mg/m³	0.02	0.002	0.01	0.04
	21/9	Quartz content in %	4.32	1.2	3.9	7.5
1995 to 2004	94/26	Respirable fraction in mg/m³	0.25	0.15	0.18	0.49
	94/26	Quartz in mg/m³	0.01	0.001	0.01	0.02
	91/26	Quartz content in %	3.91	0.6	3.0	10.0
Shaping: turning, punching						
1972 to 2004	46/15	Respirable fraction in mg/m³	0.65	0.18	0.6	1.17
	46/15	Quartz in mg/m³	0.03	0.002	0.02	0.06
	45/15	Quartz content in %	4.31	1.0	3.8	7.9
Shaping: casting						
1972 to 1984	73/13	Respirable fraction in mg/m³	0.96	0.34	0.8	1.59
	73/13	Quartz in mg/m³	0.06	0.01	0.04	0.11
	73/13	Quartz content in %	6.11	2.9	6.7	8.4
1985 to 1994	27/10	Respirable fraction in mg/m³	0.7	0.2	0.55	1.28
	27/10	Quartz in mg/m³	0.07	0.01	0.04	0.16
	27/10	Quartz content in %	8.35	3.8	7.9	11.9
1995 to 2004	119/8	Respirable fraction in mg/m³	0.78	0.15	0.49	1.33
	119/8	Quartz in mg/m³	0.07	0.005	0.02	0.07
	115/8	Quartz content in %	5.65	1.1	5.4	9.3
Drying, general						
1972 to 2004	18/4	Respirable fraction in mg/m³	0.47	0.18	0.44	0.74
	18/4	Quartz in mg/m³	0.02	0.004	0.01	0.04
	16/3	Quartz content in %	4.55	2.2	2.9	8.8
Preparation for firing, general						
1972 to 1984	101/14	Respirable fraction in mg/m³	1.11	0.36	0.87	1.94
	101/14	Quartz in mg/m³	0.09	0.02	0.07	0.18
	101/14	Quartz content in %	8.03	3.0	8.0	11.9
1985 to 1994	52/14	Respirable fraction in mg/m³	0.48	0.16	0.29	1.03
	52/14	Quartz in mg/m³	0.04	0.003	0.02	0.08
	51/14	Quartz content in %	6.86	1.7	7.2	11.1
1995 to 2004	164/25	Respirable fraction in mg/m³	0.67	0.12	0.24	1.46
	164/25	Quartz in mg/m³	0.06	0.003	0.02	0.16
	157/25	Quartz content in %	6.83	1.2	6.8	11.5
Preparation for firing: fettling, garnishing						
1972 to 1984	44/13	Respirable fraction in mg/m³	1.39	0.35	1.0	2.88
	44/13	Quartz in mg/m³	0.12	0.01	0.08	0.23
	44/13	Quartz content in %	7.21	1.9	7.8	10.0
1985 to 1994	17/7	Respirable fraction in mg/m³	0.6	0.16	0.38	1.6
	17/7	Quartz in mg/m³	0.06	0.003	0.02	0.18
	16/7	Quartz content in %	7.65	1.0	8.1	13.4

Table 43: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation for firing: fettling, garnishing (continued)						
1995 to 2004	76/19 76/19 71/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.91 0.08 6.27	0.16 0.003 1.1	0.28 0.02 6.8	1.96 0.18 11.0
Preparation for firing: glazing (excluding spray-glazing)						
1972 to 1984	16/9 16/9 16/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.82 0.07 9.08	0.38 0.02 3.2	0.8 0.07 7.4	1.09 0.11 14.8
1985 to 1994	8/1 8/1 8/1	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1995 to 2004	28/9 28/9 26/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.38 0.04 8.69	0.14 0.004 2.0	0.2 0.02 7.8	0.96 0.13 16.5
Preparation for firing: spray-glazing						
1972 to 1984	25/8 25/8 25/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.82 0.07 9.16	0.35 0.02 3.0	0.68 0.06 8.4	1.45 0.14 17.1
1985 to 1994	16/7 16/7 16/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.49 0.05 7.48	0.18 0.004 2.0	0.31 0.02 8.5	0.7 0.07 10.5
1995 to 2004	51/13 51/13 51/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.55 0.05 6.62	0.12 0.003 1.1	0.23 0.02 6.6	1.32 0.13 10.6
Kiln, general						
1972 to 1984	51/13 51/13 51/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.63 0.05 6.23	0.2 0.01 2.3	0.58 0.03 5.0	1.05 0.1 10.0
1985 to 1994	7/4 7/4 7/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1995 to 2004	32/12 32/12 29/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.2 0.01 3.9	0.18 0.002 1.1	0.18 0.01 2.8	0.39 0.03 6.9
Finishing work, general						
1972 to 1984	58/14 58/14 58/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.91 0.05 6.05	0.3 0.01 1.1	0.5 0.02 4.4	1.06 0.06 9.1
1985 to 1994	29/10 29/10 28/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.56 0.01 2.49	0.18 0.002 0.5	0.33 0.01 1.7	1.07 0.02 5.7
1995 to 2004	125/26 125/26 118/26	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.36 0.01 3.92	0.13 0.001 0.6	0.25 0.01 2.5	0.79 0.03 8.7
Finishing: grinding, polishing						
1972 to 1984	39/12 39/12 39/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.57 0.04 6.62	0.3 0.01 1.3	0.5 0.02 4.7	0.86 0.06 9.1
1985 to 1994	18/7 18/7 17/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.45 0.01 2.53	0.18 0.002 0.5	0.37 0.01 1.4	0.77 0.02 4.6

Table 43: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Finishing: grinding, polishing (continued)						
1995 to 2004	83/24 83/24 80/24	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.45 0.02 3.59	0.13 0.002 0.6	0.34 0.01 2.1	1.01 0.04 8.4
Finishing: storage						
1972 to 1984	13/4 13/4 13/4	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.97 0.08 4.58	0.35 0.01 1.0	0.73 0.04 3.6	5.66 0.07 8.0
1985 to 1994	5/3 5/3 5/3	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1995 to 2004	28/10 28/10 24/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.13 0.01 4.4	0.15 0.001 0.8	0.15 0.01 3.3	0.26 0.02 9.2

5.3.3.10 Hollow glassware, manufacture and working

Important examples of hollow glassware are glassware for the gastromony sector, such as drinking-glasses, bowls, etc., and packaging glassware, such as bottles and jars. However, this category also includes special products such as glass construction elements, TV screens, Christmas decorations, and tubular glass for ampoules. The raw materials, primarily quartz, sodium and alkali carbonates and alkaline earth oxides, are metered in according to the recipe and homogenized in mixers. The materials continue to be loaded manually into pot furnaces. The raw materials are fed by batch-charging machines to the melting furnace (see Figure 22), which operate continuously.

Figure 22:
Loading of the mixture into the melting furnace

The molten glass is processed further in droplets or in the form of parisons. The geometries are produced by pressing or blowing. Engineered ventilation measures now enable the 90th percentile value for quartz to be reduced in all areas to virtually one-tenth of 0.15 mg/m³ (see Table 44).

Table 44:
Exposure data for the manufacture and working of hollow glassware

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation, feeding in, general						
1972 to 1984	76/26 76/26 70/23	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.92 0.07 11.83	0.11 0.001 0.7	0.5 0.01 2.2	1.97 0.14 40.0
1985 to 1994	60/28 60/28 55/26	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.54 0.05 9.26	0.11 0.001 0.4	0.37 0.01 2.2	1.35 0.13 28.0
1995 to 2004	163/35 163/35 120/34	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.41 0.01 3.17	0.13 0.001 0.5	0.22 0.003 1.1	1.06 0.02 5.0
Trough, general						
1972 to 1984	21/6 21/6 20/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.43 0.02 4.42	0.06 0.002 0.8	0.28 0.005 3.1	1.03 0.05 10.0
1985 to 1994	17/9 17/9 16/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.31 0.02 4.84	0.06 0.001 0.7	0.14 0.01 5.8	0.54 0.04 9.3
1995 to 2004	43/18 43/18 26/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.28 0.004 1.54	0.12 0.001 0.4	0.12 0.002 0.9	0.47 0.01 2.7
Shaping and tempering, general						
1972 to 1984	36/8 36/8 29/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.44 0.01 1.83	0.17 0.001 1.0	0.37 0.01 1.0	0.81 0.02 4.3
1985 to 1994	31/17 31/17 23/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.24 0.03 4.12	0.12 0.001 0.6	0.12 0.002 1.4	0.48 0.01 4.1
1995 to 2004	73/28 73/28 50/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.19 0.002 1.15	0.1 0.001 0.4	0.1 0.001 0.8	0.29 0.004 1.8
Finishing work, general						
1972 to 1984	72/18 72/18 71/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.83 0.03 6.17	0.23 0.003 0.5	0.51 0.01 2.1	1.68 0.06 13.3
1985 to 1994	49/19 49/19 43/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.35 0.01 6.36	0.14 0.001 0.4	0.25 0.003 1.1	0.63 0.02 7.5
1995 to 2004	96/35 96/35 79/30	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.48 0.01 3.7	0.09 0.001 0.4	0.21 0.003 1.1	1.09 0.02 10.7

Table 44: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Finishing: grinding, polishing						
1972 to 1984	63/17 63/17 62/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.84 0.03 5.61	0.23 0.002 0.5	0.5 0.02 2.1	1.6 0.06 11.1
1985 to 1994	36/15 36/15 31/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.38 0.01 1.42	0.17 0.001 0.4	0.28 0.003 0.9	0.61 0.02 2.2
1995 to 2004	78/30 78/30 64/26	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.5 0.01 3.31	0.09 0.001 0.4	0.23 0.003 1.1	1.0 0.03 5.7
Finishing: storage						
1972 to 2004	38/16 38/16 34/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.41 0.03 11.76	0.14 0.001 0.5	0.19 0.01 2.0	1.16 0.06 35.7

5.3.3.11 Sand-lime brick, manufacture

Sand and lime are mixed. The quicklime slakes in the reactor to form calcium hydroxide. The optimum press moisture is attained by the addition of water. The bricks are formed on hydraulic presses. In autoclaves for masonry bricks, the brick blank acquires its strength by the formation of a silicate compound, which is determined by the heat and the vapour pressure. Dust exhaust measures are difficult to implement downstream of the reactor, as lines very quickly become blocked. Relatively high values for the respirable fraction are consequently measured, resulting in turn in high quartz values. Corresponding exposure data are compiled in Table 45.

Table 45:
Exposure data for the manufacture of limestone bricks

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation, general						
1972 to 1984	29/15 29/15 29/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.66 0.09 2.48	0.51 0.01 0.7	2.43 0.02 1.1	6.72 0.29 6.2
1985 to 1994	16/12 16/12 14/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.79 0.03 1.99	0.31 0.01 0.3	1.38 0.02 1.1	3.18 0.05 3.8
1995 to 2004	14/11 14/11 13/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.64 0.02 7.05	0.16 0.003 1.0	0.44 0.01 2.0	0.138 0.04 20.4

Table 45: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Pressing, general						
1972 to 1984	42/18 42/18 42/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.98 0.06 2.95	0.45 0.01 0.9	1.2 0.02 1.1	3.72 0.12 8.2
1985 to 1994	65/26 65/26 63/23	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.11 0.02 2.45	0.28 0.01 0.69	0.83 0.02 1.9	2.18 0.05 4.2
1995 to 2004	142/56 142/56 135/56	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.67 0.01 2.13	0.15 0.002 0.6	0.54 0.01 1.7	1.42 0.03 4.3
Autoclave, general						
1972 to 2004	10/6 10/6 8/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.27 0.04 ---	0.18 0.001 ---	0.24 0.02 ---	3.35 0.13 ---
Finishing work, general						
1972 to 1984	33/11 33/11 33/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.35 0.05 5.03	0.19 0.003 1.0	0.95 0.05 3.7	3.25 0.09 12.1
1985 to 1994	13/8 13/8 13/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.9 0.04 5.22	0.31 0.003 1.0	0.69 0.03 2.2	1.43 0.11 15.2
1995 to 2004	58/26 58/26 52/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.4 0.03 6.27	0.11 0.002 1.1	0.26 0.01 5.0	0.92 0.08 13.4
Finishing: sawing, milling						
1972 to 1984	27/10 27/10 27/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.44 0.05 4.42	0.19 0.003 1.0	1.03 0.04 2.0	3.42 0.09 8.0
1985 to 1994	6/5 6/5 6/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---
1995 to 2004	36/15 36/15 32/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.46 0.04 7.71	0.15 0.004 1.34	0.26 0.02 6.7	0.96 0.11 15.4
Finishing: storage						
1972 to 2004	21/17 21/17 19/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.42 0.02 3.69	0.11 0.001 1.1	0.15 0.01 2.1	0.93 0.05 6.1

