INAIL SILICA EXPOSURE DATABASE

INAIL

REPORT 2000-2019

2022

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Published by

INAIL
Technical Advisory Department for Risk Assessment and Prevention (Contarp)

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ISBN 978-88-7484-725-9

Originally published as *Banca Dati Esposizione Silice - Rapporto 2000-2019*

Tipolitografia INAIL - Milan, February 2022

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FOREWORD

Quartz, by far the most abundant polymorph of silica, is common in many rocks, sands and soils and is contained in raw materials for the manufacture of many products. Therefore, exposure to respirable crystalline silica is common in a large number of industrial activities. According to a study carried out in 2006 by the World Health Organisation, 5,300,000 European Union workers are potentially exposed, more than 70% of them in the construction sector (WHO, 2011), where exposures are particularly high in tunnelling and other earth moving operations. In Italy, besides construction, common exposure scenarios include the processing of clays for ceramic manufacturing, cutting, shaping and finishing of stone, quarrying for sand and gravel and the use of sand as moulding media in foundries. Although less common, exposure to crystalline silica is also observed in a variety of other industries in the manufacturing sector.

The adverse health effects of occupational exposure to crystalline silica have long been known. Silicosis can be considered a generalised systemic disease that originates in the lung and often affects other systems and organs. For decades, the scientific literature has recognised the association between silica disease and autoimmune pathologies, such as lupus, rheumatoid arthritis and scleroderma. Equally well known is the evidence that the effects of exposure to silica has in promoting the onset of autoimmune kidney disease. In more recent years the International Agency for Research on Cancer (IARC) has stated its opinion that *crystalline silica inhaled in the form of quartz or cristobalite from occupational sources is carcinogenic to humans (Group 1)*.

Crystalline silica may become respirable when a material containing quartz or cristobalite is handled and worked, as it happens in many workplaces. Therefore, *respirable crystalline silica* is generally a process-generated substance. The Directive (EU) 2017/2398, amending the Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (known as CMD), has included *work involving exposure to respirable crystalline silica dust generated by a work process* among those classified as carcinogens (Annex I of CMD) and has set an occupational exposure limit value of 0.1 mg/m^3 (Annex III of CMD).

In Italy, a special form of insurance against the risk of contracting silicosis in the workplace has been existing since the entry into force of Law No. 455 of 12 April 1943. This involved the payment of a supplementary premium to the National institute for insurance against accidents at work (INAIL) by the employer in whose establishment health risks associated with exposure to dust containing silica were present (a list of working processes that typically involves exposure, based on the mineralogical composition of raw materials, was annexed to the law). The transition from the assessment based on the mineralogy of materials to the measurement of exposure began in the 1960s, when INAIL created a special Technical Advisory Department for Risk Assessment and Prevention (CONTARP) to assess the actual risk level in the workplace. In the 1980s, CONTARP began to collect respirable dust samples by using personal cyclones during workplace inspections. Since then, laboratory analysis were performed at the INAIL Central Industrial Hygiene Laboratory in Rome, by XRD on the dust samples collected on filters, to determine compliance with an exposure level fixed by the Ministry of Labour.

Over the years, the intensification of preventive and protective measures implemented by employers, as a consequence of the compliance inspections conducted by INAIL and other workers' health and safety

governmental agencies, has had the effect of significantly reducing the level of silica dust pollution.

The whole dataset of approximately 8000 personal sample measurements of silica exposure collected in the workplaces during INAIL inspections conducted between 2000 and 2019 have been uploaded in the database presented in this Report.

Although the supplementary premium has been abolished from the 1st January 2019, INAIL is still giving special attention to the risk of exposure to silica as well as to other airborne carcinogens in workplaces. In fact, active research into occupational diseases is still revealing clusters of damage in unexpected workers, such as goldsmiths and artificial stone workers, and airborne dust reduction remains an issue in several production activities.

The authors conceived the database design after an in-depth analysis of the experiences that other research institutes, private organisations and government agencies had already gained on databases of crystalline silica exposure. Examples of this are the U.S. OSHA Integrated Management Information System – *IMIS* (Yassin et al., 2005; Flanagan et al., 2006), the Canadian literature-based database of silica exposure in construction developed by the Institut de Recherche Robert-Sauvé en Santé et en Sécurité du Travail (Beaudry et al, 2013), the occupational exposure database *ExpoSYN* for respirable crystalline silica personal measurements created for the *SYNERGY* project (Peters et al., 2011) and the occupational exposure database for respirable mineral dust developed by the Industrial Minerals Association - IMA-Europe (Houba et al., 2009).

The records included in the database provide information on exposure levels by production activity, job title, territorial unit, time interval, sampling and analysis methods and techniques. A most qualifying element is a new job title classification (called *CONTARP 2016*), based on the similar exposure group concept and specifically designed to describe exposure profiles for workers exposed to airborne silica dusts. The job title descriptions were constructed through the on-site analysis of worker tasks and company production cycles, as well as the machinery and the technologies adopted.

The statistical processing proposed in this Report outlines the silica dust exposure levels among Italian workers, allowing the definition of workers' exposure profiles in many production sectors. The results of this study could be useful for managing respirable crystalline silica exposure in workplaces, in order to develop good practices in industries and to identify risk control measures to be adopted in the workplaces. The database could hopefully also be used to estimate the number of workers potentially exposed to silica in industries and as a support for epidemiological and toxicological studies.

Fabrizio Benedetti

CONTARP General Coordinator

SUMMARY

The adverse health effects of crystalline silica are well known and make occupational exposure to silica dust a current issue despite the evolution of working scenarios, which have certainly benefited from the introduction of effective and proven technical solutions. As with all carcinogens, the need for measurements often arises in workplaces where the respirable fraction of crystalline silica is present either because it was introduced into the production cycle as a raw material or because it originated as a result of working processes.

INAIL Silica Exposure Database referred to in the Report, is the result of the experience gained by INAIL during surveys carried out within a large number of companies throughout Italy: the tool contains data from more than 8000 samples, collected during the air monitoring process carried out from 2000 to 2019. The strategies, criteria and methods for carrying out such measurements have been addressed by international technical standards. The most valuable data comes from personal measurements, which best represent the exposure profiles of those workers engaged in processes where materials containing crystalline silica are handled. Nearly 90% of the 8028 samples, collected in 1041 companies, come from personal samplings. Exposure measurements are accompanied by the collection of a set of information concerning production activity, job titles or working phases, weather conditions, sampling and analysis methods and techniques. Such information made it possible to draw up the national framework of exposure to silica dust by sectors of production activity and with reference to the individual job titles identified for them.

The measurements refer to 30 production activities - according to the CONTARP 2016 classification, realised by INAIL based on exposure to silica dust - or to 62 codes of economic activities identified by using the NACE rev. 2 classification. Most of the measurements have been carried out in the sectors of mining and quarrying, manufacturing and construction. The most investigated working activities belong to the production activity C12 *Stone working*, with 313 premises monitored and 1975 dust samples collected. The number of samples taken in sectors such as C16 *Foundries*, C6 *Ceramic tiles*, C9 *Ceramic sanitary fixtures*, C15 *Iron and steel industry* as well as F2 *Tunnel construction, conventional excavation* is also considerable, numbering several hundred.

Section 1.10 of the Report describes the statistical parameters and the data evaluation criteria adopted, according to the EN 689, to overcome the problem of variability and to use a relatively small number of measurements to demonstrate, with a high degree of confidence, that workers are unlikely to be exposed to concentrations exceeding the OELV. Assuming that log-normal distributions fit the exposure measurement datasets of all the job titles (assumed as *similar exposure groups*), which the statistical analysis of the data generally proves to be true, the key statistical parameters for the description of workers' exposure to silica are the geometric mean of the concentration values (corresponding to the 50th percentile, i.e. the 50% probability of exposure) and the geometric standard deviation. Knowledge of these parameters allows a quick estimation of the probability of exposure within the whole range of silica concentrations to which the worker may be exposed, as well as the checking of compliance with the limit value.

In order to assess occupational exposure levels to silica, the exposure probability is compared with four concentration thresholds: the limit value set by Directive (EU) 2017/2398: 0.1 mg/m^3; the action level which is half of the limit set by the Directive: 0.05 mg/m^3; the TLV-TWA issued by the American Conference of Governmental Industrial Hygienists (ACGIH): 0.025 mg/m^3; and the concentration of 0.012 mg/m^3, which approximately corresponds to the limit of quantification of the measurements. For respirable dust, the exposure probability is compared with three concentration thresholds: the guide value recommended by ACGIH: 3 mg/m^3; half of the guide value: 1.5 mg/m^3; a fraction equal to 1/10 of the guide value: 0.3 mg/m^3.

Sections 1.10 and 1.11 of the Report include more details on the statistical parameters and data evaluation criteria adopted as well as on the organisation of the Report, respectively.

The following is a summary of the main findings that emerge from the tabular and graphical representations contained in Parts 2 and 3 of the Report, providing an overview of the data on a national scale and by production activity, respectively.

If we look at all the personal samples analysed, the median concentration reaches values of 0.399 mg/m^3 (respirable dust) and 0.024 mg/m^3 (respirable quartz) and there is no marked seasonal variability of both

respirable dust and respirable quartz exposures. The four crystalline silica concentration thresholds, described above, were exceeded by 13% (0.1 mg/m^3), 29% (0.05 mg/m^3), 49% (0.025 mg/m^3) and 66% (0.012 mg/m^3) of the measurements, respectively.

The concentration values of crystalline silica in tunnelling seem to be particularly high, especially in construction sites where excavation is mechanised (excavation by hard rock tunnel boring machines – F3) where more than 60% of workers are exposed to concentrations above 0.1 mg/m^3. Workers were also found to be exposed to high silica concentrations in activities involving traditional excavation techniques (F2), exceeding the limit of 0.1 mg/m^3 in 25% of cases and the concentration of 0.05 mg/m^3 in 47% of the measurements.

Concentrations above 0.1 mg/m^3 are frequent in the treatment of metals (activity C17), where this level has been exceeded in more than 30% of the measurements (although the measurements do not take into account protective clothing and respiratory equipment, used by workers in the dustiest operations). Among other activities, the limit value set by the European Directive is exceeded in more than 15% of the measurements in quarrying of marble, granites and other coherent rocks (B1), in the manufacturing of ceramic sanitary fixtures (C9) and stone working (C12).

In addition to the previously highlighted F2, F3, C9, C12 and C17 activities, more than half of the tested workers were found to be exposed to concentrations higher than ACGIH's TLV-TWA for crystalline silica, within the manufacturing of bricks (C7) and on production lines for bituminous membranes (C1).

The 50th percentile of exposure to crystalline silica is in the range between TLV-TWA and the *safety* threshold (0.012 mg/m^3) in the quarrying of marble, granites and other coherent rocks (B1), in the factories for the manufacture of paints, glues and adhesives (C2) and rubber, plastic and artificial stone (C3), in artistic ceramics workshops (C8), in the manufacture of furnaces (C18), in foundries (C16) and goldsmith workshops (C19).

In the lowest exposure range, where at least 50% of workers are exposed to concentration values that do not exceed the *safety* threshold of 0.012 mg/m^3, there are some types of mining activity (B2 *Quarrying of sand and gravel*, B3 *Quarrying of clays, pozzolana and feldspar* and B4 *Quarrying of pumice stone*), manufacture of glass (C4), refractories (C5) and foundry sand cores (C14), cement factories (C10) and the manufacture of concrete products (C11), steelworks (C15) and construction activities (F1, excluding tunnel excavation and sandblasting of buildings).

For some activities, although included in the classification of those with possible exposure to crystalline silica, the number of available measurements is not sufficient to make a reliable assessment, as in the case of agriculture (A1), the production of abrasive elements (C13) the production of medical supplies (C20), denim jeans sandblasting (C21) and sand blasting for building exteriors (F4). For the sake of completeness, these measurements have also been represented graphically in the Report.

Finally, it is important to underline that the most useful information provided by the database is the exposure distribution by job title (where the job titles were classified trying to match the definition of *similar exposure groups*), since it can be directly applied in the occupational risk assessment, at least in many cases. In fact, according to the European standard EN 689, a reliable basic characterisation of exposure of the workers can come, among other methods, from measurement results from comparable installations or work processes (databases, literature, etc.) and from exposure modelling. However, when the information obtained from these sources are insufficient to decide on compliance with the OELV, workers' exposure can only be assessed by representative personal measurements in the workplace, which should comply with the requirements of EN 482.

The Report shows measurements of the exposure level to crystalline silica for 470 job titles (grouped into 30 production activities): for 238 of them, at least 6 measurements are available (making it possible to estimate exposure probability), whilst for 137 job titles the number of measurements is at least 12. Although not exhaustive, in terms of the statistical significance of the workers exposed to silica by inhalation within the working world, this database is certainly a solid source of information to be used by all the stakeholders involved in silica dust risk assessment.

Abbreviations

AM	arithmetic mean
CS	crystalline silica
CONTARP	INAIL Technical Advisory Department for Risk Assessment and Prevention
FTIR	Fourier-transform infrared (spectroscopy)
GM	geometric mean
GSD	geometric standard deviation
LOD	limit of detection
LOQ	limit of quantification
NACE	statistical nomenclature of economic activities in the European community
OELV	occupational exposure limit value
PPE	personal protective equipment
RCS	respirable crystalline silica
SD	standard deviation
SEG	similar exposure group
TLV-TWA	threshold limit value – time weighted average
XRD	x-ray diffraction

PART 1.

DATA ACQUISITION

AND PROCESSING METHODOLOGY

1.1 The INAIL Silica Exposure Database

The INAIL Silica Exposure Database is a Business Intelligence tool, created by the INAIL Technical Advisory Department for Risk Assessment and Prevention (CONTARP) in collaboration with the Directorate for Digital Organization (DCOD), in which the data of over 8,000 samples are loaded. The data were collected during the surveys, carried out by INAIL, throughout Italy.

Since the 1960s, CONTARP has been assigned the duty of assessing the risk of exposure to Respirable Crystalline Silica (RCS) in the workplace. According to the law on the compulsory insurance against accidents at work and occupational diseases (presidential decree No. 1124 of 30 June 1965), a supplementary silicosis premium was due by the employer when a limit value, fixed by the Ministry of Labour, was exceeded. However, law No. 145 of 30 December 2018 abolished this premium so that currently the monitoring carried out by CONTARP is mostly for prevention purposes.

In the past, information about the workplace being monitored (company name, workplace location, working activity, production cycle, etc.) measurement strategies and results, were collected on paper documents following a traditional procedure. Once the assessment was completed, the paper documents were stored in the INAIL archive. During a project started in 2015, the data on risk assessment of exposure to silica dust collected from 2000 to 2018 were retrieved, digitised and loaded into a database. Starting from 2019, the information collected during silica dust monitoring in the workplaces was loaded into the database directly during the assessment process, by using a specific application built by INAIL, called Silica Sampling and Analysis. The updating of the database and related statistical processing is automatic and daily.

Exposure of workers to RCS and respirable dust, obtained through personal measurements, is the main information collected in the database. Crystalline Silica (CS) concentrations measured from the static (area) respirable dust samples and bulk samples (from materials, products, natural rocks and aggregates) are also included in the database. However, personal measurements are more representative of worker exposure profiles, since the sampler is attached to the workers within their breathing zone, following the worker movements in carrying out the assigned tasks. Therefore, the heart of the database is represented by the data of personal measurements, which can be directly used for risk assessment and whose statistical processing provides a picture of exposure, specific for individual job titles or industry sectors. Besides the concentration levels of respirable dust and RCS, the information collected in the database includes the activity of the company being monitored, geographical location of the plant/site, sampling date, type of samples collected, workers' job titles (in the case of personal samplings), characteristics and operative conditions of sampling and analysis instruments.

The inclusion of information on exposure to RCS in a database requires the adoption of classifications for industries and worker occupations. The NACE rev. 2 classification (European Communities, 2008) is used in this English version of the Report. Since 1970, NACE has been the acronym used to designate the Statistical Nomenclature of Economic Activities in the European Community. NACE provides the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics (e.g. production, employment, national accounts) and in other statistical domains. The use of NACE is mandatory within the European Statistical System. The ATECO 2007 classification of economic activities, derived from the NACE rev. 2 classification by the Italian National Institute of Statistics (ISTAT), is used in Italy and in the Italian version of our database.

The NACE rev. 2 classification for economic activities has been combined with a second classification, called CONTARP 2016 which was specifically developed by INAIL to categorise industries where exposure to RCS occurs, classifying job titles in those industries. Each job title is followed by a brief job description which includes the working processes involved and/or the tasks performed (see paragraph 1.6).

This Report presents the main results from the measurement of RCS and respirable dust exposures collected in the database from 2000 until April 2019, with statistical processing extracted directly from the Business Intelligence application and adapted to the editorial requirements of a publication. Therefore, the work outlines the current state of workers' exposure to RCS in Italy, quantifying probability of exposure in the industrial sectors and for hundreds of individual job titles. The reader can check the information presented in this Report by accessing the database on the INAIL Portal and selecting the elements of interest. The application allows exporting the data to spreadsheets for further processing.

1.2 Crystalline silica polymorphs: quartz and cristobalite

Crystalline silica (CS) exists in many forms, but only quartz and cristobalite are commonly encountered in workplaces. Quartz is by far the most abundant CS form, both in nature and at the workplace. Cristobalite occurs naturally in some volcanic rocks and may form at workplaces, during some specific stages of the production cycles, by heating quartz or amorphous silica at very high temperatures.

According to the operating procedure followed by INAIL to assess silica dust risk, the samples of respirable dust taken in workplaces located throughout the country are all sent to the central laboratory, together with the request for the analysis to be carried out.

The person in charge of sampling shall indicate in the request whether the analysis should regard only airborne quartz, or if cristobalite concentration should be measured as well. This choice generally depends on the characteristics of the processes being monitored on the raw materials present in the plant as well as other information acquired from the company.

Out of about 7000 analyses, carried out on personal samples and uploaded in the database until today, only 1.3% (90 samples) concerned cristobalite. These samples were taken in iron and steel industries, foundries and a few of them in furnace repairing. Throughout this monitoring, the samplings were performed to assess the risk for workers exposed to industrial processes involving high-temperature operations. Nevertheless, only one of the 90 samples analysed gave a result above the Limit of Quantification (LOQ). Taking into account the sampled air volumes, the mean concentration of respirable cristobalite in the samples is estimated to be under 0.005 mg/m^3. Even considering the low reliability of the estimated mean value, the actual relevance of the exposure to cristobalite seems to be limited to some rare and specific situations. We must also point out that there are no known studies on the workers' actual exposure to respirable cristobalite, at least in Italy. For that reason, exposure to cristobalite will not be further discussed in this Report and all the statistical analyses and the diagrams concerning CS must be understood as referring exclusively to quartz.

1.3 Personal, static and bulk samples

The INAIL Silica Exposure Database includes data of the following three types of samples:

- personal samples of respirable dust, taken on a collection substrate (usually a filter) using a personal sampler attached to the worker's clothing, as close as possible (within 30 cm) to the nose and mouth in the worker's breathing zone. A sampling pump is attached to the worker's belt and flexible tubing connects the sampler to the pump. The sucked air flows through the sampler to simulate the human respiratory system. If a worker uses an apron or a respiratory protective device, the sampler must be placed outside them, as specified in the European standard EN 689;
- static samples of respirable dust were collected with the same sampler types used to collect personal samples. In this case, the sampler is attached to a static holder (e.g., a tripod) placed, if possible, at the height of workers' breathing zones (i.e., about 1.5 m from the ground);
- bulk samples, namely granular or powdery materials, raw materials, solid and compact products, rock fragments, sludge produced from industrial processes and dust settled on workplace surfaces.

For the purpose of risk assessment, the results of personal measurements can be compared with occupational exposure limit values (average exposure in an 8-hour work shift). In fact, according to the EN 689, personal samplings are more representative of workers' exposure profiles and should therefore be preferred to the static samplings. This explains why most of the measurements (almost 90% of the 8028 collected samples) in the INAIL Silica Exposure Database refer to personal samplings. However, static samples are a useful support in interpreting data from personal samples and may be used instead of personal samples when it can be demonstrated that the results obtained are superimposable, or when working conditions make it difficult to collect personal samples.

Sampling duration and flow rate, the mass of RCS and respirable dust collected on a filter, worker's occupational title (for personal samples) and working phase or department (for static samples) according to the CONTARP classification 2016 (see paragraph 1.6) have been reported in the INAIL Silica Exposure Database for each personal and static sample. Concentration levels of both RCS and respirable dust were then calculated for every sample and expressed as mg/m^3.

While personal sample results, associated with job titles and industry sector, are thoroughly interpreted and compared in this Report, results from static samples are only summarised for each production activity in a concentration data table.

Data on quartz content in bulk samples can be used to identify possible sources of respirable dust generation during work processes. Many materials, products and rocks in the excavation are rich in quartz and therefore represent sources of exposure to CS.

The determination of the quartz content in the sludge produced from the industrial process, or in the dust settled on the workplace surfaces, gives an indication of the average value of quartz concentration in the airborne dust generated in the workplace atmosphere.

Moreover, the determination of quartz in products and raw materials may also be useful to evaluate the compliance with regulations, regarding the classification and labelling of materials to be placed on the market, the reliability of the information contained in the Safety Data Sheets accompanying products and the classification of waste.

1.4 Workplace sampling

As requested by the Italian legislative decree No. 81/2008, workplace air samples were collected according to the technical standards applicable to this subject, in particular EN 481, which provides the respirable convention that a sampler has to represent, EN 689 for the measurement strategy, EN 482 for the performance of the procedures for the measurement of chemical agents, and EN ISO 13137 on pumps for personal sampling.

Occupational Exposure Limit Value (OELV) and other comparison values used in this Report

The main purpose of measuring RCS concentration is to compare its result with the OELV for RCS, set to 0.1 mg/m^3 by the EU Directive 2017/2398 and the Italian legislative decree No. 44 of 1 June 2020. In this Report, the measured RCS concentration values are compared with three more threshold levels: 0.05 mg/m^3 (the old insurance limit set by the Italian Ministry of Labour), 0.025 mg/m^3 (TLV-TWA for quartz and cristobalite, set by the American Conference of Governmental Industrial Hygienists - ACGIH) and 0.012 mg/m^3, which, in most cases, is a concentration level very close to the LOQ of a measurement.

INAIL sampling procedure requires that gravimetric measurement for respirable dust be performed before the sample is analysed for RCS. Therefore, exposure to respirable particulate is also a result of the measurement, together with the exposure to RCS and the percentage of CS in the respirable dust. Although the Italian national legislation does not set a limit value for respirable dust concentration, the absence of a specific limit does not mean that respirable dust is not harmful. To evaluate respirable dust exposure, the ACGIH recommendation for respirable dust, 3 mg/m^3, is adopted in this Report. This guidance value set for insoluble, or poorly soluble, respirable Particulates Not Otherwise Classified (PNOC) is often used by industrial hygienists to assess the risk of adverse effects. The measured respirable dust concentration levels are then compared with the ACGIH recommended value of 3 mg/m^3 and also to concentrations equal to half (1.5 mg/m^3) and 1/10 of the guidance value (0.3 mg/m^3).

Data on companies and workplaces

The assessment of RCS risk is of interest to all the workplaces of production sectors or activities where CS is present, either as a component of raw materials used for production, in soils and rocks in mining or excavation activities or in artefacts in the demolition and remediation sectors. The work activities mentioned above represent only a part of the labour market so that it was thought useful to develop, alongside the NACE classification of economic activities, an ad hoc classification, named CONTARP 2016, for activities that involve exposure to RCS. The CONTARP professional in charge of sampling and risk assessment carried out the classification of the company's activity in the monitored workplace. A description of the CONTARP 2016 classification is given in paragraph 1.6, together with the assignment criteria. The name of the company is confidential and is published neither in the Report nor in the INAIL Silica Exposure Database. The geographical location of the plant/site being measured is given in the Database, down to the level of the province, while in the Report, the exposure data are summarised on a regional scale and presented in maps for each industry sector or activity, depicting classes of geometric mean concentrations.

Respirable dust measurement strategy

An important step in silica dust risk assessment is the identification of Similar Exposure Groups (SEGs). This is defined as groups of workers having the same general exposure profile for RCS because of the similarity and frequency of the tasks performed, the materials and processes with which they work with and the similarity of the way they perform the tasks. Before a sampling takes place, the employer provides a list with the names of workers under each job title. The definition of SEG often coincides with that of job title (see paragraph 1.8), but specific tasks are taken into account by the appraiser. Then, a suitable number of workers are chosen for each SEG and the personal exposure measurements are carried out. During the sampling, the appraiser takes notes on the tasks effectively carried out by the workers, to evaluate the correctness of the chosen SEGs, as well as any important or unexpected event during the measurement.

Information on the variability of exposure regarding the time of day and the season of the year is considered in order to evaluate whether the measurement is representative of the actual exposure profile.

Therefore, an exposure assessment generally requires the collection of personal samples, carried out in a single day or in more sampling days. However, sometimes the workplace conditions only allow static sampling. Analysis of bulk samples can often help in identifying the sources of exposure, improving also the understanding of the exposure profile of workers.

Sampling equipment

The equipment used in airborne dust sampling consists of three basic elements: the personal size selective sampler (to collect the respirable dust fraction), the collection substrate (generally a filter) and the sampling pump.

The sampler must comply with the EN 481 and be tested according to the methods described in EN 13205-2. Particle size selectors built on different designs can guarantee compliance with the EN standard if used by setting a specific flow rate, experimentally determined by the manufacturer and usually between 1.7 and 12 L/min. All the personal and static samples presented in this Report have been collected by INAIL, using almost exclusively Higgins-Dewell design plastic cyclones (Casella and SKC), with a flow rate of 2.2 L/min. However, until 2002, samplings were performed operating at a flow rate of 1.9 L/min, with separation characteristics according to the Johannesburg convention, as established by Italian legislative decree No. 277 of 1991.

A filter suitable for the sampler must be used. Absorption of moisture and electrostatic charge can affect the weighing result. If a direct-on-filter method is used for analysis, the filter medium should be suitable for the chosen analytical technique and should not produce signals interfering with the RCS phases. Almost all INAIL respirable dust samplings have been carried out by using 25-mm silver filters with a 0.8 µm pore size.

The personal air sampling pumps for industrial hygiene studies should possess the requirements reported in the standard EN ISO 13137. INAIL has used a variety of pump models for the collection of samples. Among them, the most commonly used were the AirCheck 2000 and AirCheck 52 sample pump models (SKC) as well as the Personal Sampling Pump (Aquaria) in the early 2000s.

Collection of bulk samples

As part of the investigation aimed at assessing exposure to RCS it is sometimes considered useful, when interpreting the results obtained for personal airborne dust samples, to identify and quantify the possible sources of CS e.g. in materials, products or rocks encountered in the workplace.

The appraiser that collects a bulk sample in the workplace will characterise the material with a brief description. The bulk sample is placed in a bag or another container which is labelled and sent to the laboratory for analysis.

1.5 Laboratory analysis

The analytical methods commonly used for determining the mass of quartz and cristobalite in a dust sample are based on X-ray Diffraction (XRD) and Fourier Transform Infrared (FTIR) spectrometry techniques, which make it possible to distinguish the two main polymorphs of CS. In this regard, a guiding document is the standard ISO 24095 which contains basic principles, potential strengths and limitations of these analytical techniques applied to the quantification of RCS collected on a filter. The same standard provides information on quality controls to ensure the reliability of results and a detailed approach for calculating the measurement of uncertainty.

The INAIL Silica Exposure Database has been set up to gather data from analyses performed on personal, static and bulk samples using both FTIR and XRD techniques, according to the analytical method (standardised, non-standardised or in-house) developed by any laboratory performing the analysis. However, all data entered so far come from analyses carried out using the XRD technique in a single INAIL laboratory. The XRD analysis on a dust sample is carried out with scans in the angular positions of the most intense reflections of quartz and cristobalite. During the analysis, the sample is irradiated with incident X-rays and diffraction intensities and scattering angles of the X-rays are measured. When a dust sample is collected on a filter, such as in the case of personal and static samples, the mass of particles is always small, up to a maximum of a few milligrams. In this case, i.e. at very low dust mass, the basic principle of quantitative analysis by XRD is the proportionality between the intensity of diffracted X-rays and the amount of the crystalline phase in the sample (but a correction factor is to be applied when the sample dust mass increases).

XRD analytical determinations of quartz or cristobalite on the filter can be performed:

- directly on the filter used for dust sampling, according to ISO 16258-1 (most of the analyses included in the Database to date have been performed using this method);
- on another filter, after recovery and redeposition of the dust collected on the sampling filter (indirect analysis), according to ISO 16258-2.

The amount of quartz and/or cristobalite present in the dust collected on a filter is quantified comparing the diffraction intensity of RCS peaks measured in the sample with those in the calibration line, constructed with sample filters containing known quantities of pure quartz or cristobalite reference material of known crystallinity and particle size. The diffraction determination provides the mass content of quartz or cristobalite in the sample. In the INAIL test reports, this result is expressed in milligrams to three decimal places. Then the concentration (mg/m^3) of quartz or cristobalite in the air is calculated from the known volume (m^3) of sampled air, which, in turn, is obtained by multiplying the airflow rate (m^3/min) by the length of the sampling period (min).

The mass of respirable dust in the sample is, on the other hand, determined simply by weighing the filter before and after sampling (gravimetric analysis) and its concentration, expressed in mg/m^3, is obtained by taking into account the volume of air sampled. The ratio of the mass of quartz or cristobalite to the mass of dust gives the percentage content of the analyte in the sample. The upper limit of the measuring range can generally be given by the amount of dust that can be collected on the filter without overloading, which could lead to significant (>5%) losses of material during the transport and handling of the filter. For a respirable dust sample, collected on a 25 mm silver filter, this value is typically around 4 mg.

The lower limit of the measuring range corresponds to the Limit of Quantification (LOQ) of the analytical method. The LOQ should be determined experimentally by each laboratory, since it depends on many factors, such as instrumentation and settings, analytical procedure and acquisition parameters. As the first step for LOQ determination, the laboratory has to determine the Limit of Detection (LOD), defined as the minimum mass of quartz, or cristobalite, that can be reliably distinguished, in the diffraction pattern, from the absence of that analyte (i.e., the response given by a blank sample known to be free of the analyte) at a specified level of confidence. Therefore, the LOD is specific for each diffraction peak used for quantification. The LOQ for each peak is then estimated by applying a factor to the LOD.

The measurements collected in the Database and presented in this Report have all been performed in the INAIL Central Industrial Hygiene Laboratory, by only two analysts, using the XRD technique and analytical

methods that have evolved over time. In these analytical determinations, the LOQ values reached up to 0.007 mg and 0.017 mg for quantification, based on primary and secondary quartz reflections respectively and up to 0.007 mg and 0.048 mg for primary and secondary cristobalite reflections, respectively. In the INAIL test reports, the results below the LOQ are reported as *<LOQ* with the specification on the peak used for the determination and the LOQ value is given in the information section of the same report. The LOQ expressed in terms of concentration (mg/m^3) depends on the flow rate and sampling duration and therefore is calculated for each individual sample.

Although the basic principles described above are applicable to the analysis of both quartz and cristobalite, the statistical calculations and graphs in this Report refer exclusively to quartz.

Regarding bulk samples collected in the workplace, they are sent to the laboratory with as much information as possible. Unlike personal samples, for bulk samples, there are no national or international standardised analytical methods yet. In any case, the XRD analysis has to be performed on a powder with very fine grain size. This is generally achieved by grinding the sample until the optimal particle size has been reached. A few classic XRD methods can generally be applied for the quantitative determination of the CS content in the sample. The addition method and the Reference Intensity Ratio (RIR) method are the most commonly used among them. The choice of the analytical method also depends on the type and amount of material available as well as the expected CS content. The measurements on bulk samples reported in the Database concerns only quartz, up to now. The LOD of the analytical method has been as low as 0.1-0.2% in the absence of interference on the primary peak of quartz and more generally 1%.

1.6 Classification of working activities

As a first step to describe exposure by inhalation to RCS in the workplace, it is necessary to classify companies' production activities. Two working activity classifications have been used: NACE rev. 2 and CONTARP 2016.

NACE rev. 2 statistical classification of economic activities in the European Community

The INAIL Silica Exposure Database adopts NACE rev. 2, the statistical classification of economic activities in the European Community. The acronym NACE designates the various classifications of economic activities developed since 1970 in the European Union. Regulation (EC) No. 1893/2006 of the European Parliament and of the Council of 20 December 2006 established the last revised version, NACE revision 2.

NACE provides the framework for collecting and presenting a large range of statistical data according to economic activity. Economic activity takes place when resources such as capital goods, labour, manufacturing techniques or intermediary products are combined to produce specific goods or services. Thus, economic activity is characterised by the input of resources, a production process and an output of products (goods or services).

The structure of NACE is the following:

- a first level consisting of headings identified by an alphabetical code (sections);
- a second level consisting of headings identified by a two-digit numerical code (divisions);
- a third level consisting of headings identified by a three-digit numerical code (groups);
- a fourth level consisting of headings identified by a four-digit numerical code (classes).

Member States and the Commission established that the use of NACE should be mandatory in the EU. The NACE Regulations allow Member States to use a national version derived from NACE for national purposes. Therefore, in Italy, the ATECO 2007 classification of economic activities, derived from NACE rev. 2, was adopted by the Italian National Institute of Statistics (ISTAT), adding a 5th (category) and a 6th (subcategory) digit. The ATECO 2007 classification has been used in the Italian version of this Report. However, the differences between NACE rev. 2 and ATECO 2007 are unimportant for the scope of this Report, so that the translation from the Italian original classification fits very well into the European nomenclature, requiring only minor adjustments.

The ATECO 2007 code is self-declared by the company or assigned by the Italian Revenue Agency, or by the Italian Business Register. However, sometimes the correspondence between the official ATECO code and the actual working activities does not align accurately. In order to improve the correspondence between the company classification and the actual activity sampled at the workplace, the INAIL professional in charge of the assessment can assign the company an ATECO code different from the official one (only for the purposes pursued by the exposure silica database). However, the ATECO (or NACE) classification of economic activity was not developed with the scope of assessing exposure to the chemical agents. It has been observed that some ATECO (or NACE) classes group together working processes that do not have similar or comparable occupational exposures to airborne dust. To overcome this problem and improve the usefulness of the Silica Exposure Database, INAIL realised a second, parallel classification (named *CONTARP 2016*) focused on work activities involving exposure to silica dust. Therefore, each personal, static or bulk sample has been classified by both ATECO 2007 (NACE rev. 2) and CONTARP 2016 classifications.

CONTARP 2016 classification of working activities that may cause exposure to RCS

CONTARP 2016 classification of working activities has been formulated by an INAIL group of experts, using the NACE rev. 2 classification as a basis. According to the experience developed in INAIL, the activities that may cause exposure to RCS, belong to sections A - *Agriculture, Forestry and Fishing*, B - *Mining and Quarrying*, C – *Manufacturing* and F – *Construction*. The CONTARP 2016 classification, therefore, consists of the same four sections, which in turn are divided into 30 activities, with the addition of a fifth section Z – *Activities not elsewhere classified*.

A – AGRICULTURE — This section includes working activities that use natural resources of vegetal and animal origin in agriculture, the raising and breeding of animals and forestry. Although exposure to RCS in

agriculture has been measured in Italian farms as well as abroad, the related occupational risk is not currently receiving sufficient attention. In Italy, this is mainly because of the size of most of the enterprises, frequently small and medium; in fact, over 30% of farms are made by a single worker. Regarding the risk assessments carried out by INAIL, very few measurements were taken, since agriculture is under special management and the insurance relationship is under the responsibility of a different national body, the National Social Security Institute (INPS). INPS ascertains and collects contributions from employees and self-employed workers and then transfers the contribution portion relating to insurance against accidents and occupational diseases to INAIL (agricultural employers are therefore not required to establish insurance positions with INAIL). Except for farm contractors, the lack of direct management of the insurance relationship between INAIL and employers causes the inadequate knowledge regarding silica exposure risk. Nonetheless, we considered it useful to include information on agriculture in this Report, given the possibility of exposure to RCS. Although the section includes a wide variety of processes, it has not been divided into activities as only a very small number of data are available.

B – MINING AND QUARRYING — The section is divided into 4 activities based on the principal minerals produced: B1 *Quarrying of marble, granite and other coherent rocks*; B2 *Quarrying of sand and gravel*; B3 *Quarrying of clays, pozzolana and feldspar*; B4 *Quarrying of pumice stone*. The mechanical and compositional characteristics of different mined and quarried materials, even within the same productive context, involve considerable differences both in the quarrying and excavation techniques and in the quartz content of the materials and, as a consequence, in the workers' exposure to silica. A quarry is sometimes in close connection with the following manufacturing plants, as occurs in some ceramic factories, in stone processing plants as well as in other activities where the extracted materials are used. In these cases, the data from the measurements carried out in a company are preferably separated into two sections, B for the workers involved in mining/quarrying tasks and C for the workers involved in the following processing of the extracted materials. When it is not possible to distinguish the activity between the B and C sections, the measurement data are generally included in C - *Manufacturing*. Consequently, some mining and quarrying job titles are also included in the manufacturing section.

C – MANUFACTURING — The section includes physical or chemical transformation into new products of materials, substances or components, which in turn are products of agriculture, mining and quarrying as well as other manufacturing activities. However, the definition of what constitutes a new product can be somewhat subjective. This section includes 21 production activities. The chemical sector includes activities C1 *Bituminous membranes*, C2 *Paints, glues and adhesives*, C3 *Rubber, plastic, artificial stone*, C4 *Glass*. Raw materials with high quartz content are used only in a few processes and in specific tasks. The ceramics industry is divided into the activities C5 *Refractories*, C6 *Ceramic tiles*, C7 *Bricks*, C8 *Ceramic ornamental articles*, C9 *Ceramic sanitary fixtures*. This sector is characterised by potentially high exposure to silica, due to the quartz content in clay raw materials. Metal processing is represented by the activities C15 *Iron and steel industry* and C16 *Foundries*, generally carried out in large or medium-sized establishments. Other activities usually employ smaller numbers of workers, such as C17 *Treatment of metals* (except for work carried out directly in foundries), C18 *Ovens and furnaces*, C19 *Jewellery*, which are more frequently carried out by small and medium enterprises. Foundry sand cores production is included in C16 when the process is directly performed in a foundry, or in C14 *Foundry sand cores*, when a specialist enterprise carries out the production in its own right. Activities C20 *Medical and dental instruments* and C21 *Denim sandblasting* have also been classified in the list of the *activities*, even if the total number of employees exposed to RCS is low, because of the specificity of their processes.

F – CONSTRUCTION — This section includes general and specialised construction activities for buildings and civil engineering works, repairs, renovation and maintenance operations as well as the construction of a temporary nature. General construction concerns the building of offices and residential complexes, shops, other public and service buildings, rural buildings, etc., as well as civil engineering works such as highways, roads, bridges, tunnels, railways, airfields, harbours and other water projects, irrigation and sewerage systems, industrial facilities, pipelines and electric lines, sports facilities, etc. Tunnel excavation and construction often generate high concentrations of airborne silica dust, because of the generally high quartz content in the excavated rocks and the underground environment, which makes dust removal more difficult. Based

on the method of excavation, the CONTARP 2016 classification distinguishes two activities: F2 *Tunnel construction, conventional excavation* and F3 *Tunnel construction, mechanical excavation*. Sand blasting (of floors and walls of buildings) in construction, has also been assigned the rank of Activity (F4), even though the number of workers involved is very low, because of its peculiarity and the expected large amounts of dust usually generated. All the other construction activities are grouped in F1 *Construction*.

With regards to the workers operating in companies that are classified in the other NACE rev. 2 sections, listed below, no significant exposures to RCS are known. D - *Electricity, gas, steam and air Conditioning supply*, E - *Water supply; sewerage, waste management and remediation activities*, G - *Wholesale and retail trade; repair of motor vehicles and motorcycles*, H - *Transportation and storage*, I - *Accommodation and food service activities*, J - *Information and communication*, K - *Financial and insurance activities*, L - *Real estate activities*, M - *Professional, scientific and technical activities*, N - *Administrative and support service activities*, O - *Public administration and defence; compulsory social security*, P - *Education*, Q - *Human health and social work activities*, R - *Arts, entertainment and recreation*, S - *Other service activities*, T - *Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use*, U - *Activities of extraterritorial organisations and bodies*. A few silica exposure cases, detected by INAIL in activities included in these NACE rev. 2 sections, are contained in the section Z – *Activities not elsewhere classified*, of CONTARP 2016 classification.

Classification of a company according to CONTARP 2016 is assigned by the INAIL professional in charge of risk assessment and requires the observation of the job tasks carried out at the workplace under examination. If the job tasks carried out at a workplace are recognised as belonging to two different CONTARP 2016 activities, the company can be assigned two classifications and the measurements are consequently separated and appointed to the appropriate activity, thus improving the correspondence between activity and its related RCS exposure levels.

The CONTARP 2016 classification of working activities that may cause exposure to RCS is presented in the next paragraph, 1.7, together with its correspondence with NACE rev. 2 classification codes. Assumptions and exclusions (crossed out items) are highlighted.

1.7 Correspondence table between CONTARP 2016 and NACE rev. 2 classifications

The correspondence table describes how the units classified to the groups defined for CONTARP 2016 classification would be classified in NACE rev. 2 classification. A one-to-one link between versions is not always possible or at times only at a more aggregated level.

SECTION	CONTARP 2016 ACTIVITY	NACE rev. 2 DIVISION, GROUP OR CLASS
A AGRICULTURE	A1 - AGRICULTURE: Crop production	01 - Crop and animal production, hunting and related service activities
B MINING AND QUARRYING	B1 - QUARRYING OF MARBLE, GRANITE AND OTHER COHERENT ROCKS: Quarrying of ornamental and building stone (limestone, marble, granite, porphyry, slate, sandstone, volcanic tuff)	08.11 - Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate
	B2 - QUARRYING OF SAND AND GRAVEL: Extraction of sand and gravel (aggregate of coarse- to medium-grained particulate material used in construction) – Crushing and grinding sand and gravel - Manufacture of products for road coverings - Transport of materials by road	08.12 - Operation of gravel and sand pits; ~~mining of clays and kaolin~~
		19.20 - Manufacture of refined petroleum products (...manufacture of products...for the manufacture of road coverings)
		49.41 - Freight transport by road
	B3 - QUARRYING OF CLAYS, POZZOLANA AND FELDSPAR: Extraction and processing of clays for ceramic industries, refractory and brick manufacturing; kaolin; bentonite clays; pozzolana, bauxite (aluminium), fluorite, barite (fertiliser minerals, chemical industries); feldspar; salt	08.12 - ~~Operation of gravel and sand pits;~~ mining of clays and kaolin
		08.91 - Mining of chemical and fertiliser minerals
		08.93 - Extraction of salt
		08.99 - Other ~~mining and~~ quarrying n.e.c. (...quarrying of feldspar)
	B4 - QUARRYING OF PUMICE STONE: Extraction and processing of pumice stone	08.99 - Other ~~mining and~~ quarrying n.e.c. (...quarrying of abrasive materials)
C MANUFACTURING	C1 - BITUMINOUS MEMBRANES: Manufacture of bituminous membranes	23.99 - Manufacture of other non-metallic mineral products n.e.c. (...manufacture of mineral insulating materials: ...articles of asphalt or similar material, e.g. asphalt-based adhesives, coal tar pitch etc.)
	C2 - PAINTS, GLUES AND ADHESIVES: Manufacture of paints and varnishes, enamels or lacquers, mastics, glues and adhesives, denture fixative pastes; plaster	20.30 - Manufacture of paints, varnishes and similar coatings, printing ink and mastics
		20.52 - Manufacture of glues
		23.52 - Manufacture of ~~lime and~~ plaster
	C3 - RUBBER, PLASTIC, ARTIFICIAL STONE: Manufacture of rubber products, plastic plates, sheets, tubes and profiles, builders' ware of plastic - Manufacture of artificial stone	22.1 - Manufacture of rubber products
		22.21 - Manufacture of plastic plates, sheets, tubes and profiles
		22.23 - Manufacture of builders' ware of plastic (...manufacture of artificial stone, e.g. cultured marble)
	C4 - GLASS: Manufacture of glass and glass products	23.1 - Manufacture of glass and glass products
	C5 - REFRACTORIES: Manufacture of refractory products	23.20 - Manufacture of refractory products
	C6 - CERAMIC TILES: Manufacture of ceramic flags, paving, and wall tiles	23.31 - Manufacture of ceramic tiles and flags

Notes
- the crossed-out sentences are items of the NACE rev. 2 division, or group, or class not included in our classification;
- the underlined sentences are items extracted from the detail of the division, or group, or class, included in the classification;
- n.e.c. stands for not elsewhere classified.

SECTION	CONTARP 2016 ACTIVITY	NACE rev. 2 DIVISION, GROUP OR CLASS
C MANUFACTURING	C7 - BRICKS: Manufacture of bricks, tiles and construction products, in baked clay	23.32 - Manufacture of bricks, tiles and construction products, in baked clay
	C8 - CERAMIC ORNAMENTAL ARTICLES: Manufacture of ceramic household and ornamental articles	23.41 - Manufacture of ceramic household and ornamental articles
		23.49 - Manufacture of other ceramic products
	C9 - CERAMIC SANITARY FIXTURES: Manufacture of ceramic sanitary fixtures	23.42 - Manufacture of ceramic sanitary fixtures
	C10 - CEMENT: Manufacture of cement	23.51 - Manufacture of cement
	C11 - CONCRETE PRODUCTS: Manufacture of concrete products for construction purposes and of ready-mixed concrete	23.61 - Manufacture of concrete products for construction purposes
		23.65 - Manufacture of fibre cement
		23.69 - Manufacture of other articles of concrete, plaster and cement
		23.63 - Manufacture of ready-mixed concrete
	C12 - STONE WORKING: Cutting, shaping and finishing of stone	23.7 - Cutting, shaping and finishing of stone
	C13 - ABRASIVES: Production of abrasive products	23.91 - Production of abrasive products
	C14 - FOUNDRY SAND CORES: Production of foundry sand cores and moulds	23.99 - Manufacture of other non-metallic mineral products n.e.c.
	C15 - IRON AND STEEL INDUSTRY: Manufacture of basic iron and steel and of ferro-alloys	24.10 - Manufacture of basic iron and steel and of ferro-alloys
	C16 - FOUNDRIES: Casting of iron, steel, light metals and non-ferrous metals – Manufacture of machinery and equipment (electrical equipment, motors, generators, turbines, valves, etc.), transport equipment (and accessories) and other metal products	24.51 - Casting of iron
		24.52 - Casting of steel
		24.53 - Casting of light metals
		24.54 - Casting of other non-ferrous metals
		25.11 - Manufacture of metal structures and parts of structures
		25.21 - Manufacture of central heating radiators and boilers
		25.73 - Manufacture of tools (...manufacture of moulding boxes and moulds)
		25.99 - Manufacture of other fabricated metal products n.e.c.
		27.11 - Manufacture of electric motors, generators and transformers
		27.90 - Manufacture of other electrical equipment
		28.11 - Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
		28.14 - Manufacture of other taps and valves
		28.29 - Manufacture of other general-purpose machinery n.e.c.

Notes
- the underlined sentences are items extracted from the detail of the division, or group, or class, included in the classification;
- n.e.c. stands for not elsewhere classified.

SECTION	CONTARP 2016 ACTIVITY	NACE rev. 2 DIVISION, GROUP OR CLASS
C MANUFACTURING	C16 - FOUNDRIES: Casting of iron, steel, light metals and non-ferrous metals – Manufacture of machinery and equipment (electrical equipment, motors, generators, turbines, valves, etc.), transport equipment (and accessories) and other metal products	28.9 - Manufacture of other special-purpose machinery
		29.32 - Manufacture of other parts and accessories for motor vehicles
		30 - Manufacture of other transport equipment
	C17 - TREATMENT OF METALS: Treatment and coating of metals	25.61 - Treatment and coating of metals
	C18 - OVENS AND FURNACES: Manufacture, repair and maintenance of ovens and furnaces	28.21 - Manufacture of ovens, furnaces and furnace burners
		33.12 - Repair of machinery (...repair and maintenance of industrial process furnaces)
		43.22 - Plumbing, heat and air-conditioning installation (...maintenance and repair of heating systems and furnaces)
	C19 - JEWELLERY: Manufacture of jewellery - Precious metals production	32.12 - Manufacture of jewellery and related articles
		24.4 - Manufacture of basic precious and other non-ferrous metals
	C20 - MEDICAL AND DENTAL INSTRUMENTS: Manufacture of medical and dental instruments	32.50 - Manufacture of medical and dental instruments and supplies
	C21 - DENIM SANDBLASTING: Alteration of clothing: denim sandblasting	96.01 - Washing and (dry-)cleaning of textile and fur products
F COSTRUCTION	F1 - CONSTRUCTION: Construction of buildings - Civil engineering - Construction of roads - Asphalt paving of roads - Demolition and site preparation - Installation of machinery and systems	41.2 - Construction of residential and non-residential buildings
		42 - Civil engineering
		42.11 - Construction of roads and motorways
		42.21 - Construction of utility projects for fluids
		43.11 - Demolition
		43.12 - Site preparation
		43.22 - Plumbing, heat and air-conditioning installation
	F2 - TUNNEL CONSTRUCTION, CONVENTIONAL EXCAVATION: Construction of tunnels using mechanical diggers or conventional drilling and blasting method	42.13 - Construction of ~~bridges and~~ tunnels
		43.13 - Test drilling and boring
	F3 - TUNNEL CONSTRUCTION, MECHANICAL EXCAVATION: Construction of tunnels using hard rock tunnel boring machines or tunnelling shields	42.13 - Construction of ~~bridges and~~ tunnels
	F4 - SAND BLASTING FOR BUILDING EXTERIORS: Sand blasting for building exteriors and for cleaning of pavements	43.99 - Other specialised construction activities n.e.c. (...sand blasting and similar activities for building exteriors)
Z ACTIVITIES NOT ELSEWHERE CLASSIFIED		

Notes
- the crossed-out sentences are items of the NACE rev. 2 division, or group, or class not included in our classification;
- the underlined sentences are items extracted from the detail of the division, or group, or class, included in the classification;
- n.e.c. stands for not elsewhere classified.

Occupational titles according to the ISTAT and ISCO classifications

The national classification of occupations CP2011 was produced in 2011 by the Italian National Institute of Statistics (ISTAT). The structure of CP2011 is based on the logic of the International Standard Classification of Occupations 2008 (ISCO-08), with which it is very cross-linkable. The ISCO-08 definition of a job is *a set of tasks and duties performed, or meant to be performed, by one person, including for an employer or in self-employment*. Occupation is defined as *a set of jobs whose main tasks and duties are characterised by a high degree of similarity* (ILO, 2012). Occupational titles are formally identified in employment contracts, yet an enterprise may also adopt an internal job description, containing the list of the duties assigned to each employee. Each occupational title, as defined in employment contracts, may often include very different tasks, in particular concerning exposure to dust.

The CP2011 classification is a tool that allows comparing the national situation with those existing in the other European countries and is a fully accepted standard for international labour statistics. The criteria, on which this classification is founded, are derived from ISCO-08 and are based on the similarity of the skill level and skill specialisation required for the jobs. The classification considers four skill levels, based on the field of knowledge required, the tools and machinery used, the materials worked on or with and the kind of goods and services produced. The CP2011 occupations' classification system is structured into 5 aggregated hierarchical levels and 9 professional major groups, which are in turn divided into 37 groups, containing 129 classes disaggregated in 511 categories, including 800 professional units (5-digits codes), to which all occupations existing in the labour market can be led back. The total number of professional items included in the classification surpasses 6,700. However, as pointed out by ISTAT, this list does not make any claim of being exhaustive and it is reported by way of example. Each professional item is represented by a 6-digits code and a denomination, but a description of the ascribed tasks is not provided. The correspondence table between the CP2011 classification by ISTAT and ISCO-08 classification by ILO can be accessed via the ISTAT public website (https://www.istat.it/it/archivio/18132).

CONTARP 2016 classification of job titles in working activities that may cause exposure to RCS

Although ISCO-08 and CP2011 are occupational classifications fully supported as accepted standards for labour statistics by the international community, they do not comply with the requirement of the European standard EN 689 for the evaluation of compliance with occupational exposure limit values of inhaled chemical agents. In fact, the occupational titles included in their classifications do not generally correspond to Similar Exposure Groups (SEGs), since the criterion of *having the same general exposure profile for the chemical agent being studied, because of the similarity and frequency of the tasks performed, the materials and processes with which they work and the similarity of the way they perform the tasks* is not fulfilled.

The CONTARP 2016 classification of job titles has been established with the aim of getting to a definition, closer to the SEG one and therefore, making the use of RCS exposure measurement data more effective in the risk assessment process. As a first step, a classification of CONTARP 2016 working activities was produced as pointed out in paragraph 1.6. In the meantime, the same working group of INAIL experts developed the CONTARP 2016 classification for job titles. This classification is based on the experience acquired throughout 20 years of activity, consisting of samplings at workplaces, laboratory analyses and assessment of the silica dust risk in factories and construction sites located throughout Italy, referring to any working activity showing evidence of potential exposure to RCS. In order to better define job titles and describe tasks, a study phase of the technical literature related to those production activities characterised by the potential exposure to CS was added to the wealth of experience gained in the field.

The CONTARP 2016 classification of job titles is constructed based on the working activities classification described in paragraph 1.6. The 31 activities, in turn, are divided into a total of 250 departments or work phases, each characterised by the code given to the activity plus an additional digit and a denomination (e.g., *C5.05 Forming by casting*). Departments or work phases, in turn, include 697 job titles, each characterised by a code composed of the identifier of the department or work phase, plus an additional digit and denomination (e.g., *C5.05.01 Manual casting operator*) followed by a brief description of the working processes involved and/or the tasks performed. Codes and descriptions of the CONTARP 2016 job titles are reported in the third Part of the Report. Each CONTARP 2016 job title is part of only one working phase

and, therefore, to only one activity. Similar jobs in different activities have different codes but the same denomination or a similar one. So, for example, sandblasting operators are found in the activities C4 Glass, C12 *Stone working*, C16 *Foundries*, C17 *Treatment of metals*, C21 *Denim sandblasting* and F4 *Sand blasting for building exteriors*. Some job titles are common to almost all activities, as is the case, e.g., of the manager, the office worker, the warehouse operator, the maintenance mechanic/electrician, the polyvalent worker and the workplace cleaner.

As pointed out, CONTARP 2016 job titles tend to match the SEG definition. Mostly, a job title requires the fulfilment of several tasks within the work shift and, sometimes, provides for some tasks to be carried out intermittently, occasionally or seasonally, depending on the needs and the production rates of a specific working activity. For the purposes of assessing workers' exposure to CS, sometimes it is useful and possible, to split an activity performed by an operator into multiple titles, with the aim of distinguishing the tasks which entail exposure to CS dust from those that, on the other hand, do not show a silica dust risk. Whenever possible, in the CONTARP 2016 classification, tasks with significant differences in exposure to CS are therefore assigned to different job titles. Another characteristic considered in the definition of CONTARP 2016 job titles deals with the features of the equipment and machinery used to perform the working tasks.

From an operational point of view, the workers to be sampled have been selected according to the information about their job titles provided by the company managers. During sampling, the tasks actually performed by the worker have been observed and recorded. In the risk assessment, this check is used for the assignment of the actual job title. When processing the results of sampling, the appraiser reports a description of the tasks carried out by each worker with whom a sampling is associated. In this way, the appraiser selects, within the CONTARP 2016 classification, the corresponding job title that is then used in the statistical analysis processed in the INAIL Silica Exposure Database and in this Report. The appraiser assigns a main job title to every single measurement that has been made and, when appropriate, one or two secondary job titles. However, for the purposes of the statistical processing, exposure values are assigned exclusively and entirely to the main job title.

To clarify what was stated above, it is useful to give some examples.

In the manufacture of bricks in small factories, the provision of clay (raw material) can come from a quarry managed by the enterprise itself and clay is often extracted occasionally, depending on the request of production departments. The sampling of airborne dust will be assigned to the job title C7.02.01 *Quarryman* only if the operation that is actually sampled coincides with quarrying from an open pit. However, the same worker will usually be engaged in other duties, such as lifting and moving materials and products inside the brick factory. Therefore, a dust sample collected monitoring the same worker on a different day, when he is engaged in a different duty, will be classified with a different code, fitting the performed tasks.

In the manufacture of ornamental ceramic articles, the biscuit ware is cleaned with an air hose, releasing a blast of compressed air on the object. This task is carried out periodically, generally requiring a few hours before glazing, by a worker that in the remaining part of the work shift is engaged in other duties. The measurement will be assigned to the job title C8.04.02 *Ceramic biscuit blower* only if the worker had actually performed the cleaning of the biscuit ware during the sampling.

In the construction of tunnels by conventional excavation, a worker in charge of jetting the shotcrete for tunnel work face consolidation (F2.02.05 *Shotcrete pump operator*) performs such an operation cyclically, depending on the specific working plan, e.g. for 30 minutes every 4-5 hours. In the remaining part of the work shift, the same worker usually collaborates with the other components of the excavation crew, carrying out tasks different from that specific of his job title. The shotcrete jetting operation often lasts too short a period in order to carry out a reliable sampling of dust, so the sampling of job title F2.02.05 most frequently includes also other operations and is actually representative of the exposure of the worker throughout all the work shift.

Regarding the machines used by a worker performing a given task, in some cases the CONTARP 2016 classification splits different job titles into tasks that have the same scope but are different in terms of exposure to airborne dust, due to the characteristics of the machines used. For example, in agriculture,

processes carried out using machines equipped with cabs are associated with different job titles from those without a cab, even though the task and the effect of the process are identical in terms of production.

In foundries, sandblasting operations are separated from shot blasting ones, although both processes are similar from a technological point of view. Furthermore, the operations of sandblasting (or shot blasting) performed manually using a lance, manually but in closed cabinets, or by using automatic sandblasting machines are all associated with different job titles. In such cases, similar tasks require different machines; this situation leads to very different values regarding exposure to silica dust even though the occupational title could formally be the same.

1.9 Classification of bulk materials

Samples of bulk materials collected in a workplace can have a wide range of grain sizes as well as chemical and mineralogical compositions. As a first step in the storing of bulk sample data in the INAIL Silica Exposure Database, the type of bulk material is characterised according to its grain size or physical state, following the descriptions given in Table 1.1.