5.3.4 Foundries

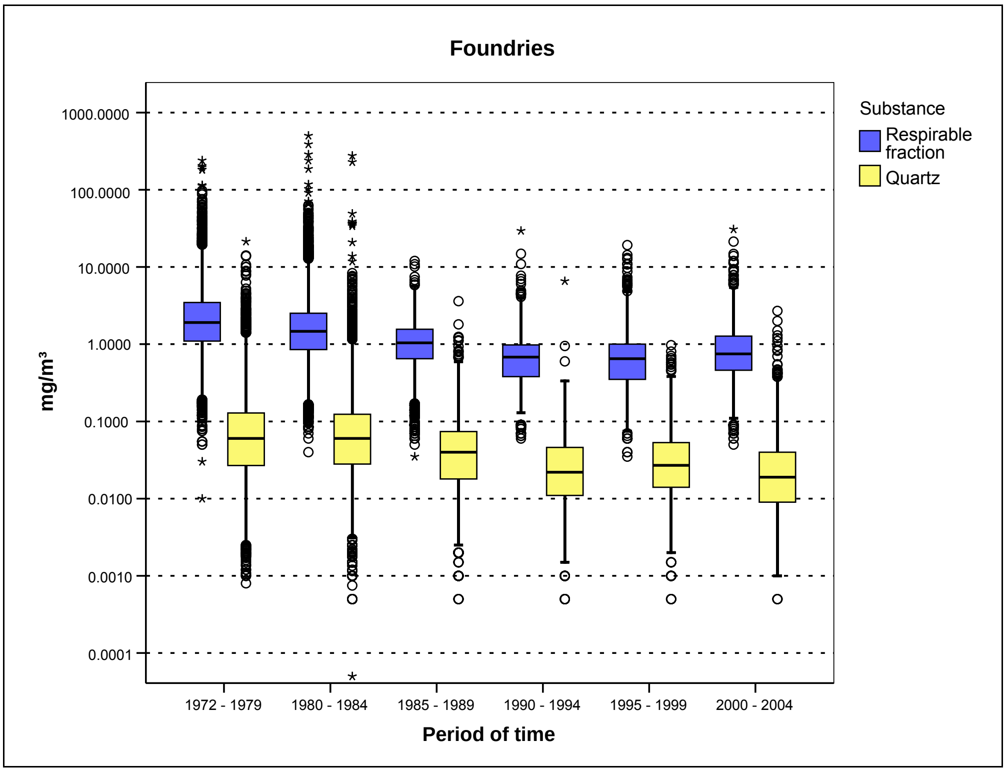
Foundries are industrial plants in which materials are shaped by casting (Figure 23, see page 108). In the casting process, a liquid material (the melt, generally metal) is poured into moulds, where it solidifies to form a casting. In terms of production technology, casting is primary forming. A distinction is drawn between the following casting processes: sand casting, shell casting, permanent mould casting, gravity die casting, centrifugal casting and art casting. Processes are further distinguished according to the casting material group: cast iron and steel, and non-ferrous metal casting. Foundries provide the quickest and most direct means by which a wide range of metal products may be given their shape. The trend in the exposure is shown in Table 46 and Figure 24.

Figure 23:
Casting process in a casting bay

Table 46:
Exposure data in foundries (all working areas)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	10,546/569 10,546/569 10,538/568	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.29 0.2 4.79	0.62 0.01 1.0	1.91 0.06 3.0	6.46 0.28 10.0
1980 to 1984	14,342/529 14,342/529 14,278/525	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.38 0.18 6.18	0.48 0.01 1.0	1.47 0.06 4.4	4.37 0.25 12.2
1985 to 1989	4,198/348 4,198/348 4,186/348	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.18 0.06 5.53	0.38 0.008 1.1	1.04 0.04 4.1	2.14 0.13 10.9
1990 to 1994	1,905/298 1,905/298 1,872/296	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.8 0.04 5.26	0.22 0.006 1.0	0.68 0.02 3.8	1.35 0.08 10.7
1995 to 1999	1,397/249 1,397/249 1,330/244	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.89 0.05 5.94	0.21 0.006 1.3	0.65 0.03 4.4	1.54 0.1 12.2
2000 to 2004	1,236/230 1,236/230 1,119/221	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.17 0.05 4.37	0.27 0.005 0.6	0.75 0.02 2.5	2.39 0.09 9.2

Figure 24:
Trend in mean shift values for the concentration of the respirable dust fraction and the quartz concentration in foundries



Sand preparation

A final sand is produced which is suitable for use in a mould in sand or shell casting or coremaking. In sand casting, the sand recovered when the castings are de-formed generally serves as the basis for the final sand, i.e. the used sand is recycled and prepared accordingly. The used sand component recovered through screening and exhaust installations or removed together with the castings must be supplemented by the addition of fresh sand. Sand preparation comprises the following steps: collection of the used sand, removal of sand lumps and metal impurities, cooling of the used sand, and mixing with additives consisting of binders, water, fresh sand, and other substances for enhancement of the quality. A continual drop in the respirable dust fraction was recorded in the period from 1972 to 1989 (see Table 47, page 110). In the course of technical progress, the mixers were encapsulated/equipped with direct exhaust systems. The state of the art appears to have been reached in the period from 1990 to 2004, and no further drops in the respirable dust fraction can be attained.

Table 47:
Exposure data for sand preparation

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	782/250	Respirable fraction in mg/m³	3.78	0.82	2.51	8.12
	782/250	Quartz in mg/m³	0.18	0.02	0.08	0.4
	782/250	Quartz content in %	4.84	1.0	3.0	10.0
1980 to 1984	1,042/235	Respirable fraction in mg/m³	2.5	0.62	1.79	4.81
	1,042/235	Quartz in mg/m³	0.15	0.02	0.07	0.23
	1,041/234	Quartz content in %	5.76	1.5	3.8	10.5
1985 to 1989	241/84	Respirable fraction in mg/m³	1.29	0.38	1.2	2.24
	241/84	Quartz in mg/m³	0.08	0.01	0.04	0.13
	240/84	Quartz content in %	6.22	1.3	3.5	11.5
1990 to 1994	75/47	Respirable fraction in mg/m³	0.82	0.17	0.69	1.35
	75/47	Quartz in mg/m³	0.03	0.006	0.02	0.08
	73/46	Quartz content in %	5.7	1.1	3.1	11.8
1995 to 1999	39/25	Respirable fraction in mg/m³	0.83	0.26	0.67	1.59
	39/25	Quartz in mg/m³	0.04	0.007	0.03	0.08
	35/24	Quartz content in %	4.94	1.3	4.1	8.5
2000 to 2004	37/24	Respirable fraction in mg/m³	0.96	0.3	0.78	1.71
	37/24	Quartz in mg/m³	0.03	0.01	0.02	0.07
	33/20	Quartz content in %	3.96	1.0	3.7	5.8

Coremaking

Cores are required in order to produce recesses or intricate cavities in castings. A distinction is drawn between destructible cores, such as sand cores, which are used for a single casting only and are destroyed when the casting is de-formed or during fettling, and permanent cores manufactured from metal, which can be re-used. Figure 25 shows a typical coremaking workplace.

Figure 25:
Immersion of the finished cores in facing solution

A continual drop in the respirable dust fraction was recorded in the period from 1972 to 1989 (see Table 48). Since 1990, the majority of coremaking machines have been encapsulated/equipped with dust exhaust. The sand mixers connected to them have also been encapsulated. The arrangements for handling the sand, formerly involving open hoppers with a large drop height, were converted progressively to enclosed systems in the period up to 1990.

Table 48:
Exposure data for coremaking

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	960/285	Respirable fraction in mg/m³	1.31	0.35	0.91	2.57
	960/285	Quartz in mg/m³	0.12	0.01	0.04	0.18
	960/285	Quartz content in %	7.35	1.0	4.5	15.8
1980 to 1984	1,569/293	Respirable fraction in mg/m³	1.11	0.18	0.81	2.22
	1,569/293	Quartz in mg/m³	0.09	0.01	0.05	0.18
	1,562/291	Quartz content in %	8.57	1.6	5.5	17.6
1985 to 1989	472/147	Respirable fraction in mg/m³	0.86	0.18	0.73	1.64
	472/147	Quartz in mg/m³	0.07	0.008	0.04	0.15
	470/147	Quartz content in %	8.0	1.5	5.2	17.0
1990 to 1994	353/147	Respirable fraction in mg/m³	0.53	0.09	0.45	0.96
	353/147	Quartz in mg/m³	0.04	0.005	0.02	0.09
	345/145	Quartz content in %	7.65	1.7	5.0	18.5
1995 to 1999	213/105	Respirable fraction in mg/m³	0.53	0.09	0.43	0.92
	213/105	Quartz in mg/m³	0.04	0.004	0.02	0.08
	208/105	Quartz content in %	8.08	1.5	5.0	16.7
2000 to 2004	213/97	Respirable fraction in mg/m³	0.56	0.1	0.47	1.08
	213/97	Quartz in mg/m³	0.03	0.005	0.01	0.05
	192/89	Quartz content in %	5.4	0.8	2.9	12.1

Moulding shop

In the manufacture of casting moulds (see Figure 26, page 112), and of sand moulds in particular, a distinction is drawn between manual moulding and mechanized moulding. Manual moulding includes the manufacture of sand moulds for smaller castings on a moulder's bench or flour moulding in a moulding pit. In mechanized moulding, moulding machines with pattern plates are employed.

During the period from 1972 to 1989, large numbers of mould halves were held in store, and were blown off in order to clean them prior to use. The moulds are still blown off; the area downstream of this process is now exhausted. The exposure data are shown in Table 49 (see page 112).

Figure 26:
Knocking out of moulding boxes following casting

Table 49:
Exposure data for the moulding shop

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	2,213/430	Respirable fraction in mg/m³	2.26	0.68	1.7	4.27
	2,213/430	Quartz in mg/m³	0.09	0.01	0.05	0.18
	2,213/430	Quartz content in %	4.29	1.0	3.0	8.9
1980 to 1984	3,051/372	Respirable fraction in mg/m³	1.73	0.51	1.33	3.16
	3,051/372	Quartz in mg/m³	0.09	0.01	0.05	0.2
	3,041/371	Quartz content in %	5.66	1.0	4.2	11.5
1985 to 1989	1,016/224	Respirable fraction in mg/m³	1.19	0.46	1.04	2.02
	1,016/224	Quartz in mg/m³	0.06	0.009	0.04	0.11
	1,016/224	Quartz content in %	4.71	1.0	3.7	9.0
1990 to 1994	509/164	Respirable fraction in mg/m³	0.86	0.32	0.79	1.4
	509/164	Quartz in mg/m³	0.03	0.007	0.02	0.07
	506/164	Quartz content in %	4.47	0.9	3.5	9.0
1995 to 1999	403/139	Respirable fraction in mg/m³	0.85	0.3	0.72	1.44
	403/139	Quartz in mg/m³	0.06	0.01	0.03	0.11
	386/135	Quartz content in %	6.35	1.6	4.6	13.2
2000 to 2004	286/115	Respirable fraction in mg/m³	1.11	0.38	0.84	2.14
	286/115	Quartz in mg/m³	0.04	0.005	0.02	0.08
	261/114	Quartz content in %	3.82	0.6	2.3	8.2

Melting shop

In order for the materials, particularly metals and their alloys, to be cast into shape, they must be melted into the liquid state (see Figure 27). The solid metals and alloys are melted in the melting furnace by the application of heat. Various property requirements are met by a suitable form of firing and by treatment with chemical or physical agents.

Figure 27:
Liquid metal is transferred to the casting ladle

Quartz sand is not used in the melting shop itself; any quartz dust present in the melting shop is carried there on the air from the adjacent casting shop and moulding shop. In the past, metal was received for recycling which had not been blasted and was still contaminated with quartz sand. Material is now increasingly blasted prior to being recycled. The exposure data are shown in Table 50.

Table 50:
Exposure data in the melting shop

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	739/265	Respirable fraction in mg/m³	3.13	0.65	2.0	5.89
	739/265	Quartz in mg/m³	0.16	0.01	0.03	0.13
	738/265	Quartz content in %	3.42	1.0	1.0	5.9
1980 to 1984	1,225/254	Respirable fraction in mg/m³	2.43	0.56	1.59	4.97
	1,225/254	Quartz in mg/m³	0.06	0.007	0.03	0.15
	1,218/250	Quartz content in %	3.28	0.5	2.0	7.4
1985 to 1989	320/101	Respirable fraction in mg/m³	1.31	0.53	1.21	2.31
	320/101	Quartz in mg/m³	0.04	0.006	0.02	0.08
	318/101	Quartz content in %	3.18	0.5	2.2	6.4
1990 to 1994	133/62	Respirable fraction in mg/m³	0.77	0.3	0.7	1.3
	133/62	Quartz in mg/m³	0.02	0.005	0.02	0.05
	129/60	Quartz content in %	2.72	0.6	2.0	5.4
1995 to 1999	79/46	Respirable fraction in mg/m³	0.79	0.2	0.69	1.39
	79/46	Quartz in mg/m³	0.02	0.002	0.015	0.04
	74/46	Quartz content in %	2.53	0.5	2.1	5.1
2000 to 2004	110/61	Respirable fraction in mg/m³	1.38	0.28	0.78	3.27
	110/61	Quartz in mg/m³	0.05	0.005	0.02	0.04
	101/57	Quartz content in %	2.5	0.7	1.9	5.0

Casting operations

Casting is the insertion of a liquid material into a mould in which, under the influence of gravity, centrifugal force or pressure, it assumes the geometry of the desired finished product, and in which it solidifies. Brushing vacuum cleaners were not used for cleaning of the shops until 1990. The dust exposure was therefore greater before this time (see Table 51).

Table 51:
Exposure data for casting operations

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Casting operations						
1972 to 1979	502/212 502/212 501/211	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.16 0.12 3.75	0.62 0.01 1.0	1.51 0.04 2.0	4.17 0.14 7.2
1980 to 1984	864/184 864/184 861/183	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.95 0.08 4.64	0.6 0.01 0.6	1.51 0.05 3.2	3.36 0.15 8.8
1985 to 1989	249/77 249/77 249/77	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.13 0.04 3.43	0.45 0.004 0.5	0.98 0.02 2.4	2.03 0.09 7.4
1990 to 1994	129/57 129/57 126/56	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.78 0.03 3.49	0.26 0.004 0.5	0.71 0.02 3.0	1.31 0.06 6.8
1995 to 1999	101/56 101/56 95/52	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.84 0.02 3.32	0.21 0.003 0.6	0.66 0.02 2.6	1.29 0.05 7.2
2000 to 2004	87/49 87/49 78/44	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.92 0.03 3.08	0.37 0.005 0.6	0.66 0.01 1.7	1.92 0.06 5.2
Casting bay, general operations						
1972 to 1979	1,176/320 1,176/320 1,176/320	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.36 0.17 5.31	0.82 0.02 1.0	2.4 0.09 4.0	7.08 0.37 10.0
1980 to 1984	1,590/275 1,590/275 1,589/275	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.23 0.15 7.08	0.58 0.03 2.0	1.6 0.09 5.7	4.34 0.3 13.8
1985 to 1989	483/149 483/149 482/149	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.27 0.07 5.9	0.45 0.01 1.5	1.13 0.05 5.0	2.11 0.15 10.9
1990 to 1994	149/81 149/81 147/81	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.9 0.05 5.59	0.32 0.008 0.9	0.8 0.03 4.5	1.66 0.1 12.6
1995 to 1999	165/61 165/61 155/58	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.82 0.06 6.78	0.22 0.009 1.7	0.67 0.04 5.4	1.39 0.12 13.1
2000 to 2004	136/71 136/71 123/66	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.09 0.05 4.45	0.33 0.005 0.8	0.86 0.02 3.3	2.31 0.11 8.8

Fettling and blasting

Fettling describes the work performed on the raw casting (see Figure 28) which is retrieved from the mould following cooling. A distinction is drawn between coarse and fine fettling. Fine fettling includes final blasting with blasting agent consisting of metal, non-ferrous metal, e.g. ore, and formerly also quartz sand, corundum or plastics, which are blasted or projected at the castings/workpieces. Closed fettling booths were the norm by 1990. Their airtightness was, however, in some cases unsatisfactory, as was the exhaust performance on the blasting installations. The current state of the art was achieved in 1990 (see Table 52).

Figure 28:
Once cooled, the casting is fettled by means of an angle grinder, for example in order to remove inclusions

Table 52:
Exposure data for fettling and blasting

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Fettling and blasting						
1972 to 1979	461/183 461/183 461/183	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.68 0.18 6.38	0.68 0.02 1.0	1.82 0.08 4.9	5.24 0.34 12.9
1980 to 1984	930/214 930/214 927/214	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.74 0.14 8.19	0.46 0.02 2.3	1.4 0.08 6.9	3.37 0.29 15.3
1985 to 1989	271/89 271/89 270/89	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.12 0.09 7.21	0.42 0.01 2.2	1.0 0.05 5.4	1.98 0.18 15.7
1990 to 1994	76/40 76/40 76/40	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.74 0.06 7.03	0.23 0.007 1.3	0.67 0.04 5.5	1.36 0.12 12.5

Table 52: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Fettling and blasting (continued)						
1995 to 1999	59/39 59/39 53/36	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.29 0.07 6.18	0.21 0.01 2.4	0.58 0.04 5.4	2.96 0.15 10.2
2000 to 2004	57/33 57/33 46/29	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.16 0.05 3.44	0.32 0.003 0.5	0.64 0.02 1.8	2.23 0.1 8.0
Fettling						
1972 to 1979	2,649/447 2,649/447 2,647/447	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.59 0.4 4.66	0.76 0.02 1.0	2.51 0.08 3.0	8.71 0.37 10.0
1980 to 1984	3,271/393 3,271/393 3,245/389	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.3 0.17 5.97	0.53 0.01 1.0	1.87 0.08 4.5	5.94 0.35 12.0
1985 to 1989	963/196 963/196 960/196	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.29 0.07 5.65	0.4 0.01 1.5	1.18 0.05 4.5	2.32 0.16 10.9
1990 to 1994	403/148 403/148 393/148	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.94 0.05 5.31	0.21 0.007 1.4	0.67 0.02 4.2	1.45 0.08 9.3
1995 to 1999	284/120 284/120 273/118	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.22 0.05 5.56	0.21 0.008 1.5	0.67 0.03 4.6	2.17 0.11 11.0
2000 to 2004	260/115 260/115 241/109	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.72 0.08 4.83	0.29 0.005 0.7	0.85 0.02 2.8	4.03 0.18 10.0

Removal of refractory linings

Refractory linings are removed from melting furnaces either manually, by means of suitable tools such as a hammer and chisel, or by means of a suitable pneumatic hammer. Alternatively, the used refractory materials are forced out by means of hydraulic rams.

Up until 1985, refractory linings were removed manually by means of suitable tools, which resulted in high dust exposure. In later periods, the inside walls of the melting furnace were doused with suitable solutions prior to removal of the material, and the dust exposure thus reduced. Cupola furnaces are now peeled from the inside beginning in the area with the strongest erosion, and subsequently relined. Work involving high dust generation is now performed during the night shift where possible. Exposure data are shown in Table 53.

Table 53:
Exposure data for the removal of refractory linings

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	76/28 76/28 76/28	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	8.09 0.67 8.44	0.89 0.01 1.0	4.27 0.18 4.1	21.58 1.91 17.4
1980 to 1984	105/40 105/40 105/40	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	6.0 0.9 10.41	1.18 0.03 1.0	3.36 0.15 5.7	11.71 1.83 25.9
1985 to 1989	18/6 18/6 18/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.6 0.17 9.78	0.6 0.01 1.2	1.45 0.04 2.5	2.73 0.43 32.6
1990 to 2004	16/7 16/7 16/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.31 0.2 10.64	0.46 0.01 0.8	0.98 0.04 4.0	2.27 0.54 26.2

Other areas of foundry work

Further areas of activity within the foundry include all maintenance and cleaning work in the casting bay, i.e. various cleaning tasks involving industrial vacuum cleaners, sweeping machines, brooms, shovels and other tools; the inspection, maintenance and cleaning of various dust collection facilities; and the lining of furnaces and casting ladles, casting tanks and launders. The area of casting also includes the construction of models and permanent moulds. Table 54 shows the exposure data.

Table 54:
Exposure data for other working areas within foundries

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	988/241 988/241 984/240	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.14 0.1 3.62	0.44 0.009 1.0	1.7 0.04 2.0	8.17 0.19 7.8
1980 to 1984	695/160 695/160 989/158	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.66 1.27 6.29	0.37 0.007 0.5	1.44 0.04 3.2	7.14 0.25 11.6
1985 to 1989	165/71 165/71 163/70	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.9 0.04 5.25	0.18 0.004 0.6	0.7 0.02 3.0	1.95 0.1 11.6
1990 to 1994	74/32 74/32 73/32	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.94 0.03 3.72	0.2 0.002 0.6	0.58 0.02 2.9	2.07 0.06 8.7
1995 to 1999	52/20 52/20 49/20	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.91 0.02 3.84	0.15 0.003 1.0	0.44 0.02 2.8	1.46 0.05 6.2
2000 to 2004	40/24 40/24 34/22	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.64 0.06 6.38	0.23 0.005 0.7	0.84 0.02 1.8	2.67 0.16 18.3

5.3.5 Metals manufacture

Iron ore is treated and converted to pig iron in a blast furnace. The pig iron is in turn melted, with the addition of scrap, in steel plants in suitable melting furnaces such as open-hearth or electric steel furnaces, and converted into steel. Exposure to dust containing quartz must be anticipated in the blast furnace and rolling mill, specifically in the furnace house and casting bay, at the permanent moulds and in the fettling shop. Exposure to quartz also occurs during the handling of slag, during maintenance work on crucibles and furnaces, and during the removal and replacement of refractory linings.

Since 1990, vacuum brusher machines have increasingly been used for the cleaning of shops. This has enabled the dust exposure to be reduced (see Table 55). In this area, occupational health and safety has benefited from the increasingly tighter environmental standards: effective dust collection installations have had the effect of reducing the dust exposure in the furnace shops.

Table 55:
Exposure data in metal production (all working areas)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1976 to 1984	505/39 505/39 484/39	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.31 0.06 2.76	0.38 0.003 0.2	1.87 0.01 0.5	8.35 0.09 4.8
1985 to 1989	193/28 193/28 189/28	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.11 0.02 1.71	0.26 0.002 0.3	1.09 0.008 0.7	3.56 0.04 4.0
1990 to 1994	49/18 49/18 47/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.89 0.01 1.79	0.21 0.002 0.5	0.76 0.007 0.9	1.46 0.04 4.4
1995 to 1999	66/15 66/15 60/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.86 0.14 4.56	0.23 0.002 0.6	0.61 0.006 0.9	1.52 0.03 4.6
2000 to 2004	38/12 38/12 37/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.49 0.01 0.92	0.23 0.002 0.7	0.78 0.01 0.7	2.57 0.02 1.6

5.3.6 Metalworking, machine and vehicle manufacture

A large number of methods are employed for the shaping, cutting and joining of metals and for modification of the material properties, by which workpieces are ultimately produced. Cutting processes include machining with geometric cutting tools, e.g. turning, drilling, planing, sawing, milling and filing, and with geometrically undefined cutting tools, e.g. grinding, honing, lapping, polishing and blasting. The joining processes include the various welding and soldering methods.

Processes such as hardening and annealing are employed for modification of the properties of a metal. In the processing methods referred to above, materials containing quartz are employed, such as blasting shot and special welding-electrode casings. Therefore, exposure of employees to quartz cannot be excluded.

Up until 1989, polishing pastes or blasting shot containing quartz were frequently used in methods for the surface treatment of metals, as were welding-electrode casings containing quartz. The comprehensive improvements to dust collection facilities and ventilation technology and modernization of the methods and machinery used for processing led to a reduction in the dust exposure (see Figure 29 and Table 56).