Table 1.1 Types of bulk samples
Clay, silt or fine-grained soil
Sludge produced from the industrial process
Fragment of raw material or finished product
Fragment of rock or mineral
Sand or gravel
Powder or granular material
Liquid, slurry or paste
Settled dust particles

Bulk materials are then classified into two groups:

- rocks and aggregates;
- raw materials and finished products.

Rocks have been classified according to characteristics such as mineral and chemical composition, texture, particle size, conditions in which they formed, mode of occurrence, the condition when being worked on and by taking into account their quartz content. Table 1.2 lists rocks and aggregates classes used in the INAIL Silica Exposure Database.

In mining and quarrying and in excavations (construction), the local rocks affected by the workings are the main source of dust generation. At the end of quarrying operations on a rock outcrop, the resulting material is transferred to stone working facilities, where in turn it represents the source of dust during stone cutting and processing for shaping blocks and slabs. Natural sand and gravel are quarried for the production of aggregates for the construction industry. In this case, rock outcrops are disintegrated and crushed to reach the required grain size. Agricultural soil, derived from rock materials, represents a special source of dust generation due to agricultural practices.

Table 1.2 Rocks and aggregates	
Amphibolite, eclogite	Marlstone (calcareous, argillaceous, arenaceous marlstone)
Basalt, trachyte, andesite, latite	Marly limestone
Baryte, fluorite	Peridotite (lherzolite), ultrabasic rock
Bauxite	Pozzolanic ash
Bentonite	Pumice
Clay, argillite, peat	Quartz-porphyry (rhyolitic ignimbrite)
Coal	Quartzite, quartz
Diatomaceous earth (diatomite)	Radiolarite
Feldspar (labradorite)	Rhyolite (liparite, pantellerite), dacite, ignimbrite
Flint, chert	Sand
Gabbro, diorite, syenite, monzonite, diabase (dolerite)	Sandstone, flysch
Gneiss	Schist (mica schist, green schist, garnet schist)
Granite, granodiorite, tonalite, quartz diorite	Serpentinite, ophiolite
Gravel, conglomerate, breccia (clastic rock)	Slate (flagstone)
Gypsum (plaster)	Soil
Halite	Talc
Kaolin	Travertine, calcareous tufa
Leucite rock, tephrite	Tuff (volcanic ash)
Limestone (calcarenite), dolomite rock	Volcanic tuff (peperino)
Marble (from metamorphism of limestone or dolomite rock)	Wollastonite

Raw materials, intermediate materials and finished products may represent sources of dust generation in the workplace of most industrial activities. Since the variety of materials is practically infinite, the classification adopted in the database, shown in Table 1.3, is based on the materials collected until now, but is updated when a request for a material that has not yet been classified is sent to the database managers.

Settled dust collected from indoor workplace surfaces and sludge produced from some industrial processes and collected in settling tanks represent special cases of bulk samples. These fine-grained materials, generally in the inhalable particles size range and often with grain size capable of reaching the lungs (respirable fraction), enable estimating the relative level of silica in the dust, since they represent the overall average production of dust in the specific workplace.

Table 1.3 Raw materials and products

Abrasive	Ceramic products: sanitary ware
Abrasive belt, abrasive cloth	Concrete
Abrasive disk, grindstone	Enamel for ceramic ware, frit for ceramic glaze
Abrasive paste	Enamel for metal, frit for metal enamelling
Additives, fillers, reinforcements for processing of plastics	Fire clay (refractory clay)
Artificial stone (marble-based)	Foundry sand
Artificial stone (quartz-based)	Gas coke, metallurgical coke
Ball clay (kaolinitic clay)	Glass-ceramic fibres
Bituminous conglomerate	Ground-granulated blast-furnace slag
Bleaching earths (purification of oils and fats)	Gypsum plaster (plaster of Paris, calcium sulphate hemihydrate)
Building coating materials	Gypsum powder for jewellery casting
Calcined diatomaceous earth	Lime (pure, hydraulic, and poor lime)
Calcined kaolin (grog, firesand, chamotte; metakaolin)	Lime plaster
Casting ladle	Mill scale (flaky surface of hot rolled steel)
Casting ladle coating	Petroleum coke
CEM I, Portland cement (clinker ≥95%)	Powders/pastes for mould preparation in dental laboratories
CEM II, Portland cement (clinker ≥65%)	Rice husk ash
CEM III, Blast furnace cement	Sand for marble sandblasting
CEM IV, Pozzolanic cement	Settled dust collected from workplace surfaces
CEM V, Composite cement	Shot-concrete (concrete applied by spraying)
Cement clinker	Slip (slurry of clay and other materials suspended in water)
Cement raw meal	Slip material for red body ceramic tiles
Ceramic products: bricks	Slip material for white body ceramic tiles
Ceramic products: floor and roof tiles	Sludge produced from the industrial process
Ceramic products: ornamental articles	Welding electrode (coating)
Ceramic products: pottery	Welding flux
Ceramic products: refractories	...

1.10 Statistical parameters and data evaluation criteria

The exposure measurement results collected in the INAIL Database are processed using statistical methods typical of industrial hygiene and are reported in tables and diagrams. The calculation procedures and the approach for graphical representation of RCS and respirable dust exposures are described in the following paragraphs.

RCS measurement below the limit of quantification (LOQ)

Sometimes the mass of quartz particles collected on a sampling filter results below the LOQ of the analytical method. Although non-measurable, these results should not be ignored, because they represent real exposure levels. Their omission would affect the calculation of statistical parameters such as the Geometric Mean (GM), the Geometric Standard Deviation (GSD) and the exposure percentiles for the measurement distribution.

The problem is known and widely discussed in the scientific literature. A number of methods have been proposed for dealing with the non-detectable values, most of which substitute *<LOQ* data with a numerical value (Hornung and Reed, 1990). The generally preferred approach, also adopted in this Report, is a simple approximation where all non-detectables are assigned the value of one-half the LOQ. Among other possible approaches, the two extremes are represented by setting the value to zero (probably underestimating the true value) and at the LOQ level (overestimating the true value). In any case, when more than half of the measurements are *<LOQ*, accurate estimates of GM and GSD cannot be achieved. In the tables of this Report, an asterisk (*) after the GM and GSD value warns the reader that more than 50% of the measurements in that dataset are *<LOQ*. In the probability graphs, each value lower than the LOQ is shown as a green circle, while black circles represent values ≥*LOQ*.

In the INAIL Silica Exposure Database, 21.1% of all of the personal measurements recorded between 2000 and 2019 were below the LOQ for the analytical method for quartz. The percentage increases to 28.0% for static samples, taken at fixed locations to assist in assessing the RCS exposure. The *LOQ/2* value expressed in milligrams of quartz is calculated from the known LOQ value for the analytical method. In the next step of the Database implementation, the *LOQ/2* value is transformed into a concentration (mg/m^3) taking into account the sampling flow rate and duration and is therefore specific for every single measurement. Following this procedure, the average concentration of RCS obtained between 2000 and 2019 for samples *<LOQ* was estimated equal to 0.007 mg/m^3.

The same procedure is applied for the analysis of quartz content in bulk samples. In the INAIL Dataset, 18.8% of the bulk samples were *<LOQ*. The LOQ value of the analytical method was generally set to 1%, except in a few cases where the analytical approach could achieve LOQ=0.1%.

RCS measurement above the upper limit of the measuring range

The width of the measuring range covered by an analytical method, for particulates collected on membrane filters, depends on the calibration filter with the highest mass of analyte used for the construction of the calibration line. In the 20 years of analyses included in this Report, the diffraction instruments were recalibrated a number of times and new calibration filters have been used, so that different maximum values have been obtained at different times. Only a few dust samples, i.e. 0.4% of personal samples and 1.6% of static samples, contained quartz amounts exceeding the upper limit of the measuring range. Their results were reported in the test reports as *greater than the maximum measurable value*. These non-measurable results should also be kept in the data set for statistical treatment. The approach chosen to deal with this issue, in this Report, consists of assigning the quartz mass value of the upper limit of the measuring range to these samples (therefore underestimating the true value). Quartz exposures (mg/m^3) were finally calculated taking into account sampling flow rates and durations. The quartz average concentration for these measurements resulted equal to 0.35 mg/m^3.

Distribution of the measurement results

The occupational exposures to RCS and respirable dust, due to the inhalation of airborne dust generated by the working activity, is influenced by many factors, including the worker's distance from the dust source, characteristics of the ventilation systems for the removal of airborne dust, climatic conditions, etc.

Therefore, the variability of the exposure of a worker, or a group of workers that carry out the same tasks, is usually wide. The European standard EN 689:2018 devises a sampling strategy able to overcome the problem of variability using a relatively small number of measurements since is not feasible to measure every worker for every working day.

This strategy, suggested by EN 689 for testing compliance with the OELV, requires the collection of a statistically significant number of personal air samples among workers within SEGs, as defined in 1.4. The job titles in the CONTARP 2016 classification, used in the INAIL database for the identification of groups of workers, have been conceived to correspond to SEGs.

The results of the measurements are then used to assess the exposure profile of the SEG. The first step in this process consists of evaluating which type of distribution fits the data better. Two types of distributions are generally considered: normal and lognormal. The normal distribution (the bell curve) is symmetric around the Arithmetic Mean (AM) and its Standard Deviation (SD) measures the variability of the data set. In the lognormal distribution, the logarithms of the concentration values are normally distributed, so that the distribution is asymmetric, with a long tail on the right. The lognormal distribution function is described completely by the Geometric Mean (GM) and the Geometric Standard Deviation (GSD). Therefore, the central tendency of a set of exposure data corresponds to AM, defined as the sum of the exposure values divided by the number of samples (for the case of normal distribution), or GM, defined as the *n*th root of the product of the *n* exposure values (lognormal distribution):

$$AM = \frac{\sum_1^n x_i}{n} \qquad GM = \sqrt[n]{x_1 \cdot x_2 \cdot \ldots \cdot x_n}$$

where x_i is the *i*th value of the exposure measurements in the SEG.

SD (normal distribution) and GSD (lognormal distribution) respectively measure the variability of distribution:

$$SD = \sqrt{\frac{\sum_1^n (x_i - AM)^2}{n-1}} \qquad GSD = exp\sqrt{\frac{\sum_1^n \left(ln(x_i) - ln(GM)\right)^2}{n-1}}$$

The smaller the SD or GSD, the lesser the dispersion around the AM or GM of the exposure data.

Figure 1.1 gives an example for a typical set of data, regarding exposure to RCS for a group of workers assumed with similar exposure. The figure represents only the concentration values included in the range from zero to 0.12 mg/m^3. This range is divided into class intervals 0.004 mg/m^3 wide and then the number of values falling into each interval is counted. Even before any statistical test is used, the long tail on the right leads to the prediction that a lognormal distribution would fit the results better than a normal one. The lognormal distribution curve has therefore been computed from the data set, calculating GM and GSD and applying the following equation:

$$f = \frac{1}{x_i \cdot ln(GSD) \cdot \sqrt{2\pi}} \cdot exp\left(-\frac{\left(ln(x_i) - ln(GM)\right)^2}{2 \cdot ln^2(GSD)}\right)$$

A visual exam of the lognormal curve overlapped to the histogram shows that the data set can actually be regarded as having come from a lognormal distribution.

This behaviour is general, as recognised for a long time (Leidel et al., 1977), based on both theoretical and empirical evidence. The results described in this Report further confirm the lognormal distribution as the best fitting representation of exposure measurement distribution in a SEG.

A statistical test, such as the Shapiro and Wilk test, can also be used to verify whether a set of concentration data follows a lognormal distribution. However, the statistical approach suggested by EN 689:2018 is a graphical one that can be used when at least six exposure measurements are available for a SEG, assuming a lognormal distribution of the measurements. This graphical approach allows the calculation of

exposure probability at any concentration level and is the suggested procedure to check whether the exposure of the SEG complies with the limit value. The statistical analysis obviously improves as the number of measurements increases, in which case the empirical distribution curve tends to match the theoretical one better. The graphical method uses the log-probability diagram with the *x*-axis (concentration) in a logarithmic scale. For the construction of this graph, the values of concentration are arranged in ascending order (Table 1.4) and then the probability of each value is calculated as:

$$P_i = \frac{i - 3/8}{n + 1/4}$$

where *i* are the corresponding ordinal values (1, 2, 3, …). The concentration values are plotted on the *x*-axis and the corresponding probability values on the *y*-axis of the log-probability diagram.

In the example shown in Figure 1.2, the points of the data set are closely scattered around a straight line. This line passes through two points of known coordinates: the GM (i.e. the concentration value at the 50%

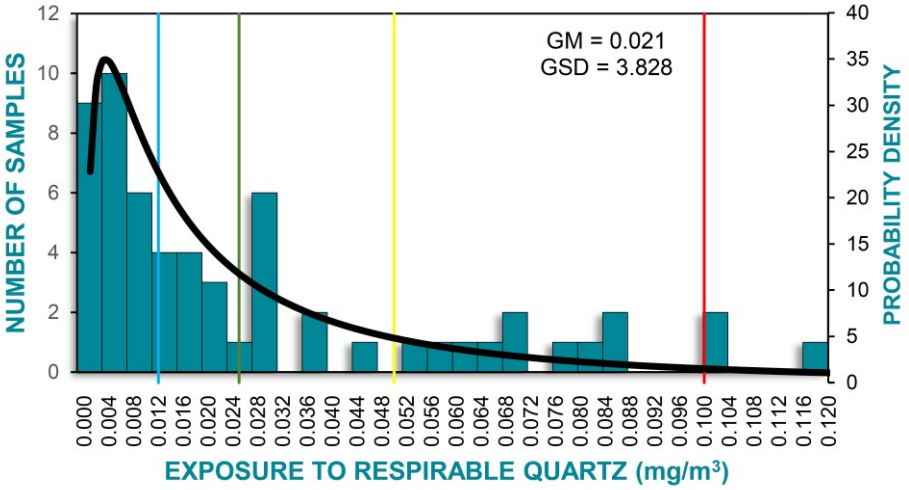


Figure 1.1 The histogram shows the number of samples occurring in concentration classes of 0.004 mg/m^3 width between zero and 0.120 mg/m^3. The lognormal probability curve, overlapped to the histogram, is constructed by using GM and GSD values calculated from the dataset.

The graph represents the RCS exposure for the job title C16.11.01 *Deburring/grinding finisher* (foundries).

Table 1.4 Example of probability calculation

i	x_i (mg/m^3)	P_i	P_i (%)
1	0.006	0.027	2.7
2	0.006	0.070	7.0
3	0.007	0.113	11.3
4	0.008	0.156	15.6
5	0.008	0.199	19.9
6	0.009	0.242	24.2
7	0.009	0.285	28.5
8	0.010	0.328	32.8
9	0.011	0.371	37.1
10	0.011	0.414	41.4
11	0.011	0.457	45.7
12	0.014	0.500	50.0
13	0.015	0.543	54.3
14	0.018	0.586	58.6
15	0.018	0.629	62.9
16	0.019	0.672	67.2
17	0.022	0.715	71.5
18	0.022	0.758	75.8
19	0.026	0.801	80.1
20	0.032	0.844	84.4
21	0.032	0.887	88.7
22	0.034	0.930	93.0
23	0.035	0.973	97.3

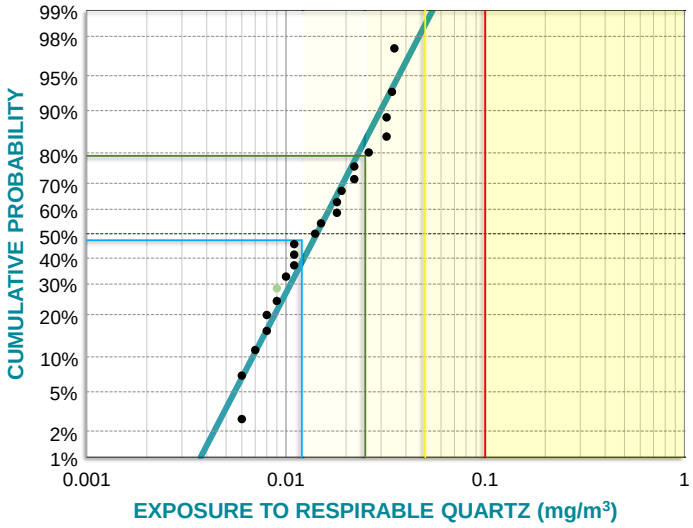


Figure 1.2 Lognormal probability diagram referred to the RCS exposure for the job title C16.04.04 *Moulding press operator*, working in foundries, constructed from the data set shown in Table 1.4. GM=0.014 mg/m^3, GSD=1.774, n=23 measurements. The green circle represents a measurement <*LOQ*.

probability) and the value equal to the product of GM and GSD (i.e. the concentration at 84% probability). The visual analysis of the log-probability diagram, shown in Figure 1.2, supports the assumption that the set of data follows a lognormal distribution, since a good fit with the straight line is obtained.

It must be underlined that the lowest concentration values are sometimes obtained when the results are $x_i<LOQ$ and therefore in this Report are calculated as $x_i=LOQ/2$, accordingly with the approach described above. Consequently, these points sometimes do not represent the true concentrations well, diverging from the straight line.

Since the graphical method cannot be applied when the dataset includes less than six measurements, in this case, the probability calculations are not performed in this Report and only the GM and GSD values are provided.

Probability of exposure

The probability distribution of exposure for a group of workers that carry out similar tasks (SEG), can be used to estimate the percentage of workers in that SEG that are exposed above fixed concentration thresholds. In this Report, four concentration thresholds for the exposure to RCS and three for the exposure to respirable dust are shown in the graphs (see 1.4).

As an example, Figure 1.2 and Table 1.4 show the RCS exposure dataset for the SEG *C16.04.04 Moulding press operator* (working in foundries). In this case, the probability that exposure to RCS exceeds the ACGIH TLV (0.025 mg/m^3) is calculated by the logarithmic interpolation between P_{18}=71.5% (at x_{18}=0.022 mg/m^3) and P_{19}=80.1% (at x_{19}=0.026 mg/m^3), with a resulting probability of 79.1%. In other words, 20.9% of the workers in this SEG are expected to be exposed to values above the TLV for RCS. This information appears to be more complete and useful than the GM value alone and is always given in this Report when at least six measurements per SEG are available.

The median, or GM, of the SEG dataset is the 50th percentile of exposure, i.e. the value that is in the middle, with the same number of results below and above. In a perfectly lognormal distribution, the product ($GM \cdot GSD$), calculated from the SEG dataset, corresponds to the 84th percentile of exposure. The straight line joining the concentration points at 50th and 84th percentiles in the lognormal diagram can therefore be used for a simplified calculation of the exposure probability. For example, the data shown in Table 1.4 and Figure 1.1 gives an 83.5% probability that exposure exceeds the RCS TLV. This value can be compared with the 79.1% probability calculated by using the interpolation approach.

The statistical procedure for assessing exposure probabilities for SEG, described above, in this Report is also used to calculate the probability of exposure for entire industrial sectors or activities, as defined in 1.7. In this case, however, a working activity cannot be considered as a similar group of exposure, because it includes groups of workers that perform many different tasks and therefore belong to different SEGs. Moreover, although the sampling strategy should be designed to be representative of the exposure of all the workers in the SEG, not all the SEGs are generally investigated with the same accuracy. As EN 689:1995 states, where it is suspected that exposure levels are well below the limit value, the investigation can be less accurate, i.e. the resources can be concentrated on those groups of workers with the highest exposure. A typical example is represented by the SEG *office workers*: since the silica dust exposure level in their workplaces is generally negligible, this SEG is often not included in the sampling plan. Hence, the probability of exposure in industrial activities, as presented in this Report, should not be misinterpreted as representative of all employees working in the factory, plant or construction site. Nonetheless, the overall probability of exposure assessed for an industrial activity gives interesting information about the general level of exposure in the departments where silica dust can be present.

Compliance with the limit value for workers in a SEG

After the results have been accepted and validated, they can be used for comparison with the Occupational Exposure Limit Value (OELV). This Report focuses on the cases in which at least six valid measurements per SEG are available and the distribution of the measurements is lognormal. In this case, accordingly with EN 689, the compliance test for an SEG is based on the comparison of the 70% upper confidence limit with

the 95th percentile of the distribution of the results. If the upper confidence limit is greater than the OELV, it is concluded that there is an unacceptable probability of exceedance (non-compliance). To verify if this condition is achieved, the variable is calculated according to the following formula:

$$U_R = \frac{ln(OELV) - ln(GM)}{ln(GSD)}$$

The result for U_R is then compared with the value U_T, tabulated as a function of the number of results (Table 1.5):

- if U_R is greater than or equal to U_T, then the conclusion is *compliance with the OELV*;
- if U_R is smaller than or equal to U_T, then the conclusion is *non-compliance with the OELV*.

As an example, we can use the data for the SEG C16.04.04 *Moulding press operator*, shown in Table 1.4 and Figure 1.2. Since n=23, in Table 1.5 it is found that U_T =1.851. Then, U_R is calculated with the formula given above, which includes the OELV and the decision (compliance or non-compliance) is taken. Taking into consideration three possible OELVs, for a more exhaustive discussion, the conclusion would be:

- *OELV* = 0.1 mg/m^3: U_R = 3.430 > U_T *compliance with the* OELV
- *OELV* = 0.05 mg/m^3: U_R = 2.221 > U_T *compliance with the* OELV
- *OELV* = 0.025 mg/m^3: U_R = 1.011 < U_T non-*compliance with the* OELV

Table 1.5 Values for U_T as a function of the number of results n (from EN 689:2018)

n	U_T	n	U_T	n	U_T	n	U_T	n	U_T
6	2.187	11	1.981	16	1.905	21	1.863	26	1.836
7	2.120	12	1.961	17	1.895	22	1.857	27	1.832
8	2.072	13	1.944	18	1.886	23	1.851	28	1.828
9	2.035	14	1.929	19	1.878	24	1.846	29	1.824
10	2.005	15	1.917	20	1.870	25	1.841	30	1.820

Bulk samples

The result for the analysis on a bulk sample is expressed as the weight fraction of quartz in the sample (percentage by weight).

For each bulk material type, as classified in 1.9, the number of samples analysed, the minimum, maximum and the arithmetic mean of the weight fraction of quartz in the samples are given in this Report.

1.11 Organisation of the Report

The Report is divided into four Parts. Part 1, of which this is the last paragraph, gave the general information on the subject of the Report, the type of measurements and data, the classification criteria for working activities and job titles as well as the statistical criteria for the presentation of the data.

In the second and third Parts of the Report, the results of personal measurements carried out to assess workers' exposure to CS and to respirable dust are presented. In Part 2, an overview of the data for production activities on a national scale is given, while in Part 3, exposure data are analysed in detail by activity and task, according to the CONTARP 2016 classification of production activities and job titles.

The fourth Part presents the results of the laboratory analyses carried out on bulk samples to quantify the quartz content.

Part 2 — Overview of data on a national scale

Tables and graphs in the general data paragraph shows the total number of plants/work sites sampled, the number of samples collected and analysed for respirable dust and the number of samples analysed for CS content.

The number of factories/construction sites where the measurements have been taken is also given. It should be noted that a company might operate in several establishments, where sometimes-different processes take place. Construction companies are usually sampled at several construction sites, active for varying time intervals, located often in different regions and possibly with different construction activity classifications. As a result, the number of monitored establishments/worksites is slightly higher than that of investigated companies.

With regard to the number of samples analysed, gravimetric analysis has been carried out on all the filters (with rare exceptions) to determine the respirable dust concentration, but not all the filters have been analysed to determine the CS content. The reason is that according to the INAIL Central laboratory's internal procedure in force until the year 2007, the XRD analysis for CS was not carried out when the quantity of dust collected on the filter was so low that it was highly unlikely to find a CS mass greater than the LOQ of the analytical method. Therefore, the number of respirable dust analyses is higher than that of RCS analyses.

The number of samples collected is shown in a map with the geographical distribution (by region) and by type (personal, static and bulk samples) both in a histogram and in a pie chart.

The mean, minimum and maximum percentage content of quartz in each production activity, measured in the respirable dust from personal samples, is shown in a histogram.

The 50th percentile (the GM) and 84th percentile (the product of GM and GSD) of exposures to RCS and respirable dust are reported for production activity according to both the CONTARP 2016 and the NACE rev. 2 classifications. Histograms and maps are also used to represent exposures by region and season.

The number of personal measurements of exposure to CS carried out annually from 2000 to 2019 is shown in a histogram. Finally, the annual 50th and 84th percentiles of exposure are presented for the six production activities with the largest numbers of measurements (at least 400 measurements per activity). The years in which less than nine measurements were available were excluded from the graphs. A polynomial line has been calculated and plotted on each histogram to show the trend change in the median value of the measured exposures over time.

Part 3 — Exposure data by activity and task

The third Part presents an in-depth examination of the CS (quartz) exposure data, being divided in 30 subparagraphs, one for each production activity described in the CONTARP 2016 classification. Each subparagraph is introduced by a brief description of the production cycle, or processes, typical of the activity. This description is not exhaustive but is intended to provide a framework for the job titles described later.

General data on the concentrations of CS and respirable dust measured for the production activity are then summarised (number of samples analysed, GM of the concentrations and relative GSD, average quartz

content in respirable dust). These general data are provided for both personal and static samples. Static samplings are not further discussed in the Report, but can be examined by accessing the Silica Exposure Database published on the INAIL website. The geographical distribution of the average exposure to quartz and respirable dust is then represented in map form, while their seasonal variations are shown in histograms.

The percentiles (probabilities) of personal exposure to quartz in the production activity and the values of the exposure probabilities below the four concentration thresholds chosen in the Report (0.1 - 0.05 - 0.025 and 0.012 mg/m^3) are reported according to the procedures described in 1.10. Similarly, for personal exposure to respirable dust in the production activity, the same information is reported with reference to three concentration thresholds (3 - 1.5 and 0.3 mg/m^3).

The quartz content percentage in respirable dust is represented in a graph quartz concentration vs. respirable dust concentration, where the two concentrations refer to the values measured in each personal sample taken. In order to make it easier to read, the concentration of respirable dust (on the *x*-axis) is limited to the maximum value of 2 mg/m^3 and the concentration of respirable quartz (on the *y*-axis) to 0.3 mg/m^3. A table shows the number of samples per quartz content class (≤5%, >5% to 10%; >10% to 15%; >15% to 20%; >20%).

The results summarised in the first part of the sub-paragraph are followed by an in-depth examination of the exposures per job title. Each job title code, name and description, is given according to the CONTARP 2016 job title classification (see paragraph 1.8). The number of personal samples analysed for respirable quartz, the GM of the measurements, the relative GSD (only if at least 3 measurements are available) and the percentiles of the measurements below the four concentration thresholds considered (only if at least 6 measurements are available) are reported in a table for each job title. It should be noted that the CONTARP 2016 job title classification also includes job titles for which no measurements have been made to date, so that they do not appear in the table.

When at least 6 measurements are available for a job title, the data of exposure to RCS are also reported in a lognormal probability graph, constructed as described in 2.1, which allows checking if the job title does effectively represent an SEG (i.e. if the points in the graph lie close to a straight line).

Data from personal samples representing exposure to respirable dust are summarised for each job title in a table compiled in the same way as described above for the respirable quartz exposure table.

Part 4 — Quartz content in bulk materials

The information on the bulk materials analysed (mean, minimum and maximum percentage content), classified as described in paragraph 1.9, is reported in two histograms, relating respectively to rocks and aggregates and to materials and products.

A similar histogram has been constructed for settled dust collected from workplace surfaces, frequently sampled during INAIL surveys and identified by production activity.

PART 2.

OVERVIEW OF DATA

ON A NATIONAL SCALE

Table 2.1 SUMMARY DATA		
Number of factories / construction sites	Samples collected	Samples analysed for crystalline silica
1041	8028	7711

Figure 2.1 NUMBER OF SAMPLES COLLECTED, BY TYPE

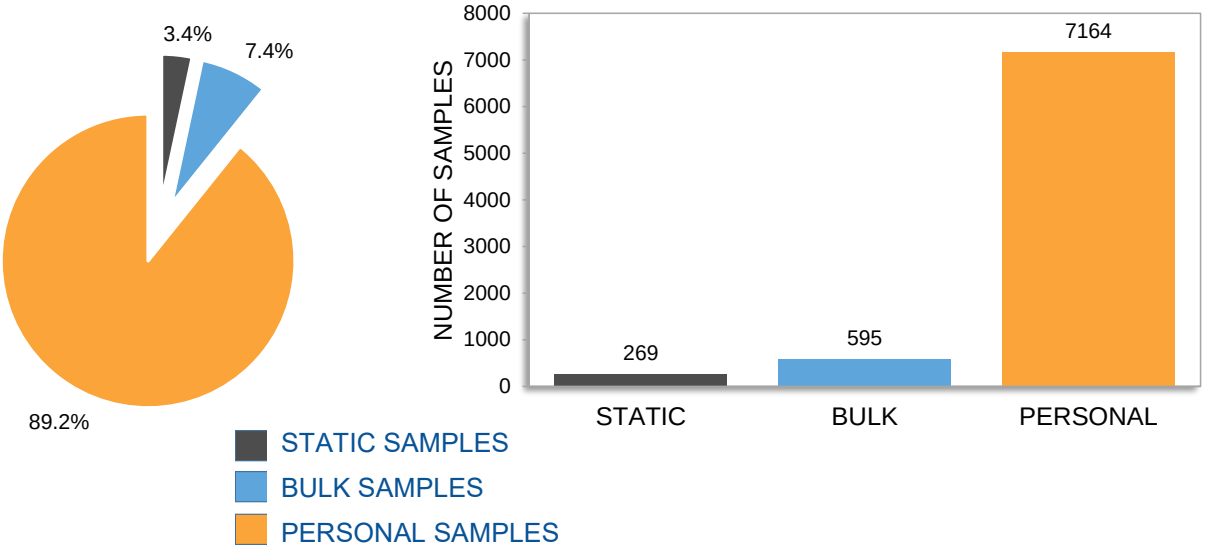


Figure 2.2 NUMBER OF PERSONAL SAMPLES COLLECTED: GEOGRAPHIC DISTRIBUTION BY REGION

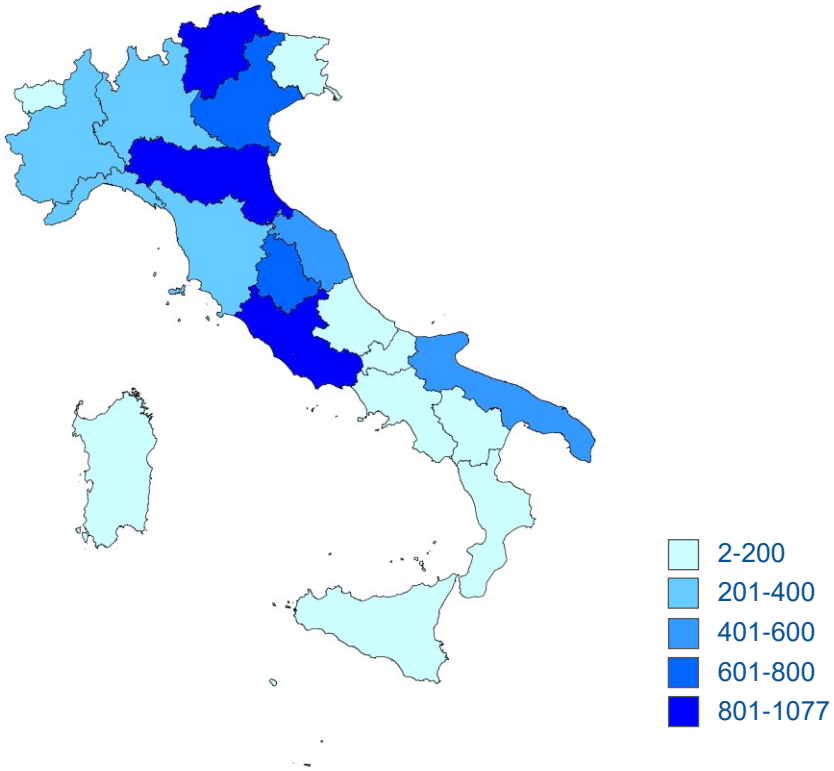


Figure 2.3 PERSONAL SAMPLES COLLECTED, BY PRODUCTION ACTIVITY

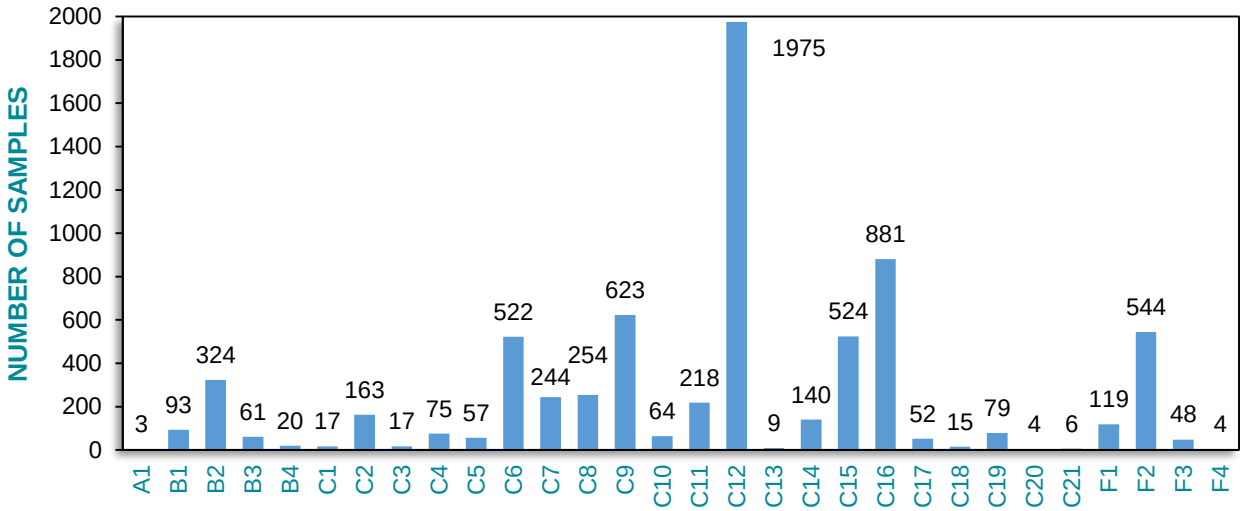


Figure 2.4 FACTORIES / CONSTRUCTION SITES INVESTIGATED, BY PRODUCTION ACTIVITY

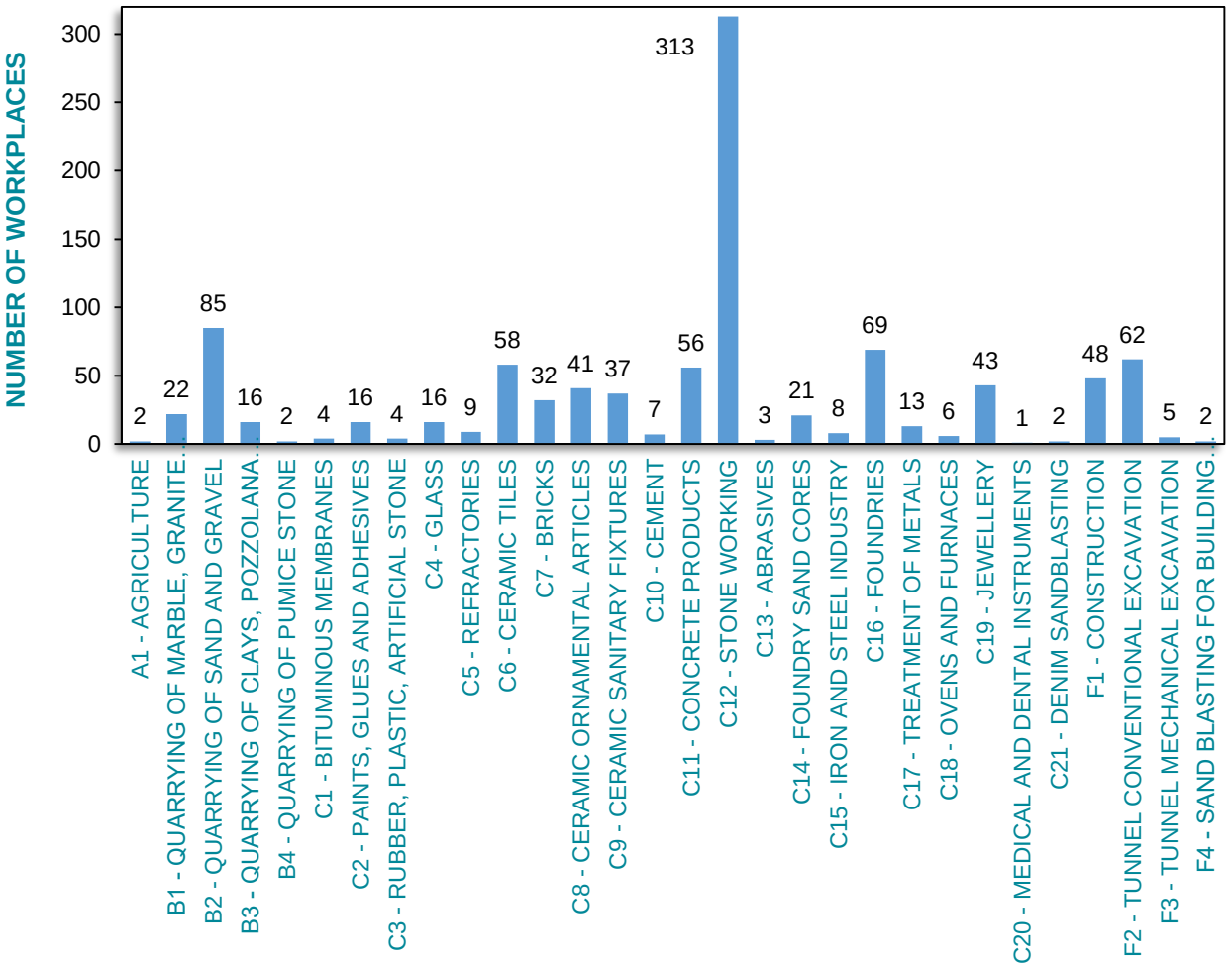


Figure 2.5 PERSONAL SAMPLES ANALYSED (QUARTZ) FROM 2000 TO APRIL 2019

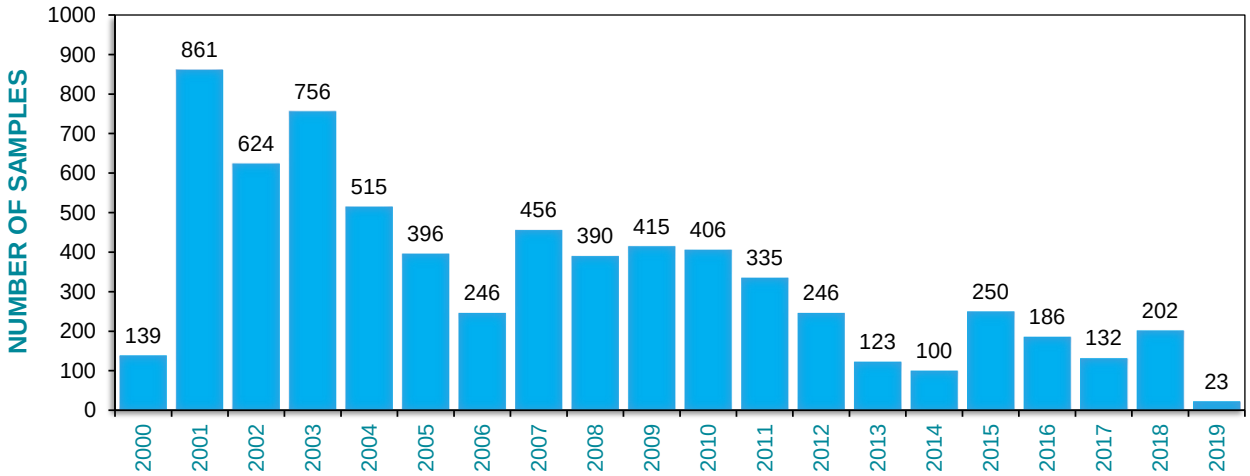


Figure 2.6 50th AND 84th PERCENTILES OF EXPOSURE, BY SEASON

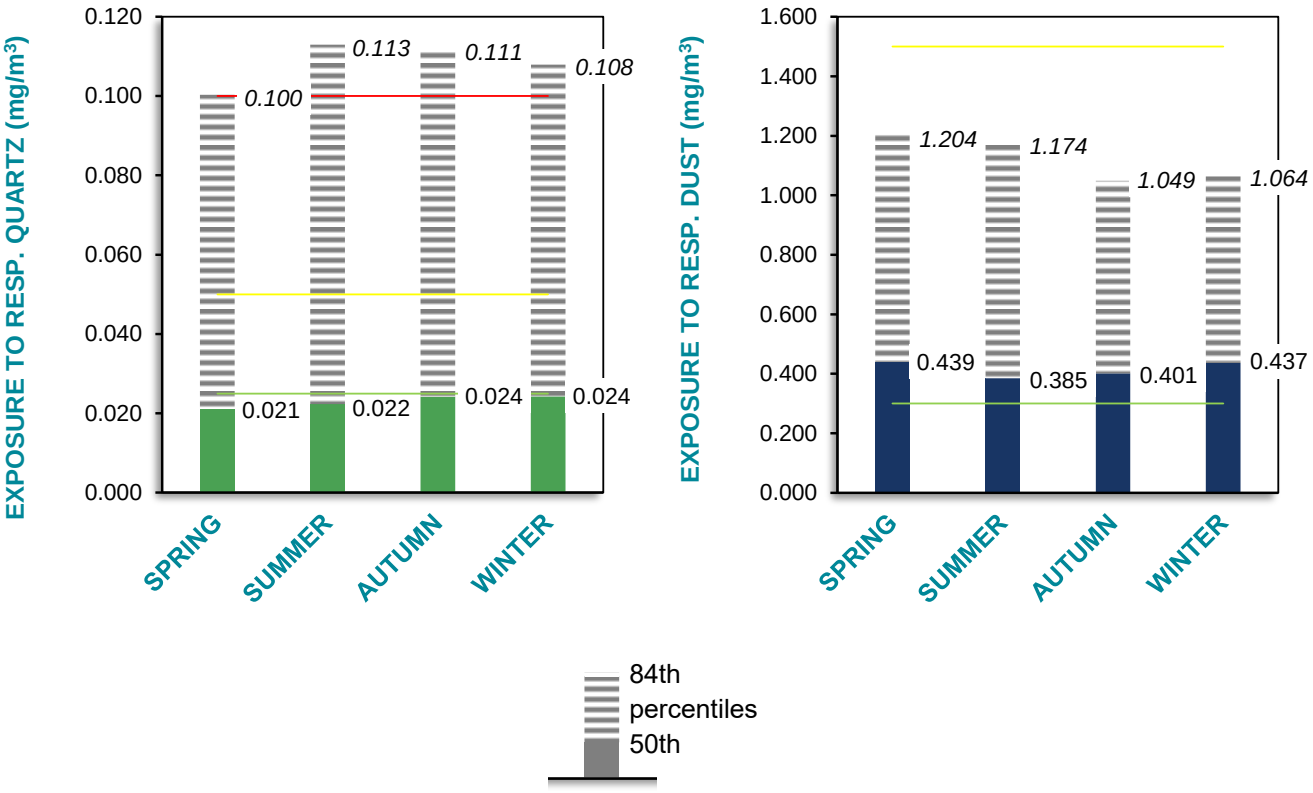


Figure 2.7 GEOMETRIC MEAN OF EXPOSURE TO RESPIRABLE QUARTZ, BY REGION

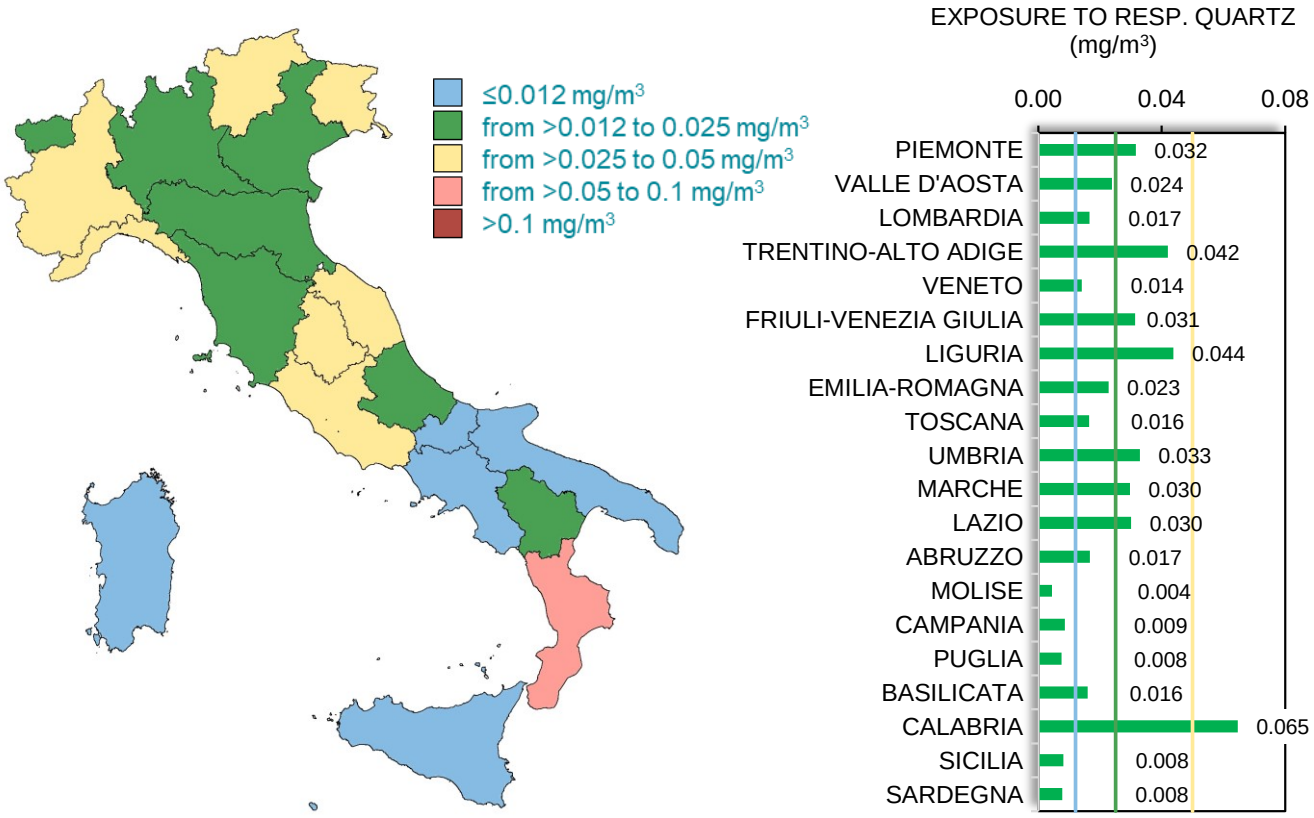


Figure 2.8 GEOMETRIC MEAN OF EXPOSURE TO RESPIRABLE DUST, BY REGION

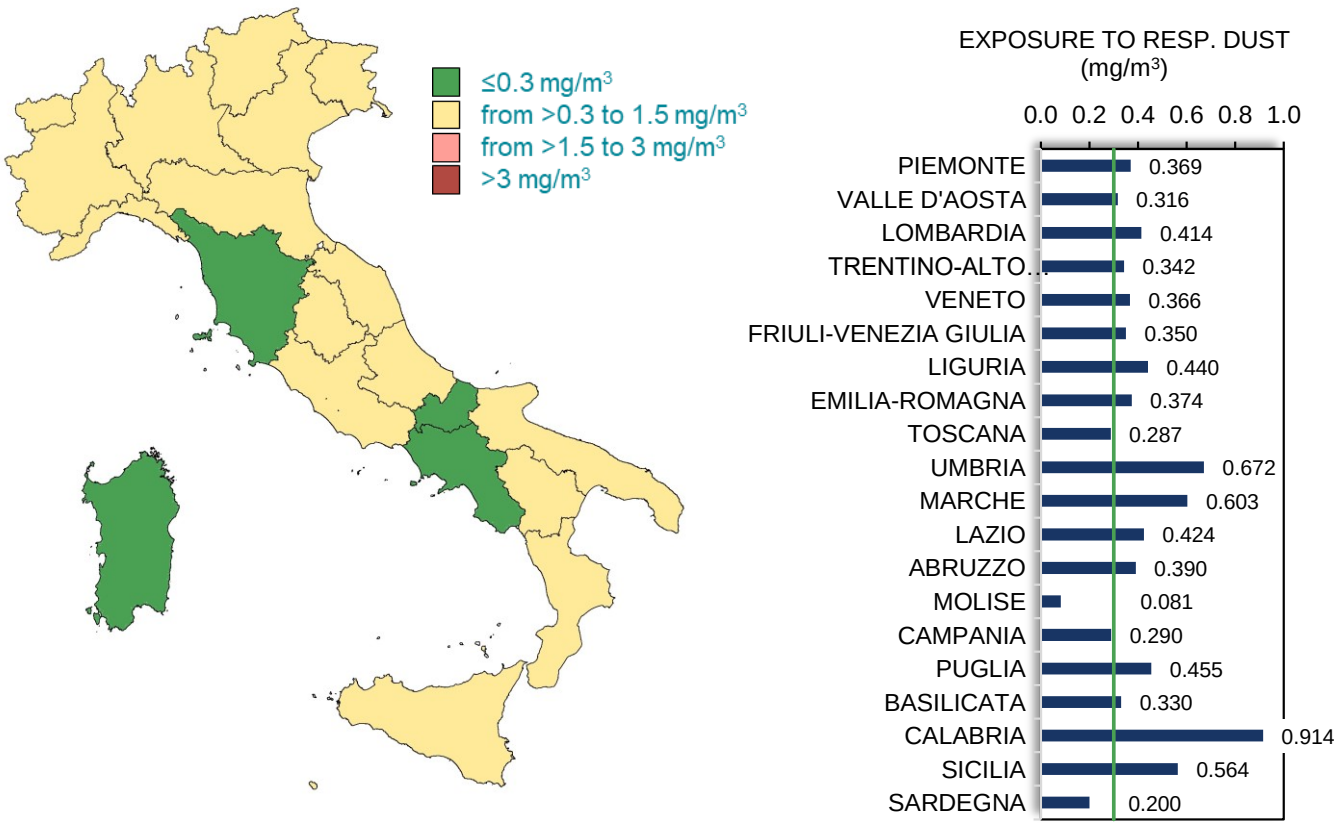
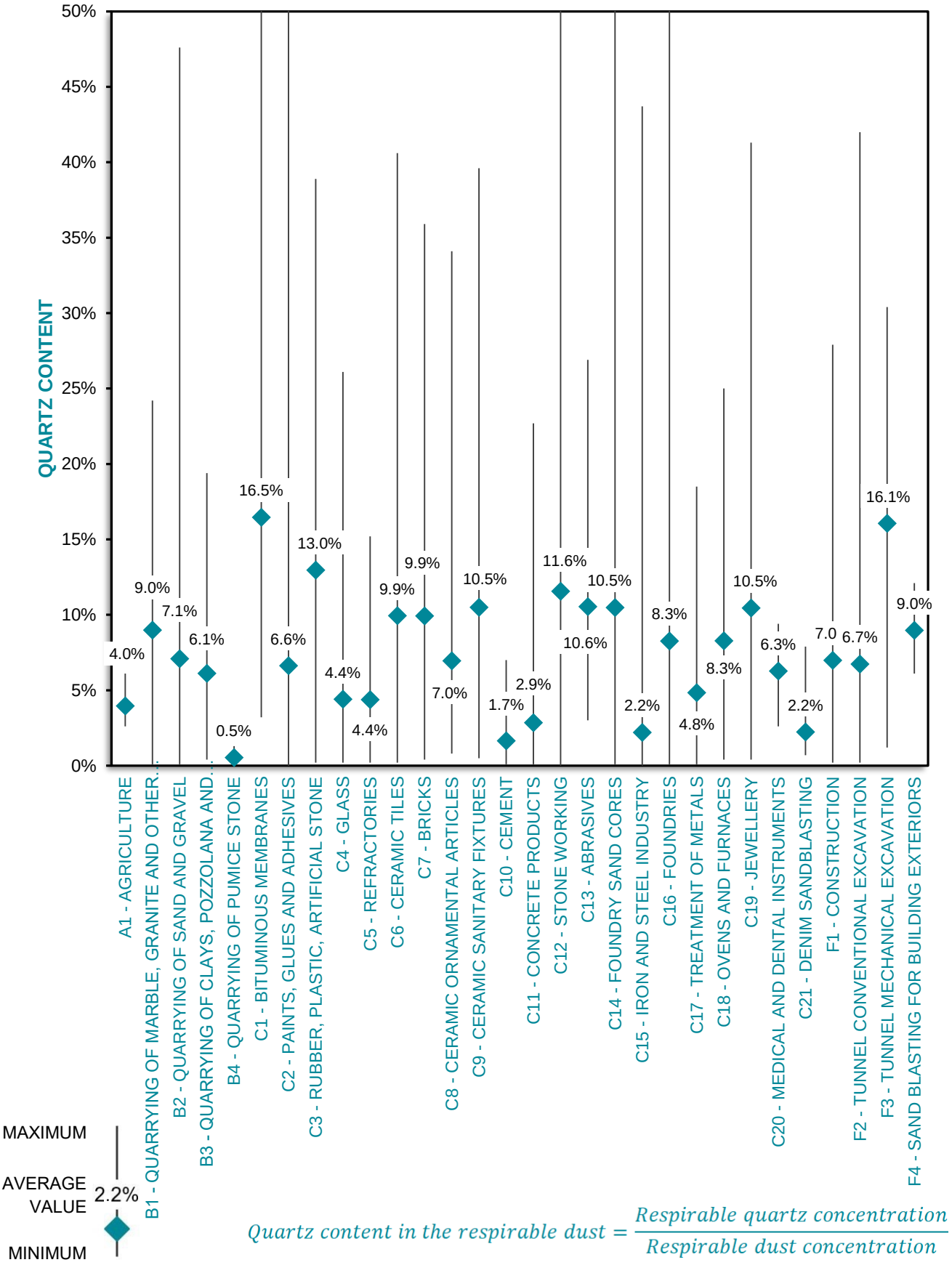


Figure 2.9 QUARTZ CONTENT IN THE RESPIRABLE DUST, BY PRODUCTION ACTIVITY



$$\text{Quartz content in the respirable dust} = \frac{\text{Respirable quartz concentration}}{\text{Respirable dust concentration}}$$