Figure 29:
Trend in average shift values for the concentration of the respirable dust fraction and the quartz concentration in metalworking and in machine and vehicle manufacture

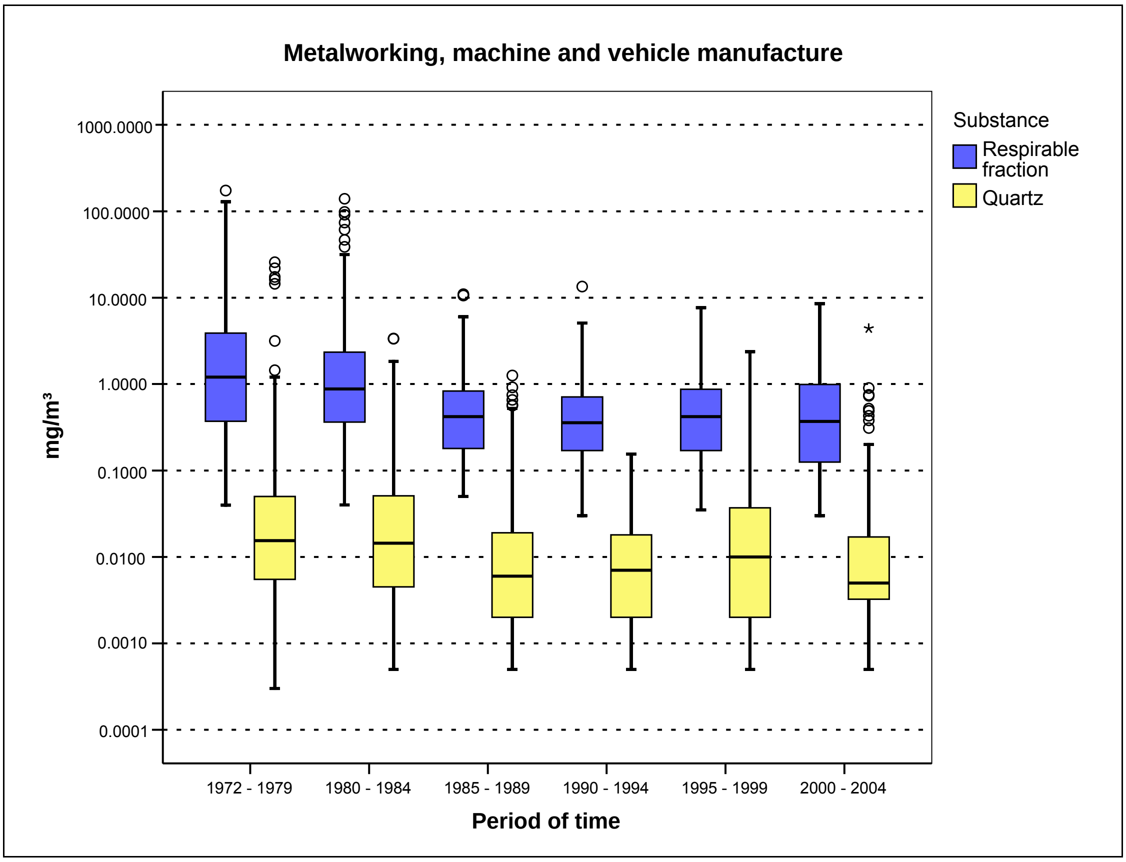


Table 56:
Exposure data in metalworking and in machine and vehicle manufacture
(all working areas)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	695/148 695/148 684/147	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.75 0.21 3.38	0.18 0.002 0.5	1.2 0.02 1.0	9.33 0.15 9.5
1980 to 1984	1,090/308 1,090/308 993/285	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.09 0.07 5.0	0.18 0.002 0.3	0.88 0.01 1.0	7.9 0.17 12.6
1985 to 1989	625/189 625/189 577/185	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.68 0.03 4.93	0.09 0.001 0.4	0.42 0.006 1.2	1.42 0.07 12.2
1990 to 1994	214/92 214/92 179/82	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.63 0.02 4.47	0.09 0.001 0.5	0.36 0.007 1.1	1.36 0.05 10.7
1995 to 1999	274/108 274/108 222/96	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.7 0.05 5.5	0.08 0.001 0.4	0.42 0.01 2.0	1.37 0.07 14.4
2000 to 2004	200/91 200/91 149/70	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.82 0.06 4.23	0.09 0.001 0.5	0.37 0.01 1.3	1.86 0.08 9.9

5.3.7 Electrical engineering

A wide range of tasks are performed in electrical engineering in which quartz compounds are employed or released. The following working areas are particularly affected.

Pouring/weighing

Quartz and compounds containing quartz are employed in a range of production processes, for example as loading agents in the production of rubber, plastics or cables, or in casting compounds for the casting of electronic components. A further area of application is the filling of resistors and fuses. Dust exposure may arise during pouring and weighing of the substances containing quartz. Engineered measures (weighing workplaces with air extraction) were increasingly employed from the 1990s onwards (see Table 57).

Table 57:
Exposure data for pouring and weighing

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	83/20	Respirable fraction in mg/m³	0.89	0.18	0.47	2.07
	83/20	Quartz in mg/m³	0.11	0.003	0.03	0.33
	77/19	Quartz content in %	19.61	0.5	6.4	53.0
1985 to 1994	37/16	Respirable fraction in mg/m³	0.61	0.18	0.26	1.43
	37/16	Quartz in mg/m³	0.09	0.002	0.02	0.17
	36/15	Quartz content in %	14.01	0.5	6.7	40.8
1995 to 2004	19/11	Respirable fraction in mg/m³	0.45	0.12	0.13	1.36
	19/11	Quartz in mg/m³	0.01	0.003	0.005	0.02
	12/9	Quartz content in %	2.15	0.6	1.2	5.8

Mixing

In some processes, the substances containing quartz must be mixed following pouring and weighing. This is generally necessary in installations for cable manufacture and during the preparation of casting compounds. Here too, workers may be exposed to quartz dust. The substantial drop in the values measured during the 1990s (see Table 58) can be attributed to the increased use of engineered protective measures.

Table 58:
Exposure data for mixing

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	81/25	Respirable fraction in mg/m³	1.38	0.18	0.59	3.4
	81/25	Quartz in mg/m³	0.36	0.005	0.08	0.53
	78/25	Quartz content in %	25.61	1.0	11.5	62.8
1985 to 1989	28/11	Respirable fraction in mg/m³	1.52	0.18	1.29	2.7
	28/11	Quartz in mg/m³	0.08	0.001	0.02	0.08
	26/10	Quartz content in %	5.89	0.3	1.5	6.1
1990 to 2004	10/5	Respirable fraction in mg/m³	0.43	0.18	0.26	0.36
	10/5	Quartz in mg/m³	0.03	0.002	0.01	0.09
	10/5	Quartz content in %	10.28	1.1	4.2	33.8

Kneading and extrusion

Quartz and compounds containing quartz are added to plastics during kneading and extrusion in order to modify the plastics' properties. Such plastics have many applications in electrical engineering, for example in enclosures for electrical appliances and components. Exposure data are compiled in Table 59 (see page 122).

Table 59:
Exposure data for kneading and extrusion

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	66/13	Respirable fraction in mg/m³	0.86	0.18	0.59	2.01
	66/13	Quartz in mg/m³	0.07	0.003	0.02	0.18
	63/13	Quartz content in %	11.15	0.3	3.1	37.8
1985 to 1994	41/13	Respirable fraction in mg/m³	0.57	0.18	0.44	1.03
	41/13	Quartz in mg/m³	0.08	0.002	0.02	0.18
	39/12	Quartz content in %	14.47	0.6	4.0	30.1
1995 to 2004	15/3	Respirable fraction in mg/m³	0.32	0.18	0.19	0.44
	15/3	Quartz in mg/m³	0.03	0.003	0.02	0.04
	10/3	Quartz content in %	8.86	0.6	4.3	22.6

Grinding

One use of quartz powder is as a loading agent for casting compounds. Electrical components (motors, transformers) are generally modified mechanically at installation. In this process, cured surplus casting compound is ground off. Quartz dust may also be produced during the machining of ceramic insulators and the plastic enclosures of electrical appliances. The exposure data are shown in Table 60.

Table 60:
Exposure data for grinding

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	51/19	Respirable fraction in mg/m³	0.84	0.17	0.19	1.43
	51/19	Quartz in mg/m³	0.12	0.002	0.03	0.2
	45/15	Quartz content in %	13.6	0.5	9.8	28.3
1985 to 1989	11/6	Respirable fraction in mg/m³	0.36	0.27	0.27	0.64
	11/6	Quartz in mg/m³	0.03	0.003	0.01	0.08
	10/6	Quartz content in %	9.01	0.8	1.8	23.9
1990 to 2004	18/10	Respirable fraction in mg/m³	0.41	0.12	0.18	0.74
	18/10	Quartz in mg/m³	0.03	0.001	0.005	0.05
	15/10	Quartz content in %	5.79	0.6	1.2	18.5

Electrical installation work

Dusts containing quartz are produced on construction sites in the electrical trades during impact drilling work, the cutting of chases for electrical wiring, and the production of recesses for switches and distribution boxes. The materials concerned are red bricks, hollow bricks, sand-lime bricks, concrete and plaster. The results of measurements (see Table 61) were obtained during a project conducted by the Institution for Statutory Accident Insurance and Prevention in the electrical, textile and precision engineering industries in the period from 1996 to 2004.

Table 61:
Exposure data for electrical installation work

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1996 to 2004	47/12 47/12 44/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.68 0.4 11.03	0.39 0.01 1.0	1.28 0.08 7.9	6.05 1.08 27.8

5.3.8 Precision mechanics

The field of precision mechanics encompasses a large number of sectors. Measured values were considered from the following sectors (see Table 62):

- precision mechanics, optics: manufacture
- dental laboratories
- manufacture of metal products
- manufacture of musical instruments
- manufacture and working of jewellery

Table 62:
Exposure data for precision mechanics (all working areas)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Precision mechanics – all working areas						
1972 to 1979	49/12 49/12 46/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.59 0.09 4.25	0.26 0.003 1.0	1.51 0.02 1.0	5.19 0.16 9.0
1980 to 1984	51/20 51/20 35/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.68 0.11 13.53	0.1 0.001 0.5	0.21 0.007 4.3	1.58 0.21 36.6
1985 to 1994	123/66 123/66 107/58	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.62 0.05 8.89	0.09 0.002 0.6	0.37 0.008 1.9	1.39 0.13 24.3
1995 to 2004	82/42 82/42 56/29	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.55 0.02 4.26	0.08 0.001 0.5	0.25 0.005 1.4	1.25 0.04 11.9

The individual sectors for which a sufficient amount of data were available are also shown separately.

5.3.8.1 Dental laboratories

Embedding compounds with a quartz or cristobalite component of up to 50% are employed in dental laboratories. Dusts containing quartz are produced primarily during embedding and deflasking and during sand-blasting. These tasks are not generally performed for a duration of eight hours per shift. The lower concentrations observed since the 1990s (see Table 63) are attributable to new and improved ventilation facilities at the workplaces.

Table 63:
Exposure data for dental laboratories (model casting, embedding, deflasking, sand-blasting)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1985 to 1994	65/37 65/37 62/37	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.59 0.31 13.92	0.15 0.006 1.5	0.62 0.09 9.8	3.32 0.59 25.4
1995 to 2004	21/12 21/12 14/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.51 0.03 4.06	0.14 0.004 1.7	0.34 0.01 1.7	0.94 0.03 11.7

5.3.8.2 Musical instruments and metal products, manufacture

Metal products are manufactured from metal blanks, the geometry and surface of which is machined by chip-forming processes such as grinding or polishing.

The far-ranging improvements to dust collection facilities and ventilation technology and the modernization of the machining methods and machinery led to a reduction in the dust exposure (see Table 64).

Table 64:
Exposure data for the manufacture of musical instruments and metal products (grinding/polishing installations)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1975 to 2004	83/17 83/17 67/16	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.56 0.03 2.59	0.09 0.002 0.5	0.53 0.01 0.7	4.88 0.03 5.9

5.3.8.3 Jewellery, manufacture and working

Dusts containing quartz may be produced during the machining of decorative and semi-precious stones by parting, sawing, cutting, grinding and polishing. Exposure data are shown in Table 65.

Table 65:
Exposure data for the manufacture and working of jewellery
(parting, sawing, cutting, grinding, polishing)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1986 to 1989	18/6 18/6 18/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.78 0.12 15.64	0.23 0.03 2.0	0.56 0.07 10.5	6.4 0.2 36.1
1990 to 2004	87/38 87/38 61/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.68 0.11 11.64	0.12 0.004 0.6	0.42 0.01 1.4	1.32 0.12 46.6

5.3.9 Chemical industry

In the chemical industry, substances containing quartz are added to a large number of products in order to improve their properties. Such substances are employed in particular as fillers and thickening agents, and also for the attainment of certain abrasive properties. Chemical processes can be used to obtain more valuable compounds from raw quartz. These include pure silicon, silicon carbide and silicon-halogen compounds. Impurities, for example in talcum, often lead to workers being exposed to quartz dusts.

The measurements focused upon the mixing processes and the pouring and weighing of products. It is clear from the measurements that over the last 30 years, both the quartz and the dust concentrations at workplaces in the chemical industry have fallen (see Figure 30, page 126). This is due to the use of substitutes for products containing quartz, for example amorphous silica instead of quartz powder, and doubtless also to improved exhaust installations. The results of the measurements (see Table 66, page 126) show that in the majority of installations studied in the chemical industry, the concentration is now substantially below 0.15 mg/m³.