Figure 2.10 RESPIRABLE QUARTZ: 50th AND 84th PERCENTILES OF EXPOSURE

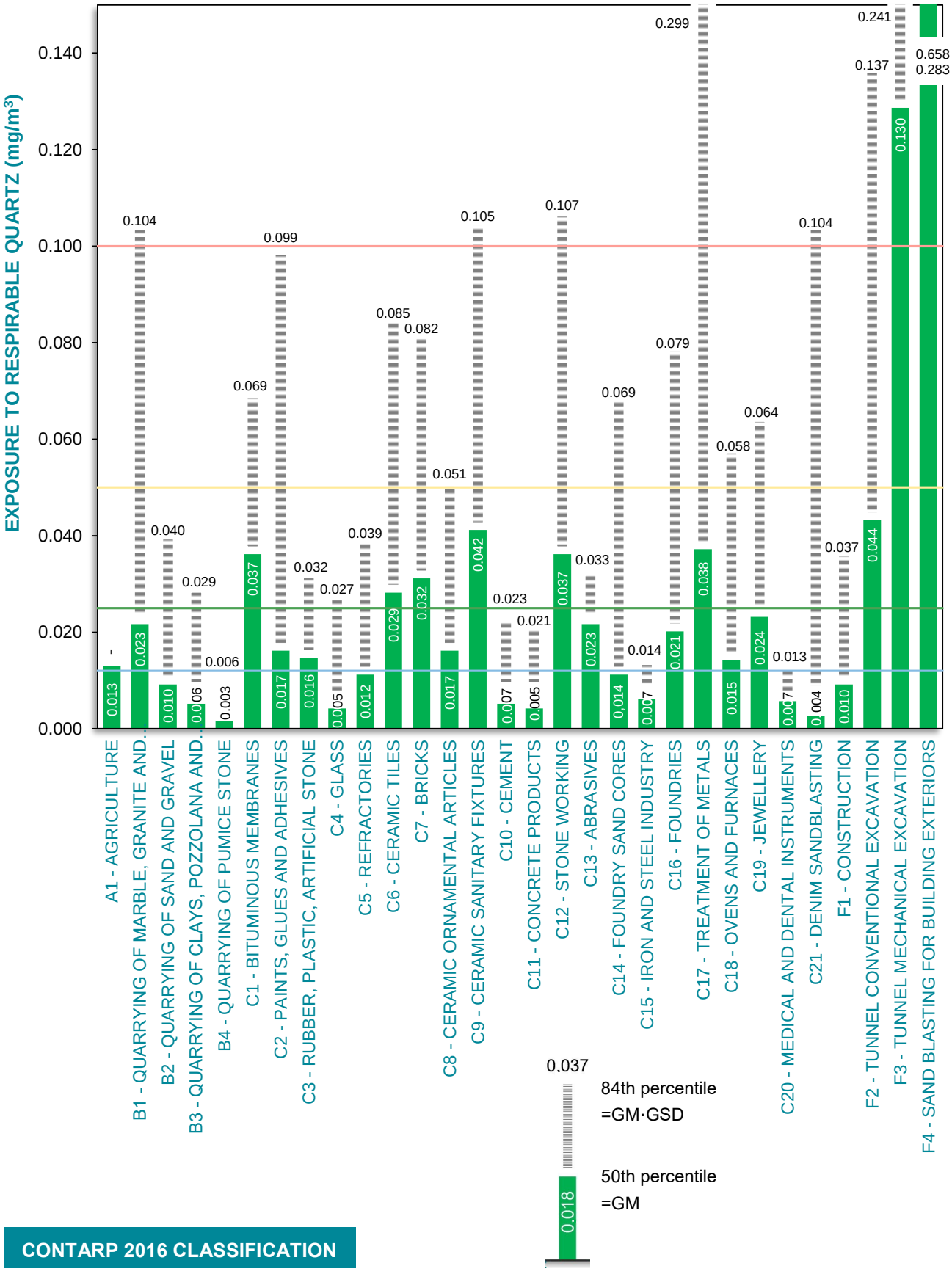


Figure 2.11 RESPIRABLE DUST: 50th AND 84th PERCENTILES OF EXPOSURE

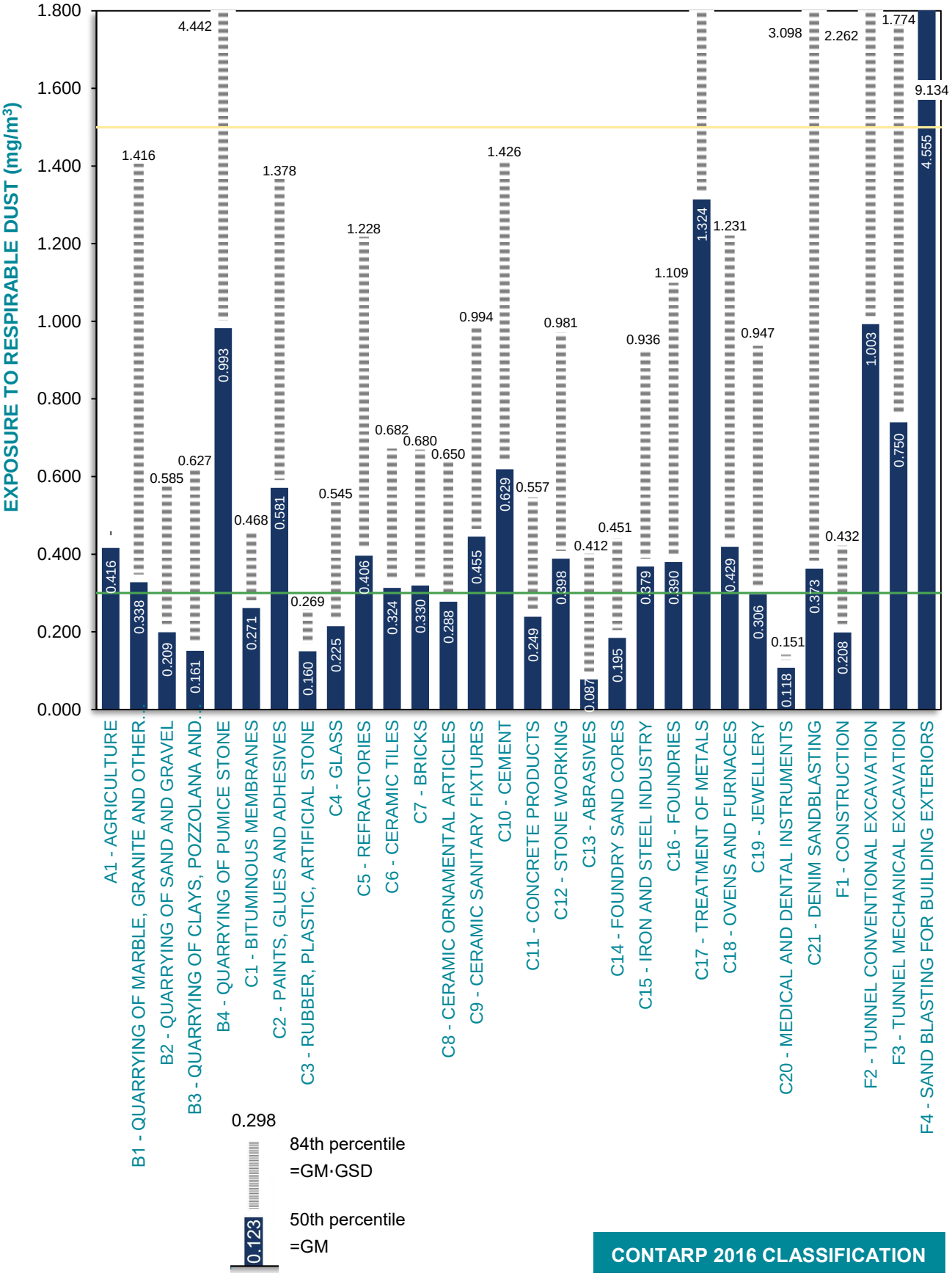


Figure 2.12a RESPIRABLE QUARTZ: 50th AND 84th PERCENTILES OF EXPOSURE

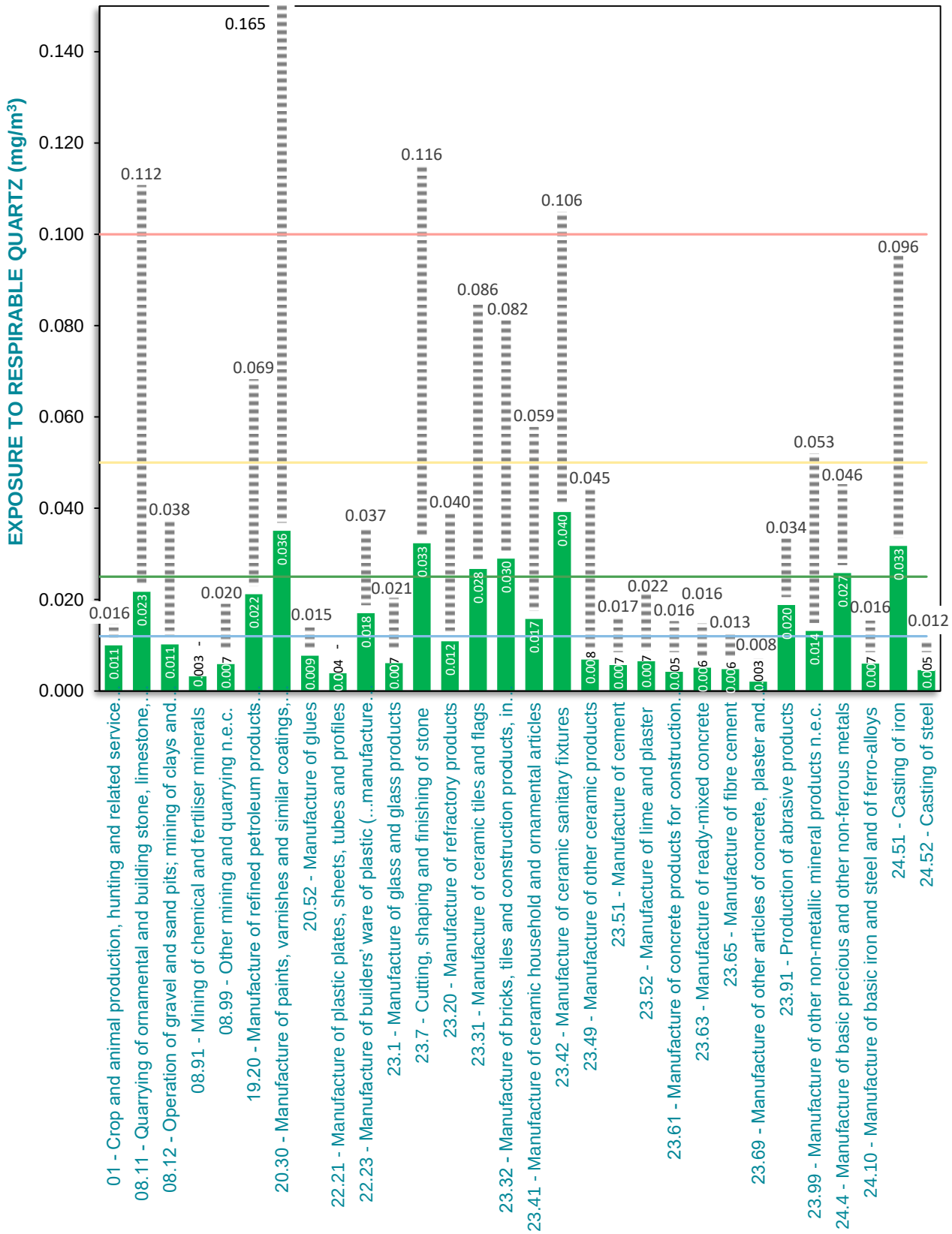


Figure 2.12b RESPIRABLE QUARTZ: 50th AND 84th PERCENTILES OF EXPOSURE

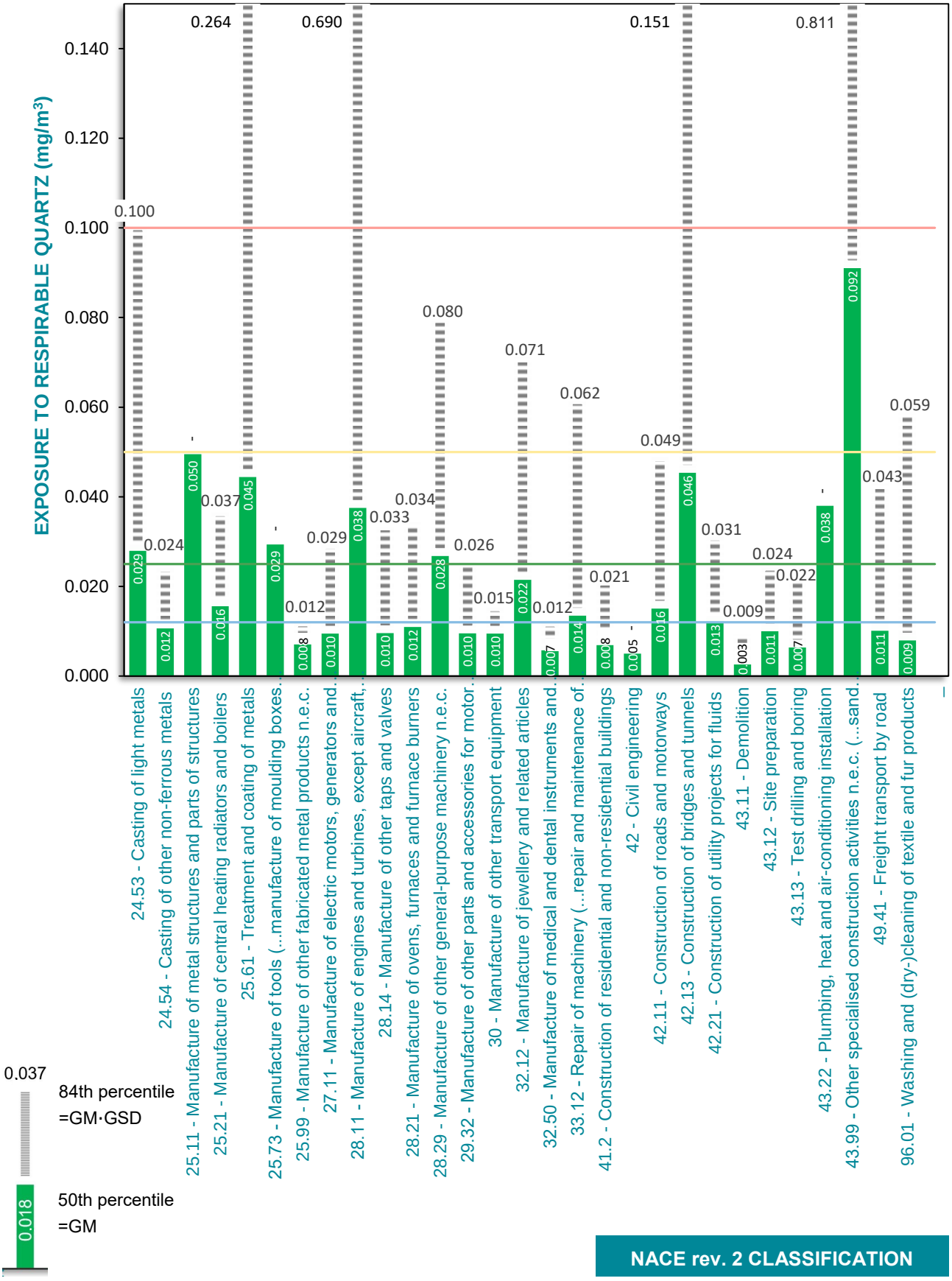


Figure 2.13a RESPIRABLE DUST: 50th AND 84th PERCENTILES OF EXPOSURE

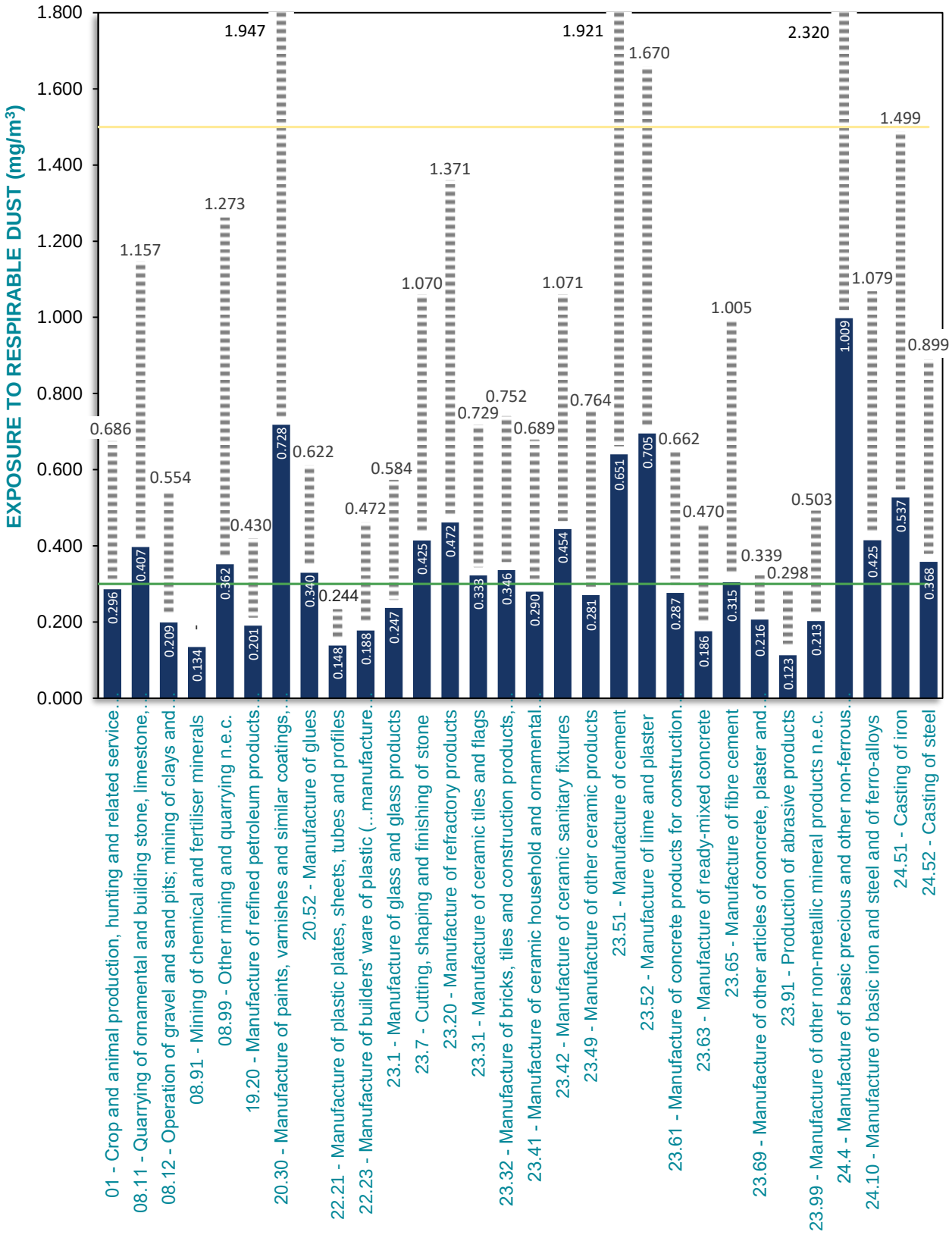


Figure 2.13b RESPIRABLE DUST: 50th AND 84th PERCENTILES OF EXPOSURE

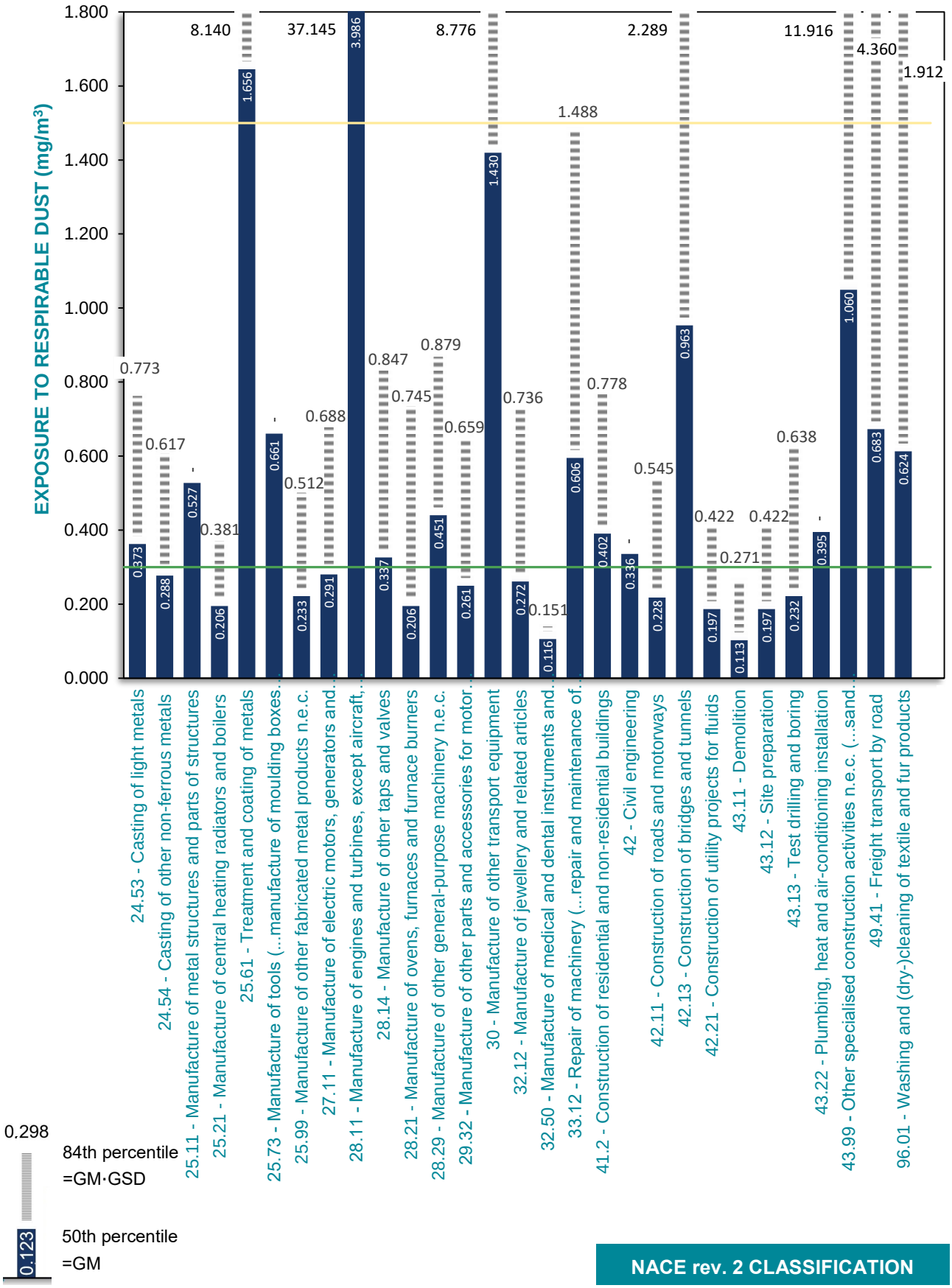


Figure 2.14 C6 - CERAMIC TILES

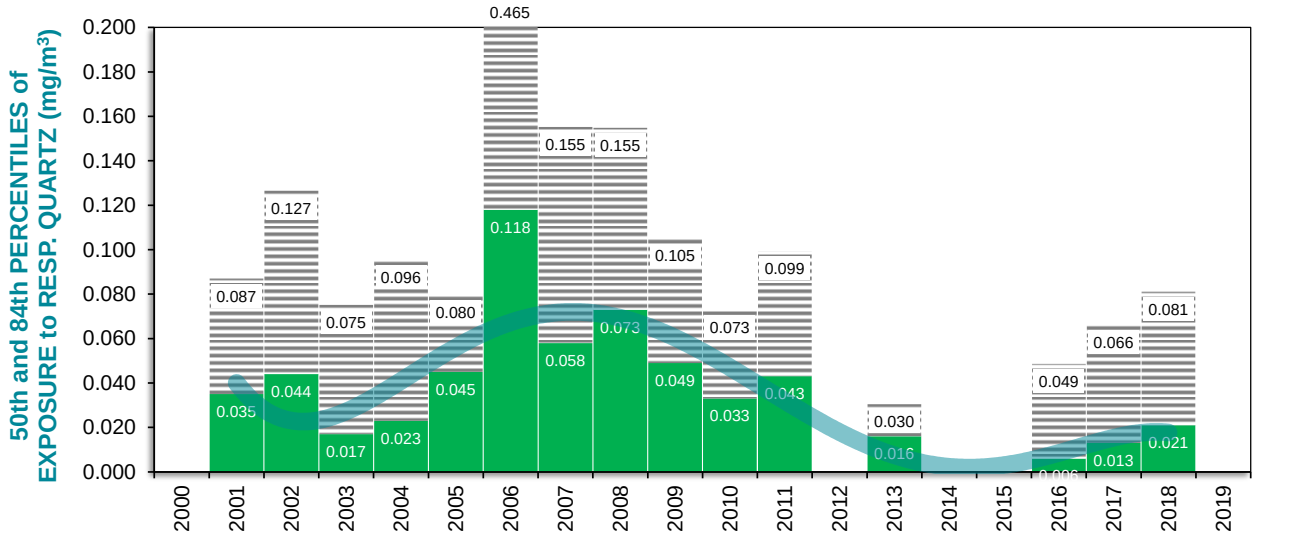


Figure 2.15 C9 - CERAMIC SANITARY FIXTURES

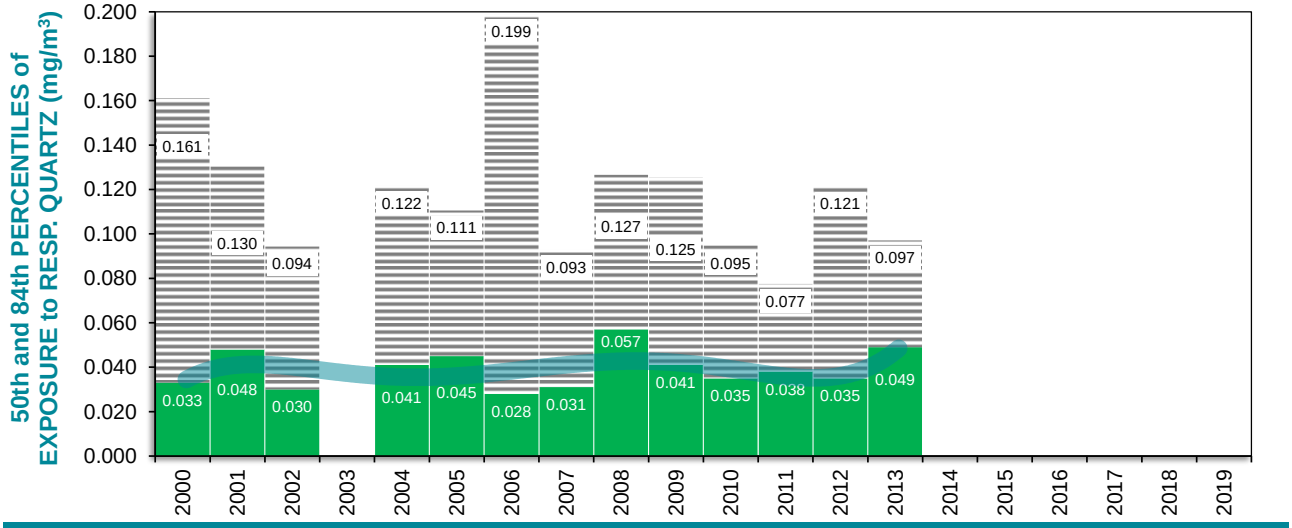


Figure 2.16 C12 - STONE WORKING

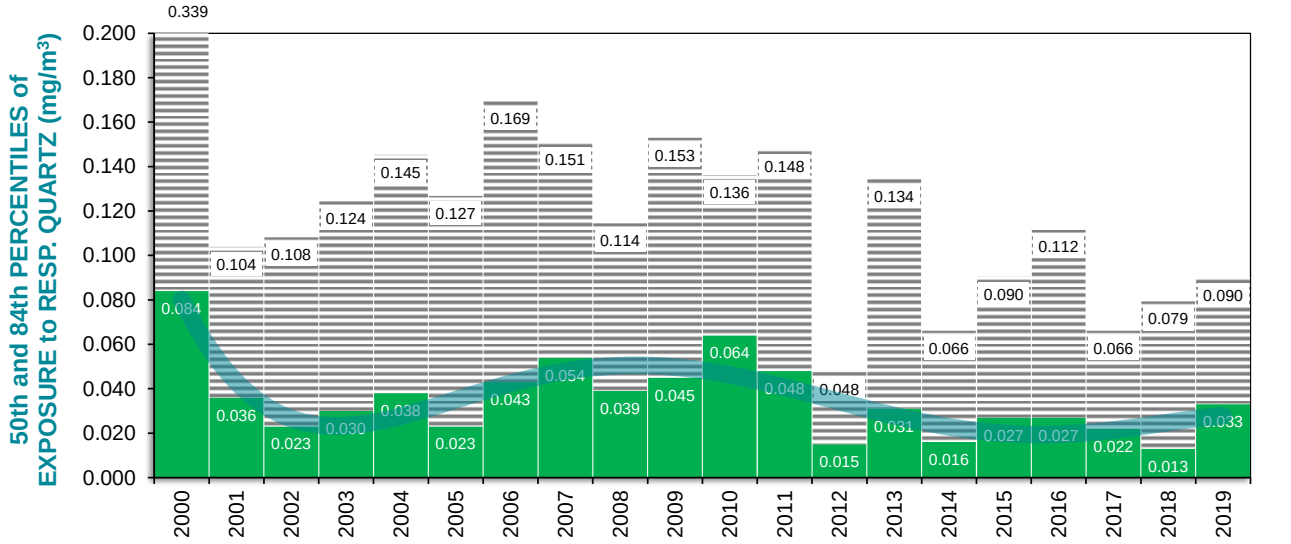


Figure 2.17 C15 - IRON AND STEEL INDUSTRY

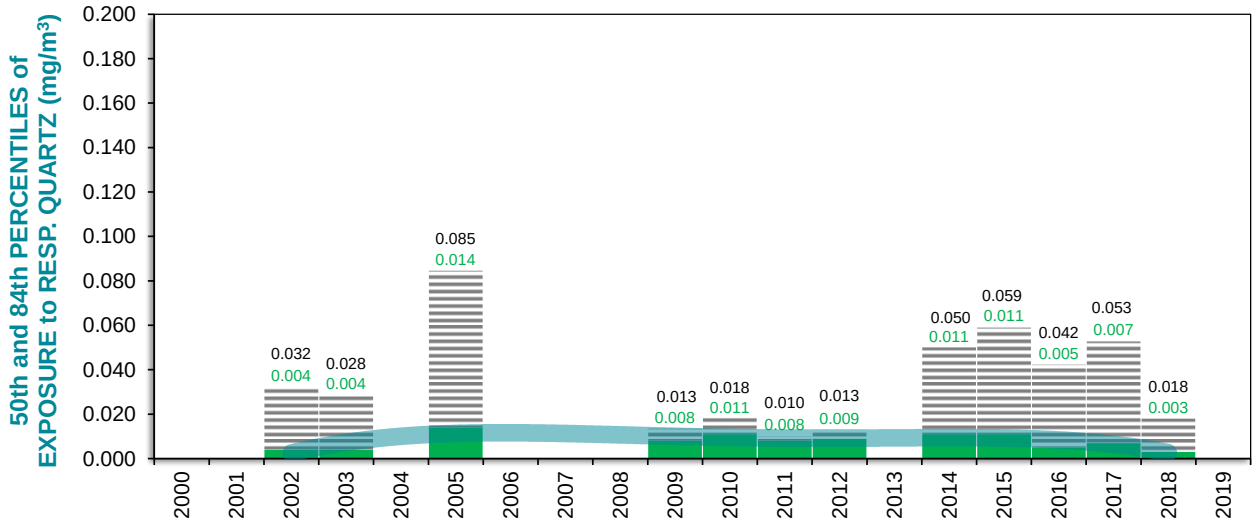


Figure 2.18 C16 - FOUNDRIES

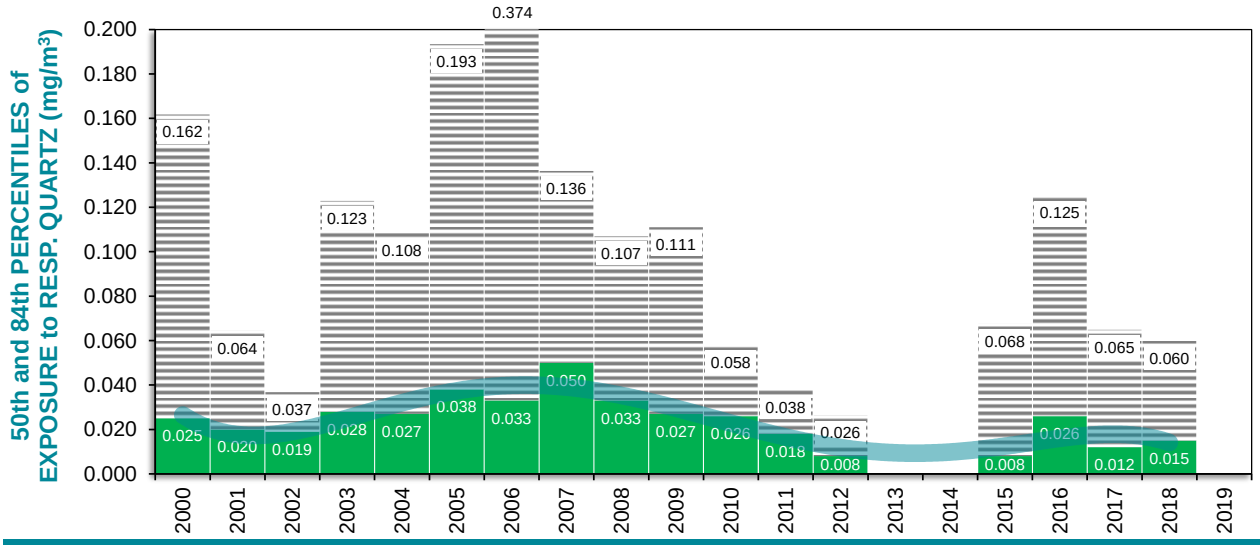
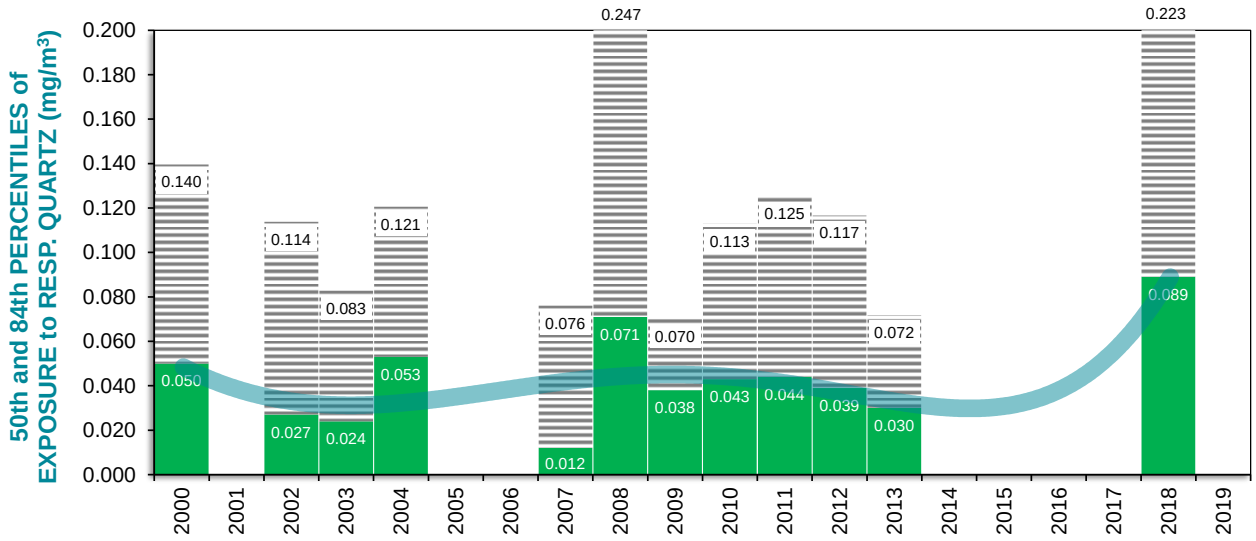


Figure 2.19 F2 - TUNNEL CONSTRUCTION, CONVENTIONAL EXCAVATION



PART 3.

EXPOSURE DATA

BY ACTIVITY AND JOB TITLE

Working processes

Agriculture involves a very large number of workers, but little is known about their exposure levels to RCS. The primary source of dust exposure is the soil, worked by hand or machine. Sandy soils, the composition of which can contain quartz percentages of up to 20% or even more, can be processed in both wet or dry conditions. On the other hand, the optimal time to work a clay soil corresponds to a water content of about 40-50% of its water capacity. However, processing often takes place at a moisture content lower than optimal (cohesive state), with the consequent crumbling of the clods and a certain degree of pulverisation. In loamy soils, pulverisation is even greater. Activities that may typically involve exposure to dust, including processing plants or livestock, are briefly described below.

1. **Soil tillage** – tasks are: manual processing (hoeing, digging); cultivation (tillage, break in, stone removal) with earthmoving machinery such as a dozer, caterpillar, spoon excavators, etc.; main agricultural processes with the use of machines (ploughing, ploughing with disc plough, subsoiling, milling, digging) for the preparation of the seedbed before each crop cycle; complementary work to prepare the seed bed (grubbing, harrowing, surface levelling, subsoiling, milling, rolling); cultivation, such as weeding and hilling up.
2. **Fertilising** – it consists of the distribution of mineral and organic fertilisers, with fertiliser and manure spreaders.
3. **Seeding** – it takes place with a sowing machine; hydroseeding is used to plant grass seed on wet ground and steep slopes.
4. **Crop treatments, pest control and disinfestation** – disinfestation by spraying pesticides (with sprayers, atomisers, dusters), weed control (with machines for spreading herbicides chemicals, for milling, with weeding machine or harrow, etc.), crop treatment.
5. **Harvesting** – threshing machine, combine harvester, combine binder and hand sickle are used for cereal grain harvesting. Grape harvests can be carried out completely by hand or with harvest facilitating machines, while potatoes are harvested using diggers and digger-harvesters. The drying of the grass (haymaking) takes place in the field by spreading, turning and accumulating in swaths or in the barn, by forced ventilation systems. A baler or wrapper can be used to collect and compress grass, hay, or straw into tight bales. The hazelnut harvest takes place with the aid of tractor towed or self-propelled suction machines and self-propelled harvesting machines.
6. **Agricultural products processing plants** – in which weighing operations, loading/unloading in storehouses, moving to dryers, processing, packing and packaging, vehicle maintenance, transport of products and materials are carried out.
7. **Livestock and forestry** – raising of beef and dairy cattle, pigs, etc. Feed mixing. Reforestation, cultivation of coppice timber, tree cutting by chainsaw or tree-cutting machines.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	3	0.296	2.314	3	0.011*	1.463*	-
STATIC	1	0.380	-	1	0.049	-	12.9

* more than half of the measurements are <LOQ

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
A1.01 - Management and office work	
A1.01.01 - Farm manager	Supervises the production cycle, from agronomic and/or zoo technical planning, to bringing products to market for sale. In small farms, the tasks are carried out directly by the owner or tenant of the farm.
A1.02 - Soil tillage	
A1.02.01 - Driver of agricultural machinery (with cab) for working the soil	Drives tractor and/or other mechanical means equipped with suitable cab, used for the preparation and working of the land. The tractor is generally used to operate moving parts such as a plough or harrow.
A1.02.02 - Driver of agricultural machinery (without cab) for working the soil	Drives tractor and/or other mechanical means without cab, used for the preparation and working of the land. The tractor is generally used to operate moving parts such as a plough or harrow.
A1.03 - Fertilisation	
A1.03.01 - Driver of agricultural machinery (with cab) for fertilising the soil	Drives tractor and/or other mechanical means equipped with suitable cab, used for land fertilisation. Spreader equipment for application of granular fertilisers are towed behind agricultural tractors. Liquid fertilisers are applied using sprayers.
A1.03.02 - Driver of agricultural machinery (without cab) for fertilising the soil	Drives tractor and/or other mechanical means without cab, used for land fertilisation. Spreader equipment for application of granular fertilisers are towed behind agricultural tractors. Liquid fertilisers are applied using sprayers.
A1.04 - Sowing	
A1.04.01 - Driver of agricultural machinery (with cab) for sowing the soil	Drives tractor and/or other mechanical means equipped with suitable cab, used for sowing in the field (sowing machine).
A1.04.02 - Driver of agricultural machinery (without cab) for sowing the soil	Drives tractor and/or other mechanical means without cab, used for sowing in the field (sowing machine).
A1.05 - Treatments on crops	
A1.05.01 - Driver of agricultural machinery (with cab) for treatments on crops	Drives tractor and/or other mechanical means equipped with suitable cab, used for treatments on vegetable crops (e.g. spraying machines for phytosanitary treatments).
A1.05.02 - Driver of agricultural machinery (without cab) for treatments on crops	Drives tractor and/or other mechanical means without cab, used for treatments on vegetable crops (e.g. spraying machines for phytosanitary treatments).
A1.06 - Harvesting	
A1.06.01 - Driver of agricultural machinery (with cab) for harvesting	Drives tractor and other mechanical means equipped with suitable cab used for harvesting, for example combine harvesters (cereals), grape harvesting machine, mower and harvester-baler (forage), machine for harvesting potatoes, for harvesting sugar beets and forage, fruit harvesting wagons, suction machine, harvester and windrower (hazelnuts), etc.
A1.06.02 - Driver of agricultural machinery (without cab) for harvesting	Drives tractor and other mechanical means without cab used for harvesting, for example combine harvesters (cereals), grape harvesting machine, mower and harvester-baler (forage), machine for harvesting potatoes, for harvesting sugar beets and forage, fruit harvesting wagons, suction machine, harvester and windrower (hazelnuts), etc.
A1.06.03 - Crop farm labourer (ground operations connected with mechanised harvesting)	Carries out ground operations connected with mechanised harvesting (e.g. blowing hazelnuts to the ground with hand-held blower, before mechanised harvesting operation takes place).

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
A1.06.04 - Crop farm labourer (manual harvesting)	Performs planting and harvesting of field crops and buried products (beets, pumpkins, watermelons, potatoes, etc.) by hand using tools such as spades. May use mechanical means equipped with motor (small operating machines).
A1.07 - Food processing plants	
A1.07.01 - Food processing plant operator	Operates machinery for processing raw fruits, vegetables, grains, meats and dairy products into semi-finished or finished goods. Prepares machinery, stores raw materials and mixes and processes substances. The tasks are differentiated according to the production, processing or preservation process of food products. For example: automatic sorting plant and packaging machine for potatoes; use of the cleaner for cereals to be stored for long periods of time, with suction and removal of the fine dust particles and the separation of good products from broken and waste; equipment for shelling hazelnuts, selection of the quality product, calibration of shelled seeds as well as packaging.
A1.08 - Livestock and forestry	
A1.08.01 - Livestock farm labourer	Breeds, raises and tends to livestock (cattle, sheep, poultry, etc.). If the cattle are grazing, typical tasks of the herdsman (feeding, watering the cattle and surveillance) are carried out.
A1.08.02 - Animal food mixing machine operator	Operates the animal food mixing machine, in which food grains are reduced to powder and mixed.
A1.08.03 - Forestry labourer	Performs tree/trunk cutting with chainsaw/circular saw.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
A1.02.01 - Driver of agricultural machinery (with cab) for working the soil	3	0.011*	1.463*	-	-	-	-

* more than half of the measurements are <LOQ

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
A1.02.01 - Driver of agricultural machinery (with cab) for working the soil	3	0.296	2.314	-	-	-

Working processes

Most rocks can provide dimension stone, with the exception of rocks with clay content, volcanic rocks rich in natural glass (pumice) and phyllites, while gravels and sands are used as construction aggregates and are described separately in activity B2 *Quarrying of sand and gravel*. Thin slabs of natural stones are mainly used in construction as cladding panels for the outside of structures, for paving, as well as in monumental -funerary structures. Commercial terms for marble and granite are broadly used in stonemasonry and are different from how these words are used by geologists. All polishable rocks of carbonate composition are commercially termed marble (therefore, in addition to the actual marble, there is also limestone). In a similar way, the term commercial granite includes a variety of igneous rocks of silicate composition. However, while real granite is composed mostly of quartz (more than 20%) and feldspars, in syenite, diorite and gabbro, quartz occurs in relatively small concentrations (less than 5%) and andesite has an intermediate composition. Their equivalent metamorphic rocks (gneisses), susceptible to polishing, are generally also included in the term commercial granite. Other coherent stones such as slate, basalt, peperino, tuff, sandstone and serpentine have less mechanical strength, are not polishable and can have a variable mineralogical composition. The typical steps in quarrying are described below.

1. **Excavation and handling** – includes the construction of access and haul roads, removal of top soil, overburden removal, construction of the landfill area, hydraulic works for water management and preparation of the quarry floor. In the quarry, the blocks are lifted by gantry or mobile cranes, power shovels equipped with forks or buckets, or derricks and then loaded onto trucks or dumpers to be moved to the quarry yard. The stone blocks or slabs are then sent to the processing plants (see activity C12 *Stone working*).

2. **Drilling** – line drilling is used in the processing of marble and limestone for passing the diamond wire or when using the chain saw, but can also be used for the loading of explosives and for secondary drilling. In granite and porphyry quarries, line drilling with subsequent dynamic splitting (by explosive) is preferred for primary and secondary cutting. The spacing of the holes depends on the type of the material and the accuracy of splitting to obtain the final blocks. The most widely used cutting machines in granite quarries are inline pneumatic or hydraulic rock drills (stationary or mobile). Drilling is also carried out by machines equipped with large diameter (e.g. 90 mm) pneumatic down-the-hole hammers for the insertion of diamond wire. In porphyry (rhyolitic or rhyodacitic ignimbrite) quarries, blast holes are usually drilled at the base of the excavation face, so as to cut the foot of the quarry wall and cause the material to fall on the quarry floor below. In sandstone quarries, drilling is carried out by means of block cutters or pneumatic drills.

3. **Stone quarrying** – the operations or techniques used to quarry the rock from the excavation face, or to detach and overturn it on the quarry floor, are as follows:

   - separation from the rock mass by drilling holes and blasting charge;

   - separation from the rock mass with cutting machine or diamond wire sawing;

   - secondary removal by demolition hammer;

   - detachment and overturning from the rock mass by manual or mechanical means.

4. **Squaring of quarried blocks or slabs** – this phase consists in making the size of quarried stone compatible with the handling and transportation systems in use in the quarry, or to finish products (e.g. kerbstones and paving stones) directly in the quarry. The squaring equipment most frequently used is the diamond-wire saw; as an alternative, the pneumatic hammer is used.

5. **Finishing of the blocks** – large blocks may be divided into smaller blocks, or thin slabs suitable for direct use or further processing, by manually splitting them according to traditional techniques such as using club hammers, hammers and chisels. In porphyry quarries, the rock is characterised by thin parallel cracks, so that the extraction produces a few large blocks, many smaller blocks which are transportable with a wheel-mounted power shovel and stone slabs. Due to the natural cracking of the blocks, slabs are

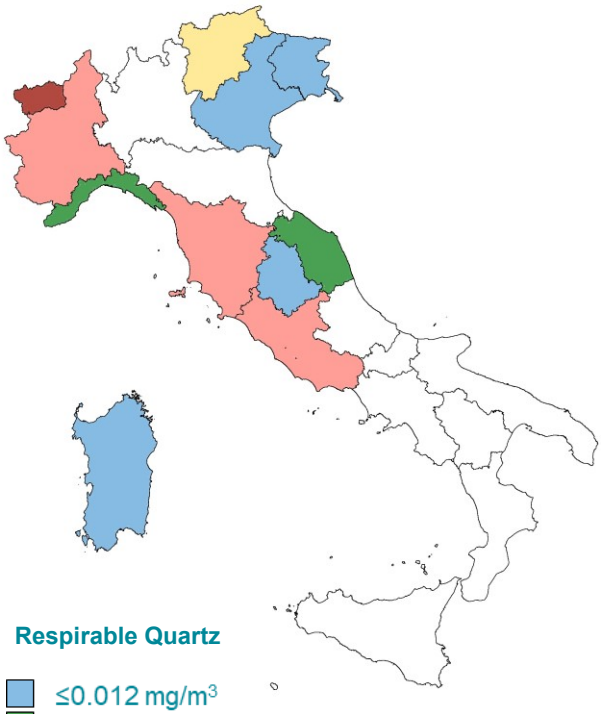
sized by manual splitting using hammers and wedges. Stone sorter labourers select slabs according to thickness and size, with some directly ready for the market (e.g. as irregular slabs), while most of the slabs require subsequent processing.

6. **Crushing** – the quarried material that does not meet the required quality or size to be used as dimension stone can be sold as a raw material to different manufacturers, as it is or after a first crushing has been carried out in a crushing plant located in the same quarry site.
7. **Packaging, storage and shipping** – the finished products are loaded on pallets, fixed with plastic films and deposited in the storage yard before shipping.

Geometric mean and geometric standard deviation values of exposure measurements

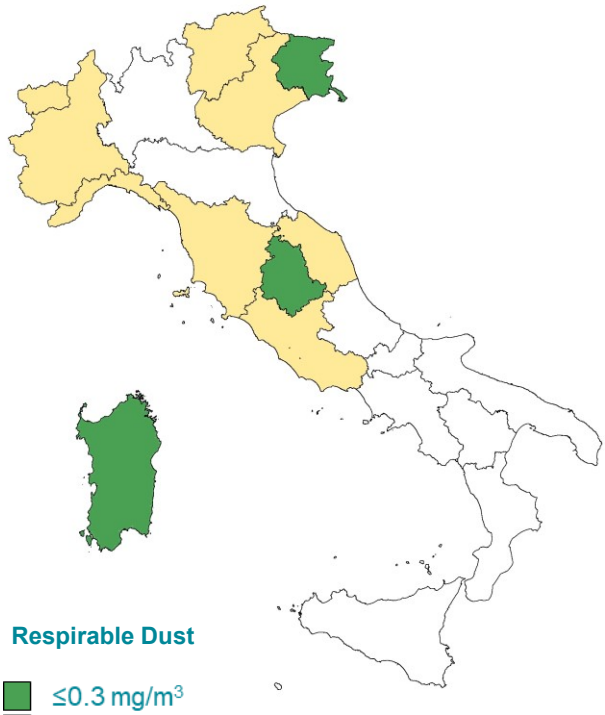
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	93	0.407	2.843	86	0.023	4.943	9.0
STATIC	6	0.427	2.172	6	0.015	4.358	4.6

Geometric mean of personal exposure, by region



Respirable Quartz

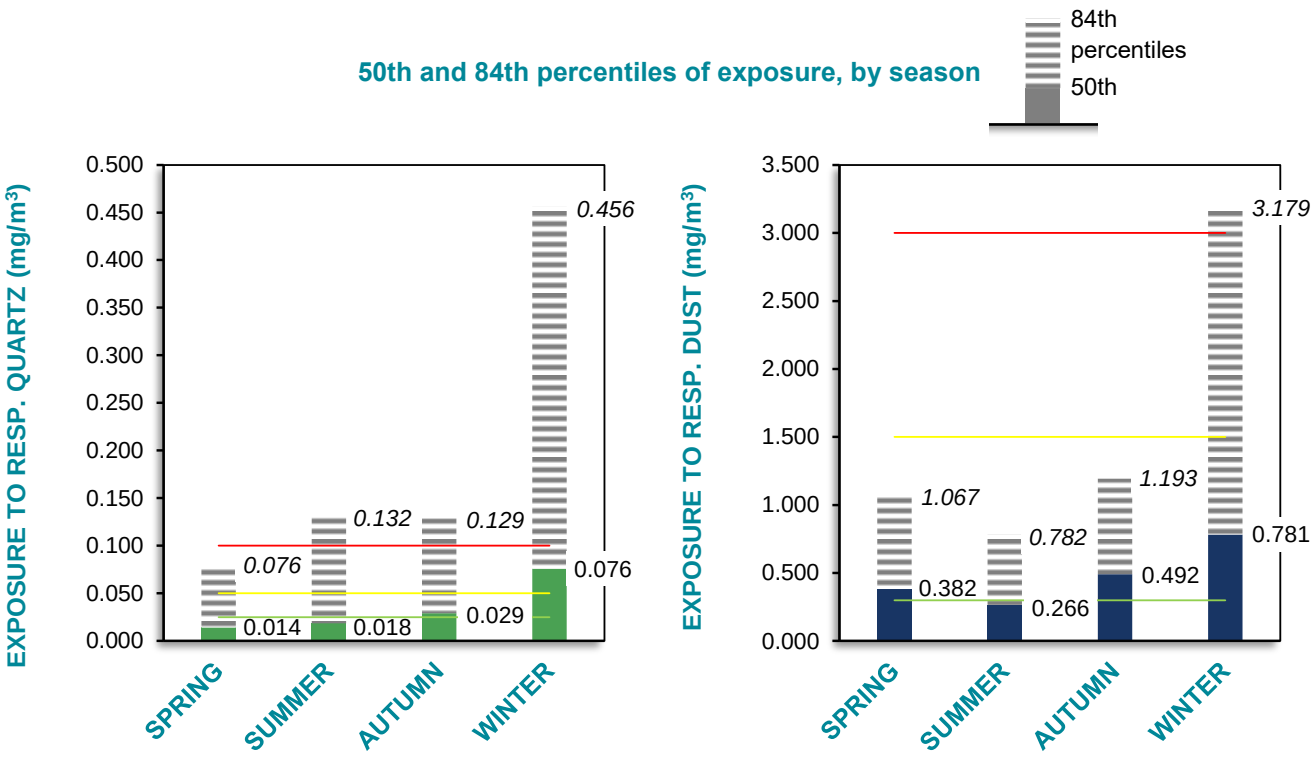
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



Respirable Dust

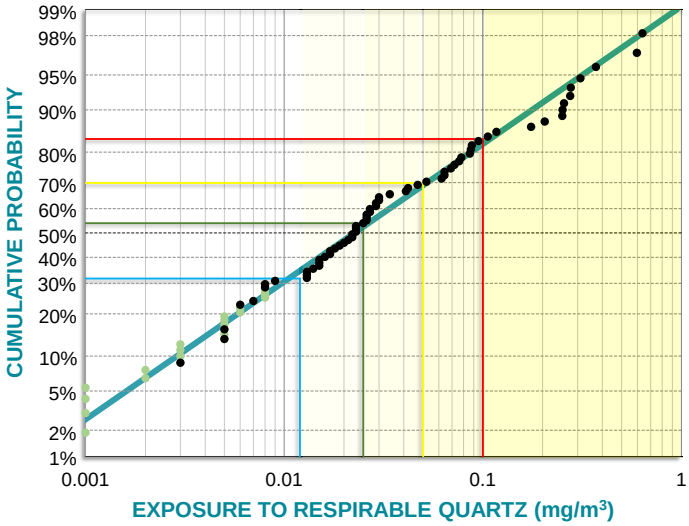
- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season



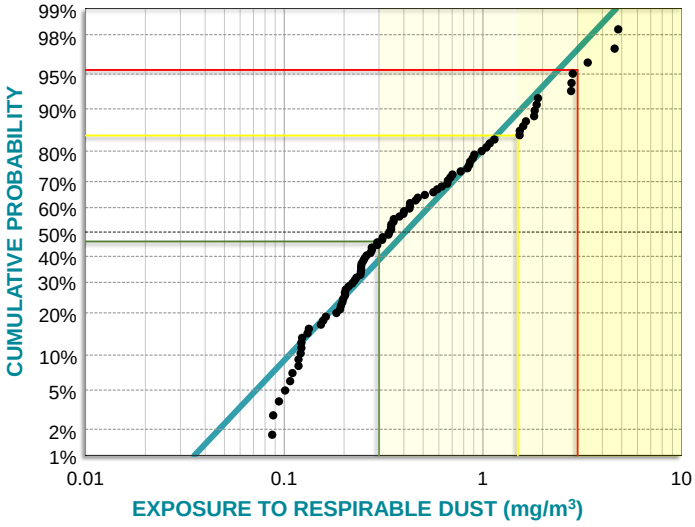
QUARRYING OF MARBLE, GRANITE AND OTHER COHERENT ROCKS: Quarrying of ornamental and building stone (limestone, marble, granite, porphyry, slate, sandstone, volcanic tuff)

Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



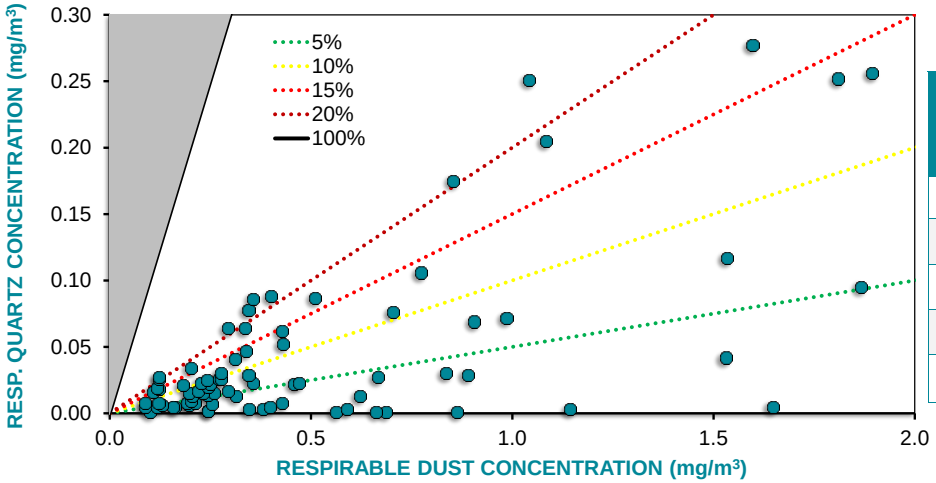
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0,1	83.6%
≤0.05	69.8%
≤0.025	54.1%
≤0.012	31.8%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	95.4%
≤1.5	84.2%
≤0.3	46.1%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	37%
>5% to 10%	24%
>10% to 15%	17%
>15% to 20%	9%
>20%	12%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B1.01 - Management and office work	
B1.01.01 - Manager	Carries out management and/or operational functions involving responsibility, coordination and control of extraction activities in quarry, pits and open-cast sites. In small companies, these tasks are often handled by the company holder (partner or owner that may fulfil both administrative and operative duties).
B1.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to visit the quarry or production plants.
B1.02 - Excavation and stone handling	
B1.02.01 - Power-shovel / loader operator (Stone handling)	Operates power-driven excavating machinery (power-shovel, excavator) to excavate or move rock and other materials. Operates loader (bulldozer) to move or load materials such as soil, rock and demolition debris into dump truck or conveyor belt. Removes overburden (preparatory to extraction operations), prepares ramps, tracks and mine yards, digs trenches, etc.
B1.02.02 - Truck driver (Stone handling)	Drives truck, dumper or other vehicle to transport and dump extracted or excavated rock and other material.
B1.02.03 - Crane operator (Stone handling)	Operates crane, derrick or other lifting machine, in handling extracted stone block and guides it into position in the yard.
B1.03 - Stone drilling	
B1.03.01 - Handheld rock drill operator	Operates handheld hydraulic and pneumatic rock drill (sinker drill, rock drill). Operates jackhammer.
B1.03.02 - Remote-controlled rock drilling machine operator	Operates drilling machine mounted on self-propelled vehicle (some drills travel on rail), with remote-control console at a distance from the drilling point.
B1.03.03 - Rock drill rig operator	Operates drill rig, self-propelled or truck-mounted drilling machine equipped with an operator's cabin. May also operate cabbed power shovel/excavator, equipped with drilling tool.
B1.04 - Stone Quarrying	
B1.04.01 - Shot-firer (Stone quarrying)	Determines positions and force of explosions required and charges and sets off explosives to dislodge rock from quarry workface. Also called blaster. The job title includes a shot-firer assistant.
B1.04.02 - Wire cutting machine operator (Stone quarrying)	Carries out stone wire cutting for quarrying. The cut is produced by an annular (helical, diamond or widia cutting edges) wire.
B1.04.03 - Diamond belt sawing machine operator (Stone quarrying)	Carries out stone cutting for quarrying by using a diamond belt sawing machine. The cutting tool may consist of a belt with sintered diamond segments.
B1.04.04 - Disc cutting machine operator (Stone quarrying)	Carries out stone cutting for quarrying by using a disc stone cutting machine. The diamond rotating disc cutting machine uses a water jet and achieves multiple cuts in sequence.
B1.04.05 - Power-shovel / loader operator (Stone quarrying)	Operates power-driven loader (bulldozer) or excavating machine (power-shovel, excavator) equipped with demolition hammer or movable shovel to detach and overturn large slabs of rock. This is often a secondary removal through the overturning or rolling of the rock blocks for crushed stone production.