Figure 30:
Trend in average shift values for the concentration of the respirable dust fraction and the quartz concentration in the chemical industry

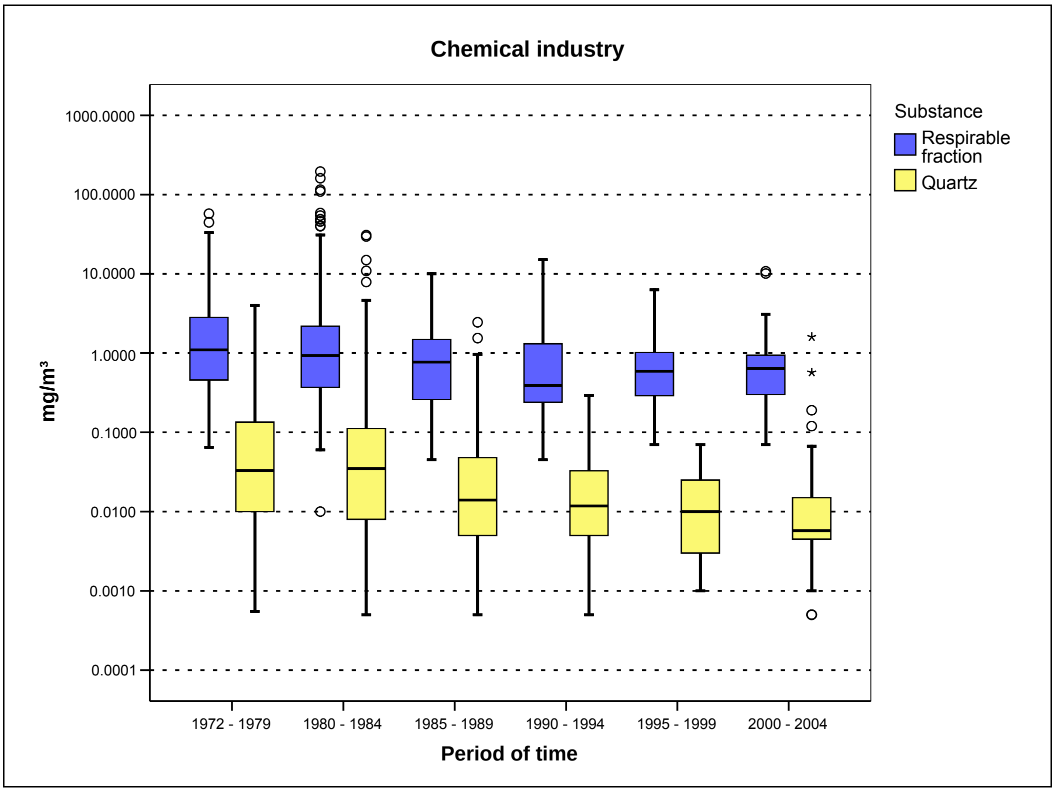


Table 66:
Exposure data in the chemical industry

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	372/74	Respirable fraction in mg/m³	3.11	0.19	1.1	6.58
	372/74	Quartz in mg/m³	0.18	0.005	0.03	0.44
	365/74	Quartz content in %	9.58	0.5	3.0	27.1
1980 to 1984	845/135	Respirable fraction in mg/m³	3.26	0.18	0.93	5.82
	845/135	Quartz in mg/m³	0.28	0.003	0.03	0.45
	792/130	Quartz content in %	9.98	0.3	3.6	28.2
1985 to 1989	282/75	Respirable fraction in mg/m³	1.11	0.09	0.76	2.37
	282/75	Quartz in mg/m³	0.07	0.002	0.01	0.14
	272/70	Quartz content in %	6.7	0.4	1.9	12.7
1990 to 1994	88/41	Respirable fraction in mg/m³	1.36	0.09	0.39	3.33
	88/41	Quartz in mg/m³	0.03	0.002	0.01	0.1
	74/37	Quartz content in %	5.6	0.5	1.5	12.2
1995 to 1999	69/34	Respirable fraction in mg/m³	0.77	0.13	0.58	1.39
	69/34	Quartz in mg/m³	0.02	0.002	0.01	0.04
	57/31	Quartz content in %	1.89	0.4	1.3	3.9
2000 to 2004	82/35	Respirable fraction in mg/m³	0.99	0.14	0.63	1.88
	82/35	Quartz in mg/m³	0.04	0.003	0.01	0.04
	70/32	Quartz content in %	4.19	0.5	1.1	5.9

5.3.9.1 Coatings and adhesives, jointing and filler compounds, manufacture

Silicates, such as silicic acid, mica or kaolin, are added to mixtures, for example as fillers or thickening agents, during the manufacture of coatings, such as paints, varnishes or adhesives. Dusts containing quartz may present a hazard during weighing and mixing processes and during the pouring of solid product.

The replacement of raw materials containing quartz by amorphous silica and the use of more effective dust collection installations during the preparation and sacking of solid substances has led to a substantial reduction in quartz exposure in the sector.

Weighing

Additives for the compounds are transferred from sacks, tubs or drums by means of a shovel, and weighed out openly on a scale. A weighing booth (weighing room) equipped with dust collection is often available for this purpose. Exposure data are shown in Table 67.

Table 67:
Exposure data for weighing

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1989	25/16 25/16 23/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.46 0.03 3.98	0.4 0.004 0.4	0.95 0.01 1.0	3.06 0.09 6.9
1990 to 2004	13/10 13/10 12/9	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.74 0.03 2.04	0.36 0.004 0.6	1.23 0.02 0.9	2.71 0.08 4.6

Preparation of liquid and solid mixtures

Solid additives for the manufacture of coatings or adhesives are added manually to the mixing vessels from sacks, drums or other containers, and also by mechanized processes from large casks or silos. Dust may be produced in the process (see Table 68, page 128).

Table 68:
Exposure data for the preparation of mixtures

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Preparation of liquid mixtures						
1972 to 1989	74/19	Respirable fraction in mg/m³	2.59	0.18	1.25	5.44
	74/19	Quartz in mg/m³	0.13	0.01	0.05	0.18
	74/19	Quartz content in %	6.71	0.5	3.0	16.4
1990 to 1999	31/13	Respirable fraction in mg/m³	1.55	0.54	1.36	2.68
	31/13	Quartz in mg/m³	0.04	0.004	0.02	0.08
	28/13	Quartz content in %	2.77	0.6	1.3	6.8
2000 to 2004	3/2	Respirable fraction in mg/m³	---	---	---	---
	3/2	Quartz in mg/m³	---	---	---	---
	3/2	Quartz content in %	---	---	---	---
Preparation of dry mixtures						
1972 to 1989	94/37	Respirable fraction in mg/m³	3.04	0.17	1.51	6.85
	94/37	Quartz in mg/m³	0.25	0.006	0.07	0.57
	92/36	Quartz content in %	10.56	0.5	3.9	39.5
1990 to 1999	34/17	Respirable fraction in mg/m³	2.09	0.29	1.21	4.13
	34/17	Quartz in mg/m³	0.06	0.01	0.06	0.12
	29/17	Quartz content in %	6.31	0.6	2.3	13.5
2000 to 2004	10/6	Respirable fraction in mg/m³	1.41	0.66	1.1	2.02
	10/6	Quartz in mg/m³	0.01	0.01	0.01	0.02
	9/5	Quartz content in %		---	---	---

Pouring of solid products (filler compound etc.)

Following the mixing process, solid product is removed from the apparatus and poured into packaging (sacks, tubs) for sale. Operating personnel may be exposed to dust in the process (see Table 69).

Table 69:
Exposure data for the pouring of solid products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1989	114/37	Respirable fraction in mg/m³	2.47	0.36	1.42	5.21
	114/37	Quartz in mg/m³	0.1	0.006	0.03	0.15
	114/37	Quartz content in %	5.0	0.5	1.6	13.2
1990 to 1999	49/25	Respirable fraction in mg/m³	1.44	0.31	1.31	2.73
	49/25	Quartz in mg/m³	0.03	0.004	0.02	0.08
	44/24	Quartz content in %	2.64	0.6	1.4	6.2
2000 to 2004	11/7	Respirable fraction in mg/m³	0.8	0.18	0.38	1.71
	11/7	Quartz in mg/m³	0.04	0.001	0.01	0.14
	7/4	Quartz content in %	---	---	---	---

5.3.9.2 Roofing felt and bitumen webs, manufacture

Whereas at one time, felt board (roofing felt) coated with bitumen – and up to around 1979, also with tar – was employed for the sealing of roofs, bitumen webs lined with glass, polyester or jute are now used. For certain applications, their surfaces are sprinkled with mineral substances such as gravel, quartz sand or slate cladding.
In the process, dusts containing quartz may be released into the workplace atmosphere, particularly on the surfacing looms used in modern, fully continuous manufacturing plants. Permanent workplaces are not generally found in these areas. Machine supervisors (personnel performing inspection patrols of the machines) or maintenance personnel may in particular be exposed to dusts containing quartz (see Table 70).

Table 70:
Exposure data for the manufacture of roofing felt and bitumen webs

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1983 to 1989	226/22	Respirable fraction in mg/m³	1.22	0.12	0.68	2.52
	226/22	Quartz in mg/m³	0.15	0.008	0.04	0.27
	224/22	Quartz content in %	9.33	1.2	6.4	20.4
1990 to 1999	130/21	Respirable fraction in mg/m³	0.7	0.15	0.51	1.46
	130/21	Quartz in mg/m³	0.05	0.008	0.04	0.12
	118/21	Quartz content in %	8.03	1.6	6.8	16.1
1995 to 2004	22/10	Respirable fraction in mg/m³	0.79	0.2	0.57	1.06
	22/10	Quartz in mg/m³	0.04	0.005	0.01	0.1
	17/9	Quartz content in %	5.7	1.3	2.3	13.8

5.3.9.3 Auxiliary materials for foundries, manufacture

Quartz sands are the material primarily used as moulding sands for the manufacture of casting moulds. Further natural minerals such as aluminium silicates, chamotte or magnesite may also be employed as the basic substance. Clays, waterglass or cement, and also artificial resins, serve as the binder.

During preparation (purification) of the substances employed, and in particular during mixing and drying processes and during pouring into sacks, personnel may be exposed to respirable quartz dust (see Table 71, page 130).

Table 71:
Manufacture of auxiliary materials for foundries

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Auxiliary materials for foundries, manufacture (total)						
1972 to 1984	190/23 190/23 190/23	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.1 0.22 8.22	0.35 0.01 0.5	1.7 0.04 2.7	7.15 0.49 23.4
1985 to 1994	86/22 86/22 84/22	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.13 0.04 5.76	0.23 0.003 0.5	0.68 0.02 2.1	2.19 0.1 16.0
1995 to 2004	83/18 83/18 78/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.67 0.29 10.85	0.12 0.003 0.7	0.55 0.03 3.9	3.54 0.35 31.5
Preparation						
1972 to 2004	68/18 68/18 65/18	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.47 0.41 11.38	0.12 0.005 0.5	1.1 0.05 6.4	4.09 0.49 25.4
Mixing and drying						
1972 to 2004	197/38 197/38 195/38	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.9 0.29 9.96	0.23 0.01 0.5	1.2 0.04 2.5	6.45 0.37 31.7
Pouring						
1972 to 2004	212/28 212/28 209/28	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.07 0.16 5.35	0.47 0.01 0.5	1.8 0.04 2.1	7.15 0.29 11.8

5.3.9.4 Rubberware, manufacture and processing

Amorphous silica is the substance most commonly added to rubber compounds in order to increase their strength. Quartz may, however, also be encountered at the workplace in the form of impurities in silicates, such as talcum. Exposure to dust containing quartz must be anticipated during weighing of the fillers and the subsequent mixing (in kneaders or mills), and during extrusion of the rubber product.

Table 72 shows a breakdown of all tasks by period, from 1972 to 2004. A clear drop in the quartz exposure at the workplace is particularly evident in the mid-1990s.

Table 72:
Exposure data for the manufacture and processing of rubber products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	465/54 465/54 459/53	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.86 0.22 7.01	0.37 0.006 1.0	1.41 0.04 2.1	6.76 0.53 19.1

Table 72: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1980 to 1984	402/62 402/62 378/61	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.67 0.25 5.71	0.21 0.003 0.3	1.2 0.02 1.4	5.13 0.22 17.2
1985 to 1989	239/48 239/48 234/48	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.23 0.05 3.7	0.24 0.002 0.4	0.9 0.01 1.2	2.29 0.1 9.4
1990 to 1994	109/46 109/46 85/42	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.94 0.03 4.59	0.21 0.003 0.5	0.65 0.01 1.4	1.83 0.07 12.7
1995 to 1999	69/26 69/26 52/21	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.08 0.07 6.07	0.22 0.002 0.7	0.57 0.02 2.3	2.65 0.11 14.4
2000 to 2004	33/17 33/17 22/12	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.7 0.01 1.09	0.16 0.002 0.9	0.42 0.005 0.9	1.89 0.01 2.2

Weighing

Loading agents for the rubber compounds are transferred by means of a shovel from sacks, tubs or drums, and weighed out openly on a scale. A weighing booth (weighing room) equipped with dust collection may be available for this purpose. Exposure data are shown in Table 73.