QUARRYING OF MARBLE, GRANITE AND OTHER COHERENT ROCKS: Quarrying of ornamental and building stone (limestone, marble, granite, porphyry, slate, sandstone, volcanic tuff)

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B1.04.06 - Flame / water-jet cutting, splitting cushion / expansive mortar operator (Stone quarrying)	Operates innovative techniques for stone quarrying, such as flame cutting machine, high-pressure water jet system, splitting and lifting cushion and expansive mortar.
B1.05 - Stone block squaring	
B1.05.01 - Single/multi-blade frame saw operator (Block squaring)	Cuts stone blocks using single-blade or multi-blade frames for sawing and squaring. Loads the stone blocks on heavy-duty forklift, handles the forklift under the frames, unloads the slabs. Carries out trimming and cutting work on blocks.
B1.05.02 - Wire cutting machine operator (Block squaring)	Carries out the wire cutting of stone blocks. The cut is produced by an annular (helical, diamond or widia cutting edges) wire.
B1.05.03 - Chain sawing machine operator (Block squaring)	Carries out stone block cutting by using a diamond belt sawing machine. The cutting tool may consist of a belt with sintered diamond segments.
B1.06 - Stone block finishing	
B1.06.01 - Stone sorter / splitter	Uses club hammer and chisel or wedges for manually separating slabs of stone into small-size blocks. The task is carried out directly in a workstation near the quarry face or in the workshop, on a bench, equipped with a conveyor belt.
B1.06.02 - Electric / pneumatic hand tool operator (Block finishing)	Uses hand tools (grinder, angle grinder, grinding wheel, drill, manual polisher) for finishing operations such as grinding, shaping, drilling, sandpapering and polishing of semi-finished products.
B1.07 - Stone crushing	
B1.07.01 - Crusher / grinder	Operates crushing plant to reduce rock debris to suitable size for further processing and mills to grind material. Performs minor maintenance and repairs plant, machinery and tools. The job title includes a crusher/grinder assistant.
B1.08 - Warehousing and packaging	
B1.08.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Drives forklift to pick up incoming stock or to deliver materials to designated area.
B1.08.02 - Bag filling operator	Fills bags with crushed stones to its proper weight through the operation of a bag filling machine or by manual means.
B1.09 - Various workspaces	
B1.09.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B1.10 - Mechanical and electrical maintenance / cleaning	
B1.10.01 - Maintenance mechanic / electrician	Maintains, repairs, and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
B1.10.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

QUARRYING OF MARBLE, GRANITE AND OTHER COHERENT ROCKS: Quarrying of ornamental and building stone (limestone, marble, granite, porphyry, slate, sandstone, volcanic tuff)

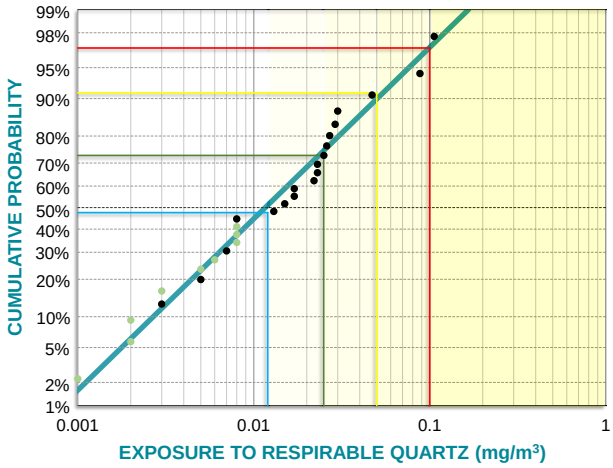
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
B1.01.01 - Manager	1	0.086	-	-	-	-	-
B1.02.01 - Power-shovel / loader operator (Stone handling)	28	0.012	3.116	97.0%	91.1%	73.0%	47.6%
B1.02.02 - Truck driver (Stone handling)	3	0.012	2.310	-	-	-	-
B1.03.01 - Handheld rock drill operator	6	0.006	4.045			>90.0%	55.1%
B1.03.02 - Remote-controlled rock drilling machine operator	8	0.128	3.688	49.3%	29.6%	8.8%	<7.6%
B1.03.03 - Rock drill rig operator	5	0.053	4.218	73.7%	63.9%	29.0%	<11.9%
B1.04.02 - Wire cutting machine operator (Stone quarrying)	1	0.256	-	-	-	-	-
B1.05.01 - Single/multi-blade frame saw operator (Block squaring)	1	0.076	-	-	-	-	-
B1.05.03 - Chain sawing machine operator (Block squaring)	2	0.001*	-	-	-	-	-
B1.06.01 - Stone sorter / splitter	6	0.116	2.431	44.6%	18.9%	<10.0%	-
B1.06.02 - Electric / pneumatic hand tool operator (Block finishing)	8	0.072	2.126	71.4%	27.1%	11.1%	<7.6%
B1.07.01 - Crusher / grinder	9	0.014	4.530	88.0%	83.7%	69.2%	47.8%
B1.08.01 - Warehouse operator	1	0.005*	-	-	-	-	-
B1.09.01 - Polyvalent worker	4	0.015	1.196	-	-	-	-
B1.10.01 - Maintenance mechanic / electrician	3	0.025	10.618	-	-	-	-

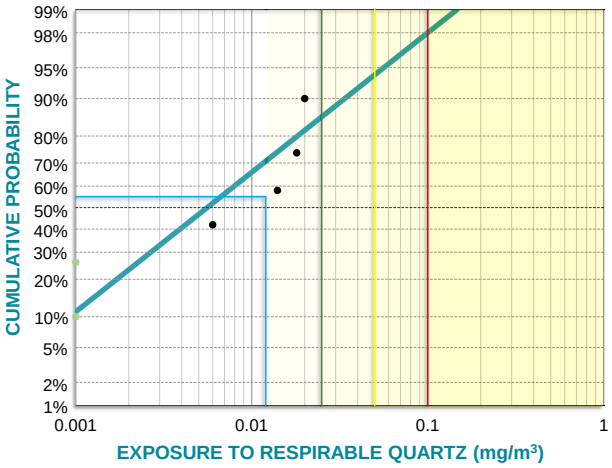
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

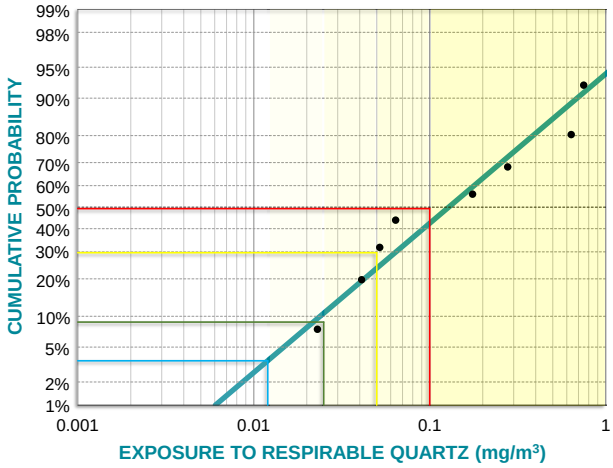
B01.02.01 - Power-shovel / loader operator (Stone handling)



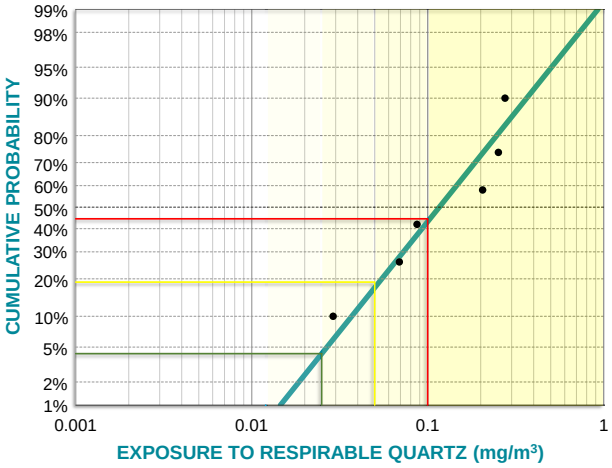
B01.03.01 - Handheld rock drill operator



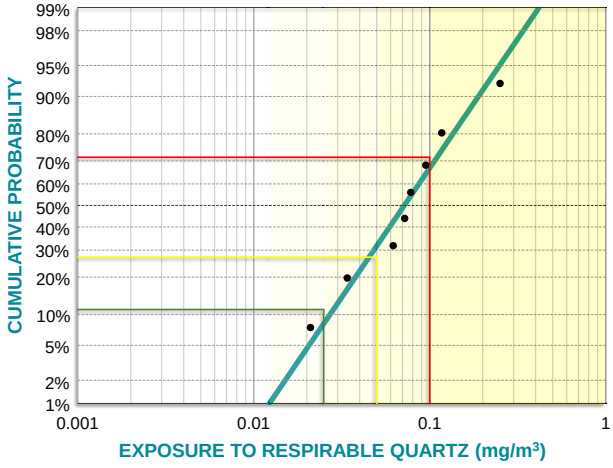
B01.03.02 - Remote-controlled rock drilling machine operator



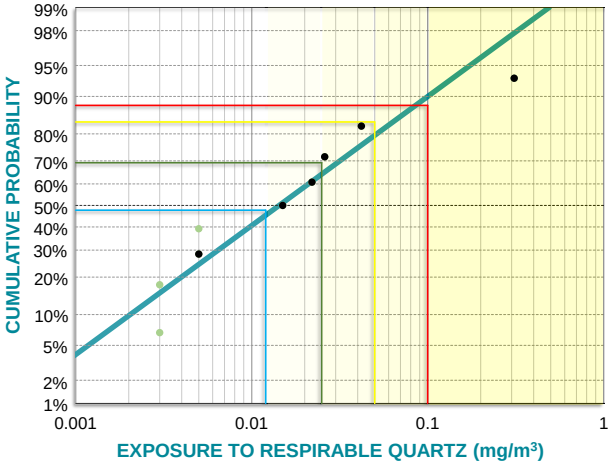
B01.06.01 - Stone sorter / splitter



B01.06.02 - Electric / pneumatic hand tool operator (Block finishing)



B01.07.01 - Crusher / grinder



QUARRYING OF MARBLE, GRANITE AND OTHER COHERENT ROCKS: Quarrying of ornamental and building stone (limestone, marble, granite, porphyry, slate, sandstone, volcanic tuff)

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
B1.01.01 - Manager	1	0.356	-	-	-	-
B1.02.01 - Power-shovel / loader operator (Stone handling)	31	0.255	1.868		>98.0%	60.1%
B1.02.02 - Truck driver (Stone handling)	4	0.133	2.255	-	-	-
B1.03.01 - Handheld rock drill operator	6	0.501	3.632	87.0%	81.6%	45.3%
B1.03.02 - Remote-controlled rock drilling machine operator	9	0.769	3.387	80.9%	70.6%	16.8%
B1.03.03 - Rock drill rig operator	5	0.265	3.959	>88.1%	83.9%	69.3%
B1.04.02 - Wire cutting machine operator (Stone quarrying)	1	1.894	-	-	-	-
B1.05.01 - Single/multi-blade frame saw operator (Block squaring)	1	0.703	-	-	-	-
B1.05.03 - Chain sawing machine operator (Block squaring)	2	0.697	-	-	-	-
B1.06.01 - Stone sorter / splitter	6	1.144	1.814	>90.0%	68.5%	<10.0%
B1.06.02 - Electric / pneumatic hand tool operator (Block finishing)	8	0.596	2.472	>92.4%	79.7%	28.4%
B1.07.01 - Crusher / grinder	10	0.751	3.229	85.6%	64.0%	36.4%
B1.08.01 - Warehouse operator	1	0.118	-	-	-	-
B1.09.01 - Polyvalent worker	4	0.197	1.491	-	-	-
B1.10.01 - Maintenance mechanic / electrician	4	0.392	3.040	-	-	-

Working processes

Gravel and sand are extracted from fluvial or marine deposits, or obtained by the mining and crushing of rocks in quarries. Aggregate products are classified as fine and coarse sand, gravel and crushed stone, according to particle size, used in the construction industry, especially in concrete manufacturing. Aggregates are used as they are for the construction of embankments, or mixed with water and cement to produce concrete, with water and gypsum or lime for plaster, or with bitumen for asphalt concrete. The mineralogical and physical-mechanical properties and the absence of frost sensitivity determine the suitability of the material. The quartz content in aggregates can be very variable, often high and only rarely completely absent. The sand and gravel extraction and processing cycle is described below.

1. **Extraction** – sand and gravel excavation is carried out by mechanical means such as by loader and bulldozer, while compact hard rocks may require the use of explosives. In the latter case, the exposed rock outcrop is drilled with hammers or drilling machines, holes are loaded with explosive cartridges and detonators. After the blasting, the rock blocks too large for transportation or for feeding the crusher are further crushed by blasting. The extracted material is then loaded with a loader onto trucks and carried to the crushing and screening plants, which are usually located close to the quarry.
2. **Crushing and screening** – the material is unloaded into the crushing chamber of a jaw crusher, usually operated by a worker in a cabin. The crushed rock material is then moved on conveyor belts and goes through a series of screens. The coarse fraction is loaded into a size-adjustable rotary mill (with steel rods, cylinders, or hammers) for the production of the different particle size fractions of commercial interest. The ground material goes through a second series of screens that select the different particle size fractions. A further grinding stage is necessary to obtain the finest product (*filler*). Conveyor belts transport the selected material to storage.
3. **Washing** – it may be carried out by washing machines (with spray bars or a wheel screw) to remove fine and organic material and then to separate the washed material from the muddy washing water.
4. **Storage and shipping** – the selected materials are transferred by conveyor belts and stockpiled or stored in silos. The finer material can be bagged. For delivery to the sites of use, the material is loaded onto a truck.

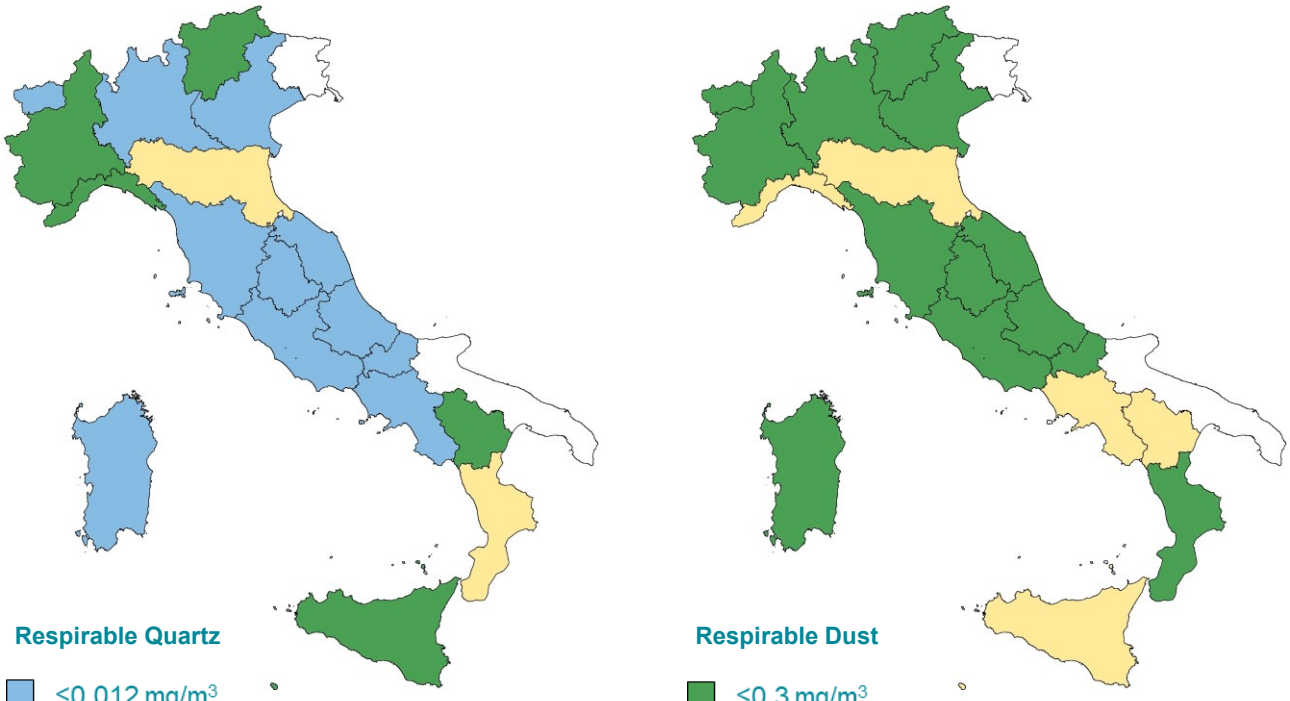
The production of concrete products generally does not take place in the quarry and is considered separately (see C11 *Concrete products*), except in cases where the concrete production plant is attached to the quarry. When the sand and gravel excavation is carried out in open-pit quarries under the water table, the material extraction takes place with the expansion of the quarry lake by using a floating dredger, which may include a long-reach excavator mounted on a float. The material is carried ashore by conveyor belts. Excavation from riverbeds is today severely limited due to the negative impact on the natural environment.

Geometric mean and geometric standard deviation values of exposure measurements

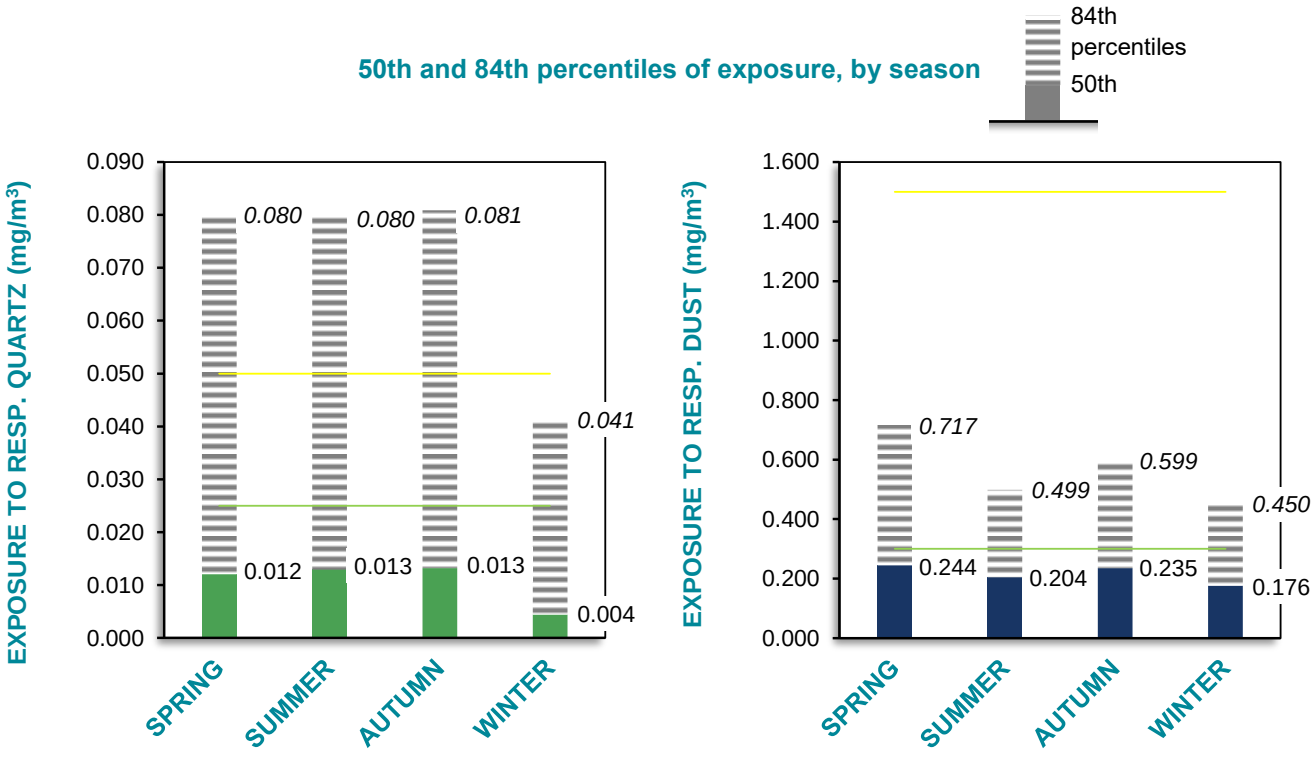
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	323	0.216	2.630	293	0.011	3.473	7.1
STATIC	13	0.180	2.569	13	0.009	4.135	5.8

QUARRYING OF SAND AND GRAVEL: Extraction of sand and gravel (aggregate of coarse- to medium-grained particulate material used in construction) – Crushing and grinding sand and gravel – Manufacture of products for road coverings – Transport of materials by road

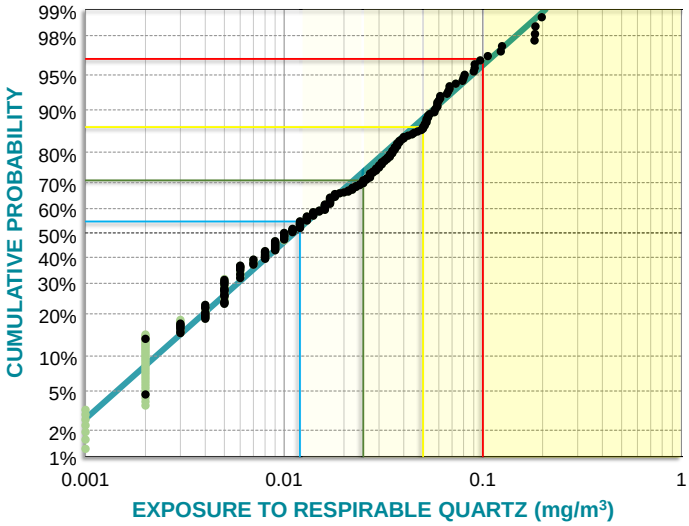
Geometric mean of personal exposure, by region



50th and 84th percentiles of exposure, by season

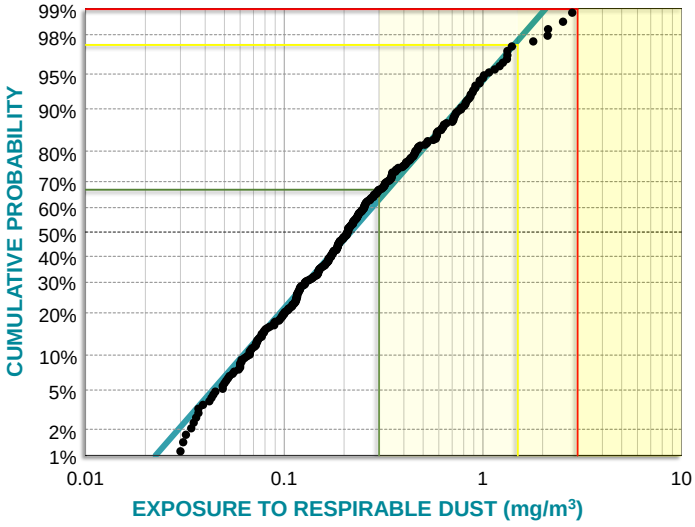


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



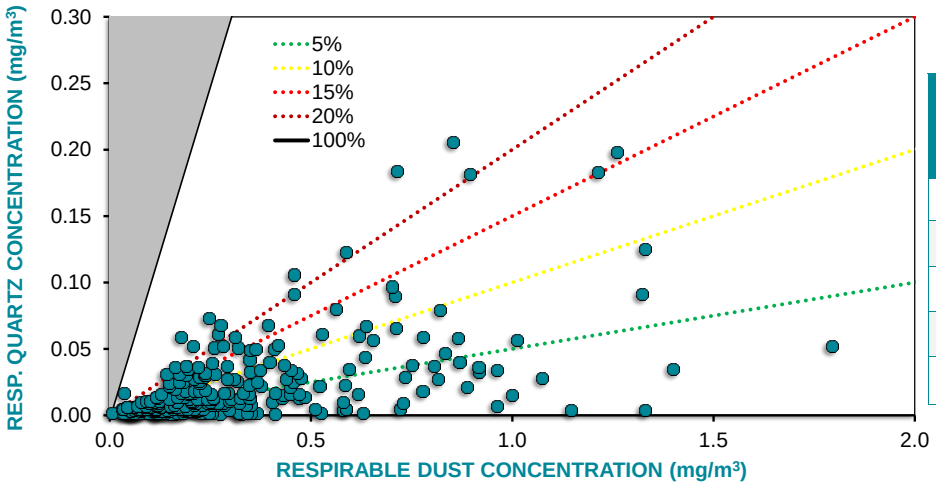
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0,1	96,5%
≤0,05	86,5%
≤0,025	70,8%
≤0,012	54.8%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	99.0%
≤1.5	97.4%
≤0.3	67.0%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	50%
>5% to 10%	28%
>10% to 15%	12%
>15% to 20%	5%
>20%	5%

QUARRYING OF SAND AND GRAVEL: Extraction of sand and gravel (aggregate of coarse- to medium-grained particulate material used in construction) – Crushing and grinding sand and gravel – Manufacture of products for road coverings – Transport of materials by road

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B2.01 - Management and office work	
B2.01.01 - Manager	Carries out management and/or operational functions involving responsibility, coordination and control of extraction activities in quarry, pits and open-cast sites. In small companies, these tasks are often handled by the company holder (partner or owner that may fulfil both administrative and operative duties).
B2.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to visit the quarry or production plants.
B2.02 - Sand and gravel excavations and handling	
B2.02.01 - Power-shovel / loader operator (at the quarry)	Operates power-driven machinery (power-shovel, excavator, loader, bulldozer) at the quarry to extract or move aggregate, debris and other materials into haul truck or conveyor belt. Removes overburden (preparatory to extraction operations), digs trenches, prepares ramps, tracks and mine yards, etc.
B2.02.02 - Power-shovel / loader operator (at the processing plant)	Operates power-driven machinery (power-shovel, excavator, loader, bulldozer) to move aggregate and other materials in the processing plant area (loading haul truck, feeding crusher, stockpiling aggregate, etc.).
B2.02.03 - Dredge / dewatering pump operator	Operates power-driven dredge to mine sand and gravel at the bottom of lakes, rivers and streams. Conducts quarry dewatering to remove water from the active parts of the quarry to allow sand and gravel extraction to continue. The job title includes both the chief operator and the assistants.
B2.02.04 - Truck driver (at the quarry/plant site)	Drives truck, dumper or other vehicle to transport and dump extracted sand and gravel and other materials. Operates in the quarry site and processing plant areas.
B2.02.05 - Delivery truck driver	Drives truck, dumper or other vehicle to transport and dump extracted sand and gravel and other materials. Operates outside the quarry site and processing plant areas, mainly for products and materials delivery.
B2.03 - Processing plants	
B2.03.01 - Crusher / grinder	Operates crushing plant to reduce rock debris/gravel to suitable size for further processing and mills to grind material. Performs minor maintenance and repairs plant, machine and tools. The job title includes a crusher/grinder assistant.
B2.03.02 - Screening plant operator	Tends screening plant for aggregates. The job title includes a screener assistant.
B2.03.03 - Washing plant operator	Tends to the sand and gravel washing plant and the maintenance of the production line.
B2.03.04 - Asphalt plant operator	Conducts and oversees asphalt plant operations.
B2.03.05 - Concrete mixing plant operator	Conducts and controls the batching and mixing concrete plant.
B2.04 - Quality control and laboratory testing	
B2.04.01 - Laboratory technician	Performs laboratory tests to determine aggregate quality.
B2.04.02 - Waste control / water treatment plant technician	Performs tasks related to the disposal, storage and transportation of wastes and hazardous materials. Operates the water treatment plant and conducts water analysis tests to ensure safety.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B2.04.03 - Selection/sorting operator	Carries out the selection and sorting for the manual separation of crushed aggregates. Operates in a cabin complete with air-conditioning systems.
B2.05 - Warehousing and packaging	
B2.05.01 - Warehouse operator	Handles duties pertaining to the processing organising, packaging and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.
B2.05.02 - Bag filling operator	Fills bags with sand or gravel product to its proper weight operating a bag filling machine or by manual means.
B2.05.03 - Silo operator	Tends the loading system that conveys materials into storage silo and the unloading system for discharging products. Is responsible for silo maintenance and delivery procedures.
B2.06 - Various workspaces	
B2.06.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
B2.07 - Mechanical and electrical maintenance / cleaning	
B2.07.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical work-shop and at the quarry. The job title includes both foreman / maintenance manager and other workers.
B2.07.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

QUARRYING OF SAND AND GRAVEL: Extraction of sand and gravel (aggregate of coarse- to medium-grained particulate material used in construction) – Crushing and grinding sand and gravel – Manufacture of products for road coverings – Transport of materials by road

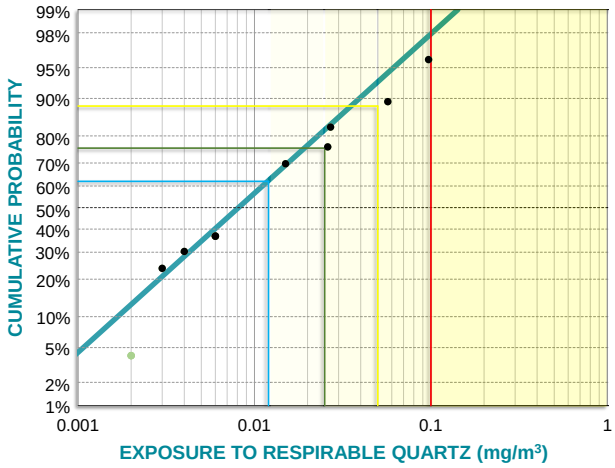
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
B2.01.01 - Manager	15	0.008	3.400	>95.9%	88.3%	75.8%	62.1%
B2.01.02 - Office worker	2	0.013	-	-	-	-	-
B2.02.01 - Power-shovel / loader operator (at the quarry)	68	0.008	3.350	>99.1%	90.3%	74.2%	62.5%
B2.02.02 - Power-shovel / loader operator (at the processing plant)	40	0.011	3.118	97.3%	93.5%	71.1%	51.2%
B2.02.03 - Dredge / dewatering pump operator	1	0.007	-	-	-	-	-
B2.02.04 - Truck driver (at the quarry/plant site)	43	0.011	2.927	>98.6%	90.7%	73.1%	54.6%
B2.02.05 - Delivery truck driver	16	0.014	3.696	93.1%	74.8%	67.8%	53.1%
B2.03.01 - Crusher / grinder	57	0.016	3.939	90.7%	76.0%	64.0%	41.3%
B2.03.02 - Screening plant operator	5	0.036	2.162	-	-	-	-
B2.03.03 - Washing plant operator	1	0.003	-	-	-	-	-
B2.03.04 - Asphalt plant operator	1	0.002	-	-	-	-	-
B2.03.05 - Concrete mixing plant operator	3	0.007	1.661	-	-	-	-
B2.04.01 - Laboratory technician	3	0.004*	5.684	-	-	-	-
B2.04.03 - Selection/sorting operator	1	0.032	-	-	-	-	-
B2.05.01 - Warehouse operator	1	0.037	-	-	-	-	-
B2.05.02 - Bag filling operator	4	0.025	3.302	-	-	-	-
B2.05.03 - Silo operator	7	0.007	2.918	>91.4%	91.1%	85.2%	74.9%
B2.06.01 - Polyvalent worker	12	0.014	3.415	93.5%	86.2%	66.5%	44.6%
B2.07.01 - Maintenance mechanic / electrician	12	0.009	4.743	92.4%	88.6%	72.6%	62.2%
B2.07.02 - Workplace cleaner	1	0.031	-	-	-	-	-

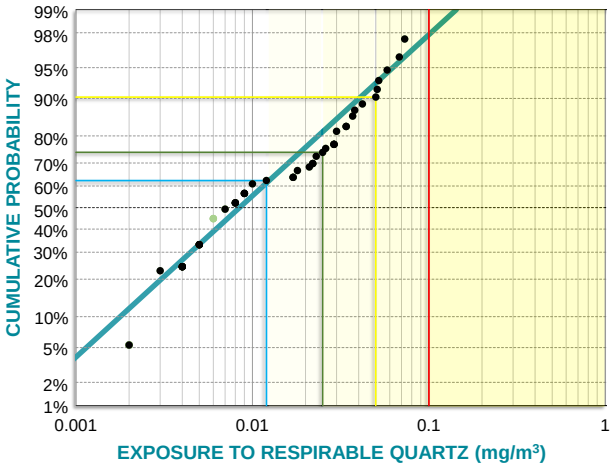
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

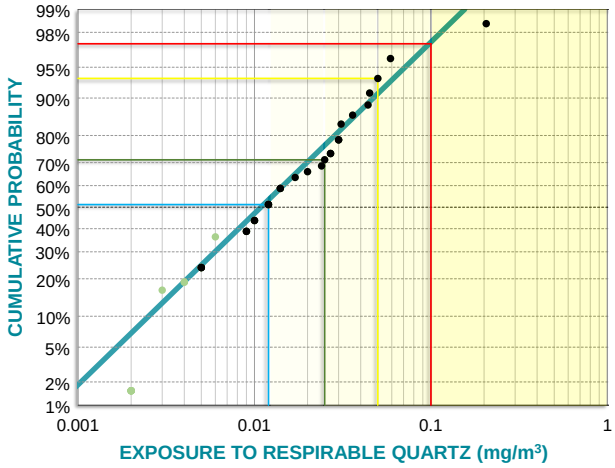
B02.01.01 - Manager



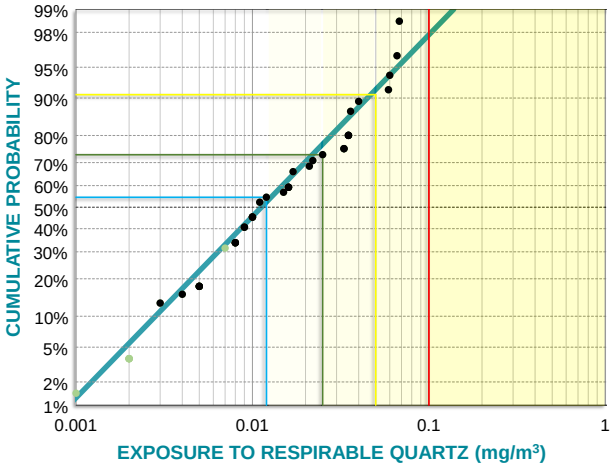
B02.02.01 - Power-shovel / loader operator (at the quarry)



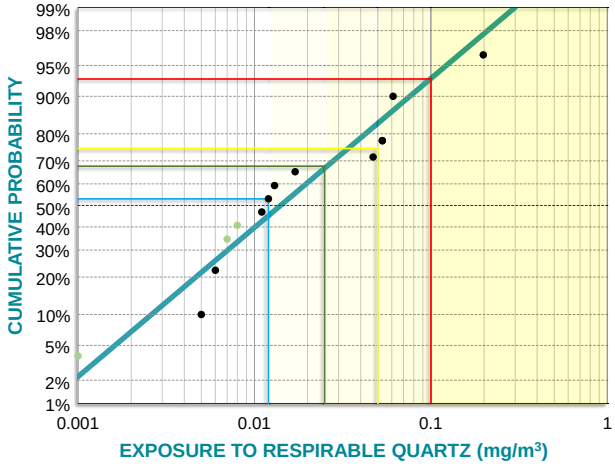
B02.02.02 - Power-shovel / loader operator (at the processing plant)



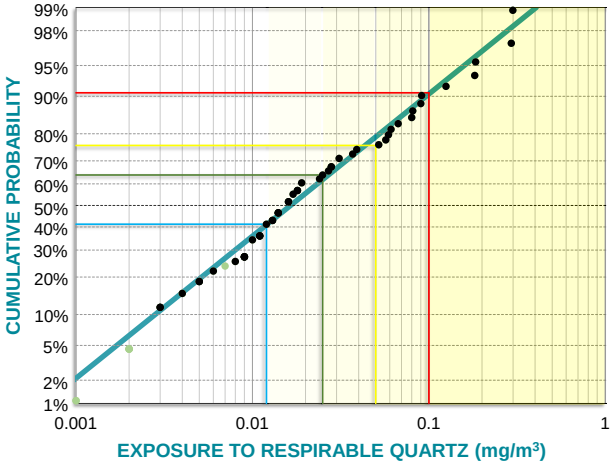
B02.02.04 - Truck driver (at the quarry/plant site)



B02.02.05 - Delivery truck driver



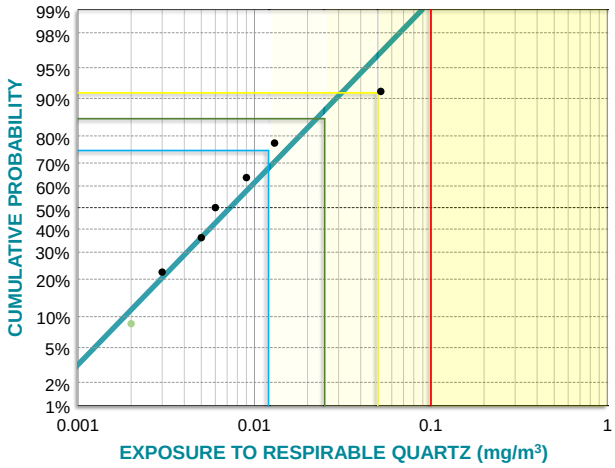
B02.03.01 - Crusher / grinder



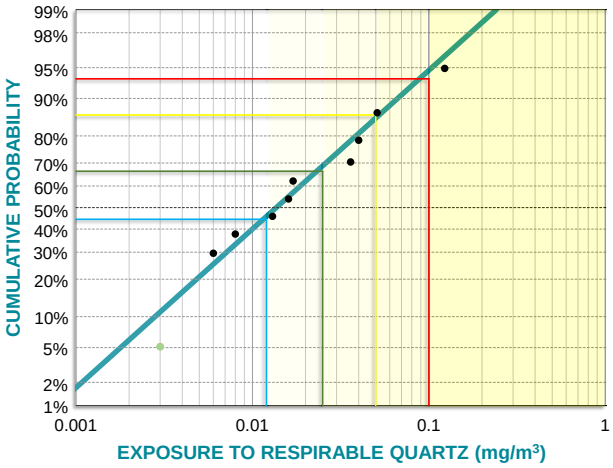
QUARRYING OF SAND AND GRAVEL: Extraction of sand and gravel (aggregate of coarse- to medium-grained particulate material used in construction) – Crushing and grinding sand and gravel – Manufacture of products for road coverings – Transport of materials by road

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

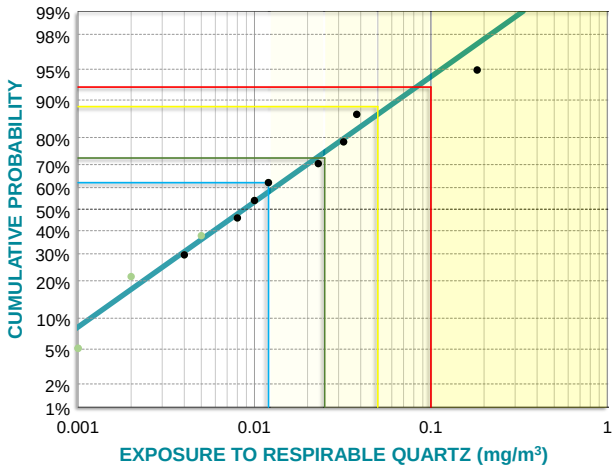
B02.05.03 - Silo operator



B02.06.01 - Polyvalent worker



B02.07.01 - Maintenance mechanic / electrician



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
B2.01.01 - Manager	17	0.191	2.279		>96.4%	66.9%
B2.01.02 - Office worker	2	0.165	-	-	-	-
B2.02.01 - Power-shovel / loader operator (at the quarry)	80	0.153	2.528		>99.2%	79.6%
B2.02.02 - Power-shovel / loader operator (at the processing plant)	47	0.179	2.555	>98.7%	97.8%	73.6%
B2.02.03 - Dredge / dewatering pump operator	1	0.187	-	-	-	-
B2.02.04 - Truck driver (at the quarry/plant site)	47	0.252	2.498	>98.7%	97.0%	60.2%
B2.02.05 - Delivery truck driver	16	0.262	3.296	94.6%	91.1%	61.0%
B2.03.01 - Crusher / grinder	59	0.361	2.738	96.2%	91.2%	50.0%
B2.03.02 - Screening plant operator	4	0.338	1.428	-	-	-
B2.03.03 - Washing plant operator	3	0.085	1.610	-	-	-
B2.03.04 - Asphalt plant operator	1	0.340	-	-	-	-
B2.03.05 - Concrete mixing plant operator	3	0.121	1.936	-	-	-
B2.04.01 - Laboratory technician	3	0.143	1.399	-	-	-
B2.04.03 - Selection/sorting operator	1	0.466	-	-	-	-
B2.05.01 - Warehouse operator	1	0.190	-	-	-	-
B2.05.02 - Bag filling operator	4	0.388	2.167	-	-	-
B2.05.03 - Silo operator	7	0.111	1.923			>91.4%
B2.06.01 - Polyvalent worker	14	0.215	1.988		>95.6%	65.7%
B2.07.01 - Maintenance mechanic / electrician	12	0.298	2.578		>94.9%	51.2%
B2.07.02 - Workplace cleaner	1	0.261	-	-	-	-

Working processes

Clays, sediments with grain size smaller than 2 μm made of clay minerals, are used for producing refractories, bricks, ceramics, cement, etc. Quartz content is very variable and on average around 20%. Bentonites are clays derived from the alteration of volcanic rocks; they swell in water, greatly increasing their volume and are used, for instance, in drilling mud. Pozzolana, a fine-grained silty-sandy material of volcanic origin, mainly made of amorphous silica, is used in the construction industry as a hydraulic binder. Bauxites are made of iron and aluminium oxides and hydroxides, with bauxite ores being the main source of aluminium; silica may constitute up to 40% of the extracted material, with a mean quartz concentration of around 4%. Feldspars, the most abundant group of minerals in Earth's crust, are found in a variety of geological environments. Ore deposits suitable for their extraction are, for instance, the quartz-feldspathic sands and the acid veins, in which the quartz content may be even higher than 5%. Examples of production cycles related to the extraction of clays and feldspars respectively are set out below.

Clay extraction for brick manufacturing

1. **Extraction of the raw material** – is typically carried out by excavators (power shovel, scraper or bulldozer) in open-pit quarries. The extracted material is loaded into trucks and stored in stockpiles.
2. **Pre-processing** – clay is mixed with water and sand (<5%) using a mixer and a roller mill until it becomes a mixture with homogeneous moisture and grain size.
3. **Store housing and shipping** – the pre-processed material is sent to the ore bins by a conveyor belt for maturing. Products are finally shipped to the site of use.

Feldspar extraction

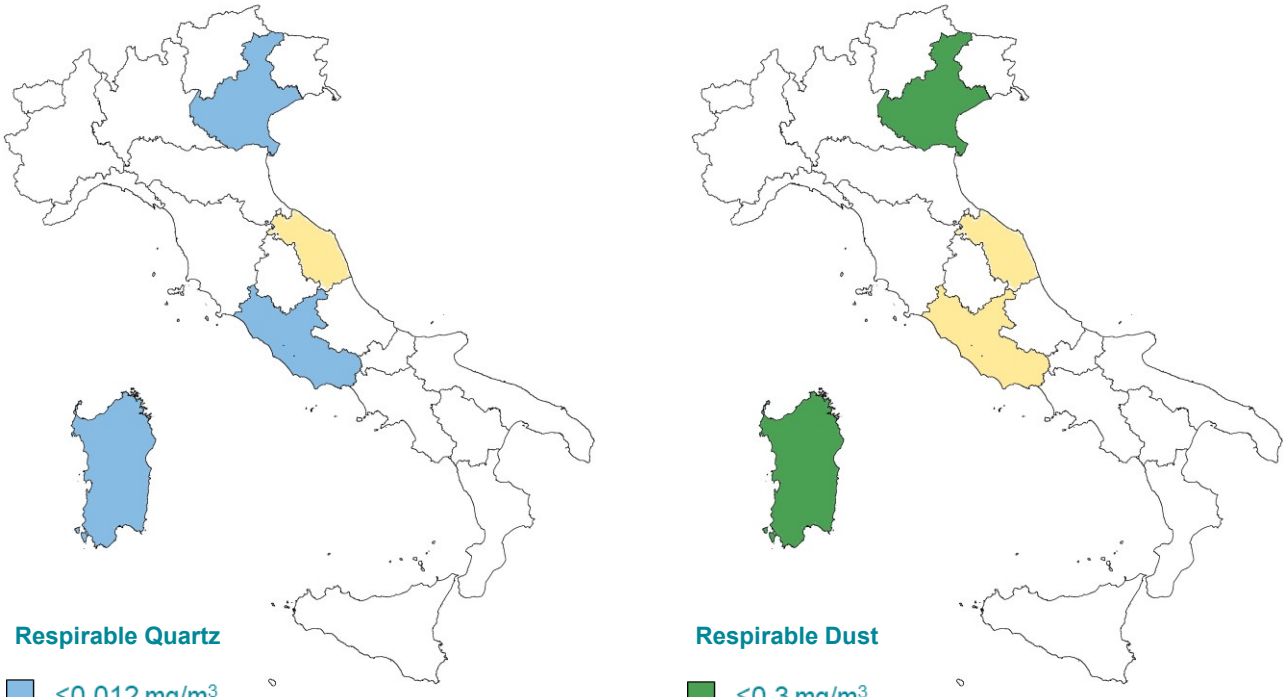
1. **Extraction of the raw material** – is carried out by excavator (power shovel, scraper or bulldozer) or by drilling and blasting in case of hard rock. The extracted material is transported to the covered storehouse by, for example, a conveyor belt, where it is mixed and homogenised.
2. **Crushing** – the raw material is dumped into the feed hopper of a jaw crusher for the primary crushing. After a first screening, the second stage of crushing is carried out in a cone-shaped crusher, then a second screening passage obtains finished grains with a size up to 6 mm. The fine grains are then loaded into a hopper by a power shovel and ground, usually in grinding tubes with grinding charges of flint (quartz) pebbles.
3. **Flotation treatment** – the first stage consists of the elimination of the finest fraction (slime removal) in a hydro cyclone. This is followed by a second stage for conditioning by adding reagents for the production of foam and, finally, a third stage for the separation of solid from liquid. The heavier minerals and the flotation foams are extracted and conveyed into a basin, while the resulting material is thickened and vibro-dripped to obtain the final product. Other treatments, such as deferrisation and electrostatic separation for feldspar extraction, may be carried out depending on the characteristics of the extracted material and the product to be obtained.
4. **Packaging, storage and shipping** - the final product is stored in bins or silos. Sometimes the product is packed in bags or sacks. The production cycle ends with the transport of products to the site of use.

Geometric mean and geometric standard deviation values of exposure measurements

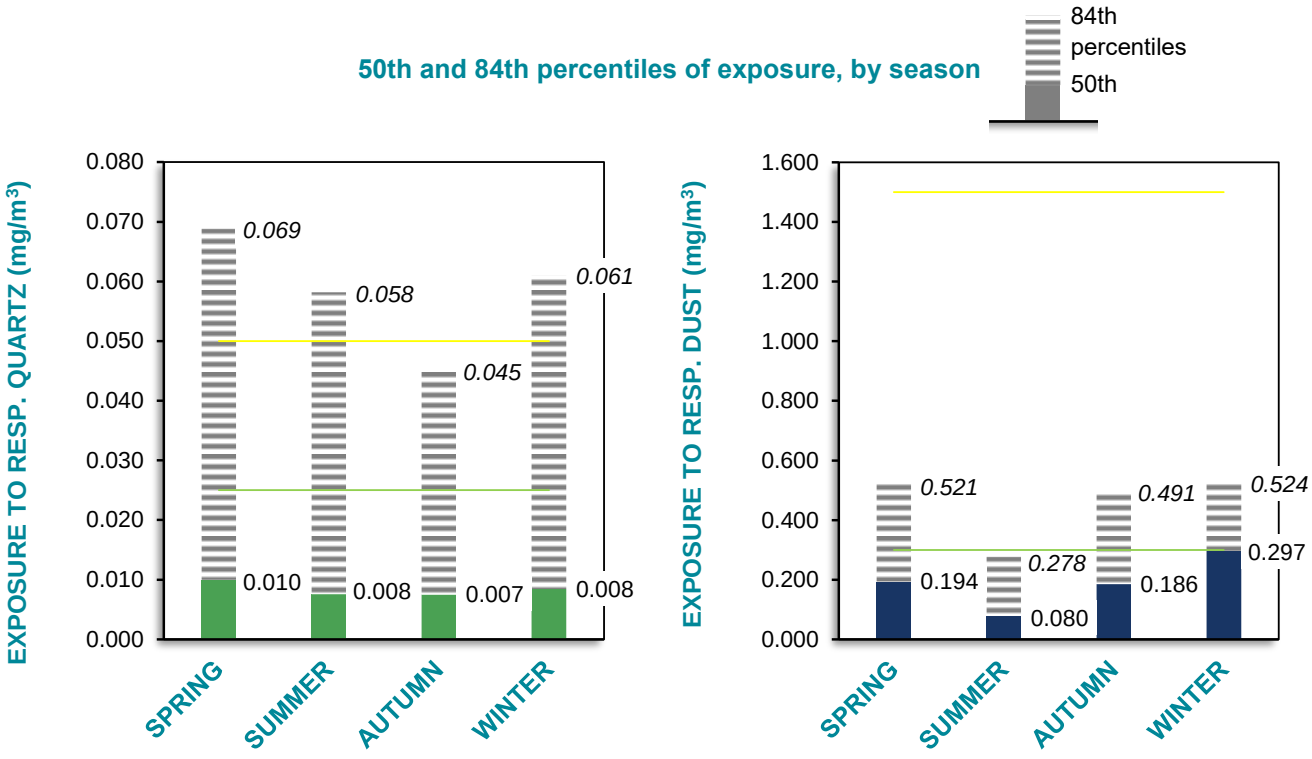
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples	Geometric Mean	Geometric St. Dev.	Analysed samples	Geometric Mean	Geometric St. Dev.	Average quartz content
PERSONAL	61	0.175	2.824	51	0.009	2.839	6.1
STATIC	1	0.873	-	1	0.007	-	0.8

QUARRYING OF CLAYS, POZZOLANA AND FELDSPAR: Extraction and processing of clays for ceramic industries, refractory and brick manufacturing; kaolin; bentonite clays; pozzolana, bauxite (aluminium), fluorite, barite (fertiliser minerals, chemical industries); feldspar; salt

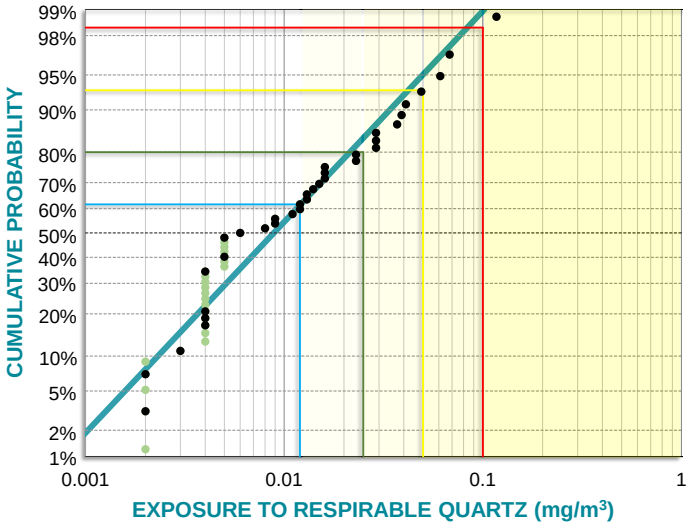
Geometric mean of personal exposure, by region



50th and 84th percentiles of exposure, by season

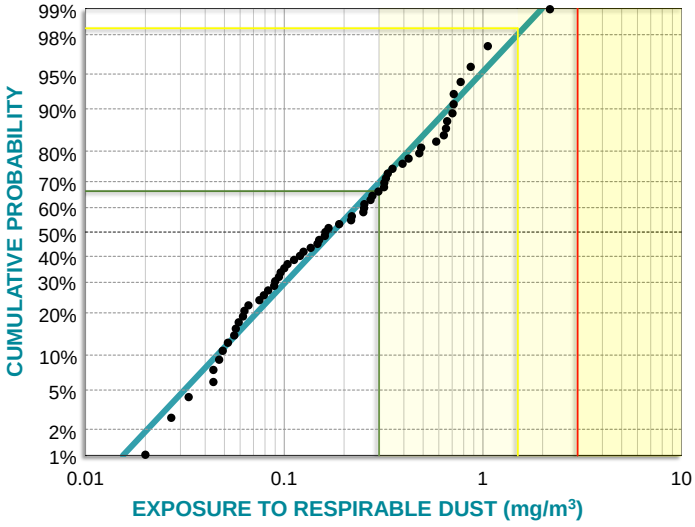


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



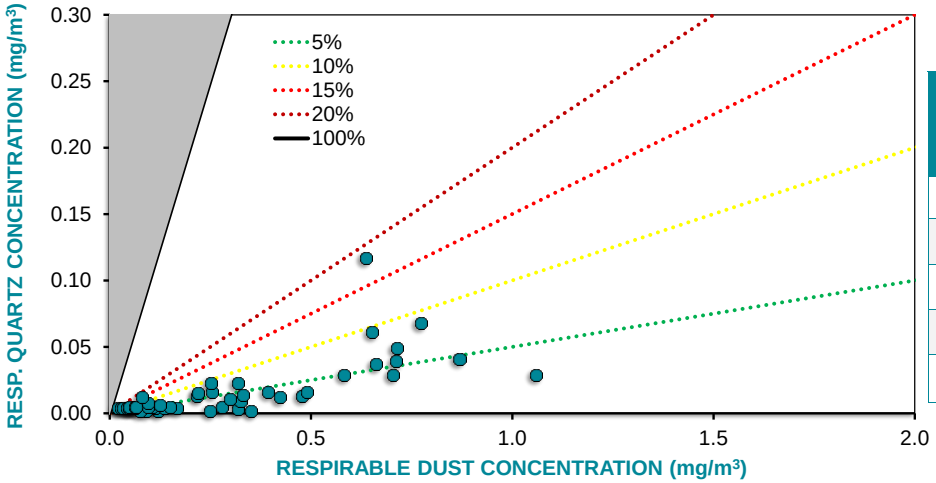
Exposure to respirable quartz (mg/m³)	Compliance probability
≤0.1	98.4%
≤0.05	93.1%
≤0.025	80.0%
≤0.012	61.7%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m³)	Compliance probability
≤3	>99.0%
≤1.5	98.3%
≤0.3	66.5%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	47%
>5% to 10%	39%
>10% to 15%	10%
>15% to 20%	4%
>20%	0%

QUARRYING OF CLAYS, POZZOLANA AND FELDSPAR: Extraction and processing of clays for ceramic industries, refractory and brick manufacturing; kaolin; bentonite clays; pozzolana, bauxite (aluminium), fluorite, barite (fertiliser minerals, chemical industries); feldspar; salt

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B3.01 - Management and office work	
B3.01.01 - Manager	Carries out the management and/or operational functions involving responsibility, coordination and control of extraction activities in the quarry, pits and open-cast sites. In small companies, these tasks are often handled by the company holder (partner or owner that may fulfil both administrative and operative duties).
B3.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to visit the quarry or production plants.
B3.02 - Quarrying and handling of extracted material	
B3.02.01 - Power-shovel / loader operator (at the quarry)	Operates power-driven machinery (power-shovel, excavator, loader, bulldozer) at the quarry to extract clay or minerals and move debris and other materials into haulage truck or conveyor belt. Removes overburden (preparatory to extraction operations), prepares ramps, tracks and mine yards, digs trenches, etc.
B3.02.02 - Rock drill operator	Operates rock drilling machine to place blasting charges and for other types of drilling operations.
B3.02.03 - Power-shovel / loader operator (at the processing plant)	Operates power-driven machinery (power-shovel, excavator, loader, bulldozer) to move clay or mineral and other materials in the processing plant area loading haul truck and stockpiling material.
B3.02.04 - Truck driver	Drives truck, dumper or other vehicles to transport and dump extracted mineral and other materials in or outside the quarry site.
B3.03 - Processing plants	
B3.03.01 - Crusher / grinder	Operates crushing plant to reduce rock debris to suitable size for further processing and mills to grind material. Performs minor maintenance and repairs to the plant, machine and tools. The job title includes a crusher/grinder assistant.
B3.03.02 - Screening plant operator	Tends screening plant for quarried material.
B3.03.03 - Loader operator (at the crushing plant)	Operates power-driven loader (bulldozer) to load materials into the crusher, feed the hopper and/or to feed the vibro-screening plant.
B3.03.04 - Clay processing plant operator	Operates and controls the clay processing plant. Clays are processed by mechanical methods (crushing, grinding and screening). Other processes (drying, calcining, bleaching, blunging and extruding) can be necessary to prepare the clay for use.
B3.03.05 - Feldspar processing plant operator	Operates and controls the flotation plant, the deferrisation plant or the electrostatic separation plant. Carries out maintenance tasks on the feldspar production line. The job title includes an operator assistant.
B3.04 - Warehousing and packaging	
B3.04.01 - Warehouse operator	Handles duties pertaining to the processing organising, packaging and shipping of materials, equipment and other items that are sent to the warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.
B3.04.02 - Bag filling operator	Fills bags with product to its proper weight operating a mechanical machinery or by manual means.
B3.04.03 - Silo operator	Tends to the loading system that conveys materials into the storage silo and the unloading system for discharging products. Is responsible for silo maintenance and delivery procedures.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B3.05 - Various workspaces	
B3.05.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
B3.06 - Mechanical and electrical maintenance / cleaning	
B3.06.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and at the quarry. The job title includes both foreman / maintenance manager and other workers.
B3.06.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

QUARRYING OF CLAYS, POZZOLANA AND FELDSPAR: Extraction and processing of clays for ceramic industries, refractory and brick manufacturing; kaolin; bentonite clays; pozzolana, bauxite (aluminium), fluorite, barite (fertiliser minerals, chemical industries); feldspar; salt

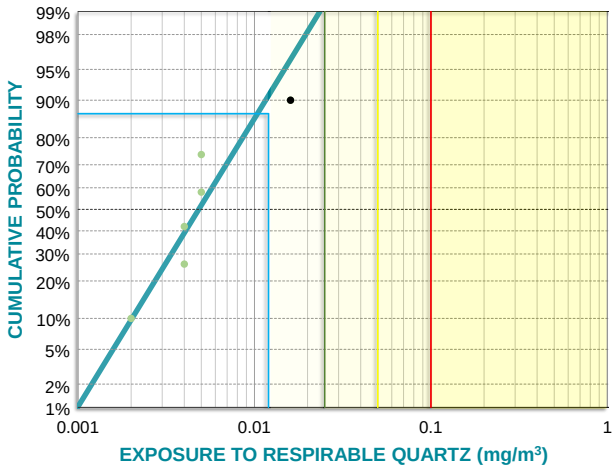
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
B3.01.01 - Manager	6	0.005*	1.966*			>90.0%	86.9%
B3.02.01 - Power-shovel / loader operator (at the quarry)	16	0.007	2.858	95.7%	92.9%	88.8%	77.7%
B3.02.02 - Rock drill operator	2	0.006	-	-	-	-	-
B3.02.03 - Power-shovel / loader operator (at the processing plant)	3	0.006*	1.701*	-	-	-	-
B3.02.04 - Truck driver	3	0.013	3.076	-	-	-	-
B3.03.01 - Crusher / grinder	12	0.020	2.649	>94.9%	87.4%	48.9%	27.7%
B3.03.02 - Screening plant operator	1	0.016	-	-	-	-	-
B3.03.03 - Loader operator (at the crushing plant)	3	0.007	3.011	-	-	-	-
B3.04.01 - Warehouse operator	1	0.013	-	-	-	-	-
B3.04.02 - Bag filling operator	2	0.017	-	-	-	-	-
B3.06.01 - Maintenance mechanic / electrician	2	0.003	-	-	-	-	-

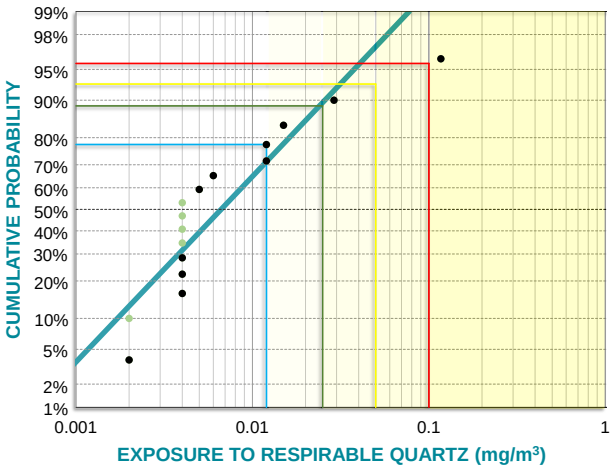
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

B03.01.01 - Manager

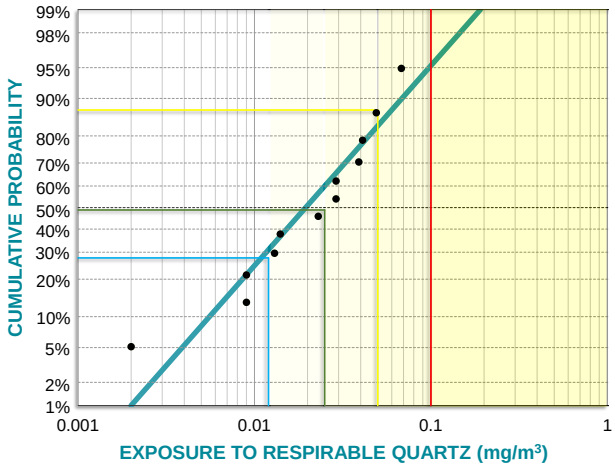


B03.02.01 - Power-shovel / loader operator (at the quarry)



Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

B03.03.01 - Crusher / grinder



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
B3.01.01 - Manager	7	0.076	2.722			>91.4%
B3.02.01 - Power-shovel / loader operator (at the quarry)	19	0.120	2.363		>96.8%	82.2%
B3.02.02 - Rock drill operator	4	0.109	-	-	-	-
B3.02.03 - Power-shovel / loader operator (at the processing plant)	3	0.101	2.577	-	-	-
B3.02.04 - Truck driver	3	0.248	4.251	-	-	-
B3.03.01 - Crusher / grinder	14	0.492	2.344	>95.6%	92.6%	15.5%
B3.03.02 - Screening plant operator	1	0.394	-	-	-	-
B3.03.03 - Loader operator (at the crushing plant)	5	0.172	1.913	-	-	-
B3.04.01 - Warehouse operator	1	0.217	-	-	-	-
B3.04.02 - Bag filling operator	2	0.250	-	-	-	-
B3.06.01 - Maintenance mechanic / electrician	2	0.134	-	-	-	-

Working processes

Pumice is an eruptive volcanic rock with a silica content (predominantly glass) greater than 70% and a quartz concentration of less than 2%. The main pumice deposit in Italy is found on the volcanic island of Lipari, where pumice extraction characterised its history until 2007, when pumice quarries were closed with the cessation of mining activities. In Lipari pumice quarries, two types of processing were carried out, called white and black respectively. In the white processing, impurity-free products were obtained, coming from selected pumice, washed, ground and sent to dryers in the desired grain size. Black (due to the presence of obsidian) processing was aimed at the production of powders and grains that did not require any preliminary process besides sieving, so the materials were directly moved into the dryers. At the end of the production cycle, about thirty different products were obtained for each of the two lines, going from impalpable powder (30-40 μm) up to grains of 3-15 mm. The two productions were used for different applications, in particular, soft abrasion could only be guaranteed by the rounded grains coming from the white production. The working cycle is described below.