Table 73:
Exposure data for weighing

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1989	169/57 169/57 168/57	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.56 0.22 7.48	0.37 0.004 0.4	1.4 0.04 2.5	5.65 0.33 19.4
1990 to 1999	32/20 32/20 16/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.71 0.05 8.64	0.21 0.007 0.3	0.54 0.01 1.8	1.49 0.08 25.7
2000 to 2004	12/10 12/10 8/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.6 0.005 ---	0.18 0.001 ---	0.58 0.005 ---	1.08 0.01 ---

Manufacture of the raw rubber compound

The constituents of the raw rubber compound are thoroughly mixed in internal mixers (kneaders) or on mills. Exposure to dust may particularly occur during the pouring/adding of loading agents containing quartz (see Table 74, page 132).

Table 74:
Exposure data for the manufacture of the raw rubber compound

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1989	382/81 382/81 369/80	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.33 0.23 8.48	0.29 0.004 0.5	1.19 0.04 4.1	4.54 0.53 22.3
1990 to 1999	58/28 58/28 48/25	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.74 0.05 4.8	0.15 0.002 0.5	0.59 0.01 1.9	1.51 0.11 13.4
2000 to 2004	8/7 8/7 7/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---

Processing of compounds

Rubber compounds are processed to formed pieces (blanks), particularly by extrusion or injection moulding; (partial) vulcanization may be performed at the same time. In order to prevent the products from adhering to each other, their surface is often treated with a separating agent (e.g. talcum), which in turn may contain quartz. Exposure to quartz dust must therefore be anticipated during these processes and further processing steps (see Table 75).

Table 75:
Exposure data for the processing of compounds

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1989 to 2004	43/15 43/15 40/13	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.46 0.05 4.36	0.18 0.003 0.7	0.72 0.01 1.4	3.2 0.09 4.1

5.3.9.5 Plastics, manufacture and processing

Minerals containing quartz are used for a wide variety of purposes in the manufacture and processing of plastic and synthetic foam products. Such substances are used for example for the reinforcement of dental materials or mineral castings. Quartz sand or powder is employed as a coating, for example in the manufacture of façade panels, floors, or glass-fibre reinforced plastic pipes. Talcum is used as a separating agent. The risk therefore exists of dust containing quartz arising at the workplace, particularly during weighing and admixture, the extrusion of moulded pieces, and the machining (grinding, sawing, etc.) of products containing quartz.

In the past, measurements have particularly been taken at grinding workplaces and during mixing processes. Measurement results showing quartz concentrations above 0.1 mg/m³ have been the exception in recent years (see Table 76).

Table 76:
Exposure data for the manufacture and processing of plastics

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1979	107/29 107/29 104/28	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.97 0.24 13.57	0.18 0.004 0.6	1.03 0.03 3.0	3.88 0.73 42.7
1980 to 1984	179/38 179/38 169/37	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.79 0.3 11.42	0.22 0.002 0.3	0.9 0.02 1.5	3.91 0.51 36.2
1985 to 1989	111/41 111/41 97/39	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.79 0.05 6.51	0.11 0.001 0.3	0.56 0.01 1.1	1.75 0.11 18.3
1990 to 1994	65/34 65/34 53/33	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.65 0.03 5.52	0.14 0.001 0.5	0.45 0.01 1.2	1.12 0.07 15.0
1995 to 1999	76/29 76/29 63/27	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.61 0.04 7.61	0.2 0.001 0.4	0.48 0.02 2.9	1.14 0.11 19.7
2000 to 2004	52/20 52/20 26/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.85 0.06 19.95	0.1 0.004 0.4	0.22 0.01 11.1	0.89 0.16 46.4

5.3.9.6 Pharmaceutical and cosmetic products, manufacture

During the manufacture of pharmaceutical and cosmetic products, in particular during formulation, substances are employed which may contain impurities which in turn contain quartz. The powder base of many cosmetics, for example, is talcum, kaolin or diatomaceous earth.

Exposure to dusts containing quartz occurs during the open filling of mixers, the manufacture of pressed articles, and the pouring of product in powder form (see Table 77).

Table 77:
Exposure data for the manufacture of pharmaceutical and cosmetic products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	10/2 10/2 9/2	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.75 0.01 ---	0.08 0.001 ---	0.58 0.01 ---	3.37 0.02 ---

Table 77: (continued)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1985 to 1994	27/13 27/13 20/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.74 0.06 9.14	0.18 0.002 0.7	0.35 0.01 5.4	1.53 0.18 14.1
1995 to 2004	9/4 9/4 7/3	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	--- --- ---	--- --- ---	--- --- ---	--- --- ---

5.3.9.7 Cleaning and care products, manufacture

In addition to containing detergent surfactants, perfumes, solvents, care components, pigments and preserving agents, cleaning and care products may contain substances containing quartz in order to facilitate the removal of dirt. In the past, this was particularly the case with scouring agents. Exposure to respirable quartz dust must particularly be anticipated during open filling of mixers and during the packing of products in powder form (see Table 78).

Table 78:
Exposure data for the manufacture of cleaning and care products

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1988 to 2004	17/11 17/11 11/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.45 0.21 22.16	0.18 0.003 0.8	0.98 0.02 2.1	3.79 0.85 78.6

5.3.9.8 Grinding and polishing agents, manufacture

Grinding and polishing agents for the treatment of metal, wood, stone, glass or other surfaces may in the past have contained quartz, and may still contain impurities containing quartz. During manufacture, dust containing quartz may occur primarily during milling of the abrasive grit, its mixture into pastes or emulsions, and its application to substrates, such as paper (see Table 79).

Table 79:
Exposure data for the manufacture of grinding and polishing agents

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	46/15	Respirable fraction in mg/m³	0.74	0.15	0.36	1.54
	46/15	Quartz in mg/m³	0.27	0.003	0.04	0.45
	41/14	Quartz content in %	23.06	1.0	10.7	63.0
1985 to 1994	71/12	Respirable fraction in mg/m³	1.53	0.16	0.82	3.7
	71/12	Quartz in mg/m³	0.03	0.002	0.01	0.06
	68/12	Quartz content in %	3.16	0.3	0.6	8.9
1995 to 2004	45/6	Respirable fraction in mg/m³	0.37	0.18	0.21	0.89
	45/6	Quartz in mg/m³	0.03	0.002	0.005	0.07
	35/5	Quartz content in %	4.9	0.8	2.4	9.2

5.3.9.9 Silicon compounds, electrothermal manufacture

Compounds such as silicon carbide, and also pure silicon, are manufactured by the electrothermal conversion of quartz sand. Dust containing quartz occurs both during the preparatory milling, drying, screening and mixing stages, and during the thermal conversion and pouring processes (see Table 80).

Table 80:
Exposure data for the electrothermal manufacture of silicon compounds

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1972 to 1984	113/5	Respirable fraction in mg/m³	4.17	0.52	1.9	8.6
	113/5	Quartz in mg/m³	0.06	0.004	0.01	0.09
	110/5	Quartz content in %	1.49	0.4	0.5	3.0
1985 to 1994	36/4	Respirable fraction in mg/m³	1.05	0.22	0.93	1.58
	36/4	Quartz in mg/m³	0.01	0.002	0.01	0.01
	34/4	Quartz content in %	0.67	0.3	0.5	1.1
1995 to 2004	18/3	Respirable fraction in mg/m³	2.46	0.09	0.77	4.13
	18/3	Quartz in mg/m³	0.04	0.005	0.03	0.06
	15/2	Quartz content in %	4.91	0.4	2.7	6.7

5.3.10 Construction industry

Materials employed in the construction industry are generally mineral in nature. The quartz component encountered during pouring processes varies. During processing of the materials, dust containing quartz may be released in varying concentrations depending upon the processing method concerned.

In contrast to stationary operation, the construction industry is characterized by changing workplaces and tasks. In addition to the task itself, other factors such as local conditions (outdoor, indoor, open, closed) and weather conditions (dry, wet, windy) may have an influence upon the dust exposure. The frequency and duration of exposure also differ widely, and may vary from a few minutes to an entire shift or even several days. Exposure may further be influenced by the background exposure, such as dust from site traffic on dry and unmetalled roads, or other extraneous influences.

The parameters affecting the intensity and duration of the exposure vary more than in any other sector; for this reason, very different exposure levels may be encountered, as a function of the boundary conditions during similar or comparable activities. The exposure data presented below should be interpreted as shift values.

5.3.10.1 Masonry work and clinker construction

Masonry work encompasses the laying of small and large bricks, moulded elements, prefabricated lintels and similar items, with the use of fresh mortar; the placing of flat elements by means of the thin-bed method; the trimming of bricks by hand; and the auxiliary tasks typically associated with masonry work, such as clearing up and the moving of scaffolds (horse scaffolds). These activities do not include dust-intensive tasks such as grinding, parting-off or cleaning work (for such tasks, see Sections 5.3.10.9 and 5.3.10.11). The data collective for "sawing" (see Table 81) covers both wet and dry cutting. Large bricks and bricks with a relatively high bulk density were cut on stationary wet brick saws (see Figure 31); bricks which are easy to cut, such as aerated cement blocks, were cut by band saws and coarse-toothed handsaws.

Table 81:
Exposure data for masonry work and clinker construction

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Bricklaying						
1982 to 2004	23/11 23/11 16/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.9 0.03 3.18	0.12 0.004 1.1	0.67 0.02 2.0	1.68 0.09 6.1
Sawing						
1983 to 2004	27/19 27/19 23/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.93 0.05 6.96	0.18 0.01 1.0	0.6 0.02 4.8	1.93 0.15 15.5

Figure 31:
Wet brick saw insufficiently effective, owing to insufficient supply of water and recirculation of the water

If bricks are cut dry with an angle grinder, the quartz dust concentration may exceed 0.15 mg/m³ by a factor of ten or more, depending upon the quartz content of the material. Concrete and sand-lime bricks are considered to have a very high quartz content (30 to 60%). The quartz content of aerated cement blocks may reach 30%; that of normal bricks lies between 5 and 15%. During wet cutting, the dust exposure is considerably lower, on average by a factor of at least five, even under unfavourable conditions.

5.3.10.2 Drywall construction

Gypsum plasterboard and fibrous plaster sheet are bonded to the masonry with gypsum in dry form, or screwed onto a strut system. Sheets are often cut to size by scoring and breaking by hand or by means of handsaws and keyhole saws. The joints are then stopped with gypsum filler, in some cases with the use of a reinforcing strip, and ground smooth. Manual, power and random orbital sanders are employed for smoothing of the joints: with integral dust collection, without dust collection, and occasionally with a dust collection facility connected to the device. Exposure data are shown in Table 82 (see page 138).

Table 82:
Exposure data for drywall construction

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Planking, laying, levelling out						
2000 to 2004	17/7 17/7 12/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.06 0.05 4.02	0.33 0.01 1.0	0.73 0.02 1.9	2.17 0.1 7.8
Grinding						
1998 to 2003	15/10 15/10 13/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.1 0.05 1.67	0.26 0.01 0.7	1.24 0.01 0.9	9.08 0.08 2.5

5.3.10.3 Plasterwork

During plastering work, anhydrous gypsum plaster, lime plaster, cement plaster and dispersion-based synthetic resin plasters are applied, generally by machine in ready-mixed form. Dust exposure during indoor plastering work does not differ substantially from that for outdoor plastering work. No differentiation was therefore made. The loading of dry ready-mixed plaster from sacks into mixers is not included in the data collective. In the course of redevelopment, decorating or renovation work, plaster was removed manually by means of hammers, or with the aid of lightweight pneumatic or electrical hammers. Indoor plasters, such as lime, gypsum and lime-gypsum plasters, generally exhibit lower strength than outdoor plasters. The dust emission (see Table 83) varies according to the type of plaster, the strength, and the local conditions. The measured values thus exhibit a wide spread.

Table 83:
Exposure data for plaster work

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Plastering, smoothing						
1994 to 2004	35/19 35/19 23/15	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.96 0.02 2.32	0.19 0.004 0.8	0.55 0.01 1.1	2.13 0.04 4.7
Removal of plaster						
1992 to 2004	24/10 24/10 23/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.97 0.14 3.67	0.43 0.01 1.0	2.79 0.09 2.5	7.5 0.32 6.8

5.3.10.4 Demolition work

Experience has shown demolition work to be amongst the most dust-intensive of tasks. A distinction is drawn between mechanized and manual demolition. In both cases, the measured values exhibit a wide spread. This is attributable on the one hand to variations in the quartz content of the demolition materials, and on the other to the type of demolition. The broad range of demolition methods extends, in the case of mechanized demolition, from the use of tongs, grippers, scrap grapplers and hydraulic hammers, to demolition excavators. The process includes loading of the demolition material for transport.