1. **Mining** – in the Lipari open-pit pumice mine the pumice outcrop was broken by the loader, bulldozer or angledozer and excavation proceeded by lowering horizontal benches. The excavated material was pushed into a rock hopper excavated in the mountain, falling into a slipway and accumulating at its bottom.
2. **First sorting** – in the Lipari quarry, from the bottom of the hopper slipway, the material fell onto a conveyor belt passing through special unloading openings. The larger blocks of pumice and the non-pumice stones (obsidian, basalt and lava stones) were manually removed from the conveyor belt in the tunnel and the material coarser than 20 cm was retained on a grid mesh at the exit of the tunnel. The material passing through this first sieve fell to a lower level through a second slipway (production channel), where particle size selection of the material was made with plan-sifter in four fractions: >90 mm, 15-90 mm, 3-15 mm and <3 mm. The selection of the material suitable for white processing and the rest, allocated to the black processing, was carried out after a series of laboratory tests on the materials and using an air knife separator to separate grains of different densities and sizes.
3. **Milling** – the grain-sized pumices were sent to a cylinder grinding system (simple, double or triple rolling mills) to reduce grains into fine and very fine powders, which were more in demand.
4. **Drying** – the ground material was carried through conveyor belts to the cylindrical dryers or rotary kilns with a combustion chamber at a temperature of 150°C. Cyclones for the removal of dust particulates from the air were used at the bottom of the dryers.
5. **Second sorting** – the dry materials were then sent to the rotating screen drums, where the final classification of the pumice grain size fractions was achieved.
6. **Packaging and storage** – roller-chain conveyors were used for the transportation of materials to the packaging department, where the bags were filled by a mechanised system and stacked in the warehouse using forklifts and bucket elevators.
7. **Shipping** – products were loaded on large trucks and boarded on ferries.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	20	0.978	3.176	20	0.003	1.985	0.5
STATIC	-	-	-	-	-	-	-

QUARRYING OF PUMICE STONE: Extraction and processing of pumice stone

Geometric mean of personal exposure, by region

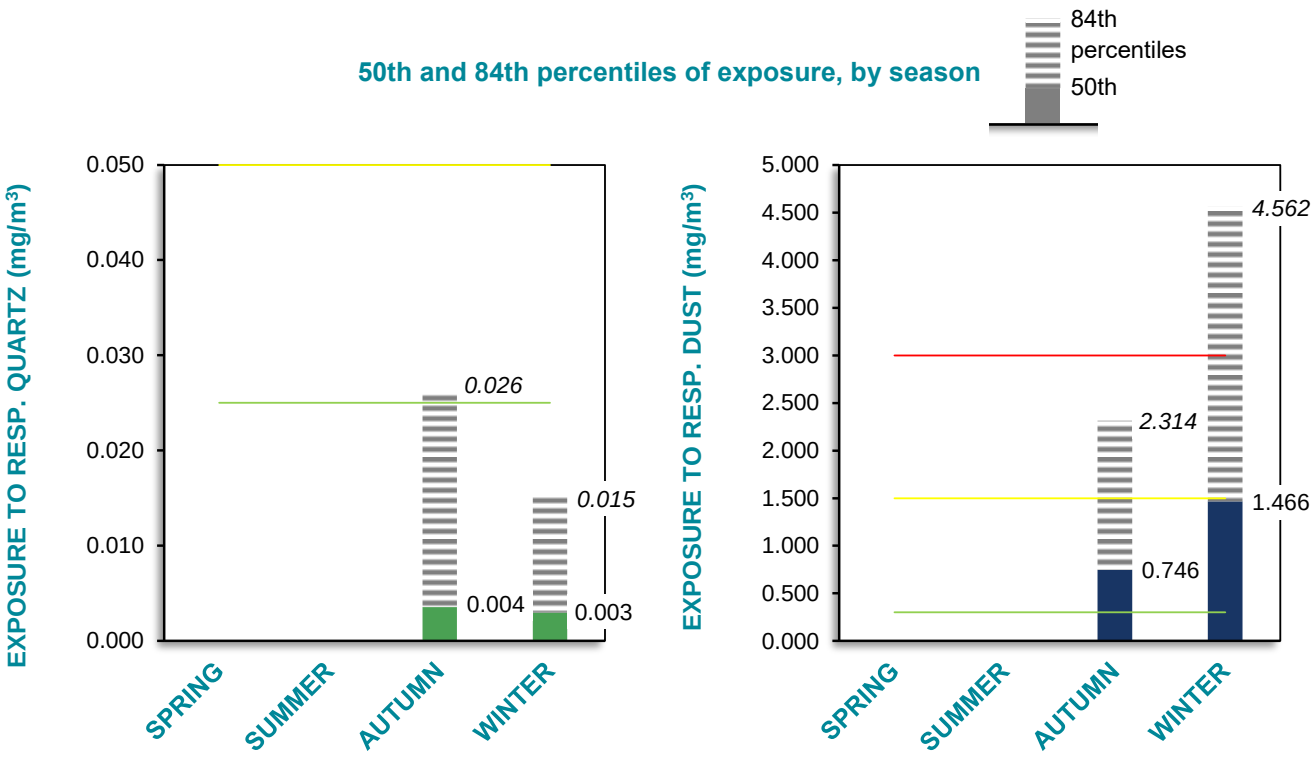
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

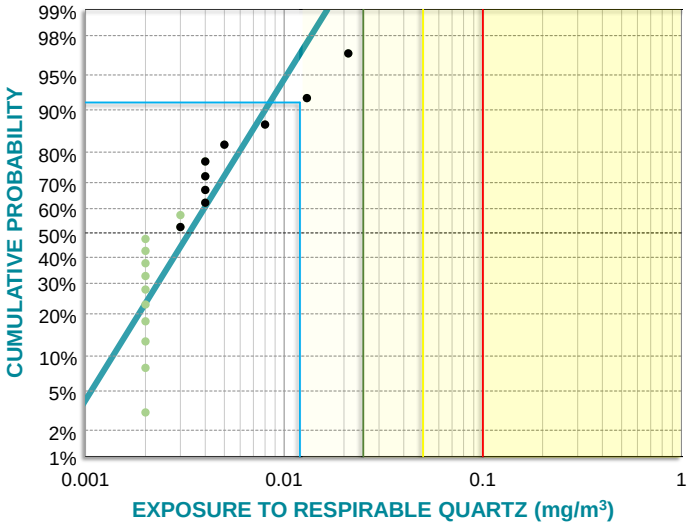
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

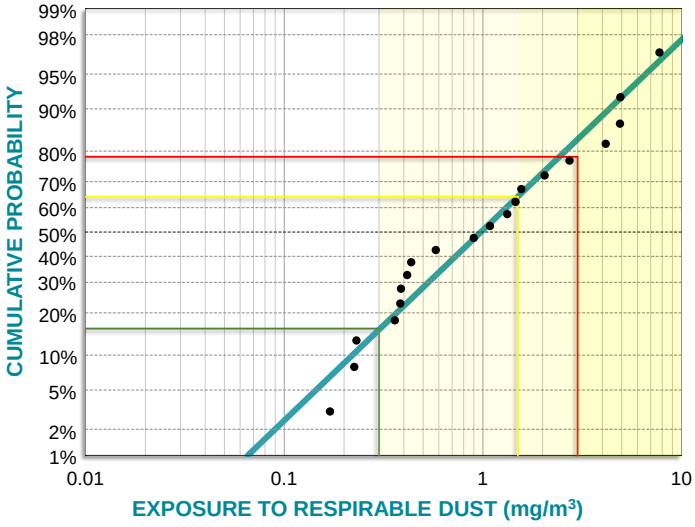


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



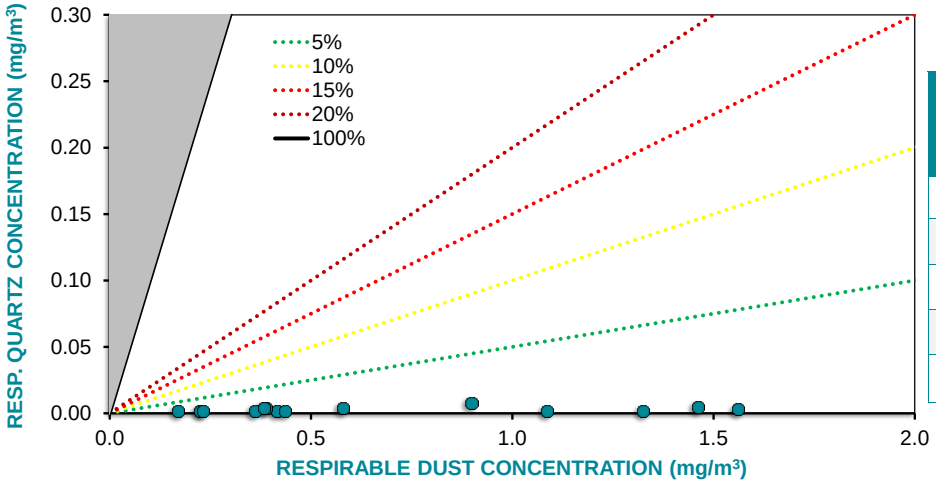
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	-
≤0.05	-
≤0.025	>96.9%
≤0.012	91.3%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	78.3%
≤1.5	64.3%
≤0.3	15.7%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	100%
>5% to 10%	0%
>10% to 15%	0%
>15% to 20%	0%
>20%	0%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B4.01 - Management and office work	
B4.01.01 - Manager	Carries out the management and/or operational functions involving responsibility, coordination and control of extraction activities in mines, pits and open-cast sites. In small companies, these tasks are often handled by the company holder (partner or owner that may fulfil both administrative and operative duties).
B4.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to visit the mine or production plants.
B4.02 - Quarrying and handling of extracted material	
B4.02.01 - Power-shovel / loader operator	Operates power-driven machinery (loader, bulldozer, angledozer, power-shovel) excavating horizontal benches in the open-pit pumice mine. Pushes the excavated material towards the first screening system. Removes the overburden (preparatory to extraction operations), prepares ramps, tracks and mine yards, digs trenches, etc.
B4.02.02 - Quarryman	Carries out different mining tasks in cooperation with the power-shovel / loader operator in the open-pit pumice mine.
B4.02.03 - Truck driver	Drives trucks, dumpers or other vehicles to transport and dump extracted rock and other materials. Operates in the mine site and processing plant area.
B4.03 - Processing plants	
B4.03.01 - Grinder	Operates grinding plant (cylinder grinding system) to reduce pumice to suitable size. Ground material is then sent to the drier plant. Performs minor maintenance and repairs plant, machinery and tools. The job title includes a grinder assistant.
B4.03.02 - Screening plant operator	Tends to the final screening plant for pumice material (screen drum, tumbler screening machine) to select the required particle sizes. The products are then sent to packaging.
B4.03.03 - Discharge hopper operator	Loads the sieved material into the discharge hopper.
B4.03.04 - Dryer operator	Operates the drum dryer in which the ground pumice material is dried before the final screening. Carries out different tasks cooperating with other workers.
B4.03.05 - First screening operator	Tends to the first size-selection of pumice material passing through a plansifter sieve system (at the bottom of a descending ramp) that divides the material into four ranges of grain size. The resulting materials are then stored in silos.
B4.04 - Stoneware finishing	
B4.04.01 - Stoneware grinder / finisher	Carries out the selection, cutting, filing and fine grinding of small stone objects (e.g. pumice *mice*).
B4.05 - Warehousing and packaging	
B4.05.01 - Warehouse operator	Handles duties pertaining to the processing organising, packaging and shipping of materials, equipment and other items that are sent to the warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.
B4.05.02 - Bag filling operator	Fills bags with pumice product to its proper weight by operating a bag filling machine or by manual means.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
B4.06 - Various workspaces	B4.06 - Various workspaces
B4.06.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
B4.07 - Mechanical and electrical maintenance / cleaning	
B4.07.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and at the quarry. The job title includes both foreman / maintenance manager and other workers.
B4.07.02 - Carpenter	Constructs, installs and repairs wooden and other structures.
B4.07.03 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
B4.02.01 - Power-shovel / loader operator	3	0.006	2.642	-	-	-	-
B4.02.02 - Quarryman	2	0.003	-	-	-	-	-
B4.02.03 - Truck driver	1	0.002*	-	-	-	-	-
B4.03.01 - Grinder	4	0.005	3.036	-	-	-	-
B4.03.02 - Screening plant operator	1	0.002*	-	-	-	-	-
B4.03.03 - Discharge hopper operator	1	0.002*	-	-	-	-	-
B4.03.04 - Dryer operator	2	0.003	-	-	-	-	-
B4.03.05 - First screening operator	1	0.004	-	-	-	-	-
B4.04.01 - Stoneware grinder / finisher	1	0.004	-	-	-	-	-
B4.05.02 - Bag filling operator	2	0.002	-	-	-	-	-
B4.07.01 - Maintenance mechanic / electrician	1	0.003*	-	-	-	-	-
B4.07.02 - Carpenter	1	0.002*	-	-	-	-	-

* more than half of the measurements are <LOQ

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
B4.02.01 - Power-shovel / loader operator	3	1.162	5.952	-	-	-
B4.02.02 - Quarryman	2	0.457	-	-	-	-
B4.02.03 - Truck driver	1	0.416	-	-	-	-
B4.03.01 - Grinder	4	2.100	1.813	-	-	-
B4.03.02 - Screening plant operator	1	0.170	-	-	-	-
B4.03.03 - Discharge hopper operator	1	0.231	-	-	-	-
B4.03.04 - Dryer operator	2	2.547	-	-	-	-
B4.03.05 - First screening operator	1	0.387	-	-	-	-
B4.04.01 - Stoneware grinder / finisher	1	0.384	-	-	-	-
B4.05.02 - Bag filling operator	2	1.722	-	-	-	-
B4.07.01 - Maintenance mechanic / electrician	1	4.920	-	-	-	-
B4.07.02 - Carpenter	1	0.436	-	-	-	-

Working processes

Bituminous waterproofing sheets (membranes) are used in the construction industry to protect civil engineering works. They are produced in rolls and consist of a non-woven fabric polyester or fibreglass reinforcement coated with a bituminous compound. The continuous production process begins with the dipping of the non-woven fabric in a tank, containing the bitumen in the liquid state, at high temperatures. After impregnation and cooling, a finishing layer is applied to the product. The coating can be non-adhesive (quartz sand, talc or plastic film) and/or protective (slate or basalt flakes, metal foil). In the case of sand coating, before the final rolling of the product at the end of the production line, the membrane is passed through the sandblasting station where it is sprinkled with silica sand, which falls on the membrane by gravity. The production cycle is described below.

1. **Raw material storage** – the raw materials (bitumen, resins, carbonate, synthetic rubbers, non-woven fabric, sand, slate and talc) are stored in silos or tanks. In case of hot processing, the bitumen may come directly from the oil refinery, maintained in the molten state, transported in insulated tank trucks and discharged by pumping it into the storage tanks of the unloading plant, where it is kept at a constant warm temperature until use.
2. **Preparation of the mixture** – special mixtures of bitumen, resins and rubbers are used. In the hot production cycle, bitumen is pumped into large heated mixers, equipped with a stirring system for polymer melting, automatically dosed with the further introduction of solid polymers, additives and fillers. Once homogenised, the molten mixture is filtered and pumped into holding mixers. From there, the molten mixture is pumped into the impregnation and coating tank of the membrane production line. Mixers and impregnation tanks are located under air extraction systems and the fumes are conveyed to the abatement systems.
3. **Production of the membranes** – the membranes are produced by impregnating a non-woven fabric or glass felt with a mixture of bitumen and additives. The membrane production line is a continuous machine, that can be even several tens of meters long, depending on the product to be obtained. At the beginning of the production line, an uncoiler is placed for the non-woven fabric (or glass felt) roll. Once unrolled, the sheet is passed into an impregnation tank containing the molten bitumen mixture. The hot sheet is then cooled by flowing water fed by a cooling tower.
4. **Application of protective materials** – at the end of the production line, the protective mineral granules are applied to the membrane. They are tenaciously bonded to the surface and consist of silica sand, talc or slate depending on the product specification. The mineral granules are loaded into a hopper placed at the end of the line and, when falling, applied on the bituminous membrane (along the production line, loading the hopper with silica sand may cause inhalation of quartz dust). Conversely, the smooth-faced membranes pass through a powdering station where talc is sprinkled on the membrane upper face, in order to prevent the coils from sticking together. Some production lines are equipped with coating systems for the production of adhesive membranes or membranes coupled with other materials for particular products. At the end of each production line, an automatic winder machine wraps the membranes in rolls.
5. **Packaging, storage and shipping** – the rolls are automatically palletised, sent to the packaging and stored before shipping.

Geometric mean and geometric standard deviation values of exposure measurements

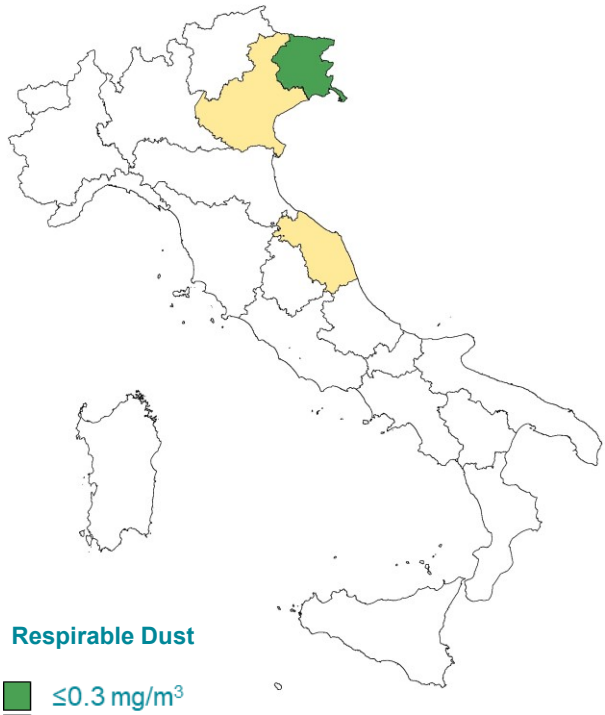
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	17	0.248	2.066	17	0.033	2.397	16.5
STATIC	-	-	-	-	-	-	-

BITUMINOUS MEMBRANES: Manufacture of bituminous membranes

Geometric mean of personal exposure, by region

Respirable Quartz

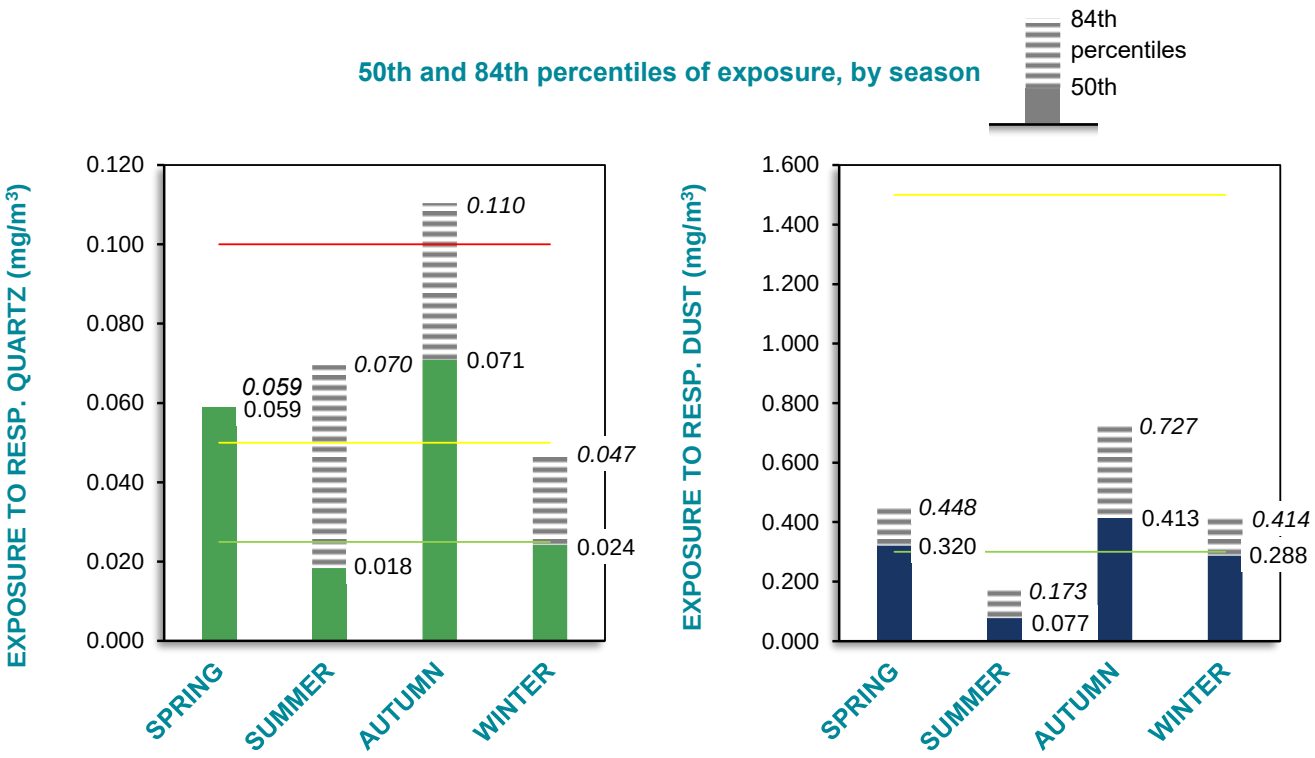
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



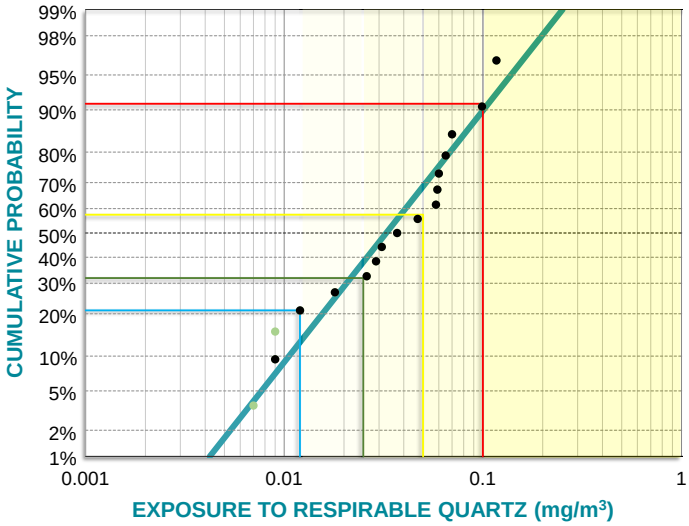
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

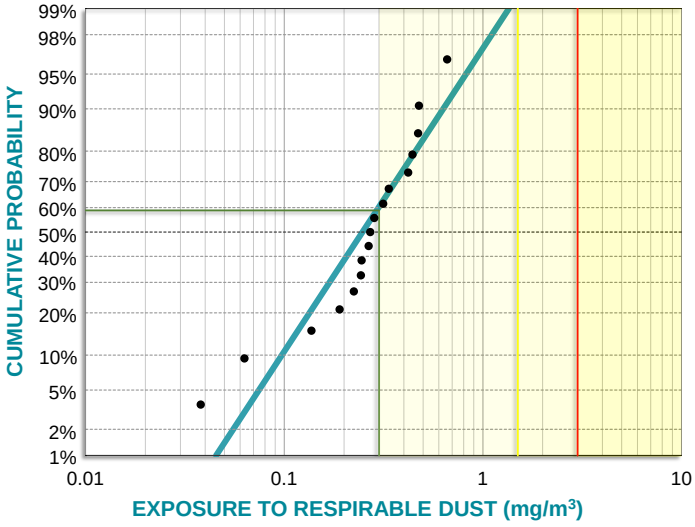


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



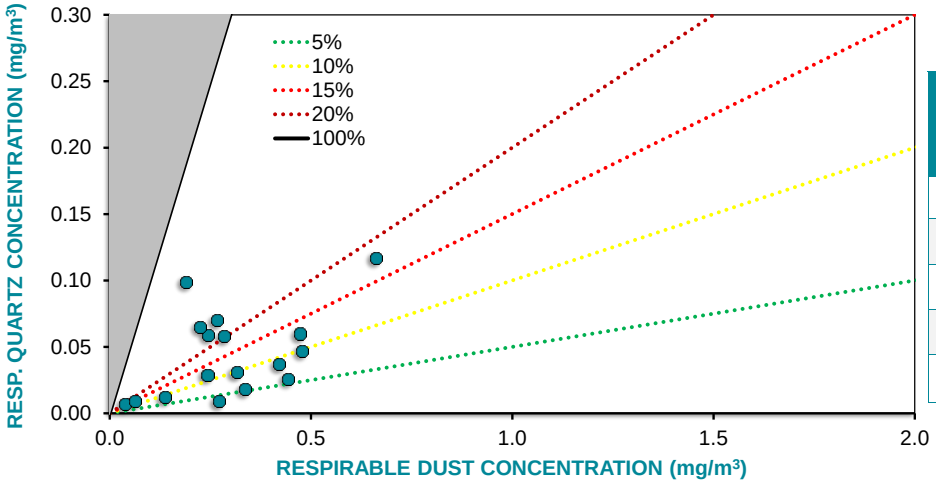
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	91.1%
≤0.05	57.5%
≤0.025	32.0%
≤0.012	21.0%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	-
≤1.5	>96.4%
≤0.3	58.9%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	6%
>5% to 10%	35%
>10% to 15%	18%
>15% to 20%	12%
>20%	29%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C1.01 - Management and office work	
C1.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C1.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C1.02 - Production lines	
C1.02.01 - Slate line supervisor	Supervises the production line of bituminous membranes coated with slate. Moves along the line checking it's functioning correctly. May also load the hopper with slate: opens the bags containing the slate grit with a manual cutter and transfer it into the hopper.
C1.02.02 - Silica sand line supervisor	Supervises the production line of bituminous membranes coated with silica sand. Moves along the line checking it's functioning correctly. May also load the hopper with silica sand: opens the bags containing the sand with a manual cutter and transfer it into the hopper.
C1.02.03 - Talc line supervisor	Supervises the production line of bituminous membranes coated with talc. Moves along the line checking it's functioning correctly. May also load the hopper with talc: opens the bags containing talc with a manual cutter and transfer it into the hopper.
C1.02.04 - Bituminous membrane winder at the slate line	Performs end-of-line controls on the slate line: places the rolls of bituminous membrane on the pallet and prepares them for palletisation and transport to the warehouse.
C1.02.05 - Bituminous membrane winder at the silica sand line	Performs end-of-line controls on the silica sand line: places the rolls of bituminous membranes on pallet and prepares them for palletisation and transport to the warehouse.
C1.02.06 - Bituminous membrane winder at the talc line	Performs end-of-line controls on the talc line: places the rolls of bituminous membranes on the pallet and prepares them for palletisation and transport to the warehouse.
C1.03 - Handling of materials and products	
C1.03.01 - Forklift operator	Operates material handling equipment (hand or battery operated pallet truck, forklift, automated pallet mover) to move pallets with rolls of bituminous membranes from the production line to the finished product storage warehouse.
C1.04 - Warehousing and packaging	
C1.04.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to the warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to the designated area.
C1.05 - Mechanical and electrical maintenance / cleaning	
C1.05.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C1.05.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C1.02.01 - Slate line supervisor	2	0.043	-	-	-	-	-
C1.02.02 - Silica sand line supervisor	3	0.065	1.462	-	-	-	-
C1.02.03 - Talc line supervisor	1	0.029	-	-	-	-	-
C1.02.04 - Bituminous membrane winder at the slate line	2	0.010	-	-	-	-	-
C1.02.05 - Bituminous membrane winder at the silica sand line	2	0.062	-	-	-	-	-
C1.02.06 - Bituminous membrane winder at the talc line	1	0.037	-	-	-	-	-
C1.03.01 - Forklift operator	2	0.011	-	-	-	-	-
C1.04.01 - Warehouse operator	3	0.039	3.764	-	-	-	-
C1.05.02 - Workplace cleaner	1	0.031	-	-	-	-	-

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C1.02.01 - Slate line supervisor	2	0.343	-	-	-	-
C1.02.02 - Silica sand line supervisor	3	0.350	1.696	-	-	-
C1.02.03 - Talc line supervisor	1	0.243	-	-	-	-
C1.02.04 - Bituminous membrane winder at the slate line	2	0.193	-	-	-	-
C1.02.05 - Bituminous membrane winder at the silica sand line	2	0.234	-	-	-	-
C1.02.06 - Bituminous membrane winder at the talc line	1	0.421	-	-	-	-
C1.03.01 - Forklift operator	2	0.113	-	-	-	-
C1.04.01 - Warehouse operator	3	0.228	3.289	-	-	-
C1.05.02 - Workplace cleaner	1	0.315	-	-	-	-

Working processes

Paints are mixtures consisting mainly of a varnish and a pigment and generally range from opaque to translucent. Among dyes, pigments are defined as inorganic or organic products, insoluble in the means in which they are used. Varnishes are transparent liquids laid in thin layers to form adherent films, for aesthetic or protective properties. Among the raw materials used in the manufacturing of dyes, clays contain significant percentages of quartz. Crystalline silica can also be found in glues (coming from organic compounds) and adhesives (chemical-based). Animal-based glues are derived from waste animal remains (skin, bones and hooves); plants are also used to produce vegetable glues. Adhesive substances are generally in liquid form and include synthetic substances such as cyanoacrylates, acrylic adhesives, polyurethane, amine, epoxy and silicone. One of the main fillers which serves for the preparation of epoxy moulding compounds is based on crystalline silica. As an example of a typical production cycle, the following outlines the process for dyes within the ceramics and construction industries.

Production of dyes

1. **Raw material first storage and drying** – raw materials include powder pigments usually made from metallic oxides as well as glass frit and many other inorganic raw materials used, such as clays (which contain a variable amount of quartz), limestone, dolomite and alumina. Raw materials are stored in warehouses, containers and silos. Drying (e.g. in rotary drum dryers) is necessary when a material has excessive moisture.
2. **Grinding and sieving** – the coarse-grained raw materials which do not meet the requested grain size are crushed in jaw crushers and different types of mills (hammer, rotating ring, peg impact or centrifugal impact) can be used for grinding. The ground material is sorted by sieves (e.g. vibrating inclined, rotating or circular sieves).
3. **Raw material storage** – raw materials are transported (e.g., by pneumatic transport, screw conveyors, belt conveyors or bucket elevators) and stored in silos or big bags in the raw materials deposit.
4. **Transport of raw material to the processing area** – forklifts and pallet jacks are used to move the pallets with the raw material.
5. **Weighing and dosing** – the addition of material can be manual or automatic. Extractors that guarantee the required precision carry out the automatic macro weighing of the main ingredients and the micro weighing for additives. The material is extracted by extraction screws and dosed by weighing belts or microdosers.
6. **Mixing** – the materials are mixed in a discontinuous ploughshare or blade mixer, in which the mixing tools rotate on the central shaft within the cylindrical horizontal chamber, producing turbulence in the mixture that incorporates all the particles in the mixing process.
7. **Packaging, storage and shipping** – most of the final product is packed in bags, palletised and subjected to automatic wrapping. Some products are not stored but are loaded directly into trucks for delivery to the customer.

In the **production of pigments** for the ceramics industry, after weighing and dosing, the material is typically subjected to the following series of operations.

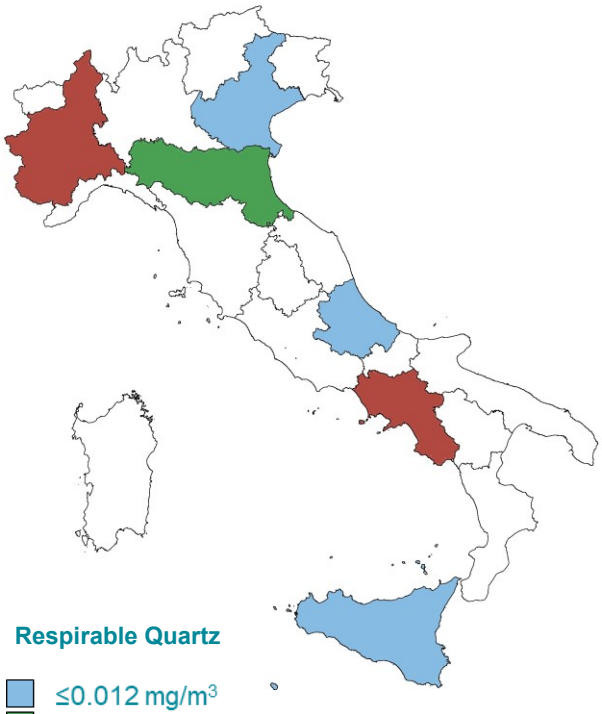
1. **Box filling and firing** - consists of a manual or automatic filling of formulation into boxes of refractory material, then loaded onto trolleys and fired in muffle kilns (calcination).
2. **Crushing and grinding** - the boxes unloaded from the kiln are emptied manually or automatically and the material is shredded in a shredding machine. The material is then transferred to the mills, through a loading system and wet ground, to produce an aqueous suspension (*slip*).
3. **Washing and drying** - the slip is washed several times in tins with hot water, transferred to trays mounted on racks and loaded into drying chambers.

4. **Pulverisation, packaging, storage and shipping** - the material is reduced to powder again, through a pulverising machine, then is transferred to the bagging machine, weighed and the filled bags are loaded on a forklift, sent to the warehouse and palletised.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	163	0.577	2.550	160	0.020	4.278	6.6
STATIC	4	0.467	1.318	4	0.006	3.641	1.9

Geometric mean of personal exposure, by region



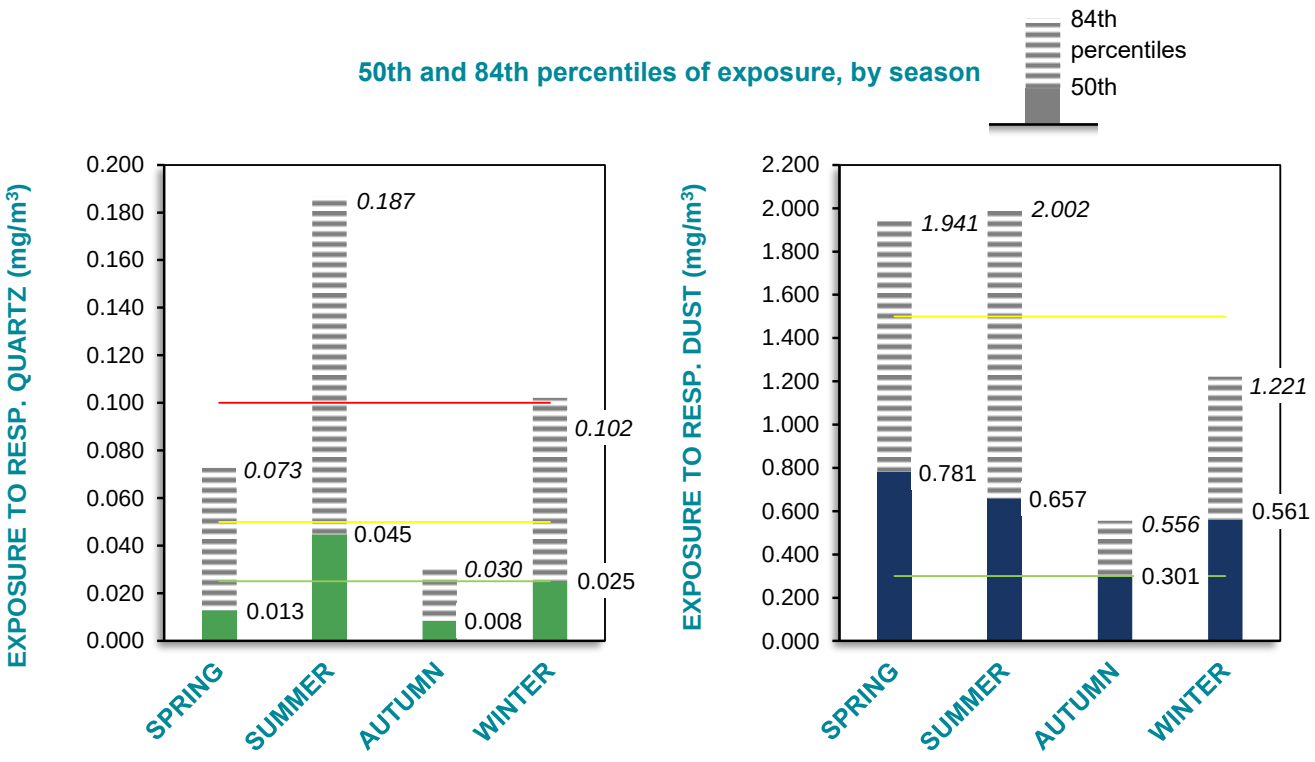
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

Respirable Dust

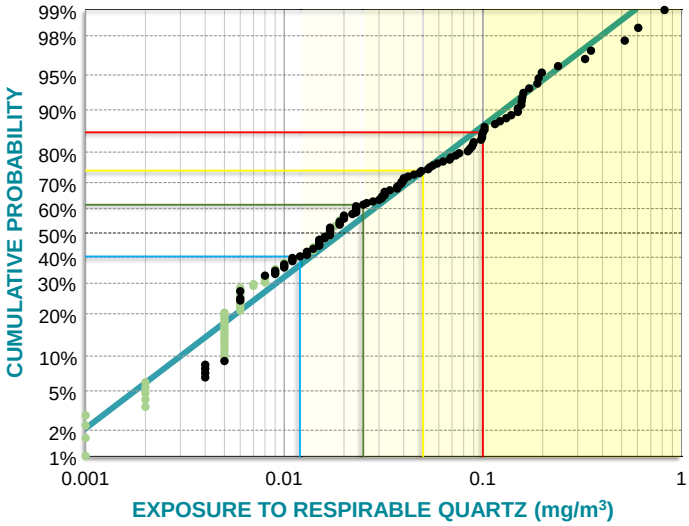
- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season



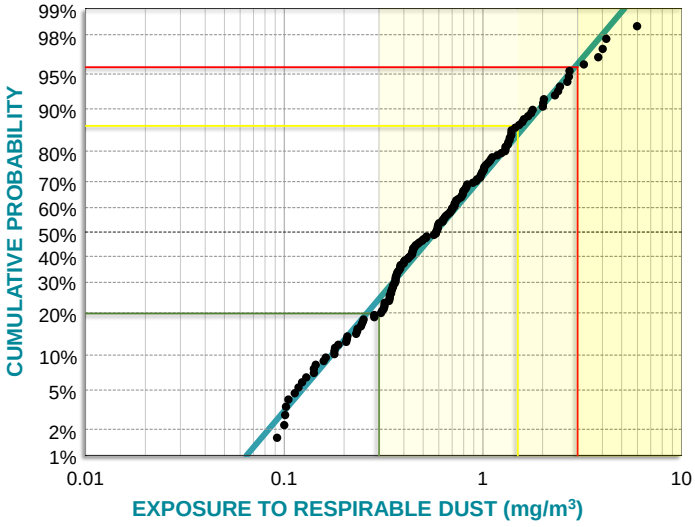
PAINTS, GLUES AND ADHESIVES: Manufacture of paints and varnishes, enamels or lacquers, mastics, glues and adhesives, denture fixative pastes; plaster

Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



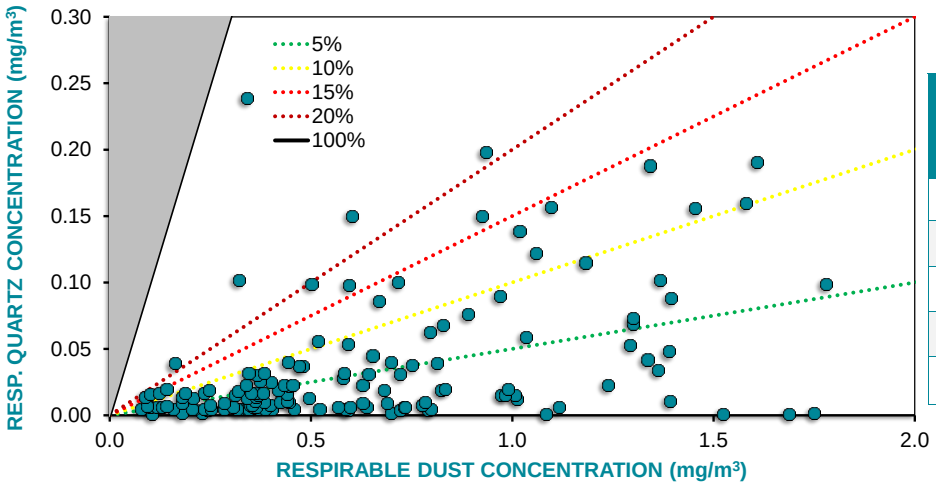
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	85.3%
≤0.05	74.2%
≤0.025	61.5%
≤0.012	40.3%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	95.7%
≤1.5	86.5%
≤0.3	19.8%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	60%
>5% to 10%	23%
>10% to 15%	9%
>15% to 20%	4%
>20%	4%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C2.01 - Management and office work	
C2.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C2.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C2.02 - Composition of the mixture	
C2.02.01 - Weigher	Weighs ingredients and adds materials and additives to ensure conformance to requirements. Carries out the task by manual operation or by controlling an automated system.
C2.02.02 - Bag breaker operator	Breaks sacks and/or big-bags containing raw materials and pours them into the mixing machine.
C2.02.03 - Composition mixer	Loads and controls the machine that blend ingredients. Examines the consistency of mix to determine whether ingredients are blended according to specifications.
C2.03 - Production	
C2.03.01 - Production line supervisor	Sets up, programs and supervises the plant or production line. Raw materials are prepared according to the formula. Finally, the discharged packaging drums are sent to the warehouse.
C2.03.02 - Production line operator	Operates and controls the different production lines. Raw materials are mixed in a kneader, poured into a grinder to meet grain size requirements and then mixed into a dispersing machine. A vacuum system is used to extract moisture and air from the paste and a discharge machine divides the paste into packaging drums.
C2.03.03 - Kiln operator	Fills the moulds (boxes) with the mixed material and loads the kiln, manually or automatically, for the firing phase (sintering, melting, calcination). Conducts the oxidation and/or finishing kilns in the production of frits, enamels and glazes.
C2.03.04 - Crusher / grinder	Operates the crushing plant to reduce raw material to suitable size for further processing and the mills to wet-grind material. The slip (slurry) obtained by wet grinding is then dried and milled in a pulverising machine.
C2.03.05 - Paste mixer	Loads and controls the mixing machine for the preparation of products in paste form.
C2.03.06 - Granulator / atomiser operator	Operates and controls the granulation plant, in which previously mixed fine particle powders are agglomerated into larger granules. Operates and controls the atomiser plant, in which a slurry is sprayed from the top of a tower, encounters a current of hot air, before solidifying into a granulate.
C2.04 - Quality control and laboratory testing	
C2.04.01 - Laboratory technician	Performs laboratory chemical-physical analysis on raw materials and products for quality assessment.

PAINTS, GLUES AND ADHESIVES: Manufacture of paints and varnishes, enamels or lacquers, mastics, glues and adhesives, denture fixative pastes; plaster

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C2.05 - Handling of materials and products	
C2.05.01 - Material handling equipment operator (to the warehouse)	Operates material handling equipment (hand or battery operated pallet truck, reach truck, forklift, bulk bag discharger) to move, load and unload raw materials (big bags, bulk products) entering the plant by truck or tankers.
C2.05.02 - Material handling equipment operator (to the production lines)	Operates material handling equipment (hand or battery operated pallet truck, reach truck, forklift) to move materials and products from the warehouse or other storage area to the production lines.
C2.06 - Warehouse and packaging	
C2.06.01 - Bag filling operator	Fills bags with product by operating a bag filling machine. Places an empty bag onto the machine's spout. The machine extracts the product from the bottom of the silos and fills the bag to its proper weight. Then the bag closes automatically and drops to the transfer conveyor. May carry out the task by manual means.
C2.06.02 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.
C2.07 - Mechanical and electrical maintenance / cleaning	
C2.07.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
C2.07.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

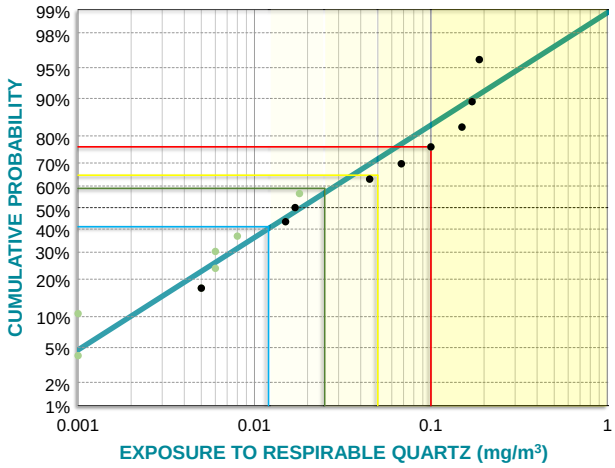
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C2.01.01 - Manager	2	0.010	-	-	-	-	-
C2.02.01 - Weigher	15	0.018	5.660	76.2%	64.8%	58.9%	41.1%
C2.02.02 - Bag breaker operator	9	0.016	3.489	86.5%	78.6%	73.4%	45.6%
C2.02.03 - Composition mixer	42	0.040	4.791	66.2%	50.0%	38.1%	25.1%
C2.03.01 - Production line supervisor	5	0.007*	1.831*	-	-	-	-
C2.03.02 - Production line operator	11	0.024	6.476	82.4%	79.7%	76.7%	44.1%
C2.03.03 - Kiln operator	10	0.013	1.828		>93.9%	78.9%	41.7%
C2.03.04 - Crusher / grinder	5	0.014	4.669	-	-	-	-
C2.03.05 - Paste mixer	6	0.003*	1.979*				>90.0%
C2.03.06 - Granulator / atomiser operator	4	0.012	2.282	-	-	-	-
C2.04.01 - Laboratory technician	1	0.017		-	-	-	-
C2.05.01 - Material handling equipment operator (warehouse)	3	0.020	4.230	-	-	-	-
C2.05.02 - Material handling equipment operator (production lines)	11	0.015*	3.564*	88.6%	80.1%	65.0%	54.6%
C2.06.01 - Bag filling operator	19	0.036	3.345	88.0%	57.4%	32.1%	17.9%
C2.06.02 - Warehouse operator	5	0.014	2.776	-	-	-	-
C2.07.01 - Maintenance mechanic / electrician	12	0.008*	1.879*			>94.9%	66.6%

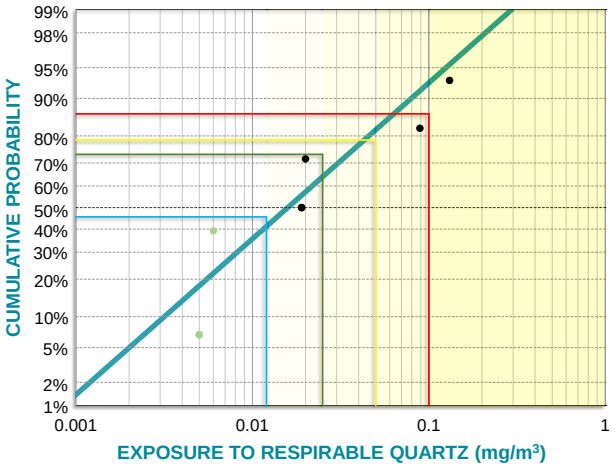
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

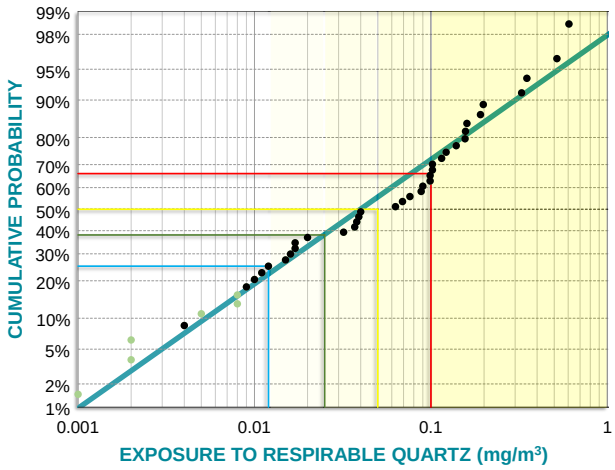
C02.02.01 - Weigher



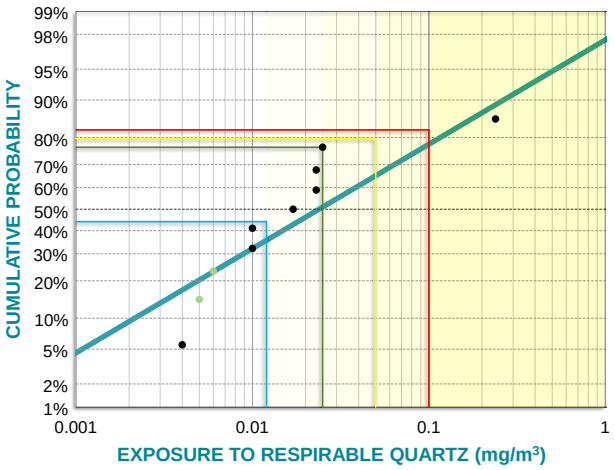
C02.02.02 - Bag breaker operator



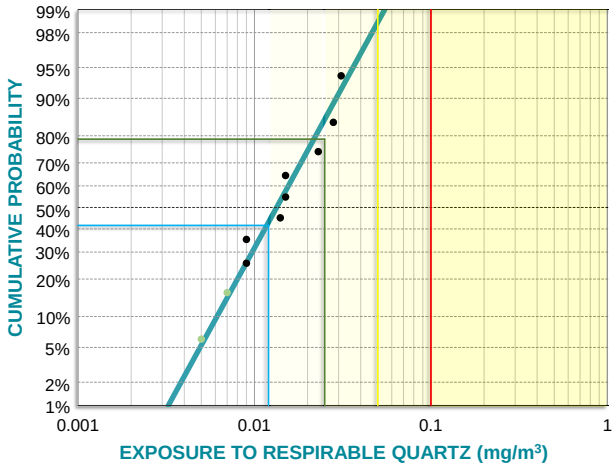
C02.02.03 - Composition mixer



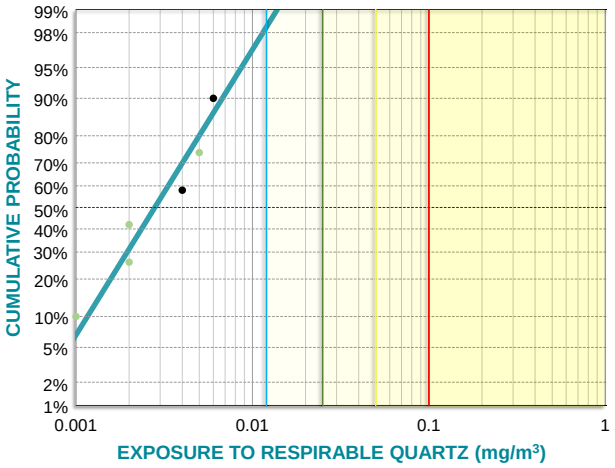
C02.03.02 - Production line operator



C02.03.03 - Kiln operator

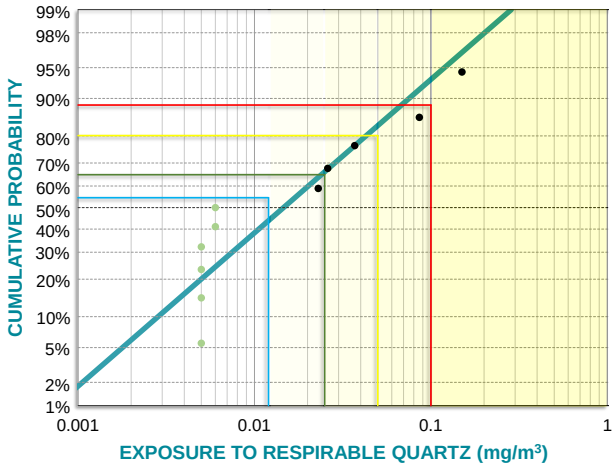


C02.03.05 - Paste mixer

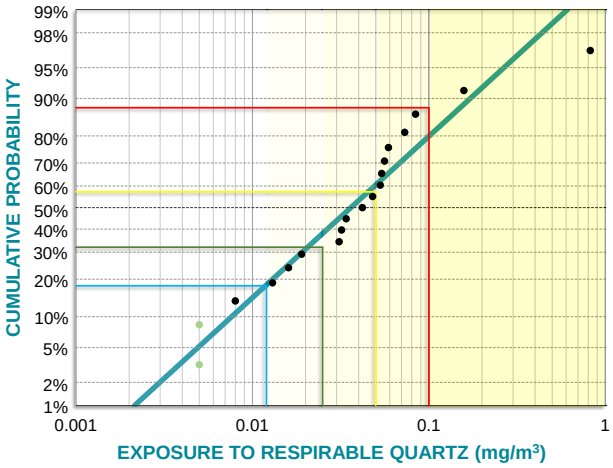


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

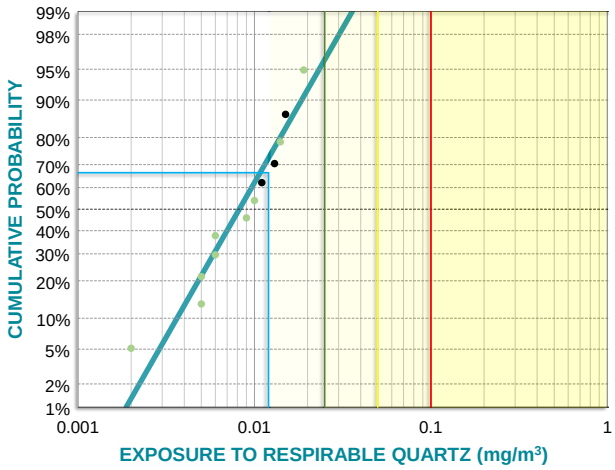
C02.05.02 - Material handling equipment operator (production lines)



C02.06.01 - Bag filling operator



C02.07.01 - Maintenance mechanic / electrician



PAINTS, GLUES AND ADHESIVES: Manufacture of paints and varnishes, enamels or lacquers, mastics, glues and adhesives, denture fixative pastes; plaster

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C2.01.01 - Manager	2	0.111	-	-	-	-
C2.02.01 - Weigher	16	0.551	2.695	95.7%	87.1%	25.1%
C2.02.02 - Bag breaker operator	9	0.796	1.983	>93.2%	78.2%	<6.8%
C2.02.03 - Composition mixer	44	0.659	2.686	92.5%	83.6%	21.2%
C2.03.01 - Production line supervisor	5	0.207	1.613	-	-	-
C2.03.02 - Production line operator	11	0.446	2.115	>94.4%	91.4%	20.1%
C2.03.03 - Kiln operator	10	0.504	2.074		>93.9%	15.5%
C2.03.04 - Crusher / grinder	5	0.891	2.211	-	-	-
C2.03.05 - Paste mixer	6	3.364	2.891	49.1%	22.1%	<10.0%
C2.03.06 - Granulator / atomiser operator	4	0.651	2.052	-	-	-
C2.04.01 - Laboratory technician	1	0.234	-	-	-	-
C2.05.01 - Material handling equipment operator (warehouse)	3	0.251	2.185	-	-	-
C2.05.02 - Material handling equipment operator (production lines)	11	0.362	1.660		>94.4%	31.1%
C2.06.01 - Bag filling operator	19	0.808	1.982	>96.8%	82.3%	5.8%
C2.06.02 - Warehouse operator	5	0.520	1.372	-	-	-
C2.07.01 - Maintenance mechanic / electrician	12	0.352	1.868		>94.9%	23.8%

Working processes

Rubber processing has developed significantly, mostly in relation to the automotive sector and in particular with respect to tyres. Raw materials containing quartz are used as mineral fillers in rubber, resin and plastic compounds. The main working phases where exposure to RCS may occur are within the dosage of fillers and compounds. Artificial stone made of quartz agglomerates (>90%) and resin as a binder are used in the building sector and in the manufacture of decorative and furnishing elements, in particular for the construction of kitchen countertops, bathrooms, shop counters.