Samples were taken during mechanized demolition primarily in the operator's cab of the construction machine, with the operator's door both open and closed. During demolition work, the dust was precipitated with water in some cases. With the operator's door open, the quartz dust concentration in the cab was on average twice as high or higher than with the cab door closed.

Very high quartz concentrations occur during the demolition of concrete and reinforced concrete components. During demolition work with no additional measures to combat emissions, for example, quartz concentrations of several times the value of 0.15 mg/m³ were measured in the working area up to the level of the 90th percentile value (see Table 84).

Table 84:
Exposure data for demolition work

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Mechanized demolition						
1996 to 2000	25/12 25/12 17/11	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	1.15 0.12 9.4	0.25 0.01 1.3	0.75 0.06 5.4	2.67 0.23 18.1
Manual demolition, impact drilling and chiselling						
1987 to 2004	56/27 56/27 51/27	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.04 0.26 9.92	0.42 0.01 1.2	1.94 0.13 8.9	7.21 0.67 23.0

The data for manual demolition include results from demolition work both inside and outside buildings. Pneumatic or electric demolition hammers were employed. Only in a small number of cases were a hammer and chisel used.

5.3.10.5 Earthmoving, levelling, compaction and paving work

Soil, sand and gravel were loaded onto a wheel loader and then transported and dumped, or loaded onto trucks. Samples were taken with the driver's cab both, open and closed. In some cases the material had dried out; in others, it was earth-damp. The highest value was measured with the driver's cab open.

Levelling, compaction and paving work encompass the following tasks and working methods: heaping, levelling, smoothing of sand, chippings or gravel, compaction of the material with manually-guided or ride-on compaction machines, laying of small and large paving stones, sand-backfilling and vibrating. Cutting and parting-off work are not contained in the data (see Table 85). The highest quartz concentrations were observed during vibrating.

Table 85:
Exposure data for earthmoving, levelling, compaction and paving work

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Transport						
1998 to 2003	10/8 10/8 2/2	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.54 0.02 ---	0.17 0.01 ---	0.28 0.01 ---	0.72 0.06 ---
Levelling, compaction, vibrating, laying and back-filling work						
1998 to 2003	30/13 30/13 13/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.51 0.05 6.36	0.17 0.01 1.9	0.24 0.01 4.6	0.78 0.03 14.9

If concrete or natural hewn stone is dry-cut during paving work or the laying of slabs, extremely high quartz dust exposure may arise, depending upon the quartz content of the material. Quartz concentrations ten or more times the value of 0.15 mg/m³ were observed for example during the dry-cutting of kerb and edging stones and the sizing of paving stones without dust collection.

The average quartz content in the respirable dust was in excess of 30%. Where wet brick saws were used, the exposure values were substantially lower; in four discrete measurements, however, not below 0.15 mg/m³ on average. The quartz content in the respirable dust was approximately 18%. Since the number of data records was lower than ten in both cases, no statistical analysis was performed.

5.3.10.6 Construction of stoves, chimneys, furnaces and industrial ovens

A wide variety of materials may be encountered during demolition and excavation work. In refractory construction, for example, quartz-free calcium silicate board and moler brick with a quartz content of 5 to 10% are employed for rear insulation, and silica or chamotte brick with a high quartz content for the lining of furnaces and melting tanks. The quartz content of the mortars used also varies widely, from less than 10 up to 80%. The variation between the materials is reflected in the spread of the measured values (see Table 86). Experience shows that particularly high quartz concentrations are encountered during the removal of furnace linings, owing to the constrained spaces.

Table 86:
Exposure data for the construction of stoves, chimneys, furnaces and industrial ovens

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Mixing						
1994 to 2004	12/5 12/5 12/5	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	4.6 0.66 25.03	0.38 0.01 0.6	0.77 0.15 10.8	10.24 2.16 57.7
Demolition work, impact drilling and chiselling						
1984 to 2002	47/22 47/22 44/22	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	7.34 1.16 14.89	1.25 0.03 1.2	5.23 0.49 8.3	14.21 3.01 43.1

In addition to quartz, refractory materials generally also give rise to the silicosis-inducing dust cristobalite. The exposure to cristobalite must therefore also be considered for the total exposure assessment. Guideline measurements have shown that during the removal of refractory materials, the cristobalite concentration may be approximately half the quartz concentration. By contrast, the cutting of refractory materials with a high bulk density (silica brick, chamotte brick) may produce more cristobalite than quartz dust.

During mixing, premixed dry product delivered in sacks was stirred with a blunger or loaded into a mixer and mixed. Table 86 shows the corresponding exposure data.

Where silica or chamotte bricks must be cut for the purpose of refractory construction, stationary wet brick saws are employed for the purpose. A guideline average value of 0.1 mg/m³ for the quartz dust emission was obtained from five discrete measurements.

The sizing of insulating materials with a low bulk density such as quartz-free calcium silicate board or moler brick (5 to 10% quartz) is generally performed dry by means of band saws. Here again, the few studies performed have shown that more cristobalite dust than quartz dust is released during the cutting of moler brick. On band saws without dust collection, the quartz concentration lay well above 0.15 mg/m³.

5.3.10.7 Roofing work

The data in Table 87 are limited to the cutting of roof tiles and concrete roof tiles by means of parting-off grinders: dry and without dust collection. During consideration of the data collective, it must be remembered that concrete roof tiles contain substantially more quartz than other roof tiles (see also Section 5.3.10.1).

Table 87:
Exposure data for the abrasive cutting-off of roof tiles and concrete roof tiles

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1990 to 1997	42/31	Respirable fraction in mg/m³	3.49	0.94	1.83	8.85
	42/31	Quartz in mg/m³	0.81	0.13	0.36	1.42
	40/31	Quartz content in %	21.61	11.0	19.7	36.6

5.3.10.8 Concrete work (mobile)

Guideline measurements show the quartz exposure to be lower during formwork setting and concrete work than during formwork removal. During cleaning of the formwork treated with form release agent, scrapers, hand and steel brooms, and coarse brushes were used to remove concrete residue following formwork removal. Exposure data are shown in Table 88.

Table 88:
Exposure data for concrete construction (mobile)

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Formwork removal						
1975 to 2003	40/8 40/8 24/6	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.45 0.03 4.27	0.09 0.001 0.6	0.11 0.004 1.7	1.02 0.04 11.4
Cleaning of formwork						
1995 to 2003	26/11 26/11 21/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.52 0.01 1.95	0.09 0.003 1.0	0.35 0.01 1.5	0.88 0.02 4.6

5.3.10.9 Construction site cleaning

Coarse loose waste, solidified mortar residue adhering to the ground, and granular powder waste can be found on construction sites. Scrapers, brooms and shovels are employed for cleaning, and the waste dampened in some cases.

Quartz exposure during cleaning work (see Table 89) is dependent primarily upon the quartz content of the dust-forming swept waste, as well as upon the ventilation measures and the form of water sprinkling. The influencing factors are reflected in the wide spread of the exposure data.

Table 89:
Exposure data for construction site cleaning

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Cleaning, general and with brooms, sweeping						
1980 to 2003	33/20 33/20 28/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.38 0.11 4.76	0.16 0.005 0.9	1.24 0.03 2.4	5.93 0.3 14.0
Cleaning, with sweeping machines, vacuum cleaners						
1985 to 2003	19/11 19/11 12/7	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	0.93 0.02 2.51	0.25 0.006 1.0	0.51 0.01 1.7	1.69 0.03 5.1

If sweeping machines are used for cleaning work and the swept waste is sprinkled with water, or hand-held power brushes or industrial vacuum cleaners are used, dust exposure is considerably lower. A differentiated analysis should consider that the exposure data for the use of sweeping machines were measured in the open air, whereas industrial vacuum cleaners were encountered only in cleaning work in dry-wall construction.

5.3.10.10 Blasting work

If materials containing quartz, such as concrete, are dry-blasted with quartz sand, over half the quartz dust exposure is attributable to the blasting agent. For this reason, blasting agents containing quartz (including quartz sand) have been prohibited since 1 October 1994 in order to reduce quartz dust emissions.

During blasting, the dust/quartz dust exposure is dependent among other factors upon

- the quartz content and the properties (e.g. hard, soft) of the substrate
- the blasting method (dry, wet, slurry)
- the blasting equipment employed
- the jet pressure and distance

In order to permit abrasive removal on hard substrates (e.g. concrete), power blasting is employed with pressures of up to 8 bar. Conversely, low pressures of 2 to 3 bar (gentle blasting) are employed for the surface cleaning of structures or listed buildings.

The data collective shown in Table 90 (see page 145) includes both, free-jet blasting and blasting with blasting machines on which the blasting agent is recovered, such as the Blastrac shot-blasting system or suction-head blast devices such as those employed for stencil blasting. Materials containing quartz and quartz-free materials (such as steel components) were blasted, in some cases wet, in others dry, with both high-pressure and low-pressure blasting. Quartz-free blasting agent was used for the most part, but quartz sand was also encountered during sampling prior to 1994.

Where suction-head units are employed, the quantity of dust released depends primarily upon the sealing of the blasting head. If the head is carefully sealed, quartz exposure is below 0.15 mg/m³ during stencil blasting.

Table 90:
Exposure data for blasting work

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Blasting, dry						
1975 to 2004	90/45 90/45 86/45	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	11.7 0.79 9.5	0.56 0.02 0.9	1.75 0.1 5.5	14.03 1.39 21.8
Blasting, moist, wet, slurry						
1981 to 2001	38/18 38/18 27/14	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.1 0.09 6.94	0.18 0.003 0.8	0.7 0.04 4.58	4.26 0.26 14.5

During moist or slurry blasting, the dust emissions are influenced substantially by the type and quantity of water feed. The lowest dust exposure has been observed during slurry blasting. During moist blasting of concrete with quartz-free blasting agent (Asilikos), at a pressure of 7 to 8 bar, and with a supply of barely 10% water, values for quartz of up to 6 mg/m³ were still measured in the atmosphere on test-bench tests. Quartz exposure is even higher during dry blasting.

In order for the dust exposure to be reduced, slurry blasting units with a pressure of approximately 2,000 bar (ultra-high-pressure slurry blasting units) are employed in place of pneumatic blasting units, for example for concrete remediation work. An average quartz dust concentration of 0.5 mg/m³ was measured for such a case during remediation of a concrete silo. Even though the result obtained for a single construction site cannot be considered representative, the use of ultra-high-pressure slurry blasting units for the blasting of construction materials containing quartz is unlikely to result in a quartz concentration in the aerosol of less than 0.15 mg/m³.

5.3.10.11 Road works

Asphalt surfacings are milled by means of cold milling machines with water sprinkling on the miller rotor. The exposure values (see Table 91) were obtained primarily during wide milling with working widths of up to 2.0 m, and only to a small degree during narrow milling with working widths of up to 1.0 m. The variation in the exposure data is primarily a result of the variations in quartz content of the mineral particles used. The exposure is also influenced by further factors, including the weather, the wind conditions, the depth of milling, the feed rate, the type and quantity of water sprinkling, and the technical condition of the milling unit.

Sampling was performed at the control panel, and on wide milling machines also alongside the machine. The majority of measurements covered only milling work; a small number of results also include brief interruptions to the milling work, for example for adjustments to or minor maintenance work on the machines, such as refuelling and filling of the water tank.

Table 91:
Exposure data for milling in road construction

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1999 to 2004	146/23	Respirable fraction in mg/m³	4.65	0.37	2.03	11.44
	146/23	Quartz in mg/m³	0.42	0.01	0.04	1.13
	112/21	Quartz content in %	6.72	0.6	3.3	18.6

5.3.10.12 Further activities in the construction industry

- **Sawing of concrete**

Concrete slabs were cut on stationary wet saws. Fresh water was used in some cases; in others, a recycling loop was employed.

- **Drilling of concrete**

For the most part, electric and pneumatic hammer drills without dust collection facilities were employed.

- **Grinding of surfaces**

The measured values were obtained primarily during the grinding-off of concrete screed floors and industrial floors, for which grinding machines with dust collection facilities were employed. The data collective also covers remediation work involving the grinding-off of concrete screed floors contaminated with adhesive residue containing polycyclic aromatic hydrocarbons (PAH), and guideline measurements taken during the superficial grinding of flowing screed, with and without dust collection.