Manufacture of rubber tyres for vehicles

1. **Raw material storage** – most of the raw materials are discharged and stored in the yards. Compounds are available in form of strips, sheets or buns wrapped with nylon and placed inside metal containers or cardboard boxes. They are stored in a dedicated warehouse, from which are sent to the compounding departments using forklifts or transpallets.

2. **Dosage and mixing** – the ingredients needed to mix a batch of rubber compounds (fillers, antioxidant, anti-adhesive and accelerating substances, vulcanising agents, activating and protective chemicals and compounds, etc.) are weighed and then combined depending on the product requirements. Mixing is initially carried out at room temperature, then stepwise heated, gradually pouring the additives.

3. **Preparation of intermediates**

   - Extrusion: for the manufacturing of tyre components such as tread and sidewall profile; the compound is forced through an extruder, made essentially by an extruder barrel and extruder head, plasticised by a rotating screw-type system and pressed against an opening (nozzle), corresponding to the desired profile configuration.

   - Die-cutting: used to turn sheets of rubber into flat, small and thin shaped pieces (square, rectangular, rounded, etc.) by using lasers or blades. After that, the operator collects the pieces to be sent for vulcanisation, separating them from waste, to be sent back to mixers.

   - Calendering: a rubber compound is squeezed through the rollers of a calender, producing thin sheets or plates (e.g. the tyre body plies and belts). Rubber sheets can be laminated with fabrics: the operator inserts rubber pieces between the rollers of the calender so that the pieces are dragged and crushed onto the fabric; such operation is carried out until a homogeneous covering is obtained.

   - Coating and spreading, for rubberised fabrics: coating solutions are made from compounds and, secondarily, from pure rubber. Cut or granular compounds (or rubber) and appropriate solvents are mixed and stirred into a coating machine, until complete dissolution. Then, the fabric roll is placed in a spreading machine and the operator spreads the rubber solution, taken from a bucket, on the fabric using a spatula. As the fabric slides between the rollers, the solution is spread and pressed on the fabric.

   - Assembly: a tyre is built by a robotised tyre building machine, which assembles the semi-manufactured pieces into a *green* tyre. In the first stage, the carcass is created by positioning plies, bead wires and sidewalls around the bladder of a drum; inflating the bladder, the assembly is pushed into place. In the second stage, belts, nylon cap ply and tread are mounted on the first stage.

4. **Release agent application** – a layer of a water-based release agent (zinc stearate was used in the past) is applied on rubber products before vulcanisation, to prevent sticking between rubber products and the vulcanising mould, chamber and press. Alternatively, the surfaces of the moulds can be coated with a detaching agent, such as soap solutions, polyethylene dispersions and silicone oil emulsions.

5. **Vulcanisation** – this irreversible process is designed to improve the elasticity and resistance to wear and tear of rubber products. Rubber is vulcanised by increasing the temperature and pressure in plants equipped with press moulds which define the final shape of the product. In some cases (e.g., the manufacture of fluorinated rubbers), a further thermal treatment (post-vulcanisation) is carried out inside an oven. The material is removed from the moulds and dosed using micro-feeders, weighing belts or extraction screws.

6. **Deburring** – the material in excess remaining around the rubber product after vulcanisation in a press has to be removed. Deburring is carried out manually by a drum machine or by an abrasive particle jet.
7. **Finishing** – a series of visual and instrumental checks, to ensure safety and reliability of the tyres (quality control), is carried out.
8. **Storing, packing and shipping** – metal containers, cardboard boxes or nylon bags, which contain the products ready to be shipped to customers, are stored on shelves.

Manufacture of plastic tubes by extrusion

1. **Raw material storage** – raw materials are stored in big bags, sacks, and cardboard bins. Handling is usually carried out by forklifts.
2. **Loading and mixing** – raw materials are taken, manually or by using a crane, from their storage containers and poured into metal vessels. The material granules, pellets, or powders are dragged out of the vessels by means of suction pipes and sent to the hoppers of the extruders. If colouring is needed, grained pigments are mixed with plastic materials in the hoppers.
3. **Extrusion and calibration** – inside the extruder barrel, the mixed material is heated up to the melting point and then pushed through a cavity (die-head) where the tubes are formed. Each tube is then calibrated in tanks filled with water to the correct size and cooled by water in a series of spraying tunnels, using recycled water in sprinkler systems.
4. **Hauling off** – the extruded tubes move ahead, at a constant speed in a continuous process, through a haul-off machine.
5. **Tube marking** – a laser marking machine or a hot marking machine for plastic tubes is used. Then the tubes are cut into the requested lengths.
6. **Winding** – plastic tubes are coiled by a winding machine.
7. **Storing, packing and shipping** – the final products are handled with forklifts, packed, then stored.
8. **Shredding of production waste** – carried out in a shredding mill for plastic and loaded manually. Plastic waste is reused as raw materials.

Manufacture of artificial quartz stone for kitchen countertops

1. **Mixing** – quartz granules or sand, acrylic resin (e.g. methyl methacrylate polymer), aluminium trihydrate and, when required pigments, are dosed, loaded into a mixer and mixed.
2. **Homogenisation** – the dispersions in the barrels are blended until homogeneous. Then a part of the dispersion is transferred into a vessel for moulding.
3. **Moulding** – the operator connects the outlet of the vessel containing the dispersion to a mould, with the shape of a flat slab, of a pressing machine. The polymerisation of the organic matrix to obtain the slab occurs through a thermal cycle.
4. **Finishing** – the solidified slab is cut to size and encloses the sink in the kitchen countertop and drilled to insert the drain, by means of numerical control machines equipped with water-based dust suppression systems.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	17	0.178	2.299	10	0.013	2.492	13.0
STATIC	-	-	-	-	-	-	-

Geometric mean of personal exposure, by region

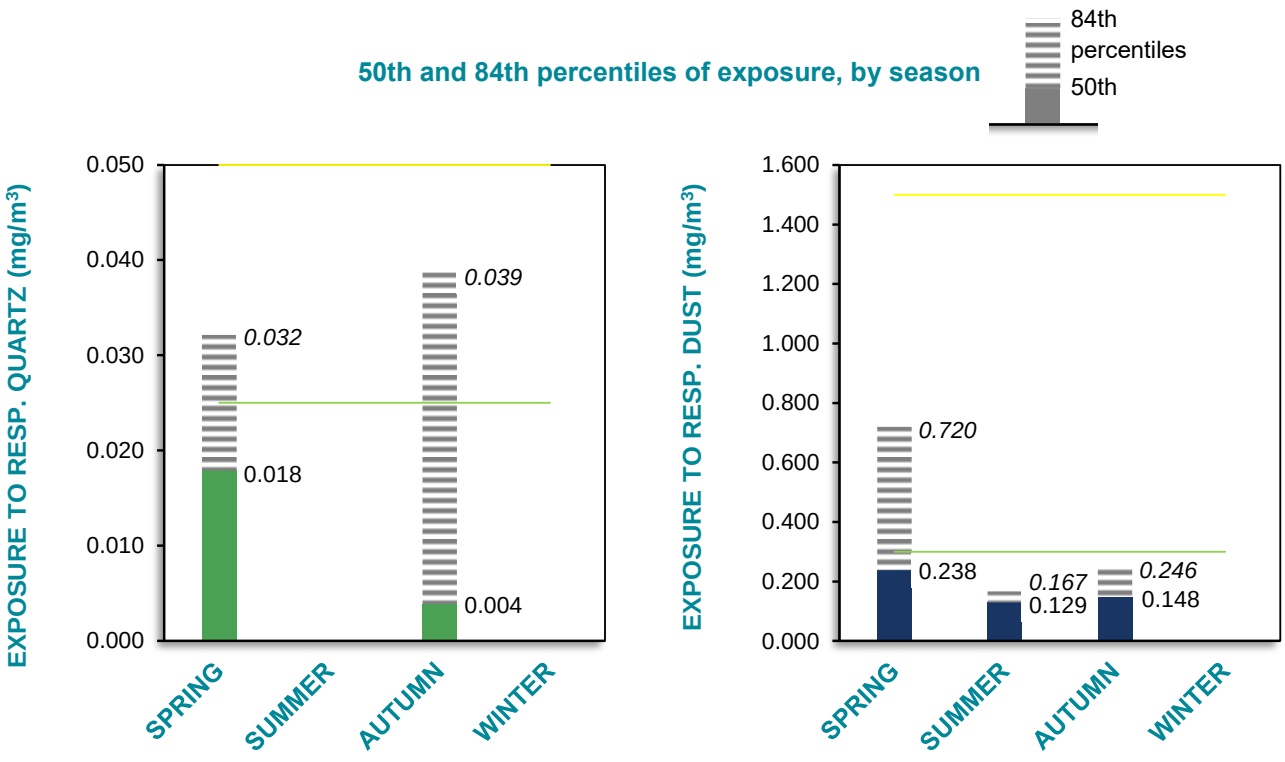
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

Respirable Dust

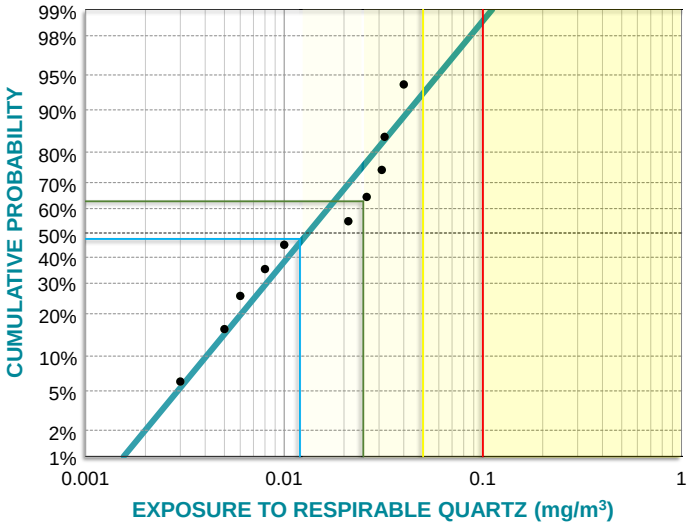
- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season



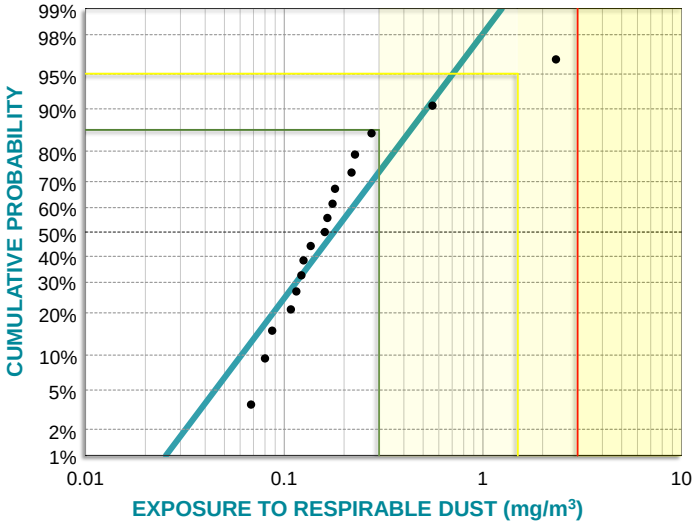
C3 RUBBER, PLASTIC, ARTIFICIAL STONE: Manufacture of rubber products, plastic plates, sheets, tubes and profiles, builders' ware of plastic - Manufacture of artificial stone

Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



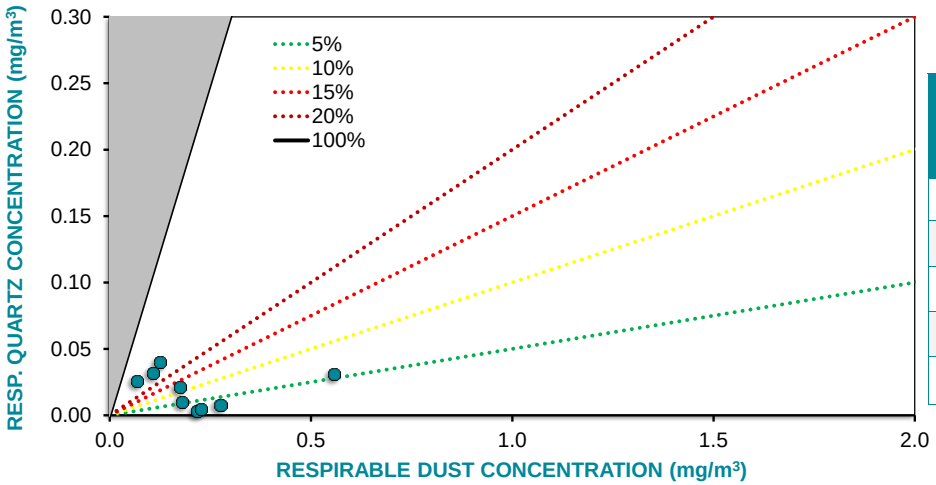
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	-
≤0.05	>93.9%
≤0.025	62.9%
≤0.012	47.5%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	>96.4%
≤1.5	95.0%
≤0.3	85.6%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	40%
>5% to 10%	20%
>10% to 15%	10%
>15% to 20%	0%
>20%	30%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C3.01 - Management and office work	
C3.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C3.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C3.02 - Manufacture of rubber (tyres)	
C3.02.01 - Weigher (rubber)	Manufacture of rubber tyre – Weighs ingredients to ensure conformance to requirements and sends the materials to the mixing plant.
C3.02.02 - Mixer (rubber)	Manufacture of rubber tyre – Loads and controls the closed mixers (banbury-type) that knead raw materials in order to properly disperse the ingredients for rubber compound production. The compound is then extruded out of the banbury and provided to the subsequent departments.
C3.02.03 - Calender roll press operator (rubber)	Manufacture of rubber tyre – Operates and controls the calender, in which a series of hard pressure rollers are used to finish a sheet of textiles. Applies two leaflets of rubber on both sides of the textile fabrics (generally purchased by third parties in the form of cloths) and inserts them into the calender for textile fabric rubberising. A similar process is used for metallic fabrics, made up by hundreds of steel strings, perfectly aligned and then rubberised.
C3.02.04 - Extruding machine operator (rubber)	Manufacture of rubber tyre – Operates and controls machines to extrude or draw thermoplastic materials into elongated shapes (tubes, rods, hoses, wire, bars, etc.). Most parts of a tyre are created by forcing uncured rubber compounds through an extruder to shape the tyre tread or sidewall profiles.
C3.02.05 - Rubber components building machine operator	Manufacture of rubber tyre – Prepares tyres components to be assembled to produce finished products. Each group of operators generally work on a single component (e.g. tyre bead bundles, bead filler, tread, inner liner, sidewall, etc.).
C3.02.06 - Rubber components assembler	Manufacture of rubber tyre – Assembles tyre components for articles. An article can be built by a robotised machine which assembles all semi-manufactured goods. A tyre is generally built in a two-stage process: the first produces a carcass (made of body-plies, bead wires and sidewalls), in the second stage another machine is used to apply belts, nylon cap and tread material on top of the first stage, producing the semi-finished product (green tyre).
C3.02.07 - Green article test technician (rubber)	Manufacture of rubber tyre – Examines green tyres for defects by visual and non-destructive instrumental tests.
C3.02.08 - Green rubber article repairer	Manufacture of rubber tyre – Tests the green article (tyre) for defects. Repairs the defects, if possible, before sending it to painting and vulcanisation or the article is rejected.
C3.02.09 - Water-based release agent applier (rubber)	Manufacture of rubber tyre – Applies a water-based mould release agent on the inner part of the carcass (green tyre), so that the detachment of the coverage from the vulcanising chamber becomes easier.
C3.02.10 - Vulcanising press operator (rubber)	Manufacture of rubber tyre – Operates and controls vulcanising press for hardening rubber.

C3 RUBBER, PLASTIC, ARTIFICIAL STONE: Manufacture of rubber products, plastic plates, sheets, tubes and profiles, builders' ware of plastic - Manufacture of artificial stone

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C3.02.11 - Quality control technician (rubber)	Manufacture of rubber tyre – Examines product (tyres) for defects by visual and non-destructive instrumental tests (X-ray videography).
C3.03 - Manufacture of plastic (fibreglass tubes)	
C3.03.01 - Fibreglass pipe machine operator	Manufacture of fibreglass tubes – Operates and controls the fibreglass pipe machine to form fibreglass tubes used in manufacturing articles.
C3.04 - Manufacture of artificial stone	
C3.04.01 - Weigher and mixer (artificial stone manufacturing)	Weighs raw materials to ensure conformance to requirements. Loads the material in the milling machine and controls the mixing in the mill. Discharges the suspension into a metallic barrel.
C3.04.02 - Moulding press operator (artificial stone manufacturing)	Operates the moulding press: carries the barrel containing the suspension next to the press; connects the barrel to the mould with a tube and injects the suspension by a jet of compressed air at low pressure.
C3.04.03 - Mould loading/unloading operator (artificial stone manufacturing)	Follows the hardening process of the piece in the mould and, when finished, gives permission to open it. Withdraws the hardened piece and places it on a pallet. Prepares the mould for the subsequent injection.
C3.04.04 - Cutter / driller (artificial stone manufacturing)	Finishes edges and holes on the intermediates, such as holes for drains, for fixing sinks upon the tops and for overflow. Such operations are carried out with numerical control and/or water-cutting machines.
C3.05 - Quality control and laboratory testing	
C3.05.01 - Laboratory technician	Performs laboratory chemical-physical analysis of compounds and tests new formulations. Performs analysis on raw materials and products for quality assessment.
C3.06 - Handling of materials and products	
C3.06.01 - Forklift operator	Operates material handling equipment (hand or battery operated pallet truck, reach truck, forklift, bulk bag discharger) to move, load and unload materials in storage area and to production departments.
C3.07 - Warehousing and packaging	
C3.07.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.
C3.08 - Mechanical and electrical maintenance / cleaning	
C3.08.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both the foreman / maintenance manager and other workers.
C3.08.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C3.03.01 - Fibreglass pipe machine operator	2	0.004	-	-	-	-	-
C3.04.01 - Weigher and mixer (artificial stone manufacturing)	1	0.006	-	-	-	-	-
C3.04.02 - Moulding press operator (artificial stone manufacturing)	2	0.009	-	-	-	-	-
C3.04.04 - Cutter / driller (artificial stone manufacturing)	3	0.030	1.118	-	-	-	-
C3.05.01 - Laboratory technician	1	0.040	-	-	-	-	-
C3.06.01 - Forklift operator	1	0.021	-	-	-	-	-
C3.08.01 - Maintenance mechanic / electrician	-	-	-	-	-	-	-

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C3.03.01 - Fibreglass pipe machine operator	2	0.222	-	-	-	-
C3.04.01 - Weigher and mixer (artificial stone manufacturing)	1	2.332	-	-	-	-
C3.04.02 - Moulding press operator (artificial stone manufacturing)	2	0.222	-	-	-	-
C3.04.04 - Cutter / driller (artificial stone manufacturing)	7	0.137	1.975		>91.4%	85.6%
C3.05.01 - Laboratory technician	1	0.125	-	-	-	-
C3.06.01 - Forklift operator	2	0.170	-	-	-	-
C3.08.01 - Maintenance mechanic / electrician	2	0.099	-	-	-	-

Working processes

Glass is a mixture of variable composition, which for simplicity is expressed by convention in terms of the relative proportions of the oxides of the constitutive elements (SiO_2, Na_2O, CaO, B_2O_3, etc.). The most widely used classification of glass type is by chemical composition, which gives rise to four main groupings: soda-lime glass, lead crystal and crystal glass, borosilicate glass and special glass. Most glasses are silicate-based, the main component of which is silicon dioxide (SiO_2). The glass industry is comprised of the following sectors: container glass, flat glass, continuous filament glass fibre, domestic glass, special glass (without water glass), mineral wool (with two divisions, glass wool and stone wool), high-temperature insulation wools (excluding polycrystalline wool) and frits. The industrial activities are significantly diversified from each other for manufacturing techniques employed. Container glass and flat glass are the higher volume sectors of the glass industry. In the following, the main steps of flat glass and hollow glass manufacturing cycles are described.

Manufacturing of flat glass (Float method)

Flat glass is produced in the form of plates. The float process consists in pouring the molten glass coming from a melting furnace onto a bath of molten tin. Glass plates do not need surface sanding or annealing and are capable of undergoing any further processing useful for the provision of desired thermal, aesthetic, mechanical or electrical performance.

1. **Storage of raw materials** – chemical composition of flat glass consists of variable percentages of silicon, sodium, calcium, magnesium, aluminium, potassium and sulphur oxides and minor materials (colour modifiers and incidental impurities from raw materials). Raw materials are supplied and stored in special warehouses and handled using wheelbarrows and buckets or mechanical devices such as conveyor belts, forklifts, transpallets or with the aim of automated means directly from the storage facilities.
2. **Blending** – components are weighed out and mixed either manually or automatically using mechanical mixers. Blending is followed by a humidification phase to form a vitrifiable mixture.
3. **Melting** – the vitrifiable mixture is placed in the melting basin consisting of molten tin. In the float tank, a controlled atmosphere is maintained; the melting temperature may reach 1550°C.
4. **Cooling** – at 1100°C molten glass drips from the furnace onto a bath of molten tin. The molten glass floats on the liquid and flat surface and is drawn: the glass flow is controlled by means of an adjustable suspended refractory shutter in the canal (the front *tweel*). Where the glass first makes contact with the tin, the temperature of the metal is about 1000°C cooling to about 600°C at the exit of the bath. As it passes over the surface of the bath, the glass develops a uniform thickness and assumes the almost perfect flatness of the molten tin. On the edges of the ribbon, the top rolls extend or retract the glass laterally to obtain the desired thickness, between 1.1 and 19 millimetres.
5. **Furnace annealing** – placed at 600°C on the rollers of a cooling tunnel, the glass belt cools under control until it reaches room temperature. At about 500°C, the glass belt acquires the properties of a perfectly elastic solid.
6. **Cutting the casting sheet** – once cooled to free air, the glass strip is checked and squared, i.e. cut into sheets of the maximum present size, with longitudinal edge cut. The elements are then positioned vertically on trestles by means of suction cup elevators. The large-sized sheets are then ready to be cut either manually or automatically, through computer-programmed systems, into the sizes suitable for the various uses for which they are intended.
7. **Storage of finished products and shipment** – the sheets are stored and prepared for shipment to the processing industries. They can be processed at the edge in different ways: filleting, raw edge grinding, polished edge grinding, industrial polished edge grinding, chamfering and bevel grinding. They can also be decorated through different processes such as sandblasting, satin-finishing, painting or lacquering, enamelling, opacification and silk-screen printing or undergo further processing including heat treatment, hardening, bending, layering, coatisation and silvering.

In the production of **curved glass**, the glass sheet undergoes a gradual heating process, until it becomes plastic enough to adhere, by gravity or with mechanical or pneumatic devices that facilitate the process, to a mould placed inside the bending furnace. The glass can then be cooled very slowly (through detensioning or annealing) or it can undergo instant cooling, resulting in a curved tempered glass.

Manufacturing of hollow glass

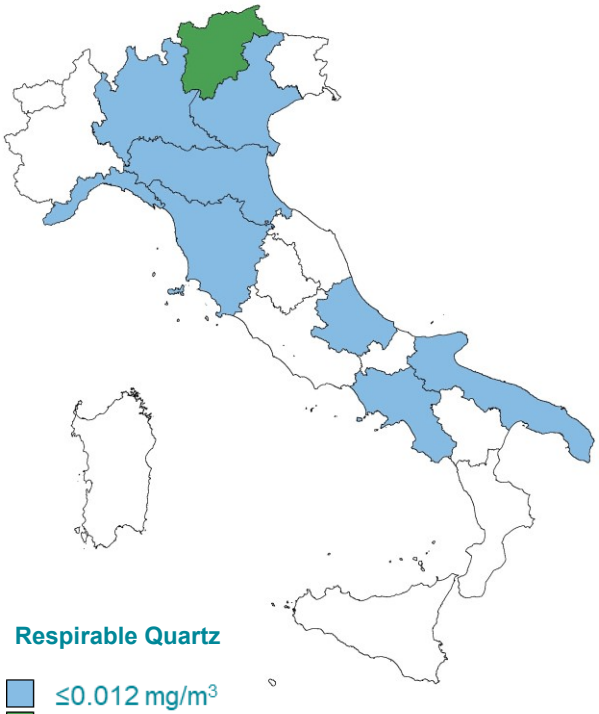
Glass for the manufacture of containers has a soda-lime basic formulation that is melted in furnaces powered by fossil fuels or occasionally electrically heated. The industrial production involves transforming the molten glass mass into final products using special automated machines using a mould blowing process. Where required, colouring agents are added to the glass or appropriate surface coatings are applied to the finished products. Of the three hollow glass production sectors, the most important is that of bottles for beverages, followed by the food and cosmetic-pharmaceutical sectors.

1. **Melting** – the raw materials, contained in silos, are properly dosed, mixed and injected in the melting furnace by way of conveyor belts. The furnace reaches melting temperatures of 1600°C, remains active 24 hours a day and is controlled by monitors and process calculators that allow constant checking of the operating parameters and obtaining the correct vitrification of the raw materials.
2. **Forming** – the molten glass mass coming out of the kiln enters the thermal conditioning channels and, once the appropriate viscosity has been reached, it is cut into drops of a size and weight proportionate to the object to be made and the function to be used. The drop of incandescent glass (about 1200°C) reaches the mould of the forming machine by guided vertical drop. The shape of the desired object is given by blowing it into moulds, pneumatic vacuum, gravity or manipulation using specific equipment. The evolution of technology has made it possible to obtain lighter containers with better mechanical performance.
3. **Annealing** – a procedure that eliminates glass tensions by preliminary heating and subsequent gradual cooling of the object until it reaches room temperature. It eliminates the effects of thermal imbalance that could compromise the mechanical resistance of the container.
4. **Quality control** – the pieces produced are checked concerning dimensions, shape, thickness, calibration of the mouths, integrity and resistance. Containers that do not pass the control are automatically removed from the packaging line and immediately recycled in the same production process to be melted down. The finished hollow glass products (bottles, vases, vials, glasses, goblets, etc.) can undergo further treatments for aesthetic or functional purposes. The processing industry includes decoration (including screen-printing), pad printing, engraving with tips soaked in hydrofluoric acid or using abrasive tools, painting, sandblasting and satin finishing.

Geometric mean and geometric standard deviation values of exposure measurements

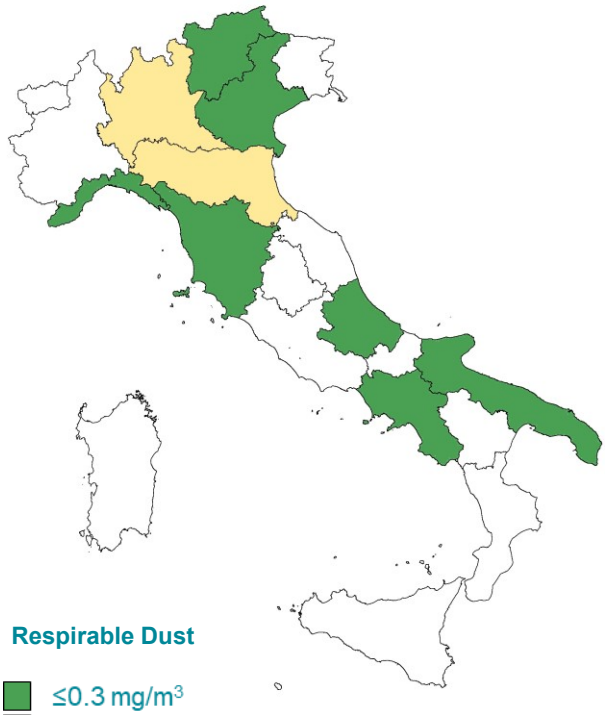
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	74	0.247	2.362	71	0.007	3.050	4.4
STATIC	2	0.344	1.061	2	0.001	1.633	0.5

Geometric mean of personal exposure, by region



Respirable Quartz

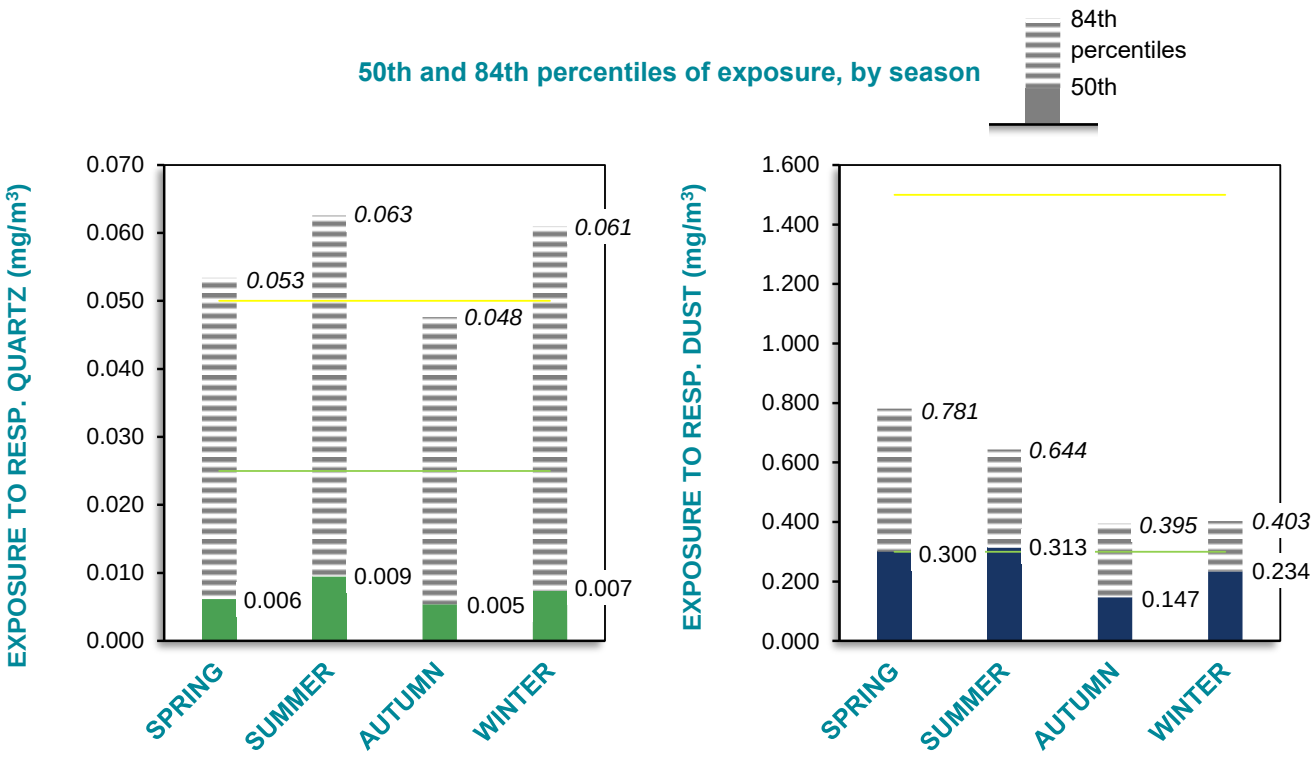
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



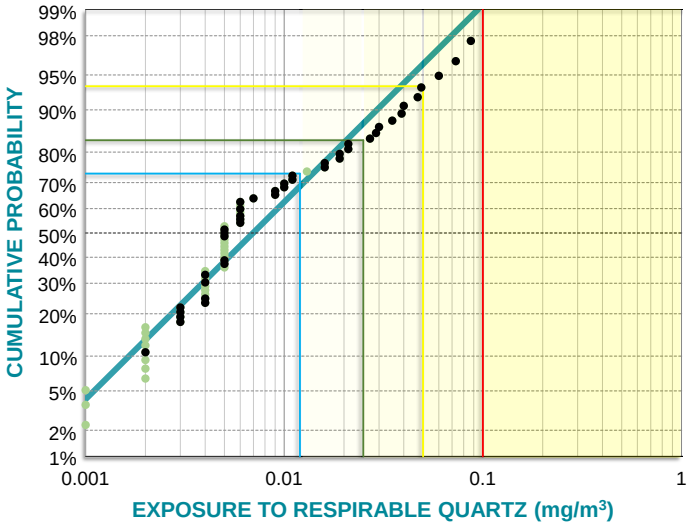
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

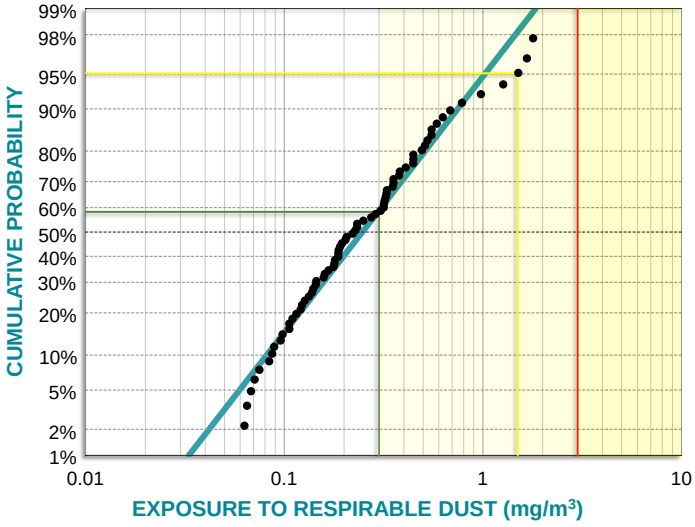


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



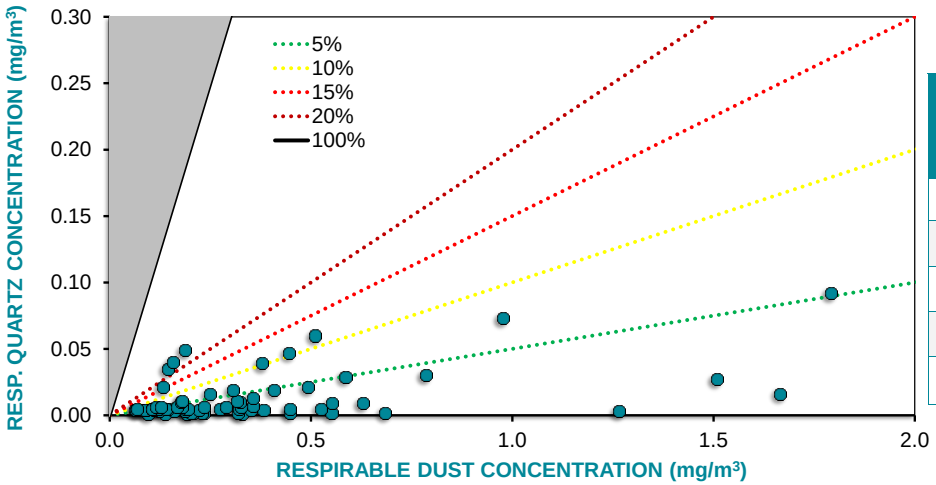
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	>99.1%
≤0.05	93.7%
≤0.025	83.3%
≤0.012	73.2%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	99.0%
≤1.5	95.1%
≤0.3	58.3%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	74%
>5% to 10%	16%
>10% to 15%	4%
>15% to 20%	1%
>20%	4%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C4.01 - Management and office work	
C4.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C4.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C4.02 - Composition of the mixture	
C4.02.01 - Weigher and mixer	Weighs and combines ingredients according to specifications. Loads and controls partially or fully automated machines that mix ingredients. Carries out handling of material by hand (wheelbarrow and bucket), mechanical equipment (conveyor belts, hand or battery operated pallet truck, forklift) or controlling automated systems, to move materials and products from the warehouse or other storage area to the production lines.
C4.03 - Melting	
C4.03.01 - Melting furnace loading operator	Introduces the vitrifiable mixture inside the melting furnace. Carries out the operation manually, semi-manually (a forklift and/or other suitable equipment transport the charge to the furnace mouth with the operator being responsible for its introduction into the furnace) or automatically (the operator is in charge of controlling the automatic system). May also control the melting of the vitrifiable mixture (refining).
C4.03.02 - Melting furnace operator	Controls the melting furnace for the transformation of the vitrifiable mixture into a homogeneous viscous liquid, ready to be processed. In automatic industrial plants, works in a control room and intervenes on the plant if necessary. The job title includes both the furnace manager and the operator assistant.
C4.04 - Forming	
C4.04.01 - Blower / hand moulder	Shapes molten glass by blowing or hand moulding, in artisan or artistic glassworks. In blow moulding, dips end of blowpipe into molten glass (from the melting furnace), gathering the amount required for object to be made; shapes glassware by free blowing glass into blowpipe to obtain the desired shape or by blowing glass into a mould. In hand moulding (without blow), an operator gathers the required quantities of molten glass on the end of metal rod and hands them to the other operators, which use special tools to give the glass masses the desired shapes.
C4.04.02 - Moulding machine operator	Operates moulding press or other forming machine, which produces hollow glass products (bottles, vials, lighthouses, etc.) on industrial scale. Controls machine (the forging process of pieces is usually automated) and manufactured products. May also operate a semi-automatic production line (pressing machine) to carry out samples and mould tests. In the past, the semi-automatic press was the forming machine most commonly used for production.
C4.04.03 - Mould maker	Makes moulds for glass containers (bottles, jars, etc.), tableware (plates, cups, etc.), etc. Repairs moulds.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C4.05 - Tempering / annealing	
C4.05.01 - Annealing / tempering furnace operator	Operates the annealing furnace for the gradual heating and cooling process to remove stress from glass (the pieces are kept in the furnace until room temperature is reached). Operates the tempering furnace designed to make heat resistant and stronger glass. Controls the loading/unloading of the pieces.
C4.06 - Finishing and assembly	
C4.06.01 - Ware grinder / finisher	Carries out the cutting, grinding and drilling for finishing glass products.
C4.06.02 - Sandblasting operator	Operates sandblasting equipment to finish glass products. Creates decorations and engravings or opacification of glass surfaces which eliminates transparency without compromising on brightness. Carries out the task continuously in industrial companies and sporadically in artisan or artistic firms.
C4.06.03 - Decorator	Decorates glass articles by painting freehand design on glassware or by applying printed designs to surfaces through a moisture process (decalcomania). May also etch designs on articles.
C4.06.04 - Glassware assembly operator	Assembles glassware, as well as using other materials (e.g. chandeliers made of metal skeleton with application of electrical components and glasses). Finishes glassware by attaching lips, handles and pedestals.
C4.07 - Refractory maintenance	
C4.07.01 - Refractory maintainer	Carries out maintenance of furnace refractories and other parts of the system (forehearths, feeders, cuvettes, etc.). Operates in the rebuilding of melting furnace.
C4.08 - Quality control and laboratory testing	
C4.08.01 - Laboratory technician	Performs laboratory chemical-physical analysis on raw materials and products for quality assessment.
C4.09 - Handling of materials and products	
C4.09.01 - Loader / crane / forklift operator	Operates mechanical loader, crane, forklift or other material handling equipment to move materials and products.
C4.10 - Warehousing and packaging	
C4.10.01 - Warehouse operator	Picks up the pieces at the exit of the annealing furnace, examines them and prepares them for their packaging in the warehouse or, if required, sends them to the grinder wheel department. After possible subsequent processes (milling, decorations, assembly, etc.), examines, sorts and packages the products. Drives forklift to pick up incoming stock or deliver materials to the designated area.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C4.11 - Various workspaces	
C4.11.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called a multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C4.12 - Mechanical and electrical maintenance / cleaning	
C4.12.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
C4.12.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

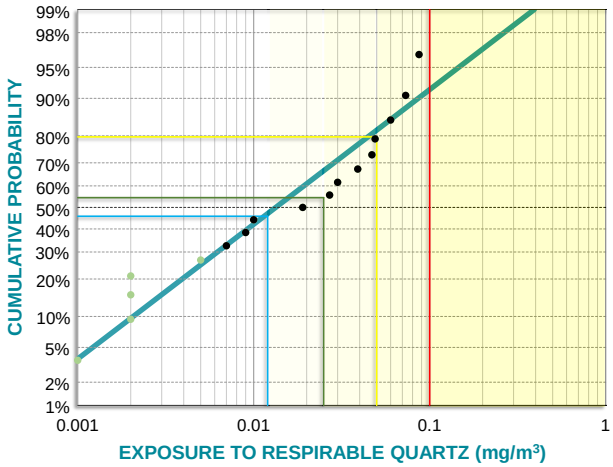
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C4.01.01 - Manager	2	0.018	-	-	-	-	-
C4.02.01 - Weigher and mixer	17	0.013	4.251	>96.4%	79.6%	54.5%	45.8%
C4.03.02 - Melting furnace operator	17	0.004	2.487		>96.4%	93.2%	88.5%
C4.04.01 - Blower / hand moulder	1	0.006*	-	-	-	-	-
C4.04.02 - Moulding machine operator	4	0.009	6.456	-	-	-	-
C4.04.03 - Mould maker	-	-	-	-	-	-	-
C4.06.01 - Ware grinder / finisher	6	0.005*	1.137*	-	-	-	-
C4.06.02 - Sandblasting operator	5	0.005*	2.696*	-	-	-	-
C4.07.01 - Refractory maintainer	2	0.004*	-	-	-	-	-
C4.09.01 - Loader / crane / forklift operator	6	0.007	2.170		>90.0%	88.3%	77.4%
C4.10.01 - Warehouse operator	1	0.011	-	-	-	-	-
C4.12.01 - Maintenance mechanic / electrician	10	0.006	2.477		>93.9%	88.2%	78.0%

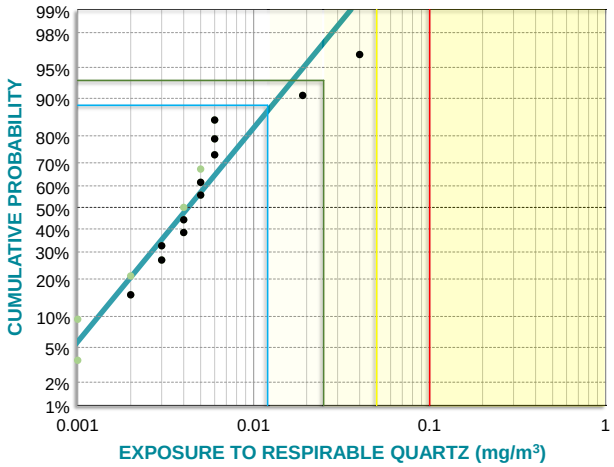
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C04.02.01 - Weigher and mixer

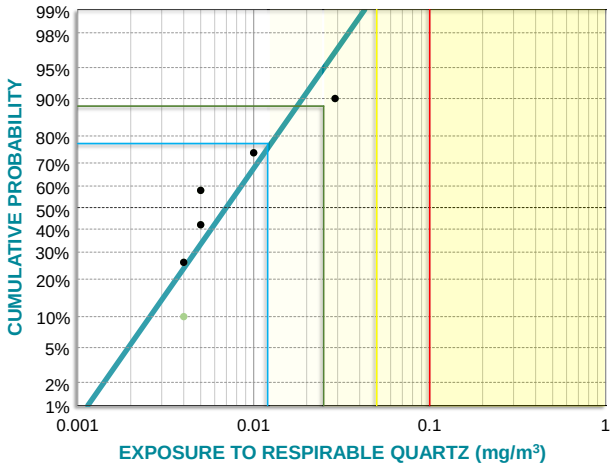


C04.03.02 - Melting furnace operator

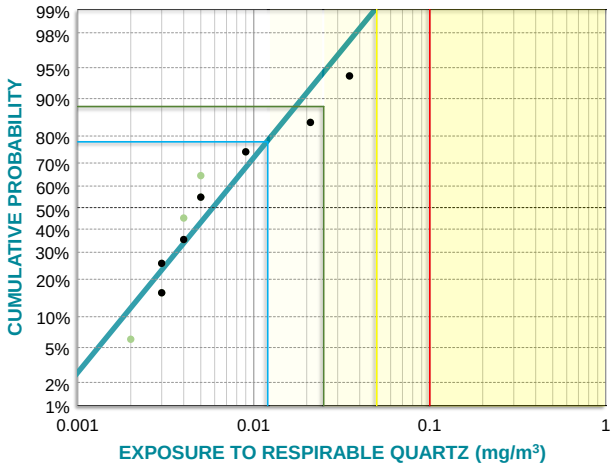


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C04.09.01 - Loader / crane / forklift operator



C04.12.01 - Maintenance mechanic / electrician



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C4.01.01 - Manager	3	0.133	1.876	-	-	-
C4.02.01 - Weigher and mixer	17	0.419	2.297	96.0%	90.5%	38.0%
C4.03.02 - Melting furnace operator	17	0.194	1.779		>96.4%	75.7%
C4.04.01 - Blower / hand moulder	1	0.167	-	-	-	-
C4.04.02 - Moulding machine operator	4	0.434	2.656	-	-	-
C4.04.03 - Mould maker	1	0.058	-	-	-	-
C4.06.01 - Ware grinder / finisher	6	0.184	1.710		>90.0%	72.2%
C4.06.02 - Sandblasting operator	5	0.490	2.565	-	-	-
C4.07.01 - Refractory maintainer	2	0.079	-	-	-	-
C4.09.01 - Loader / crane / forklift operator	6	0.276	2.248		>90.0%	39.4%
C4.10.01 - Warehouse operator	1	0.179	-	-	-	-
C4.12.01 - Maintenance mechanic / electrician	11	0.184	2.534		>94.4%	71.9%

Working processes

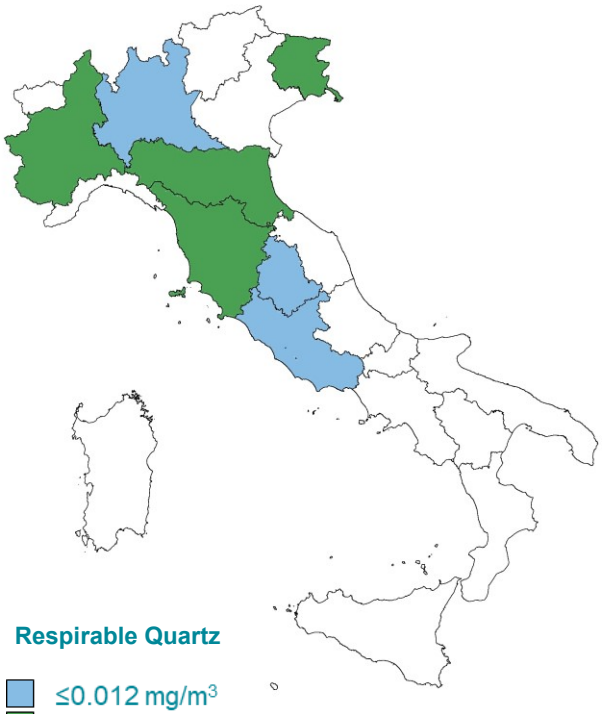
Refractory ceramic materials are designed to withstand the high temperatures, often over 1500°C, required in many processes. The production includes shaped (bricks, plates), unshaped (mortars, concrete, plasters) and fibre (blankets, ropes, boards) refractories. Refractory materials are used for high-temperature insulation linings in blast furnaces, melting furnaces, pot furnaces, chemical plants, industrial heaters and boilers, steam insulation, or as thermal barriers and fire protection equipment, for the production of crucibles, tundish boxes, distribution plates, etc. Silico-aluminous and aluminous refractories represent most of the commercial refractories. They are dry-processed with mixtures of chamotte (2-12% quartz) or so-called quartz (25-40% quartz) and small percentages of slips or binder pastes. The not very humid mixture is placed into moulds and then into high-pressure presses. Wire drawing or extrusion is mostly used in the manufacturing of pipes and other hollow parts. The casting process requires very fluid refractory pastes and the use of gypsum moulds. Siliceous refractories are produced from ground quartzite, having quartz content of around 95%, but at about 1500°C firing converts quartz to tridymite, cristobalite, or amorphous silica. A typical refractory processing cycle is described as follows.

1. **Storage of raw materials** – on arrival at the factory, some raw materials (e.g. clays) are dried and then are stored in silos. Refractory waste materials coming from other industrial sectors (e.g. glass, metals and ceramics) can also be used as raw materials.
2. **Grinding** – depending on the type of production and raw material, the operation may involve the crushing of coarse materials in jaw crushers, or directly being ground in a mill, to obtain the desired particle size.
3. **Screening** – the ground material is screened to separate the different particle size fractions, which are stored and later sent to processing.
4. **Dosing** – is carried out by an automated system.
5. **Mixing** – depending on the type of product to be made, a chemical binder can be added to the mixture in order to provide the cohesion necessary for shaping.
6. **Shaping** – is carried out with presses and extruders, or by casting. Unshaped refractories are sent directly to the packaging department.
7. **Drying and firing** – shaped refractories can be dried and then fired, obtaining a sintered mixture that gives the product the required characteristics. Otherwise, shaped or prefabricated refractories may undergo a thermal cycle, in which the chemical binder plays an essential role.
8. **Testing** – after cooling, the pieces are classified and checked with respect to their dimensional characteristics and aesthetic appearance.
9. **Storing, packing and shipping** – the products are placed on pallets, packaged according to the customer's needs, stored in the warehouse and eventually loaded on a truck for delivery.

Geometric mean and geometric standard deviation values of exposure measurements

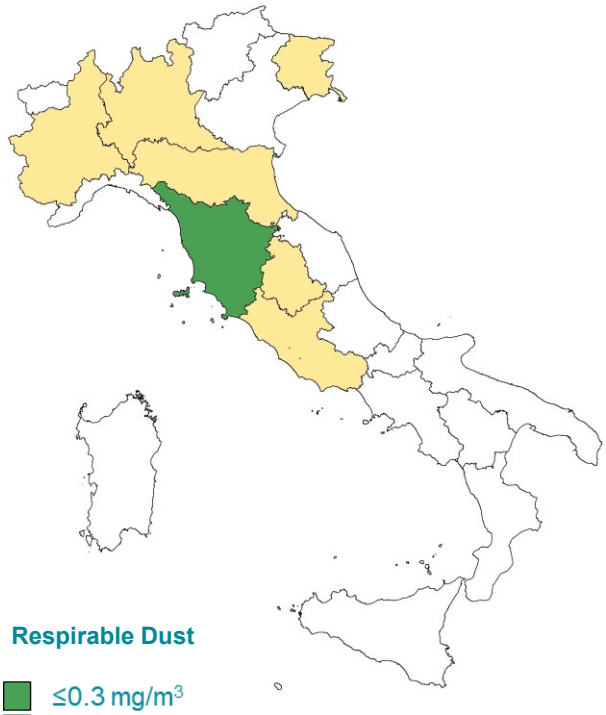
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	57	0.472	2.905	55	0.011	3.676	4.4
STATIC	-	-	-	-	-	-	-

Geometric mean of personal exposure, by region



Respirable Quartz

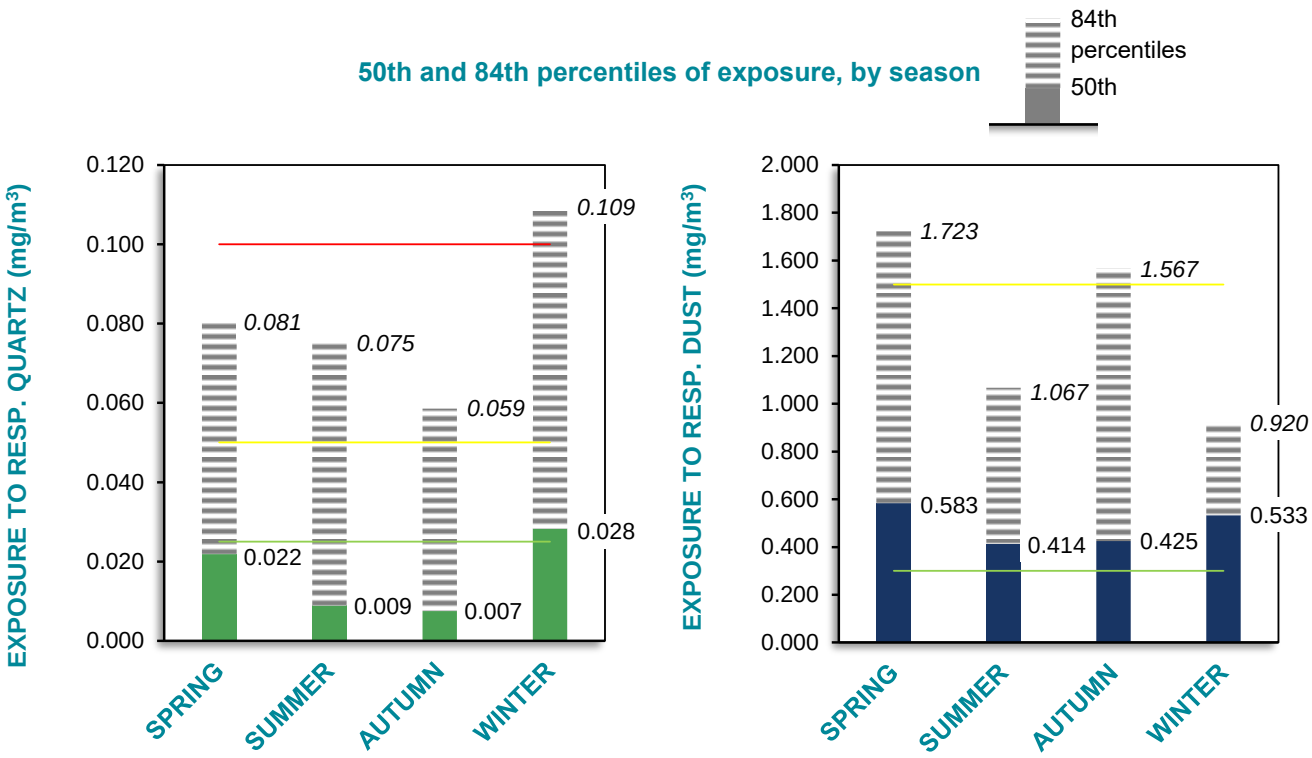
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



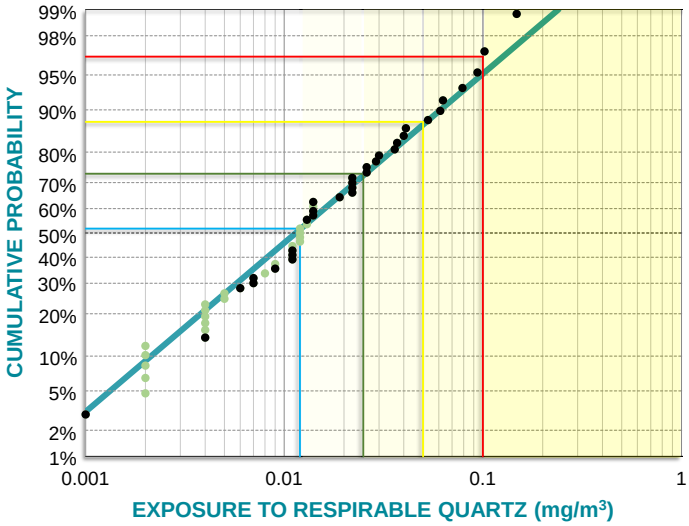
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

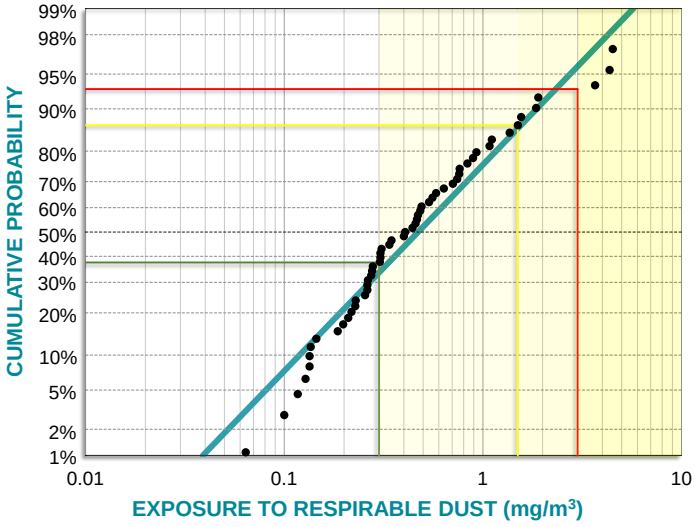


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



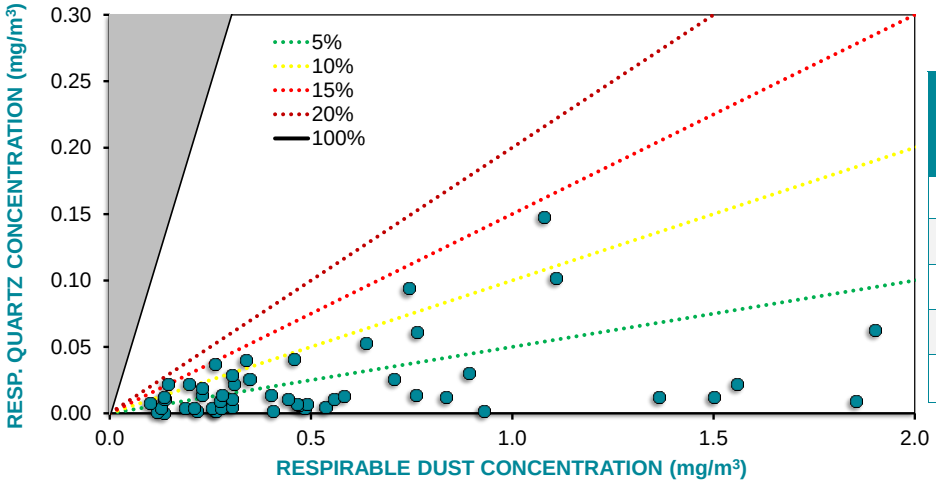
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	96.7%
≤0.05	87.6%
≤0.025	73.1%
≤0.012	51.8%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	93.2%
≤1.5	86.7%
≤0.3	37.6%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	67%
>5% to 10%	22%
>10% to 15%	9%
>15% to 20%	2%
>20%	0%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C5.01 - Management and office work	
C5.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C5.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C5.02 - Grinding	
C5.02.01 - Crusher / grinder and screening plant operator	Operates crushing plant to reduce raw material to suitable size for further processing and mills to grind material. Controls the screening plant. Pours specified quantities of material into hoppers, generally by using a loader or a lift truck. In case of production of granulate from used product, controls the process up to the final mixing and bagging.
C5.03 - Composition of the mixture	
C5.03.01 - Weigher and mixer	Weighs ingredients according to specifications. Loads the material into mixing machine by hand (with a bucket), then adds water and starts the mixing process. Since tending the mixing machine requires only a part of the daily work shift (approximately 2 hours) this is often a secondary task for a worker operating in a different production line (drawing line, casting line, etc.).
C5.04 - Forming by extrusion	
C5.04.01 - Extrusion press operator	Operates extrusion press where a continuous column of refractory mixture is formed, extruded and cut to size. Picks up the elements (e.g. refractory bricks) coming out of the shaping machine and places them on trolleys. Carries out maintenance (lubrication) of trolleys and conveyor belts.
C5.05 - Forming by casting	
C5.05.01 - Manual casting operator	Fills mould with refractory mixture using bucket or casting pump. Sets full mould on bench to dry. Removes ware from mould and places it on pallets.
C5.06 - Forming by press moulding	
C5.06.01 - Moulding press operator	Operates pressing machine to make refractory products. Fills mould with required quantity of refractory mixture, puts mould in press, starts and operates press. Withdraws and transfers the shaped products (e.g. bricks) onto a trolley. May remove loose dust from the brick surface by using jets of compressed air.
C5.07 - Kiln firing	
C5.07.01 - Kiln loading/unloading operator	Operates (periodic batch, shuttle or continuous tunnel) kiln for refractory products. Loads the kiln car with the green refractories and introduces it into the kiln. After the firing is completed, unloads the products and stacks them on pallets in the warehouse.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C5.08 - Glazing	
C5.08.01 - Glazing operator	Applies a coat of glaze slip (a glass usually made up of oxides of non-metals and oxides of metals) to the green refractory brick or other shapes, by hand or machine dipping, spraying or painting.
C5.09 - Finishing and assembly	
C5.09.01 - Ware finisher	Operates the lathe machine, cuts and finishes greenware and biscuit ware. Sets the machine, loads pieces on conveyor rollers and unloads them at the end of the line. Sends pieces to the packaging department.
C5.09.02 - Refractory elements assembly operator	Mounts and assembles refractory elements.
C5.10 - Handling of materials and products	
C5.10.01 - Crane / loader operator	Operates crane, mechanical loader or other material handling equipment to move materials and products into the storage area and production line.
C5.11 - Warehousing and packaging	
C5.11.01 - Warehouse operator	Handles duties pertaining to the processing organising, packaging and shipping of materials, equipment and other items that are sent to the warehouse or storage yard. Drives the forklift to pick up incoming stock or deliver materials to designated area.
C5.12 - Mechanical and electrical maintenance / cleaning	
C5.12.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment, both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C5.12.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

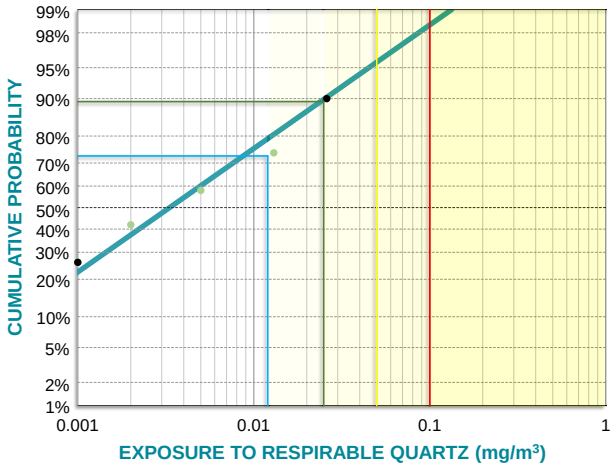
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C5.01.01 - Manager	3	0.003*	1.492*	-	-	-	-
C5.02.01 - Crusher / grinder and screening plant operator	6	0.003*	7.358*		>90.0%	89.4%	72.8%
C5.03.01 - Weigher and mixer	9	0.013	2.517	>93.2%	91.1%	86.9%	39.2%
C5.04.01 - Extrusion press operator	1	0.006	-	-	-	-	-
C5.05.01 - Manual casting operator	3	0.041	2.656	-	-	-	-
C5.06.01 - Moulding press operator	5	0.014*	2.296*	-	-	-	-
C5.07.01 - Kiln loading/unloading operator	10	0.012	2.586	>93.9	90.7%	77.2%	56.1%
C5.08.01 - Glazing operator	2	0.033	-	-	-	-	-
C5.09.01 - Ware finisher	9	0.024	3.655	82.1%	66.7%	48.0%	40.1%
C5.09.02 - Refractory elements assembly operator	2	0.023	-	-	-	-	-
C5.11.01 - Warehouse operator	3	0.007*	3.360*	-	-	-	-
C5.12.01 - Maintenance mechanic / electrician	2	0.007	-	-	-	-	-

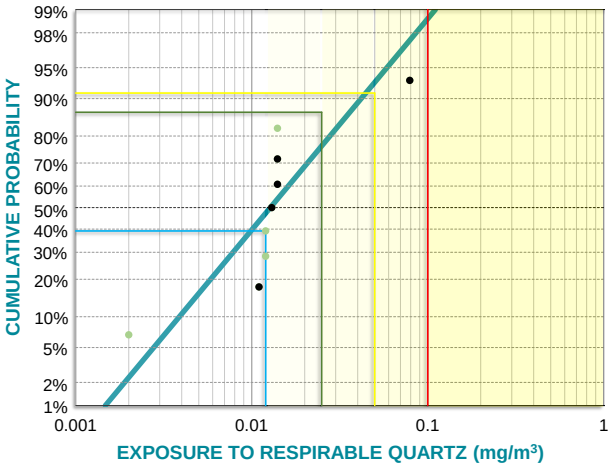
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

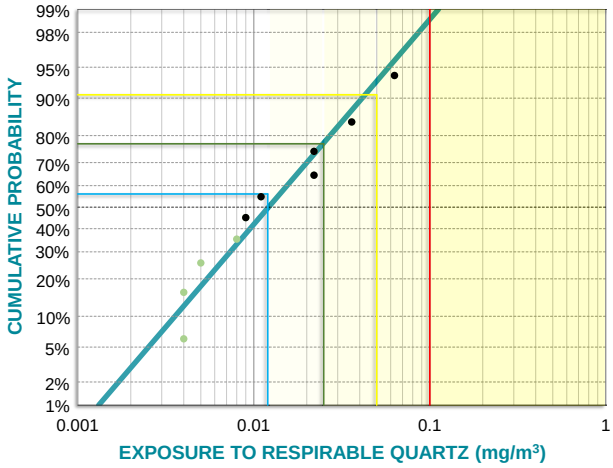
C05.02.01 - Crusher / grinder and screening plant operator



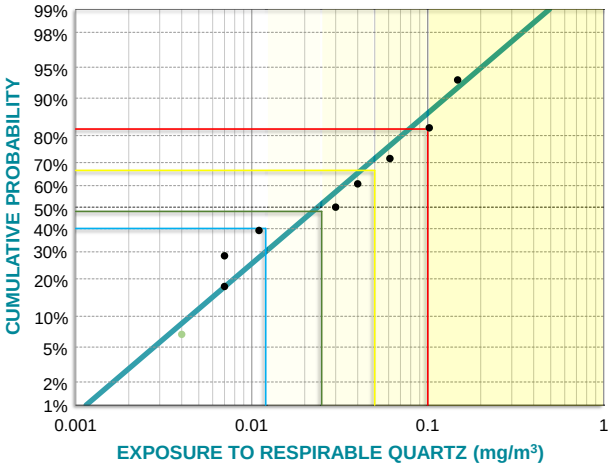
C05.03.01 - Weigher and mixer



C05.07.01 - Kiln loading/unloading operator



C05.09.01 - Ware finisher



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C5.01.01 - Manager	3	0.244	1.104	-	-	-
C5.02.01 - Crusher / grinder and screening plant operator	7	0.608	4.512	75.0%	69.9%	38.6%
C5.03.01 - Weigher and mixer	9	0.652	2.347	91.6%	83.8%	19.4%
C5.04.01 - Extrusion press operator	1	0.471	-	-	-	-
C5.05.01 - Manual casting operator	4	0.332	3.089	-	-	-
C5.06.01 - Moulding press operator	5	0.402	3.498	-	-	-
C5.07.01 - Kiln loading/unloading operator	10	0.468	4.883	86.5%	82.5%	53.9%
C5.08.01 - Glazing operator	2	0.399	-	-	-	-
C5.09.01 - Ware finisher	9	0.511	2.017		>93.2%	21.5%
C5.09.02 - Refractory elements assembly operator	2	0.264	-	-	-	-
C5.11.01 - Warehouse operator	3	0.811	2.469	-	-	-
C5.12.01 - Maintenance mechanic / electrician	2	0.253	-	-	-	-

Working processes

The range of the ceramic and porcelain tile production is basically related to three types:

- unglazed tiles (terracotta tiles, red stoneware, porcelain stoneware, clinker tiles);
- single-fired glazed tiles (light red terracotta tiles, glazed porcelain stoneware, glazed clinker tiles and glazed terracotta tiles): enamel and decorations are applied on the dried ceramic support before a single cooking phase;
- double-fired glazed tiles (majolica tiles and strong terracotta tiles): two distinct thermal cycles are necessary: the first to consolidate the support, the second to stabilise the enamels and decorations.

Two-thirds of Italy's industrial production is made of porcelain stoneware, half of which is glazed. The stoneware is made with natural clay mixtures transformed into vitrified ceramics. In order to obtain white stoneware, powders based on white firing clays and quartz-feldspar rocks (quartz content 20-30% of the mixture), that induce vitrification of the mass, are used. The tiles are glazed and coloured after firing: the chromatic variations depend on the iron compounds in the material. The main stages of the tiles production are listed below.

1. **Storage of raw materials** – raw materials stored in a stock house consist of clays and kaolin (loose materials are stored in concrete boxes), quartz and feldspars ground to an appropriate particle size (supplied by a silo truck, they are directly unloaded and stored into silos, conveyed by means of compressed air generated by a compressor unit on board of the truck; when contained in paper bags, they are unloaded from trucks by forklift trucks), calcium carbonate, zirconium silicate, barium carbonate, etc., for enamel composition (supplied in paper bags on pallets or in big-bags, moved by means of forklifts).
2. **Mixture preparation** – two types of mixtures are used: fire-clay and vitreous-china, with different percentages of raw materials used; chamotte (produced by firing selected fire clays in a rotary kiln) may also be added in vitreous-china mixtures. The preparation of a mixture includes the following steps:

   - Batching: dosing and weighing of raw materials (usually by using automatic systems).
   - For fire-clay production: wet (in ball or drum mill) or dry (e.g. in peg mill, hammer mill, pendulum mill) grinding, until required particle size is achieved.
   - For vitreous-china production: dissolution of clay and kaolin (in turbin mixer) to form a casting slurry.
   - Screening (by vibrating screens) and iron removal (by using magnetic filters).
   - For fire-clay production: the atomisation of the slurry, that enables the reduction of the particles into small granules.
   - For vitreous-china production: the clay, quartz and feldspar slurry is mixed in a turbine mixer and then aged in a large cylindrical storage tank, in which the slow rotation of mixing paddles enhances the homogenisation of the slurry.

3. **Tile forming** – the clay mixture is pressed into a press machine mould, where the wet powder is compacted to form the *green* tile. The green tile, with the remaining moisture content, undergoes preheating in a continuous tunnel dryer or in a rapid dryer, acquiring strength and durability.
4. **Glaze preparation** – the glaze is most often purchased from specialised suppliers, or otherwise it is prepared in the factory by mixing a glass-like substance or frit, together with melting materials (heavy metals compounds), dyes and additives (deflocculant/fluidiser such as sodium tripolyphosphate or sodium silicate, or additives which improve the adhesion of the glaze to the body, such as organic glues or carboxymethyl cellulose). Particle sizes of raw materials and among them quartz (often around 30% of the mixture), are reduced by milling in drum mills and then the mixture is suspended in water. The glaze suspension is stored in metal tanks equipped with a mixing paddle in slow rotation and finally transferred to the glazing department by means of forklifts.

5. **Decorating and glazing** – carried out on green tiles (in the case of single-fired products) or on semi-finished ceramic biscuits (in the case of double-fired products). The tiles are decorated, then the glaze is applied with the automated equipment, using adaptable modular systems. After glazing, special aesthetic effects can be realised (e.g. by screen printing, brushing, airbrushing) and a particular ceramic mixture can be applied to the back side of the tiles to prevent adhesion to the roller conveyor of the tunnel kiln. Tiles are then loaded onto storage carts or, less commonly, directly sent to the kiln.
6. **Kiln firing** – the glaze ware can be subjected to only one heating cycle to directly obtain the finished product, or the green tile is fired a first time and then fired again after glazing. Firing produces a hard and water-resistant product and should allow the glaze to reach its optimal level of melting. The tiles, carried on the storage carts, are unloaded, by an automatic unloading machine, onto the roller conveyor at the entrance of a single-layer roller kiln. The rollers convey the tiles into the firing chamber; and after firing, the tiles are again loaded on storage carts.
7. **Quality control and packaging** – the products are checked to detect manufacturing defects as well as to classify the tiles according to their quality and commercial value. The tiles are made to slide on conveyor belts along which the sorting stations are located; semi-automatic or automatic equipment can be used for sorting. The products are then packaged inside cardboard boxes and stored on pallets.
8. **Store housing and shipping** – the products are moved to the storehouse and eventually loaded onto a truck for delivery.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	522	0.333	2.191	509	0.028	3.114	9.9
STATIC	7	0.200	2.415	7	0.037	3.617	21.1

Geometric mean of personal exposure, by region

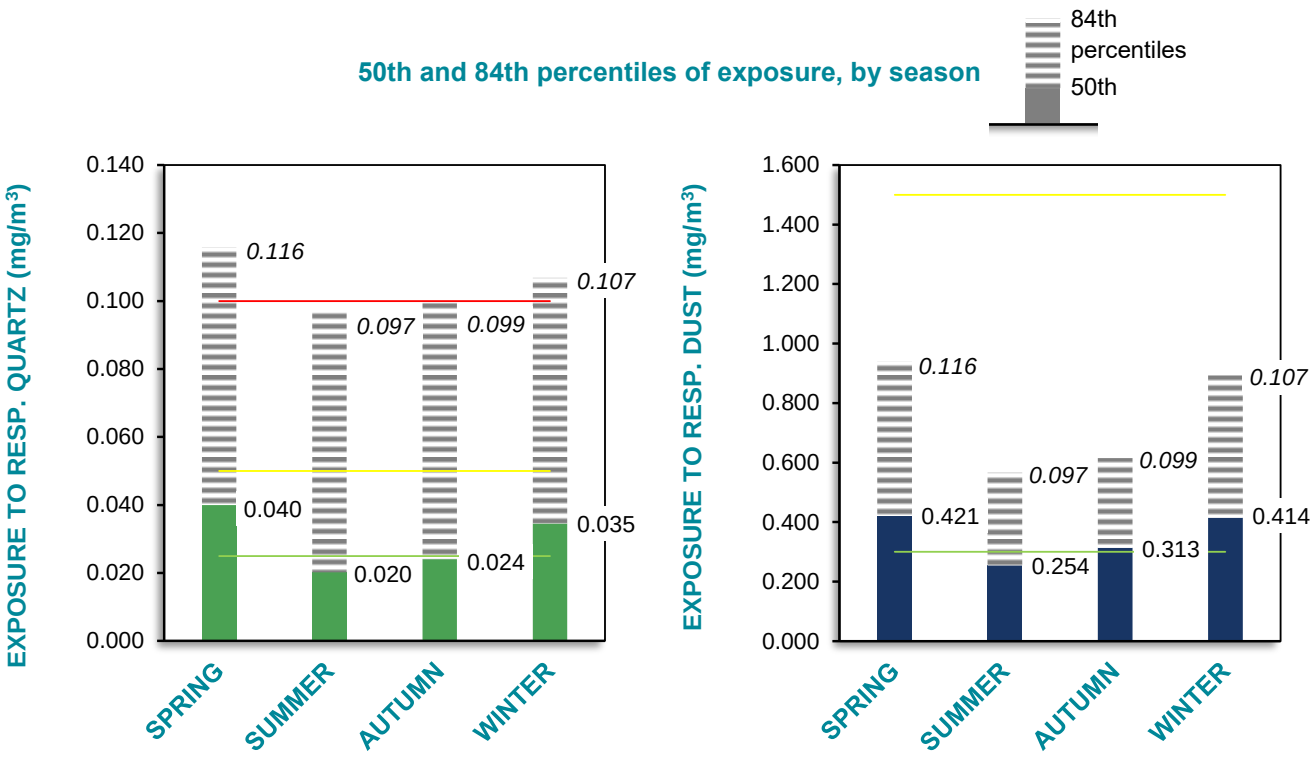
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

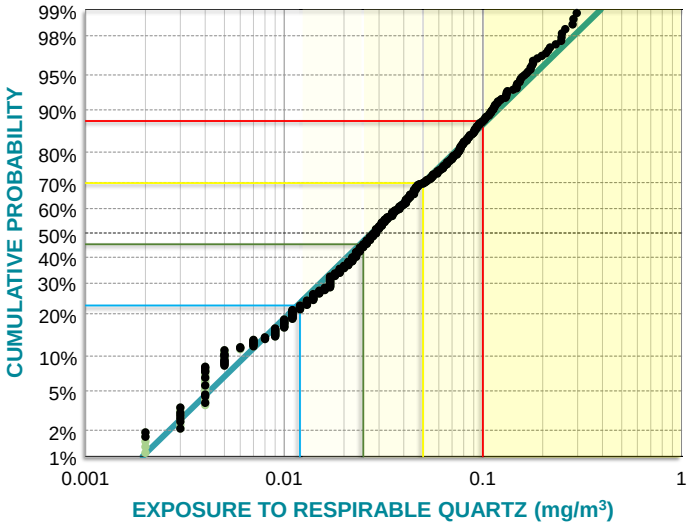
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

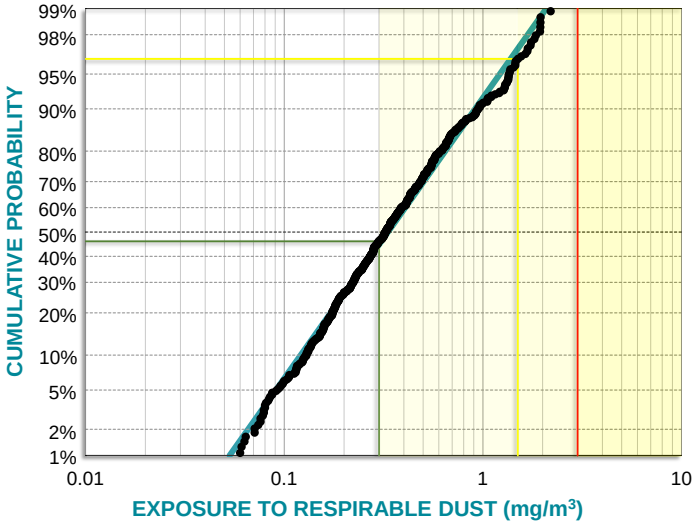


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



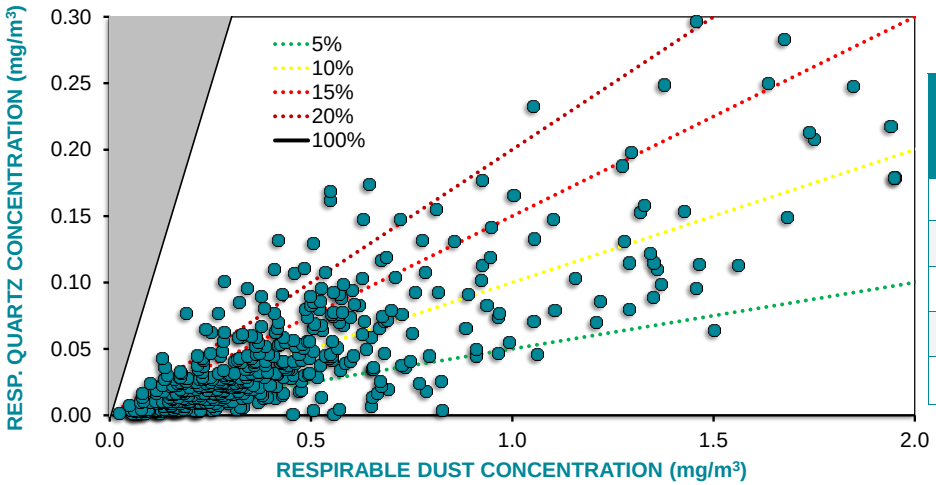
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	87.8%
≤0.05	69.8%
≤0.025	45.3%
≤0.012	22.5%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	99.5%
≤1.5	96.4%
≤0.3	46.2%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	21%
>5% to 10%	38%
>10% to 15%	23%
>15% to 20%	11%
>20%	6%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C6.01 - Management and office work	
C6.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C6.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C6.02 - Handling of materials and products	
C6.02.01 - Crane / loader operator	Operates crane, mechanical loader, belt conveyor or other material handling equipment to move raw materials into the storage area and production department.
C6.02.02 - Forklift operator (palletisation)	Operates material handling equipment (hand or battery operated pallet truck, reach truck, forklift) to move finished products. Operates palletiser and packaging systems.
C6.03 - Composition of the mixture	
C6.03.01 - Weigher and mixer	Weighs raw materials to ensure conformance to requirements. Loads the material in the (continuous or discontinuous) milling machine and controls the mixing process.
C6.03.02 - Atomising plant operator	Operates and controls the atomising plant in which the barbotine (slurry - aqueous suspension of ground materials) is pumped and pulverised, comes in contact with hot air, loses humidity forming fine granules (atomised powder).
C6.04 - Forming	
C6.04.01 - Moulding press operator	Operates the pressing machine to make tiles from clay mixture in mould. Starts, operates and controls press.
C6.04.02 - Production line loading/unloading operator	Loads/unloads the production line. Fills mould with required quantity of clay mixture and puts mould in press. Unloads the pieces from the production line. May also operate the production line (including the tasks of C6.04.01).
C6.05 - Glaze preparation	
C6.05.01 - Glaze maker	Grinds raw materials in the mill and prepares glaze and silkscreen pastes.
C6.05.02 - Colour maker	Prepares the ceramic colours used in coloured wall tiles, etc. Zirconium based pigments are used.
C6.06 - Glazing and decorating	
C6.06.01 - Glazing operator	Applies a coat of glaze slip to the green tile by operating an automatic glazing machine or by spraying.
C6.06.02 - Decorator	Decorates unglazed tile articles by painting freehand design or by printing design on tiles using silk screen process.
C6.06.03 - Mosaic maker	Cuts, shapes and sets blocks of coloured marble, ceramics, glass, etc., for decoration on ceramic tiles. Applies blocks on the tile using fingers or automatic machine.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C6.07 - Kiln firing	
C6.07.01 - Kiln operator	Operates and monitors (tunnel or other type) kilns to produce tiles.
C6.07.02 - Kiln loading/unloading operator	Loads the green tiles on the kiln car. After the firing is completed, sorts the products during the unloading of the kiln or the tunnel kiln car either automatically or by hand.
C6.08 - Finishing	
C6.08.01 - Ware cutter and finisher	Carries out cutting of ceramic or stone using, for example, a splitting machine that divides the slabs of marble or stone into two parts. Finishes greenware and biscuit ware (polishing, grinding, brushing, etc.).
C6.08.02 - Labelling and pasting operator	Carries out pasting of parts and labelling of pieces.
C6.09 - Quality control, warehousing and packaging	
C6.09.01 - Quality control sorter	Examines tile product for defects, such as cracks, spots, warping and dents and grades it according to quality standards.
C6.09.02 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to the warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to the designated area.
C6.10 - Various workspaces	
C6.10.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C6.11 - Mechanical and electrical maintenance / cleaning	
C6.11.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C6.11.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

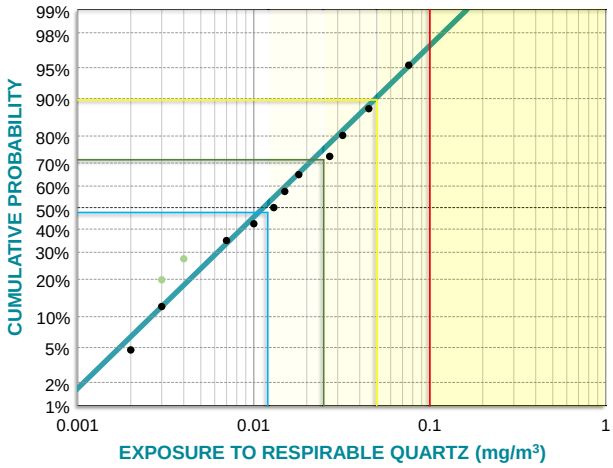
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C6.01.01 - Manager	13	0.011	3.120	>95.3%	89.7%	71.3%	47.7%
C6.02.01 - Crane / loader operator	5	0.041	2.677	-	-	-	-
C6.02.02 - Forklift operator (palletisation)	8	0.016	3.271	90.9%	78.9%	66.8%	39.6%
C6.03.01 - Weigher and mixer	30	0.050	2.895	72.9%	54.4%	8.7%	5.9%
C6.03.02 - Atomising plant operator	13	0.060	2.168	83.3%	44.2%	12.3%	<4.7%
C6.04.01 - Moulding press operator	91	0.052	2.491	78.3%	43.4%	19.3%	5.3%
C6.04.02 - Production line loading/unloading operator	13	0.017	2.022	>95.3%	91.7%	76.0%	42.5%
C6.05.01 - Glaze maker	41	0.033	3.045	83.6%	60.3%	37.9%	12.9%
C6.05.02 - Colour maker	7	0.057	1.811	83.9%	43.3%	<8.6%	-
C6.06.01 - Glazing operator	70	0.025	3.542	85.2%	68.9%	46.4%	27.9%
C6.06.02 - Decorator	6	0.004*	1.095*				>90.0%
C6.06.03 - Mosaic maker	4	0.042	1.461	-	-	-	-
C6.07.01 - Kiln operator	18	0.015	1.956		>96.6%	73.7%	47.3%
C6.07.02 - Kiln loading/unloading operator	5	0.004*	1.513*	-	-	-	-
C6.08.01 - Ware cutter and finisher	71	0.020	2.206	>99.1%	90.7%	61.9%	24.7%
C6.08.02 - Labelling and pasting operator	4	0.021	2.370	-	-	-	-
C6.09.01 - Quality control sorter	31	0.013	3.268	95.1%	89.3%	77.8%	45.3%
C6.09.02 - Warehouse operator	2	0.023	-	-	-	-	-
C6.10.01 - Polyvalent worker	10	0.020	4.072	81.6%	76.6%	65.6%	38.6%
C6.11.01 - Maintenance mechanic / electrician	65	0.033	2.849	87.3%	66.4%	43.4%	14.0%
C6.11.02 - Workplace cleaner	2	0.006	-	-	-	-	-

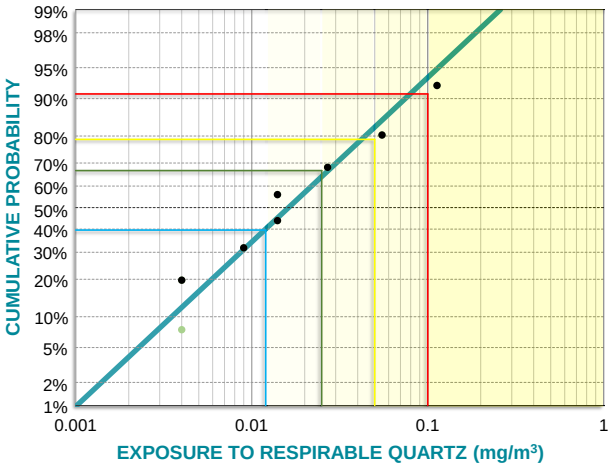
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

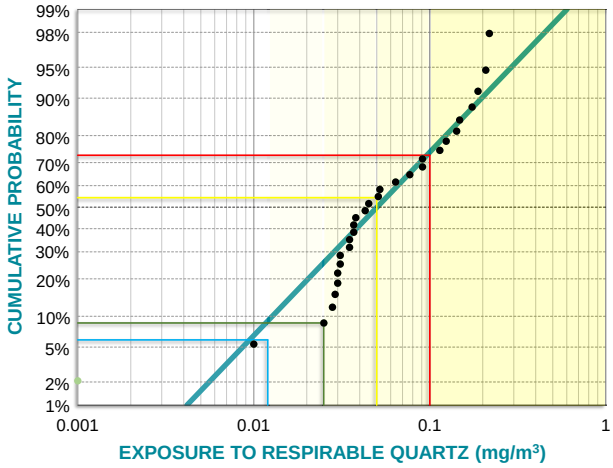
C06.01.01 - Manager



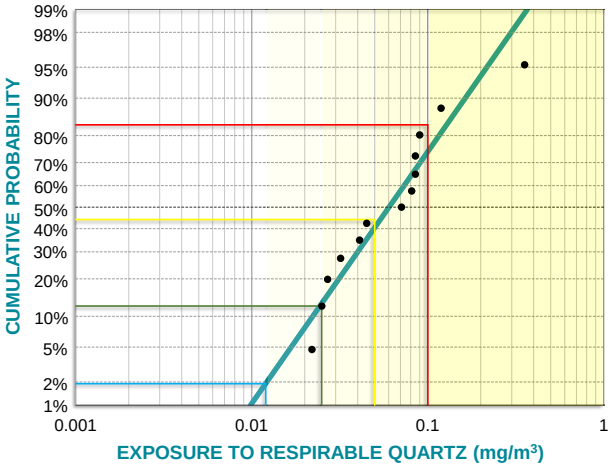
C06.02.02 - Forklift operator (palletisation)



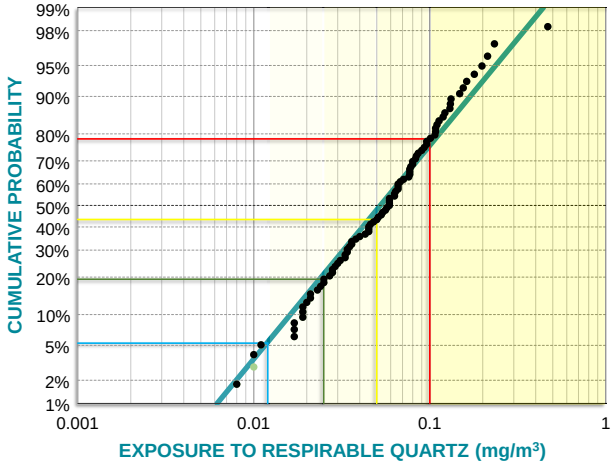
C06.03.01 - Weigher and mixer



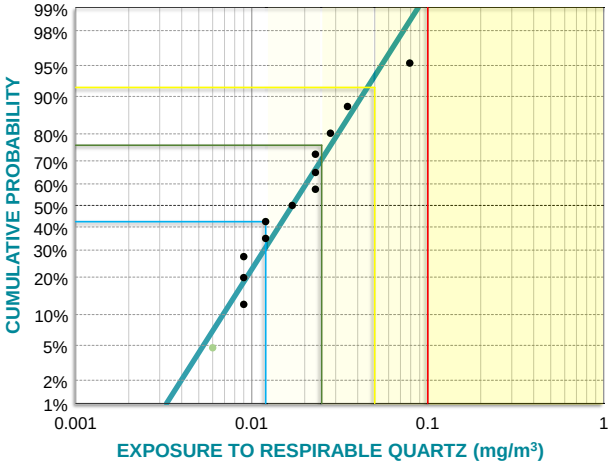
C06.03.02 - Atomising plant operator



C06.04.01 - Moulding press operator

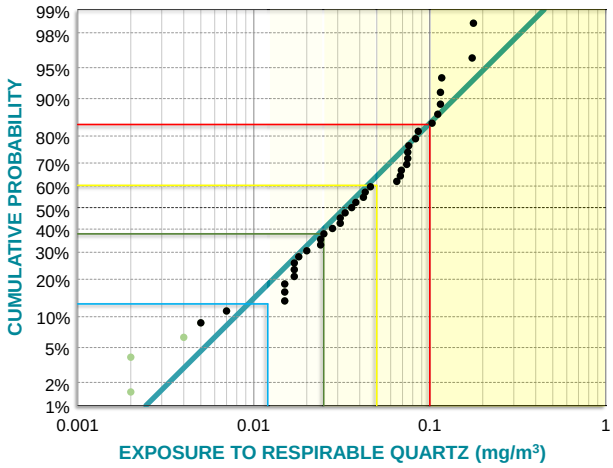


C06.04.02 - Production line loading/unloading operator

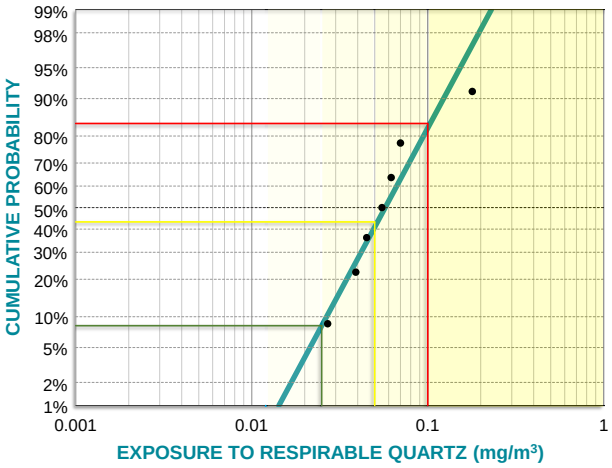


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

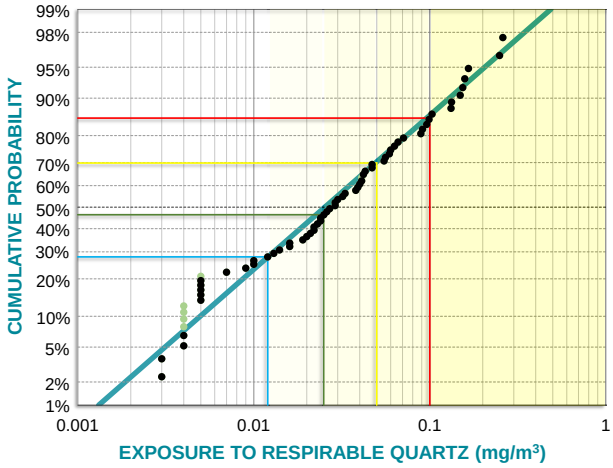
C06.05.01 - Glaze maker



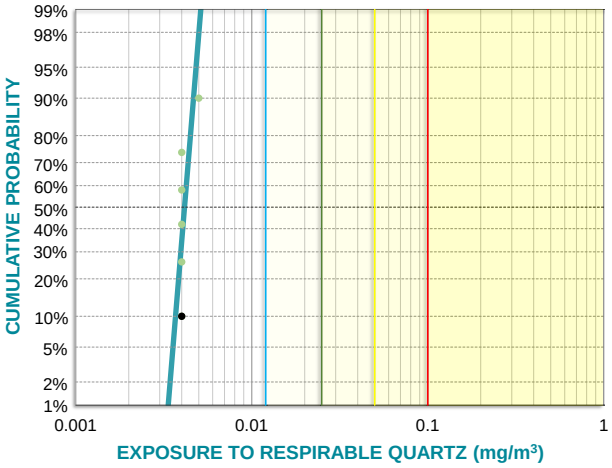
C06.05.02 - Colour maker



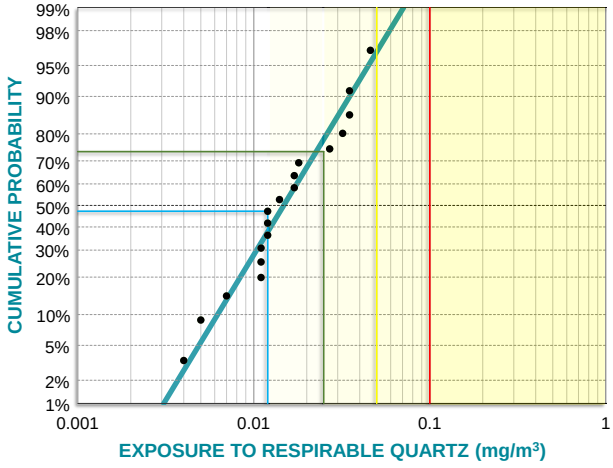
C06.06.01 - Glazing operator



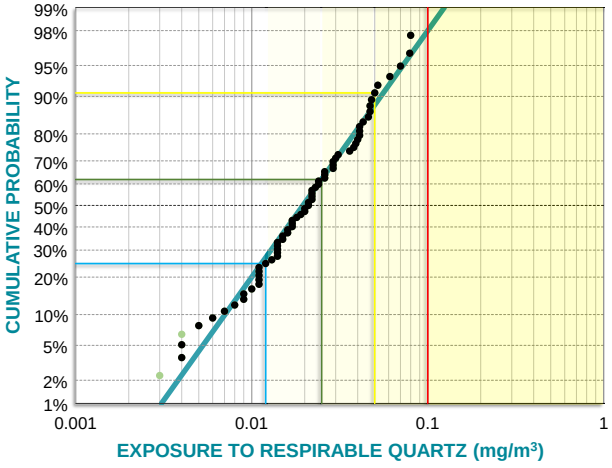
C06.06.02 - Decorator



C06.07.01 - Kiln operator

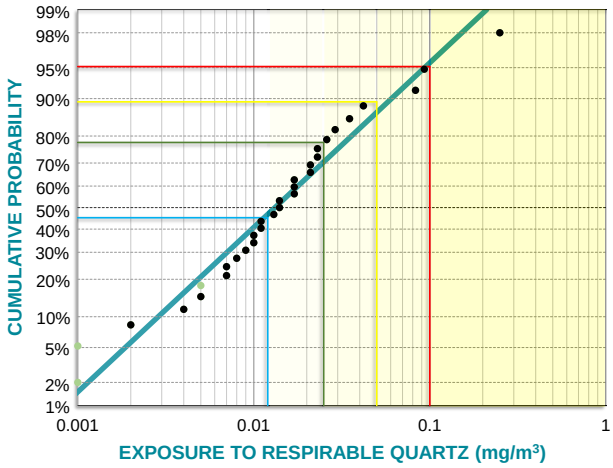


C06.08.01 - Ware cutter and finisher

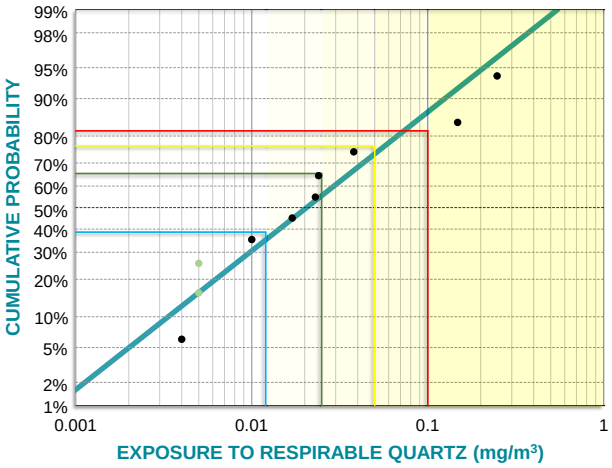


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

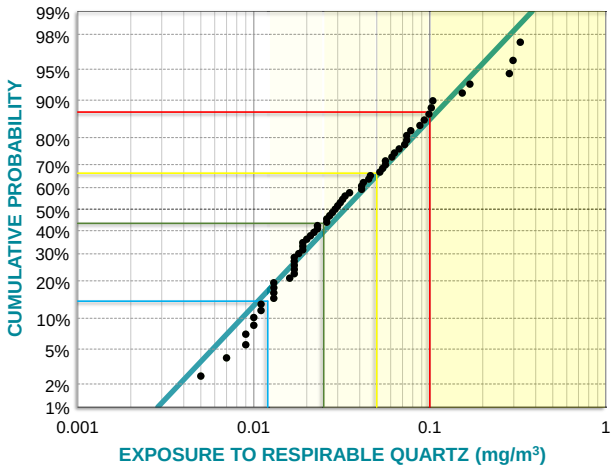
C06.09.01 - Quality control sorter



C06.10.01 - Polyvalent worker



C06.11.01 - Maintenance mechanic / electrician



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C6.01.01 - Manager	13	0.261	1.896		>95.3%	62.9%
C6.02.01 - Crane / loader operator	5	0.269	2.289	-	-	-
C6.02.02 - Forklift operator (palletisation)	8	0.246	2.309		>92.4%	61.3%
C6.03.01 - Weigher and mixer	30	0.499	2.281	97.2%	85.2%	30.7%
C6.03.02 - Atomising plant operator	13	0.353	1.888		>95.3%	40.4%
C6.04.01 - Moulding press operator	93	0.416	2.123	99.3%	94.0%	35.3%
C6.04.02 - Production line loading/unloading operator	13	0.233	1.658		>95.3%	70.3%
C6.05.01 - Glaze maker	41	0.396	2.017		>98.5%	30.8%
C6.05.02 - Colour maker	7	0.660	2.018	>91.4%	87.1%	13.6%
C6.06.01 - Glazing operator	70	0.410	2.352	>99.1%	95.2%	37.6%
C6.06.02 - Decorator	9	0.092	1.513			>93.2%
C6.06.03 - Mosaic maker	4	0.503	1.156	-	-	-
C6.07.01 - Kiln operator	22	0.194	1.879		>97.2%	79.3%
C6.07.02 - Kiln loading/unloading operator	6	0.113	1.504			>90.0%
C6.08.01 - Ware cutter and finisher	72	0.322	1.754		>99.1%	43.3%
C6.08.02 - Labelling and pasting operator	5	0.268	1.689	-	-	-
C6.09.01 - Quality control sorter	32	0.220	1.991	>98.1%	97.9%	72.5%
C6.09.02 - Warehouse operator	2	0.328	-	-	-	-
C6.10.01 - Polyvalent worker	10	0.235	2.896	>93.9%	90.8%	73.2%
C6.11.01 - Maintenance mechanic / electrician	65	0.339	2.163	>99.0%	94.8%	49.3%
C6.11.02 - Workplace cleaner	2	0.138	-	-	-	-

Working processes

Bricks are produced in various materials and sizes and used for building walls, pavements and other elements in masonry construction. Natural clays, the main constituent of bricks, have a quartz average content of between 25-30%, so that their effective grain size is intermediate between those of *true* clays and sands. When clay is heated to a high temperature, it loses most of the water contained in its pores, a chemical reaction occurs and hard blocks of baked clay form. The typical steps involved in the manufacture of bricks and roofing tiles in baked clay is described in the following.

1. **Quarrying of clays** – clay is extracted using mechanical equipment such as excavators and power shovels and transported by trucks. This work phase is preferably classified as B3 *Quarrying of clays, pozzolana and feldspar*, but can also be classified here when unpractical to separate it from the other working phase. The quarried material is then moved to the factory.
2. **Store housing** – clay is stored in the stockpile area in the factory and then taken by loaders or bulldozers to the grinding and mixture composition department.
3. **Crushing and composition of the mixtur**e – raw clay is worked into a uniform mass, either through wet or dry processing techniques.

   - Wet preparation: clay lumps are loaded in batching containers and then conveyed to a crusher where they are reduced in size. The raw material is then transferred into a preliminary roller mill for further reduction in size before being passed through a mixer to get a smooth mass, which is finally stored in silos or containers

   - Dry preparation: clay lumps are loaded in batching containers and then into a disintegrator, where they are crushed and crumbled to small-sized clay clods. Next, the material feeds a mill, where it is further reduced in size and then sent to the vibrating screens. The material is moistened and homogenised in a mixer and finally stored in silos or containers.
4. **Forming** – carried out by extrusion (e.g. in brickmaking, drawing, or roof tile machines) or pressing (e.g. brick casting machines, i.e. presses equipped with moulds where wet or dry raw materials are poured). In the production of traditional hand-made bricks, the paste is poured into a wood mould placed on a bench covered by a layer of sand and every single piece is pressed by hand.
5. **Drying** – a continuous dryer (into which hot air is pulled, while the trolleys carrying products slowly pass through the dryer tunnel) or a rapid dryer is most commonly used. Traditional hand-made bricks are left to dry naturally.
6. **Firing** – the dried *green* bricks are loaded onto cars and fired in kilns (e.g., tunnel kiln, chamber kiln, Hoffman kiln). At the exit from the kiln, the fired pieces are unloaded from the cars (manually or with stacking machines) and transferred to the packaging department.
7. **Sanding and trimming** – in special cases, the bricks are polished with sanding, or a trimming machine can be used for trimming the surplus material and quality control is generally required.
8. **Storing, packing and shipping** – the products are packed or wrapped in sheets of cellophane or polyethylene, stored in the warehouse and eventually loaded on a truck for delivery.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	244	0.346	2.169	223	0.030	2.748	9.9
STATIC	4	0.193	1.667	4	0.018	3.350	11.6

BRICKS: Manufacture of bricks, tiles and construction products, in baked clay

Geometric mean of personal exposure, by region

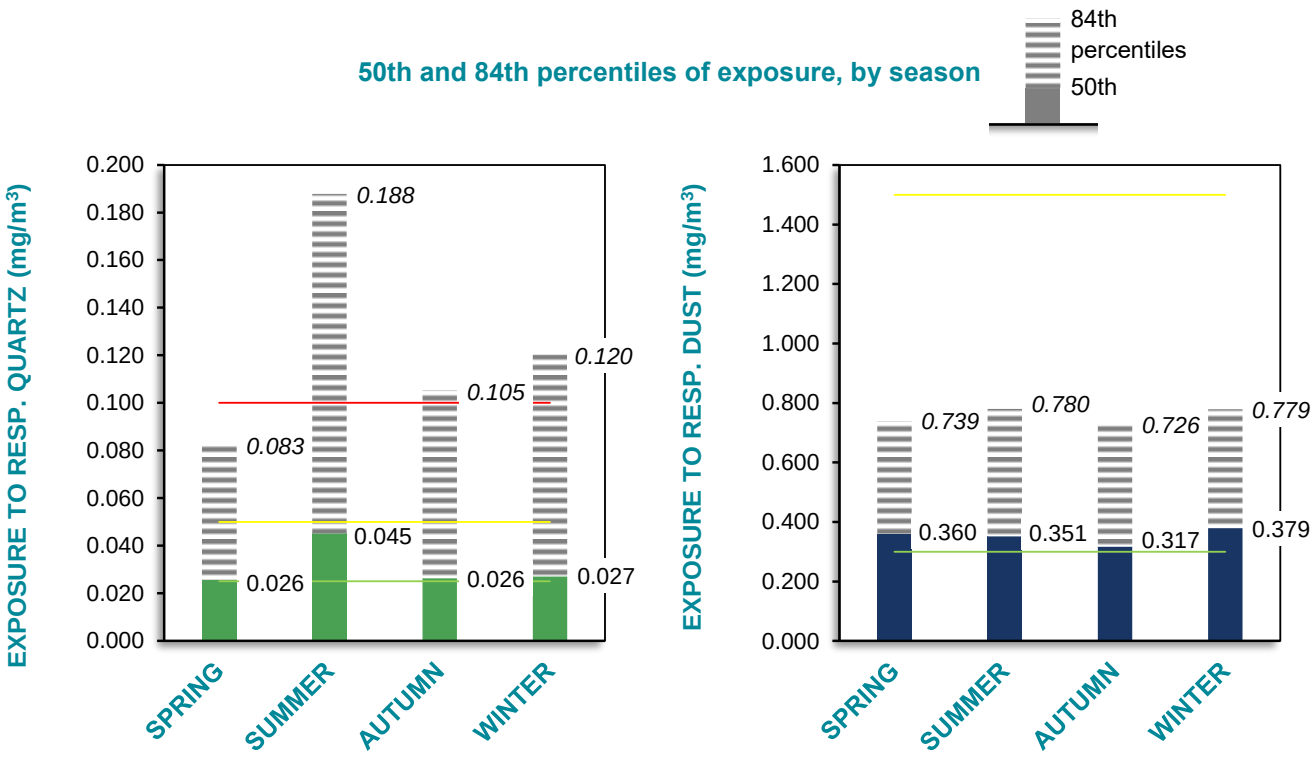
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

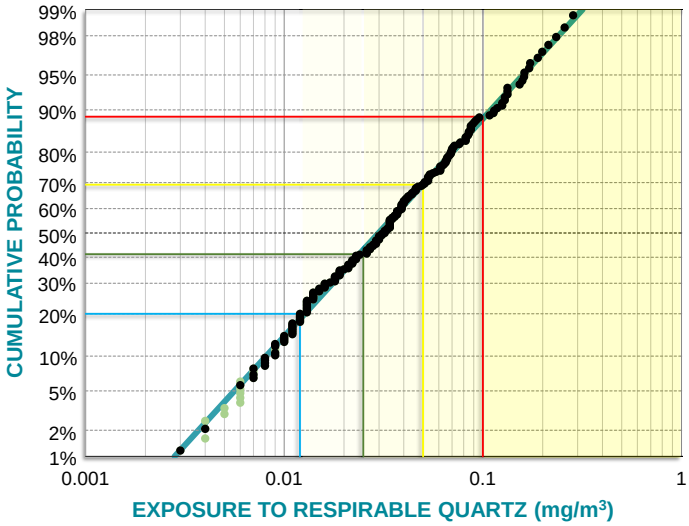
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

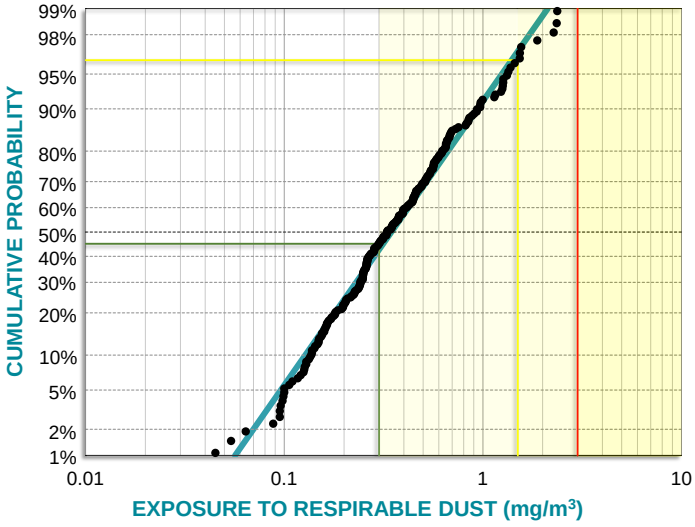


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



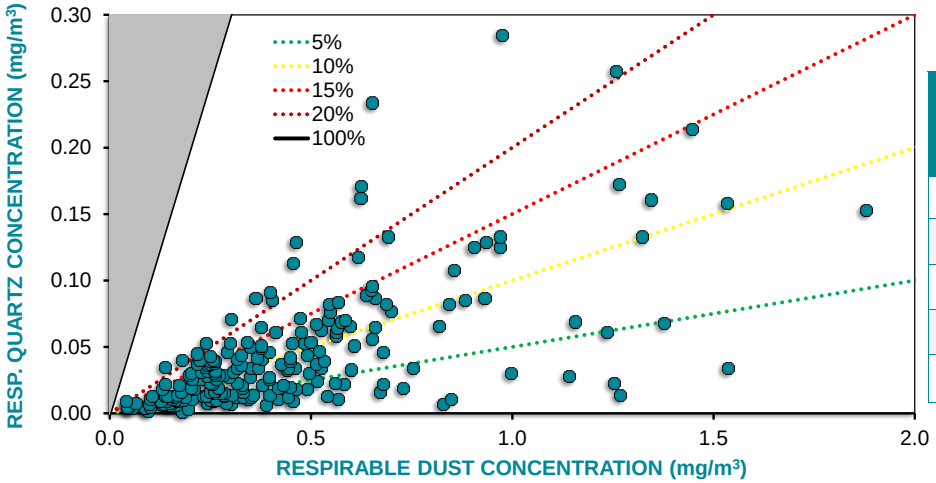
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	88.7%
≤0.05	69.3%
≤0.025	41.3%
≤0.012	20.0%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	99.5%
≤1.5	96.3%
≤0.3	45.2%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	26%
>5% to 10%	29%
>10% to 15%	30%
>15% to 20%	7%
>20%	8%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C7.01 - Management and office work	
C7.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both the administrative and operating tasks).
C7.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C7.02 - Quarrying	
C7.02.01 - Quarryman	Extracts clay from quarry, for brick manufacturing. May carry out all the duties at the quarry: operates power-driven excavating machine (power-shovel, excavator, loader, bulldozer) to extract clay and move materials into haul the truck; assists in various assignments. The job title is better included in B3 - *Quarrying of clays, pozzolana and feldspar*, but is included here when it is difficult to separately classify this operator.
C7.03 - Grinding and composition of the mixture	
C7.03.01 - Grinder / screener operator	Operates milling machine (e.g. hammer mill) to reduce raw material to suitable size. Controls the screening plant.
C7.03.02 - Paste mixer	Loads and controls the mixing machine for the preparation of clay paste for the subsequent drawing or moulding.
C7.04 - Forming	
C7.04.01 - Brickmaking machine operator	Operates brickmaking machine, where a continuous clay column is formed, extruded and cut to size by fixed steel wires for hollow bricks production.
C7.04.02 - Tile drawing machine operator	Operates drawing machine, where a continuous clay column is formed, extruded and cut to size by a cutting tool for tiles production.
C7.04.03 - Roof tile machine operator	Operates machine for roof tile production. An automated plant is often used, where a mixer automatically feeds the mixture to the extrusion machine.
C7.04.04 - Brick casting machine operator	Operates automated casting machine for bricks production. Raw materials are mixed and the slurry is then poured into mould frame.
C7.04.05 - Brick hand moulder	Packs moulding mixture into mould by hand for solid brick production. Places the mould on a bench covered by a layer of sand to prevent casting from sticking. Removes excess mixture from the top of the mould, using steel wire.
C7.04.06 - Vase hand moulder	Moulds and smooths clay by hand inside plaster mould cavity to produce odd-shaped vase. Removes the plaster mould after a few days before finishing and smoothing the wet raw vase using hand-moulding tools on the outside vase surface, before sending it to be dried and then to fired.
C7.04.07 - Stacking machine operator	Operates stacking machine, which lifts shaped bricks, roofing tiles and tiles and places them on cars (for loading-unloading from dryer and from kiln). May use a forklift or carry out stacking by hand.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C7.05 - Kiln firing	
C7.05.01 - Kiln and dryer operator	Operates the (tunnel or other type) kiln for bricks. Loads the green bricks on the kiln car. After the firing is completed, sorts the products during the unloading of the kiln or the tunnel kiln car, automatically or by hand. Operates the dryer (natural drying by air can also be used).
C7.06 - Finishing	
C7.06.01 - Brick polishing / trimming machine operator	Operates wet polishing and trimming machines on bricks.
C7.06.02 - Hand brick polishing and trimming operator	Carries out the manual polishing and trimming of bricks by using an angle grinder.
C7.07 - Quality control and laboratory testing	
C7.07.01 - Quality control technician	Carries out product sorting and quality assessment.
C7.08 - Handling of materials and products	
C7.08.01 - Crane / loader operator	Operates crane, loader or other lifting machine, to store and move clay from deposit to crushing and screening line.
C7.08.02 - Forklift operator	Operates forklift or other material handling equipment to move material in the production department, transporting and stacking products in outside storage yard.
C7.09 - Warehousing and packaging	
C7.09.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to the warehouse or storage yard. Drives a forklift to pick up incoming stock or deliver materials to designated areas.
C7.09.02 - Delivery truck driver	Drives truck or lorry for the delivery of products.
C7.09.03 - Silo operator	Tends to the loading system that conveys raw materials into storage silo and the unloading system for discharging materials. Is responsible for silo maintenance and delivery procedures.
C7.10 - Various workspaces	
C7.10.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C7.11 - Mechanical and electrical maintenance / cleaning	
C7.11.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
C7.11.02 - Box feeders and conveyor belts operator	Controls and maintains box feeders which receive the clay from the quarry as well as the conveyor belt that brings the material to the milling machine to reduce it to suitable size.
C7.11.03 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