Flowing screeds contain calcium sulphate as the binder, and generally natural anhydrite and powdered limestone as the loading agents. Quartz sand is also used in some cases in place of natural anhydrite. In these cases, quartz dust may be released during grinding. Depending upon the residual moisture and the quartz content, the quartz concentration (see Table 92) exceeded 0.15 mg/m³ in some cases for grinding machines without dust collection. Conversely, where grinding machines were employed with dust collection and dust cover ring, and otherwise under identical boundary conditions, the concentration was below 0.015 mg/m³.

Table 92:
Further exposure data for the construction industry

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
Drilling, concrete remediation						
1989 to 2004	18/9 18/9 17/8	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.01 0.5 16.8	0.57 0.02 3.5	1.07 0.21 12.7	3.07 1.02 31.3
Sawing of concrete						
1975 to 2000	39/11 39/11 30/10	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	3.92 0.07 4.25	0.61 0.01 0.5	2.15 0.03 1.0	7.18 0.2 10.6
Grinding of surfaces						
1976 to 2003	41/19 41/19 37/17	Respirable fraction in mg/m³ Quartz in mg/m³ Quartz content in %	2.16 0.08 6.82	0.24 0.01 0.6	0.99 0.04 2.9	4.84 0.19 19.7

5.3.11 Tunnel driving, galley driving, augering

The measured data were obtained exclusively from excavation and safeguarding measures in tunnels and galleys which were constructed by means of the shotcreting method, a further development of the "new Austrian tunnelling method" (NATM). They do not include measured data for tunnel drifts involving tunnelling and augering machines and the possible quartz concentrations encountered during production of the inner formwork.

The quartz concentration in the breathing air is substantially dependent upon the quartz content of the rock to be driven through. This variable cannot generally be influenced. Also significant is the excavation method, such as heading by blasting, milling or excavator. Once again, the technical and economic parameters are of major significance for selection of the method.

Further factors influencing the quartz concentration in the breathing air are selection of the suitable shotcreting method (wet rather than dry spraying), the use of low-quartz additives, the efficiency of the tunnel ventilation, and the dust precipitation measures, such as sprinkling of the excavated material, dust collection and filtering at the source of emission, and care of the roadway.

The parameters shown in Table 93 are average shift values. In the period from 1996 to 1999, the average shift was still 10.5 hours per working day. In the period from 2000 to 2004, it fell slightly to an average of 10.3 hours per working day.

Table 93:
Exposure data for galley and tunnel driving and shaft construction, augering – shotcreting

Period of time	Number of measured data items/plants	Substance Dimension	Arithmetic mean value	10th percentile value	50th percentile value	90th percentile value
1996 to 1999	226/41	Respirable fraction in mg/m³	4.9	1.13	3.6	10.2
	226/41	Quartz in mg/m³	0.15	0.02	0.1	0.33
	226/41	Quartz content in %	4.39	0.8	2.3	11.7
2000 to 2004	181/43	Respirable fraction in mg/m³	3.77	0.5	1.82	8.5
	181/43	Quartz in mg/m³	0.15	0.01	0.05	0.31
	181/43	Quartz content in %	4.66	0.8	2.4	11.5

A drop in the fine-dust concentration is observed for the period from 2000 to 2004. This can be attributed essentially to increased use of the wet-spraying method, improved ventilation, and more intensive dust precipitation measures. Overall, however, the concentration for the 90th percentile value still exceeds the limit value.

5.3.12 Special civil engineering works

Special civil engineering work essentially includes the production of sheet-pile walls, Berlin-type retaining walls, subterraneous curtains and bored diaphragm walls, and the drilling and placing of roof bolts. Owing to the procedures used, the dust released by these methods is minor. During drilling work for roof bolts, a distinction must be drawn between whether water or air is used for flushing the bore. Whereas considerable dust exposure must be anticipated if air flushing is employed, the debris is bound in the water when water flushing is used, and little dust if any is produced.

Several dust measurements were performed during pile-drilling work with rotary drills and during drilling work for roof bolts in which air flushing was employed. The results confirm that dust is released only on a minor scale during the production of concrete piles by means of rotary drilling. During drilling for roof bolts, the release of dust and quartz dust is exacerbated by flushing with compressed air. The quartz content in the soil types encountered in the boreholes varies considerably, not least from one region to another. Only rough predictions are therefore possible.

In addition to the soil type, factors such as the wind and weather, the topographical location and the soil moisture have a major influence upon the measurement results. Drilling for roof bolts with air flushing is thus associated with a high risk of dust exposure. The possibility of employing water flushing in place of air flushing should therefore be examined on a case-by-case basis. Where bores are produced with air flushing, facilities must be provided for collection of the dust at the point of creation.

6 Literature

[1] *Wright, G. W.*: The pulmonary effects of inhaled inorganic dust. In: *Clayton, G. D.; Clayton, F. E.* (Hrsg.): Patty's industrial hygiene and toxicology. Vol. I, Part A. S. 289-327. John Wiley & Sons, New York 1991

[2] Silica, some silicates, coal dust and para-aramid fibrils. IARC Monographs on the evaluation of carcinogenic risks to humans. Vol. 68. Ed.: International Agency for Research on Cancer (IARC), Lyon 1997

[3] *Bonnermann, R.*: Silikose und Siliko-Tuberkulose. Entschädigung – Rehabilitation – Prävention. Teil 1: Kompaß (1992) No. 2, p. 60-66; Teil 2: No. 3, p. 118-123

[4] BG-Statistiken für die Praxis. Ed.: Hauptverband der gewerblichen Berufsgenossenschaften (HVBG), Sankt Augustin 2003 und 2004

[5] Zentrales Informationssystem der Gesetzlichen Unfallversicherung (ZIGUV) beim Hauptverband der gewerblichen Berufsgenossenschaften (HVBG), Sankt Augustin

[6] Technische Regeln für Gefahrstoffe: Grenzwerte in der Luft am Arbeitsplatz – Luftgrenzwerte (TRGS 900). Ausg. 10/2000. Zul. geänd. BArbBl. 5/2004, berichtigt BArbBl. 7/8-2004. www.baua.de, Rubrik Gefahrstoffe

[7] *Schütz, A.*: Der MAK-Wert für Quarzfeinstaub unter dem Gesichtspunkt der Verhältnisse in der obertägigen Industrie. Staub – Reinhalt. Luft 31 (1971) No. 11, p. 443-448

[8] DIN EN 481: Arbeitsplatzatmosphäre; Festlegung der Teilchengrößenverteilung zur Messung luftgetragener Partikel (9/1993). Beuth, Berlin 1993

[9] *Siekmann, H.; Blome, H.*: Auswirkungen der Europäischen Norm EN 481 auf die Probenahme von Partikeln in der Luft in Arbeitsbereichen. Staub – Reinhalt. Luft 54 (1994) No. 3, p. 95-98

[10] DIN ISO 7708: Luftbeschaffenheit – Festlegung von Partikelgrößenverteilungen für die gesundheitsbezogene Schwebstaubprobenahme (1996). Beuth, Berlin 1993

[11] Deutsche Forschungsgemeinschaft: Quarz, Analytische Methoden, Luftanalysen. In: Analytische Methoden zur Prüfung gesundheitsschädlicher Arbeitsstoffe. Bd.1, S. D1, 8. Lfg. Ed.: Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe der Deutschen Forschungsgemeinschaft, 1993.

[12] Quarz (Kennzahl 8522). In: BGIA-Arbeitsmappe Messung von Gefahrstoffen. 34. Lfg. IV/2005. Ed.: BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Sankt Augustin. Erich Schmidt, Berlin 1989 – loose-leaf edition. www.bgia-arbeitsmappedigital.de/8522

[13] *Heidermanns, G.*: Zur phasenkontrastmikroskopischen Quarzanalyse staubförmiger Proben unter besonderer Berücksichtigung schwach doppelbrechender Minerale. Staub – Reinhalt. Luft 27 (1967) No. 12, p. 546-550

[14] *Schmidt, G.*: Die Routinebestimmung von freier Kieselsäure im Phosphorsäureaufschluß. Staub 20 (1960) No. 11, p. 404-411

[15] *Talvitie, N. A.*: Determination of quartz in presence of silicates using phosphoric acid. Anal. Chem. (1951) No. 4, p. 623-626

[16] *Heidermanns, G.*: Quarzgehalte in Arbeits- und Hilfsstoffen. Kennzahl 140 220. In: BGIA-Handbuch Sicherheit und Gesundheitsschutz am Arbeitsplatz. Ed.: BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Sankt Augustin. Erich Schmidt, Berlin 1985 – loose-leaf edition. www.bgia-handbuchdigital.de/140220

[17] *Bartholomé, E.* et al. (Hrsg.): Ullmanns Encyklopädie der technischen Chemie. Schwefel bis Sprengstoffe. 4. Ed. Vol. 21, p. 439-476. Verlag Chemie, Weinheim 1982

[18] *Bartholomé, E.* et al. (Hrsg.): Ullmanns Encyklopädie der technischen Chemie. 4. Ed. Vol. 21, p. 417 ff. Verlag Chemie, Weinheim 1978

[19] $(SiO_2)_x$, Quarz, Fraktionen. Informationsschrift der Valentin Busch KG Quarzwerk, Schnaittenbach 1973

[20] *Matthes, S.*: Mineralogie. Eine Einführung in die spezielle Mineralogie, Petrologie und Lagerstättenkunde. 4. Ed. Springer, Berlin 1996

[21] *Rösler, H. J.*: Lehrbuch der Mineralogie. VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1979

[22] *Vogler, H.*: Gewinnungsstätten von Festgesteinen in Deutschland. Ed.: Geologisches Landesamt Nordrhein-Westfalen, Krefeld 1999

[23] *Heidermanns, G.*: Quarzgehalte in technisch genutzten Gesteinen. Kennzahl 140 210. In: BGIA-Handbuch Sicherheit und Gesundheitsschutz am Arbeitsplatz. Ed.: BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Sankt Augustin. Erich Schmidt, Berlin 1985 – loose-leaf edition. www.bgia-handbuchdigital.de/140210

[24] *Burkart, W.; Schmotz, K.*: Handbuch für das Schleifen und Polieren. 4. Ed. Eugen Leuze, Saulgau 1974

[25] *Horowitz, I.*: Oberflächenbehandlung mittels Strahlmitteln. Vol. 1. Forster, Zürich 1976

[26] *Heidermanns, G.*: Ersatzstoffe für silikogene Strahlmittel. Kennzahl 140 250. In: BGIA-Handbuch Sicherheit und Gesundheitsschutz am Arbeitsplatz. Hrsg.: BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Sankt Augustin. Erich Schmidt, Berlin 1985 – loose-leaf edition. www.bgia-handbuchdigital.de/140250

[27] Unfallverhütungsvorschrift BGV D26 „Strahlarbeiten" (formerly VBG 48). Vom 1. April 1994, in der Fassung vom 1. Januar 1997, Ausgabe 1999. Hauptverband der gewerblichen Berufsgenossenschaften, Sankt Augustin bzw. Carl Heymanns Verlag KG, Köln, 1999.

[28] Berufsgenossenschaftliche Regel für Sicherheit und Gesundheit bei der Arbeit: Betreiben von Arbeitsmitteln (BGR 500). Ausg. 10/2004, aktualisiert 7/2005. Carl Heymanns, Köln 2004

[29] Quarzsand, Produktion und Einsatz. Werbematerial der Fa. Quarzwerke

[30] *Stopford, C. M.; Stopford, W.*: Respirable quartz content of farm soils. Appl. Occup. Environm. Hyg. 10 (1995) No. 3, p. 196-199

[31] Staubemissionen bei Kehrfahrzeugen. Pilotprojekt bei den Berliner Stadtwerken abgeschlossen. Bericht über das Projekt Nr. 1124 des Umweltbundesamtes, Berlin. In: Umwelt (1995) No. 9, p. 320-322

[32] Cristobalit, Produktion und Einsatz. Werbematerial der Fa. Quarzwerke

[33] *Binde, G.*: Sind Hochtemperaturglasfasern eine Alternative für Keramikfasern? VDI-Berichte No. 1776, p. 49-54. VDI, Düsseldorf 2003

[34] *Binde, G.; Bolender, T.*: Rekristallisation und Cristobalitbildung in Hochtemperaturglasfasern (AES) nach thermischer Belastung. Gefahrstoffe – Reinhalt. Luft 62 (2002) No. 6, p. 273-278

[35] BG/BIA-Empfehlungen Herstellung und Transport von Asphalt (Kennzahl 1029). In: BGIA-Arbeitsmappe Messung von Gefahrstoffen. 26. Lfg. III/2001. Hrsg.: BGIA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Sankt Augustin. Erich Schmidt, Berlin 1989 – loose-leaf edition