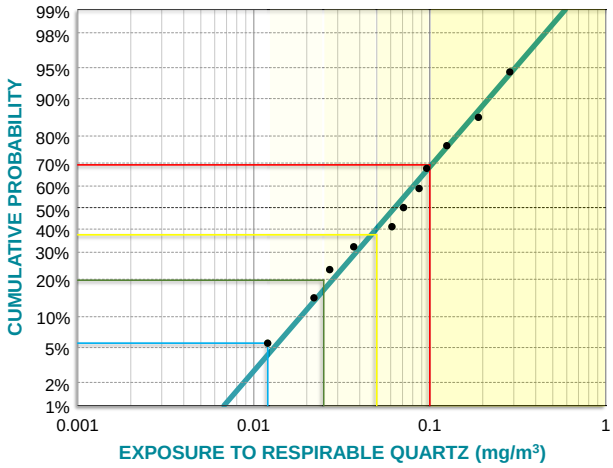
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C7.01.01 - Manager	2	0.006*	-	-	-	-	-
C7.02.01 - Quarryman	2	0.039	-	-	-	-	-
C7.03.01 - Grinder / screener operator	11	0.063	2.597	69.2%	37.5%	19.7%	5.6%
C7.03.02 - Paste mixer	7	0.021	3.431	>91.4%	63.0%	52.6%	22.4%
C7.04.01 - Brickmaking machine operator	23	0.042	2.524	85.8%	53.6%	31.4%	9.1%
C7.04.02 - Tile drawing machine operator	5	0.012	2.817		>88.1%	67.8%	55.2%
C7.04.03 - Roof tile machine operator	3	0.038	1.142	-	-	-	-
C7.04.04 - Brick casting machine operator	1	0.061	-	-	-	-	-
C7.04.05 - Brick hand moulder	30	0.028	2.159	93.6%	76.8%	44.0%	18.6%
C7.04.06 - Vase hand moulder	4	0.060	1.381	-	-	-	-
C7.04.07 - Stacking machine operator	41	0.020	2.626	94.5%	82.0%	63.4%	28.2%
C7.05.01 - Kiln and dryer operator	7	0.022	1.879	>91.4%	89.7%	47.4%	17.3%
C7.06.01 - Brick polishing / trimming machine operator	6	0.013	6.468	84.1%	78.0%	67.8%	50.0%
C7.06.02 - Hand brick polishing and trimming operator	10	0.021	2.634	89.3%	81.3%	71.4%	30.5%
C7.07.01 - Quality control technician	8	0.039	2.830	76.2%	59.6%	30.6%	14.8%
C7.08.01 - Crane / loader operator	18	0.038	2.482	81.8%	70.3%	29.4%	11.5%
C7.08.02 - Forklift operator	21	0.061	2.707	66.8%	43.4%	11.2%	7.1%
C7.09.01 - Warehouse operator	5	0.013	2.079	-	-	-	-
C7.09.02 - Delivery truck driver	1	0.012	-	-	-	-	-
C7.09.03 - Silo operator	3	0.029	2.463	-	-	-	-
C7.10.01 - Polyvalent worker	3	0.038	3.012	-	-	-	-
C7.11.01 - Maintenance mechanic / electrician	9	0.026	1.916	>93.2%	81.6%	53.1%	9.8%
C7.11.02 - Box feeders and conveyor belts operator	3	0.048	1.083	-	-	-	-

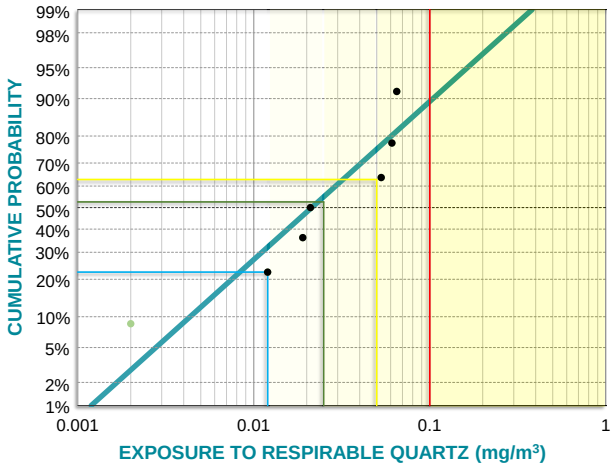
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

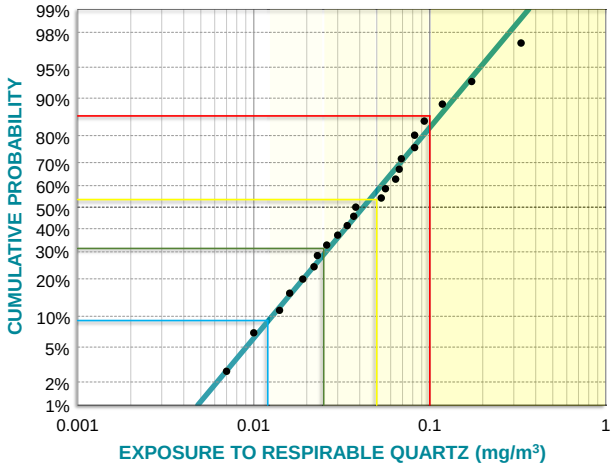
C07.03.01 - Grinder / screener operator



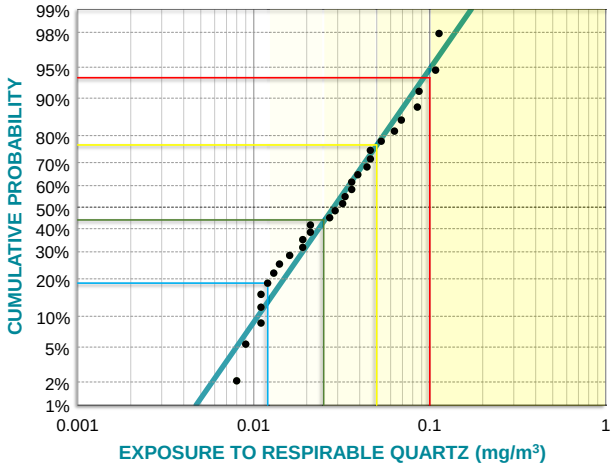
C07.03.02 - Paste mixer



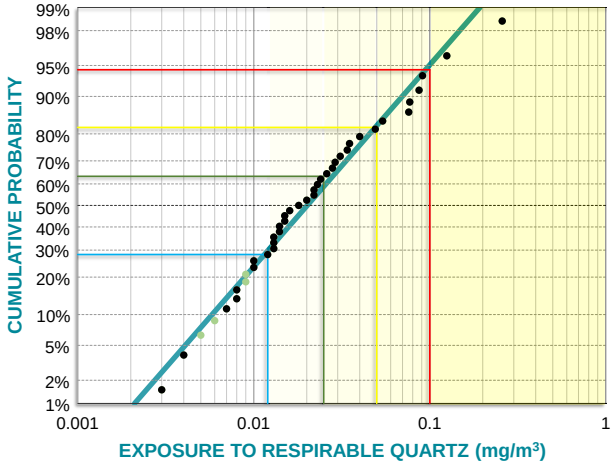
C07.04.01 - Brickmaking machine operator



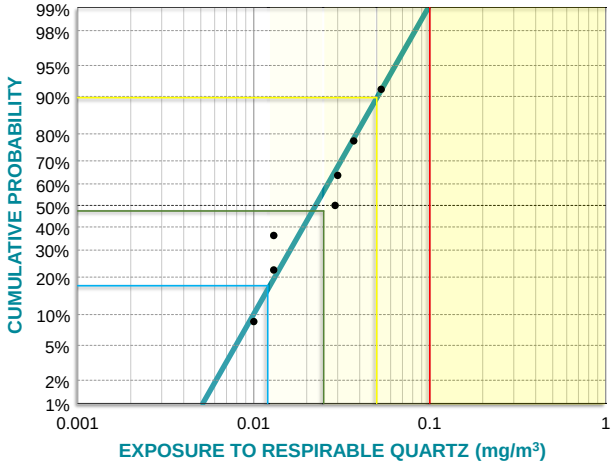
C07.04.05 - Brick hand moulder



C07.04.07 - Stacking machine operator

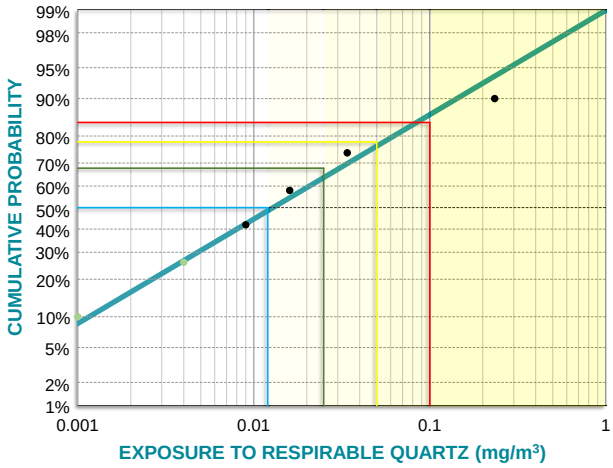


C07.05.01 - Kiln and dryer operator

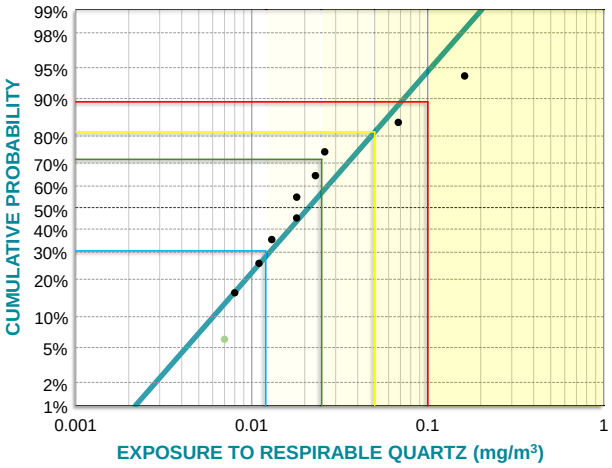


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

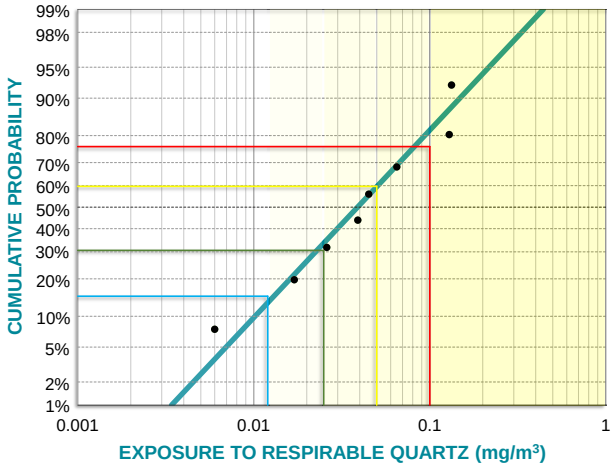
C07.06.01 - Brick polishing / trimming machine operator



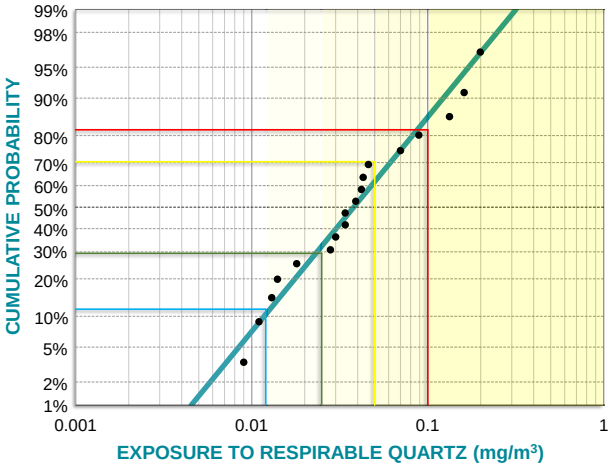
C07.06.02 - Hand brick polishing and trimming operator



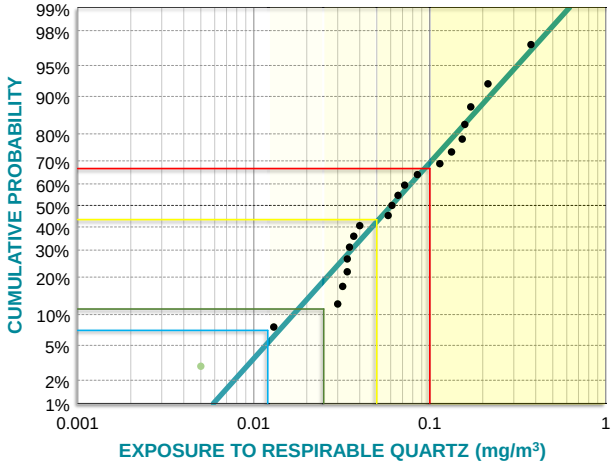
C07.07.01 - Quality control technician



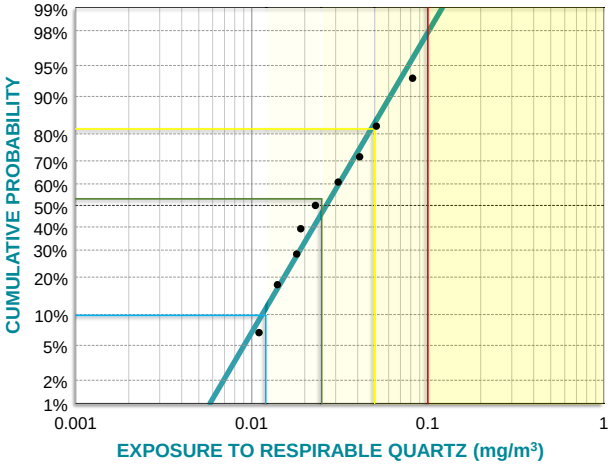
C07.08.01 - Crane / loader operator



C07.08.02 - Forklift operator



C07.11.01 - Maintenance mechanic / electrician



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C7.01.01 - Manager	2	0.150	-	-	-	-
C7.02.01 - Quarryman	2	0.374	-	-	-	-
C7.03.01 - Grinder / screener operator	11	0.522	2.244	>94.4%	90.7%	23.1%
C7.03.02 - Paste mixer	9	0.227	1.666		>93.2%	66.4%
C7.04.01 - Brickmaking machine operator	25	0.418	1.882	>97.5%	97.0%	34.0%
C7.04.02 - Tile drawing machine operator	5	0.206	1.957	-	>88.1%	69.6%
C7.04.03 - Roof tile machine operator	3	0.440	1.376	-	-	-
C7.04.04 - Brick casting machine operator	1	0.412	-	-	-	-
C7.04.05 - Brick hand moulder	36	0.327	1.695		>98.3%	41.0%
C7.04.06 - Vase hand moulder	4	0.399	1.583	-	-	-
C7.04.07 - Stacking machine operator	45	0.278	2.088		>98.6%	58.2%
C7.05.01 - Kiln and dryer operator	7	0.263	1.699		>91.4%	64.0%
C7.06.01 - Brick polishing / trimming machine operator	7	0.295	2.840		>91.4%	43.7%
C7.06.02 - Hand brick polishing and trimming operator	12	0.395	2.694	>94.9%	88.4%	39.6%
C7.07.01 - Quality control technician	9	0.365	1.785	-	>93.2%	54.0%
C7.08.01 - Crane / loader operator	19	0.374	2.874	95.3%	92.2%	43.6%
C7.08.02 - Forklift operator	21	0.631	2.723	>97.1%	76.5%	23.2%
C7.09.01 - Warehouse operator	6	0.222	1.554	-	>90.0%	65.1%
C7.09.02 - Delivery truck driver	1	0.186	-	-	-	-
C7.09.03 - Silo operator	3	0.278	2.864	-	-	-
C7.10.01 - Polyvalent worker	3	0.315	1.392	-	-	-
C7.11.01 - Maintenance mechanic / electrician	9	0.422	1.997		>93.2%	44.0%
C7.11.02 - Box feeders and conveyor belts operator	3	0.349	1.071	-	-	-
C7.11.03 - Workplace cleaner	1	0.100	-	-	-	-

Working processes

The most popular ornamental ceramic types are maiolica (tin-glazed earthenware) and porcelain (from white clay fired at high temperatures). The main source for exposure to RCS is represented by the quartz contained in clay, which in this production has an average quartz content of around 15%. A typical ceramic production cycle, in which red clay (rich with iron oxide) is processed, is described below.

1. **Raw material extraction and storage** – clay is mined in quarries, operating earthmoving equipment such as excavators in combination with dumper trucks. This work phase is preferably classified as B3 Quarrying of clays, pozzolana and feldspar, but can also be classified here when impractical to separate it from the other working phase. Quarried material is then moved to the stockpile area in the factory.
2. **Plastic clay preparation** – the clay is mechanically crushed and charged in a blunger, where it is added to water in a tank and mixed into a slurry (*slip*), then sieved in screens and conducted into a filter press to remove the excess water, finally obtaining rolls of clay. Clay is then maturated for several months in order to increase its plasticity. In small factories, rolls of clay ready for use are bought directly from specialist producers. In earthenware production, dolomite or limestone are added to the clay.
3. **Forming** – the objects are often hand-shaped using a rotating potter's wheel or throwing the wet clay by hand into a shaped plaster mould. Clay can also be placed in metallic moulds and the ceramic ware formed with a mechanic press, or by slip casting of a clay-water suspension into a plaster-cast mould.
4. **Finishing** – the objects are finished using special metal tools to clean off the edges. When ceramic appendages such as handles, spouts and feet are required, they are shaped by hand, or in a mould before being attached to the ceramic body.
5. **Drying and first firing** – the ceramic objects are left to dry naturally, by the sun or indoor, or in dryers for ceramics. Then the artefacts are loaded on cars on rotating wheels with refractory cassettes and put into a kiln for a first firing, after which they are called *biscuits*. Methane gas-fired kilns, lined internally with ceramic fibre blankets are often used; refractory brick insulations and muffle kilns are less common.
6. **Enamelling** – the ceramic enamel/glaze is purchased in powder or liquid form (raw materials include silica, various metal oxides, alumina, colourants and opacifiers) and mixed with water, using a stirrer-agitator motor and a colourant is added if required. Most commonly, the glaze is applied by dipping the biscuit into a glazing bath, where the aqueous solution is absorbed covering the porous terracotta.
7. **Decoration** – each piece is hand-painted in colours, using a fine brush and following design, or the decorative element is added to the object as appliqué. The ceramic piece may also bear patterns incised into the clay (*sgraffito*). Imperfections are removed using a hand-held smoothing/polishing stone.
8. **Transparent glaze application** – a thin film of liquid glass (*vetrina*) applied on the painted biscuit gives resistance to the object and brightness to the colours. Transparent glaze is generally hand-sprayed in a water veil spray booth.
9. **Second firing** – the glazed biscuit is fired a second time to mature the glaze to full hardness.
10. **Storing, packing and shipping** - the products are packed and stored in the warehouse and eventually loaded on a truck for delivery.

Geometric mean and geometric standard deviation values of exposure measurements

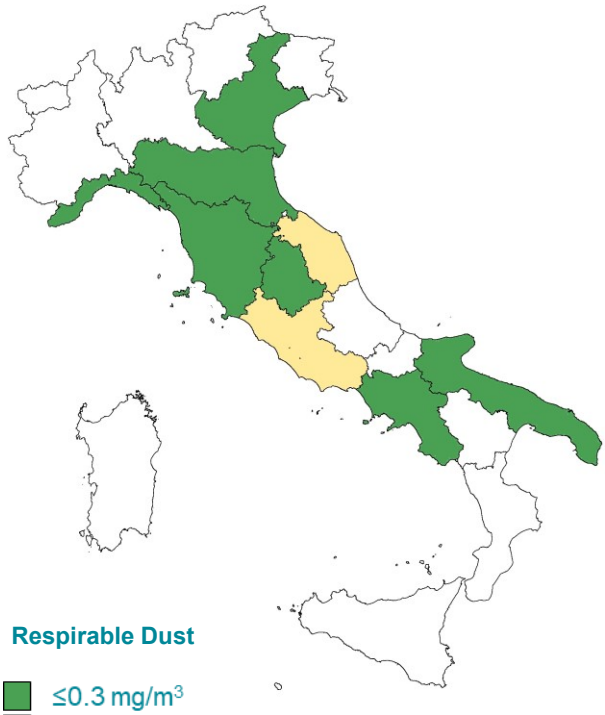
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	254	0.290	2.377	235	0.016	3.546	7.0
STATIC	3	0.182	1.707	3	0.010	1.594	5.7

CERAMIC ORNAMENTAL ARTICLES: Manufacture of ceramic household and ornamental articles

Geometric mean of personal exposure, by region

Respirable Quartz

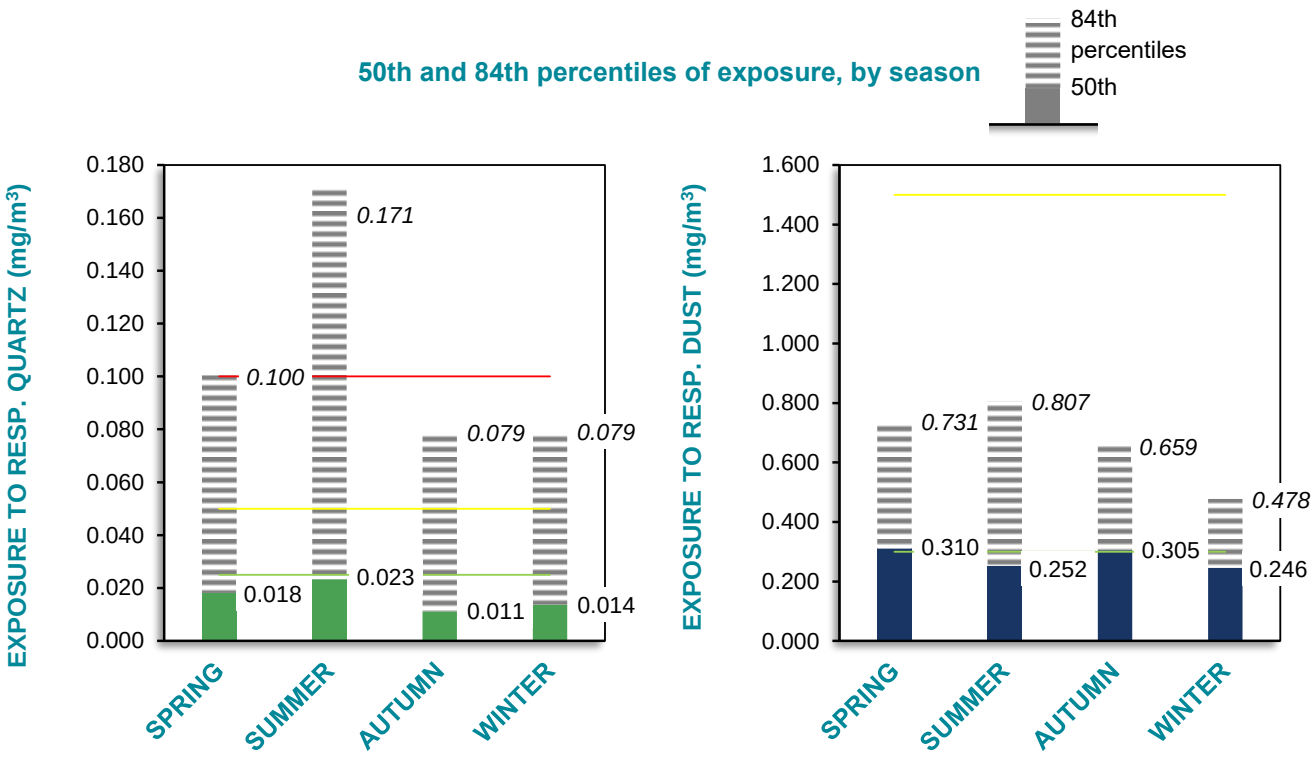
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



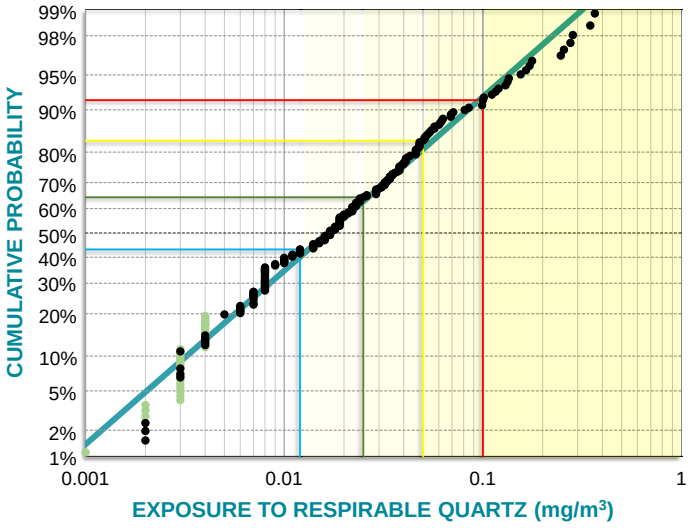
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

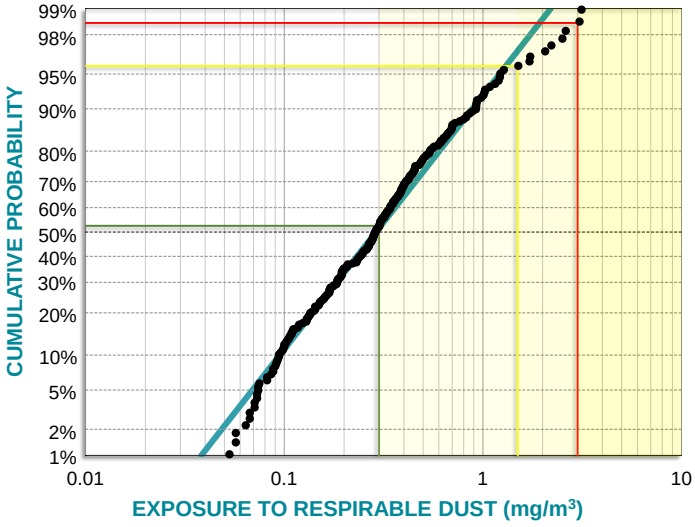


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



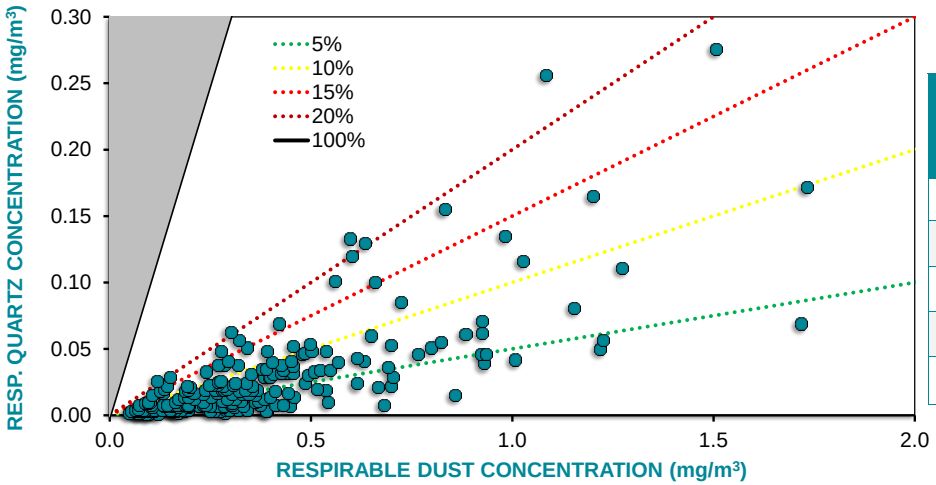
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	91.7%
≤0.05	83.2%
≤0.025	64.5%
≤0.012	43.2%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	98.5%
≤1.5	95.8%
≤0.3	52.6%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	46%
>5% to 10%	35%
>10% to 15%	11%
>15% to 20%	4%
>20%	3%

CERAMIC ORNAMENTAL ARTICLES: Manufacture of ceramic household and ornamental articles

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C8.01 - Management and office work	
C8.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C8.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C8.02 - Composition of the mixture	
C8.02.01 - Paste mixer	Loads and controls the mixing machine for the preparation of rolls of clay paste for the subsequent drawing or moulding. Clay raw material is ground in a mill, charged in a water-filled blunger (mixing machine) to blend and mix clay into a slurry (slip). The mixture passes through screens, excess water is then removed by passing through a filter press and finally the clay mix is de-aired through an extruder (plug mill) that makes the clay denser and more plastic.
C8.03 - Forming	
C8.03.01 - Clay thrower	Places a plastic clay body on top of a rotating plaster mould and forms ware of clay by moulding it with hands into desired shape as it revolves on a potter's wheel.
C8.03.02 - Forming machine operator	Operates automatic ceramic forming machine that shapes clay into ceramic ware such as cups and bowls. Fully automatic machine can make different sizes and shapes of ceramic ware at the same time.
C8.03.03 - Manual casting operator	Casts ceramic ware by filling plaster moulds with semiliquid clay-water suspension (slip). Pours excess slip from moulds when clay shell inside mould has built up to the desired uniform thickness.
C8.03.04 - Moulding press operator	Operates pressing machine that forms clay into ceramic ware. Places a metal mould on the press plate, in which plastic clay is pressed. The forming process can be fully automated through a set of sequential operations in a production line.
C8.03.05 - Plaster mould maker	Makes plaster moulds in which semi-liquid clay (slip) is cast to form ceramic objects. A model with the exact shape of the object to be reproduced is used to pour the liquid plaster. Carries out the process by operating an automated machine or manually.
C8.04 - Finishing	
C8.04.01 - Ware finisher	Trims excess clay and smooths edges of greenware preparatory to biscuit firing, by using a moist sponge and moving a knife over the ware surface of the object positioned on a whirler. Cleans and finishes biscuit ware by hand, grinding down rough spots with abrasive stones or smoothing ware surfaces with sandpaper.
C8.04.02 - Ceramic biscuit blower	Cleans biscuit ware with an air hose, releasing a blast of compressed -air hose on the object (preparatory to glazing).
C8.04.03 - Ceramic handle sticker	Applies appendages such as handles, spouts and feet to wares (pitchers, vases, bowls), when required. Pieces are shaped by hand, pressing or slip casting them into moulds and attached to ceramic bodies by hand.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C8.05 - Kiln firing	
C8.05.01 - Kiln loading/unloading operator	Operates the kiln for ceramic products. Loads the kiln cars on rotating wheels with the refractory cassettes and introduces them into the kiln. After the firing is completed, unloads the cooled wares and stacks them on pallets in the warehouse.
C8.06 - Enamelling and glazing	
C8.06.01 - Glazing operator	Applies a coat of opaque enamel by dipping biscuit ware in a solution (Dipper) to cover article before decoration is applied. Coats ware surfaces with enamel or glaze using a spray gun (Sprayer). After decoration, sprays pottery with a coating of transparent glaze. Enamel/glaze products are generally bought in powder or liquid forms and prepared in the ceramic factory.
C8.07 - Decoration	
C8.07.01 - Decorative painter / sgraffito decorator	Decorates plates, bowls, saucers and other biscuit ware by painting freehand design using a very fine brush, e.g. by transferring a preparatory drawing from paper to the ware surface (pounce technique). May use incision into the clay body when the clay is soft (*sgraffito*). Decoration is generally hand-made by an individual artisan but can also be applied by line decorators.
C8.07.02 - Engraving / screen printing decorator	Incises a design onto ware surface by cutting grooves into it (engraving). Transfers ink onto ware substrate using a mesh (screen printing). May apply decorations onto glazed biscuits or into clay body.
C8.07.03 - Decal applier	Transfers pictures or printed designs to surfaces by moisture process (decalcomania) onto pottery and porcelain ware, by hand or using an automated machine. The images are first screen printed on a special paper and then pressed against the ceramic substrate.
C8.08 - Quality control and laboratory testing	
C8.08.01 - Quality control technician	Examines finished ware to verify accuracy of shapes and sizes using hand tools as well as physical and chemical properties of ceramic objects.
C8.09 - Warehousing and packaging	
C8.09.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Drives forklift to pick up incoming stock or to deliver materials to designated area.
C8.10 - Various workspaces	
C8.10.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C8.11 - Mechanical and electrical maintenance / cleaning	
C8.11.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C8.11.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

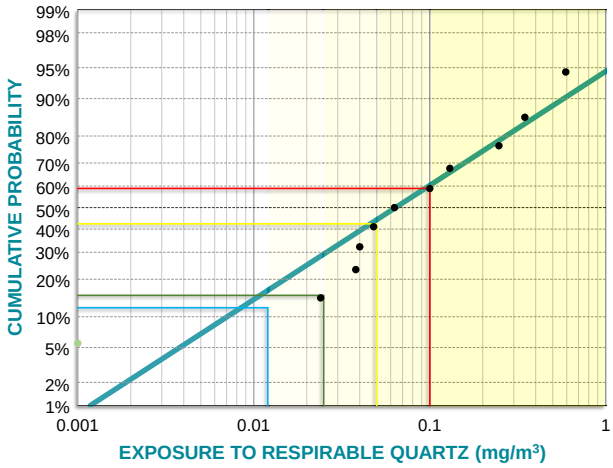
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C08.01.01 - Manager	5	0.017	3.330	-	-	-	-
C08.02.01 - Paste mixer	11	0.064	5.517	58.9%	42.4%	15.1%	12.0%
C08.03.01 - Clay thrower	6	0.029	2.932	84.0%	67.7%	51.8%	19.3%
C08.03.02 - Forming machine operator	6	0.024	1.907	>90.0%	73.6%	59.8%	12.9%
C08.03.03 - Manual casting operator	17	0.029	3.766	77.8%	72.3%	52.2%	21.0%
C08.03.04 - Moulding press operator	26	0.030	1.834	>97.6%	78.6%	38.6%	11.8%
C08.03.05 - Plaster mould maker	4	0.017	1.949	-	-	-	-
C08.04.01 - Ware finisher	43	0.036	3.028	78.9%	64.6%	37.7%	19.9%
C08.04.02 - Ceramic biscuit blower	2	0.005*	-	-	-	-	-
C08.04.03 - Ceramic handle sticker	9	0.014	1.591		>93.2%	82.4%	39.2%
C08.05.01 - Kiln loading/unloading operator	18	0.010	2.942	>96.6%	94.4%	78.0%	58.2%
C08.06.01 - Glazing operator	26	0.013	4.044	93.8%	90.3%	75.6%	53.3%
C08.07.01 - Decorative painter / sgraffito decorator	19	0.005	2.154			>96.8%	89.2%
C08.07.02 - Engraving / screen printing decorator	1	0.041	-	-	-	-	-
C08.07.03 - Decal applier	16	0.007	2.051			>90.0%	68.8%
C08.08.01 - Quality control technician	4	0.004*	1.693*	-	-	-	-
C08.09.01 - Warehouse operator	15	0.005	1.711			>95.9%	93.8%
C08.10.01 - Polyvalent worker	5	0.012	3.131	-	-	-	-
C08.11.01 - Maintenance mechanic / electrician	1	0.006	-	-	-	-	-
C08.11.02 - Workplace cleaner	1	0.047	-	-	-	-	-

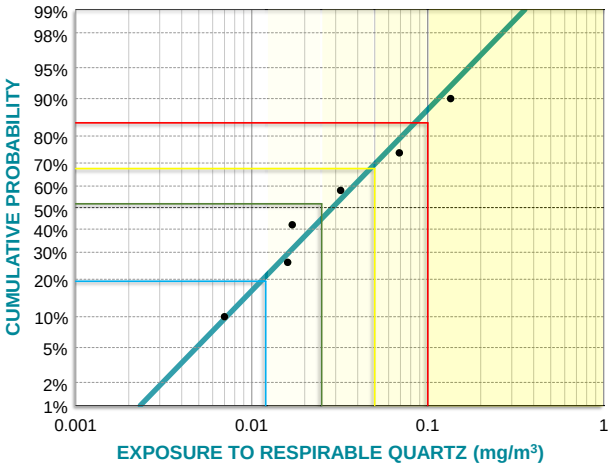
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

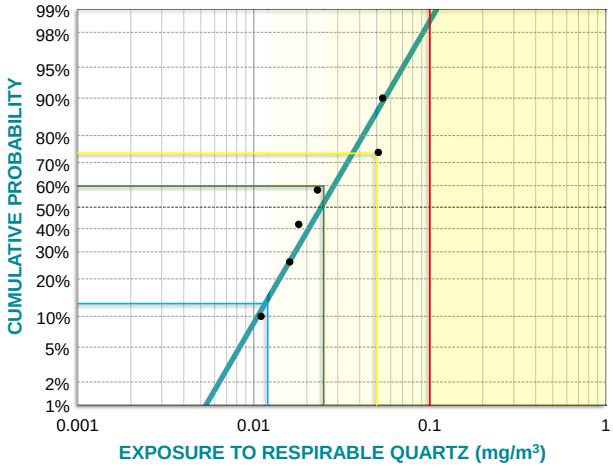
C08.02.01 - Paste mixer



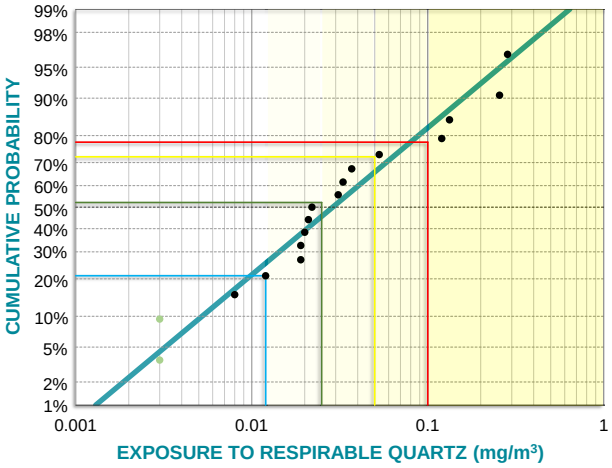
C08.03.01 - Clay thrower



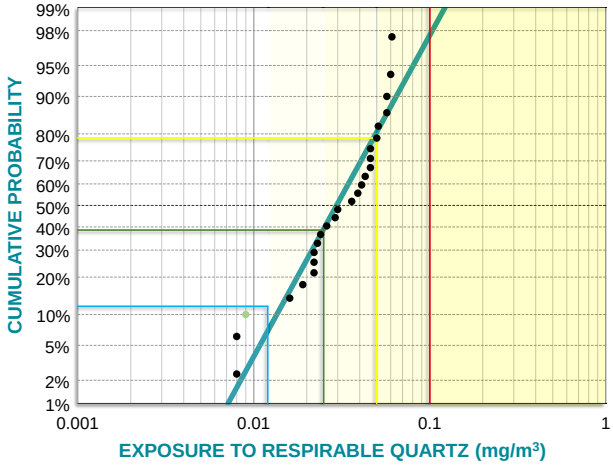
C08.03.02 - Forming machine operator



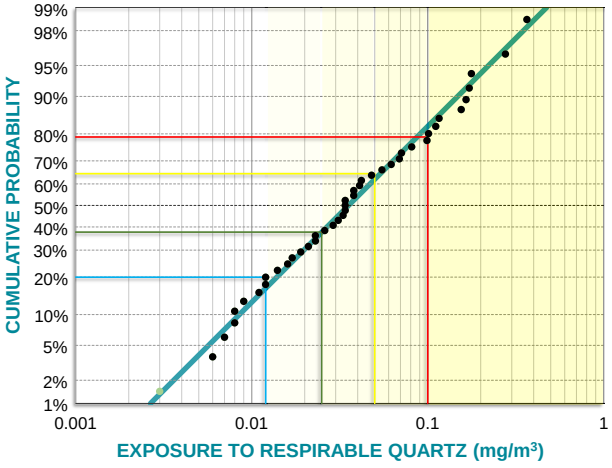
C08.03.03 - Manual casting operator



C08.03.04 - Moulding press operator

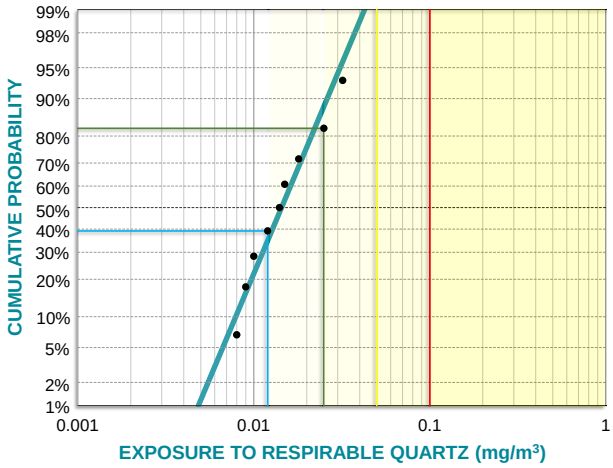


C08.04.01 - Ware finisher

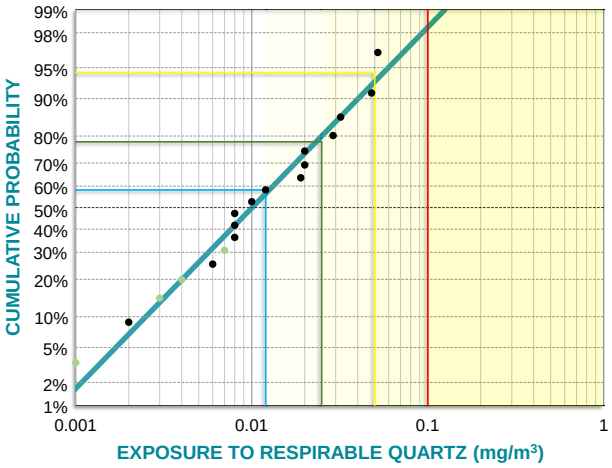


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

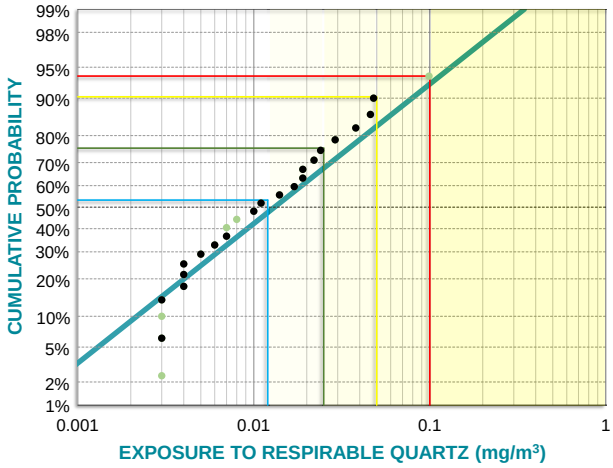
C08.04.03 - Ceramic handle sticker



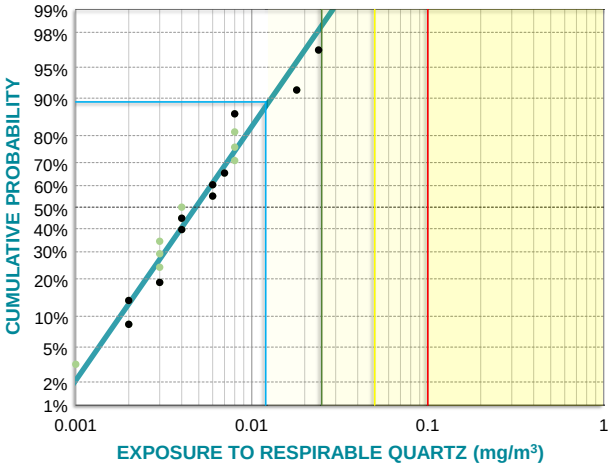
C08.05.01 - Kiln loading/unloading operator



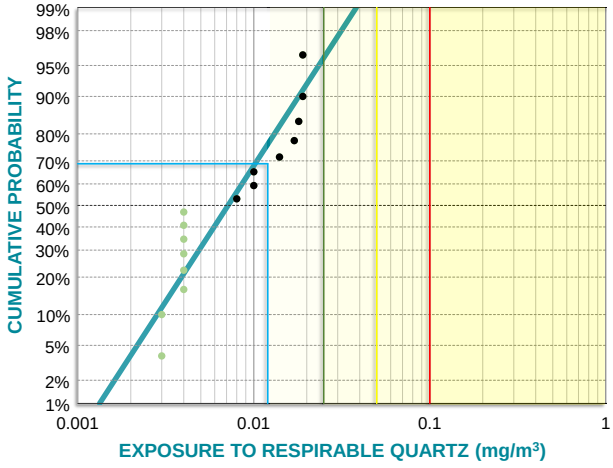
C08.06.01 - Glazing operator



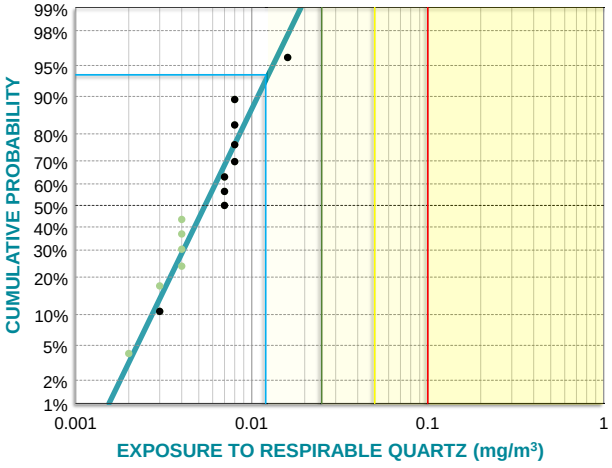
C08.07.01 - Decorative painter / sgraffito decorator



C08.07.03 - Decal applier



C08.09.01 - Warehouse operator



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C08.01.01 - Manager	5	0.273	2.203	-	-	-
C08.02.01 - Paste mixer	14	0.401	3.131	95.1%	84.9%	39.5%
C08.03.01 - Clay thrower	8	0.345	2.607	>92.4%	90.2%	42.5%
C08.03.02 - Forming machine operator	6	0.341	1.227		>90.0%	18.9%
C08.03.03 - Manual casting operator	17	0.412	1.997	>96.4%	94.0%	34.3%
C08.03.04 - Moulding press operator	27	0.418	2.241		>97.7%	33.7%
C08.03.05 - Plaster mould maker	4	0.405	1.465	-	-	-
C08.04.01 - Ware finisher	44	0.466	2.521	96.1%	89.5%	30.8%
C08.04.02 - Ceramic biscuit blower	2	0.261	-	-	-	-
C08.04.03 - Ceramic handle sticker	10	0.289	1.667		>93.9%	44.0%
C08.05.01 - Kiln loading/unloading operator	20	0.195	1.791		>96.9%	77.7%
C08.06.01 - Glazing operator	32	0.239	2.681	95.6%	94.1%	60.5%
C08.07.01 - Decorative painter / sgraffito decorator	20	0.161	1.899		>96.9%	81.2%
C08.07.02 - Engraving / screen printing decorator	2	0.321	-	-	-	-
C08.07.03 - Decal applier	16	0.127	1.557			>96.2%
C08.08.01 - Quality control technician	4	0.196	1.978	-	-	-
C08.09.01 - Warehouse operator	15	0.220	1.661		>95.9%	74.1%
C08.10.01 - Polyvalent worker	6	0.286	2.640		>90.0%	34.3%
C08.11.01 - Maintenance mechanic / electrician	1	0.194	-	-	-	-
C08.11.02 - Workplace cleaner	1	0.484	-	-	-	-

Working processes

Fire-clay and vitreous china are the two types of ceramics used in the production of sanitary ware, with differences in composition and technological characteristics of workability, performance and aesthetics. Vitreous china is generally used for common sized flush toilets, bidets and washbasins. For larger pieces (shower trays, consoles, etc.), fire-clay is employed. In the following, the main steps of the production cycle are described.

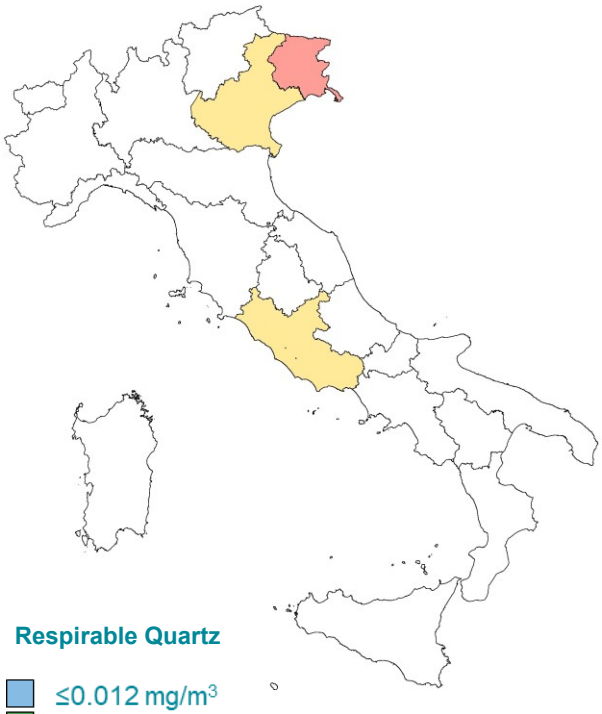
1. **Plastic clay preparation** – the ingredients (clays, kaolin, feldspars, quartz and chamotte) are generally deposited in storage silos and from there are transferred to special concrete compartments, from which they are removed by vehicles such as forklifts, trucks or power shovels. The powdery raw materials are loaded, dosed and water is added to form a liquid suspension (slip). Today, production generally uses ready-to-use mixtures and glazes.
2. **Modelling** – consists of making models and plaster moulds to pour slip in. Complex models are made using synthetic resins. Moulds are often purchased from specialist firms that create them for a project.
3. **Casting** – the slip is poured into moulds, whose surface is covered with a thin layer of talcum powder to facilitate the subsequent detachment of the solidified object. In manual pouring, the slip is fed through a portable tube connected to the feeding line. In the automatic casting lines, the filling of the moulds takes place by means of a pressure adduction system. The operator controls the system instrumentally, waiting for the mixture to form a suitable thickness against the wall of the mould: then the mould is emptied of the excess slip and disassembled.
4. **Demoulding and finishing** – the pieces are left to dry for about a day on special bases. During that time period the workers are engaged in finishing the pieces that were de-moulded the previous day. Finishing consists of the elimination of casting burrs by means of an abrasive sponge and scraper. The operation is carried out by positioning the single pieces on small lathes equipped with suction systems.
5. **Drying and testing** – the pieces are mounted on trolleys and placed in a dryer for several hours until they reach the required level of humidity. In the subsequent testing, the integrity of the product is verified. The surface is cleaned from dust deposits by compressed air jets. The surface of identified critical areas is wet with a sponge soaked in water and petroleum, in order to highlight any potential cracks. This operation is also carried out by positioning the piece on lathes.
6. **Glazing** – the glaze (a mixture of quartz, kaolin, clays, feldspars and colourants, with water) can be purchased from third-party companies or prepared in-house. In this case, once the mixing is finished, the glaze is withdrawn through pumps, sieved and transferred into tanks where an adhesive is added. Glazing the surface of the piece can be manual, using an airbrush gun inside a vacuum cabin, or automatic using a spraying robot. Pot siphons can be glazed by wetting (filling and subsequent emptying of excess glaze).
7. **Firing, sorting, retouching and annealing and storage** – once the glazing has been completed, the pieces are loaded onto trolleys and fired in intermittent furnaces at temperatures of about 1250°C. After cooling, they are sent to quality control for sorting. The imperfection-free pieces are sent to the warehouse for packaging.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	623	0.454	2.358	606	0.040	2.643	10.5
STATIC	7	0.158	1.831	7	0.006	1.582	3.6

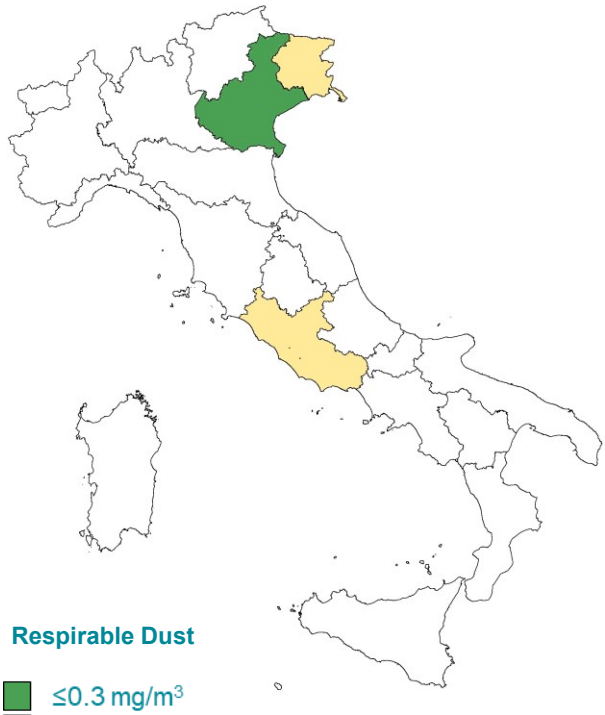
CERAMIC SANITARY FIXTURES: Manufacture of ceramic sanitary fixtures

Geometric mean of personal exposure, by region



Respirable Quartz

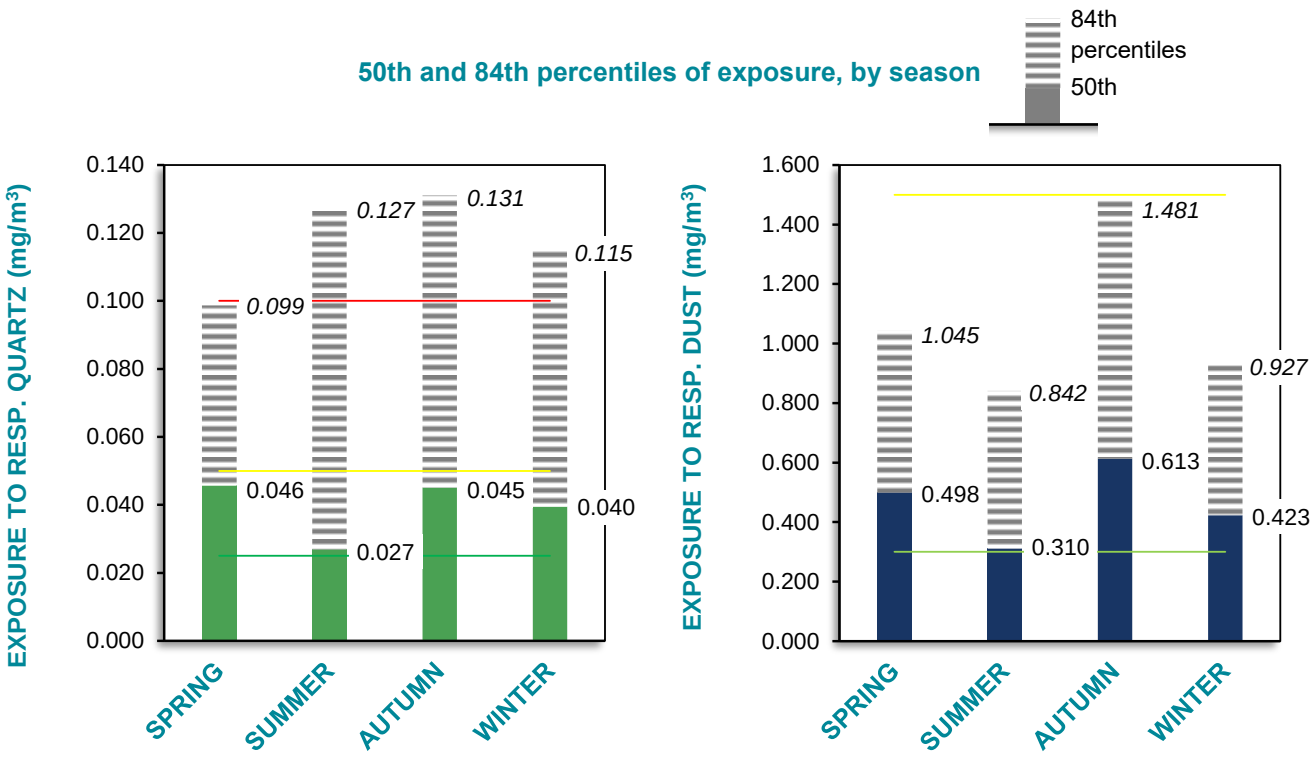
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



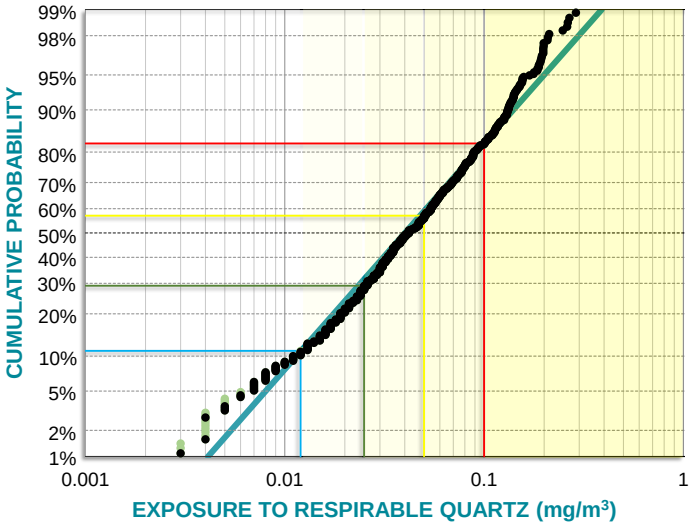
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

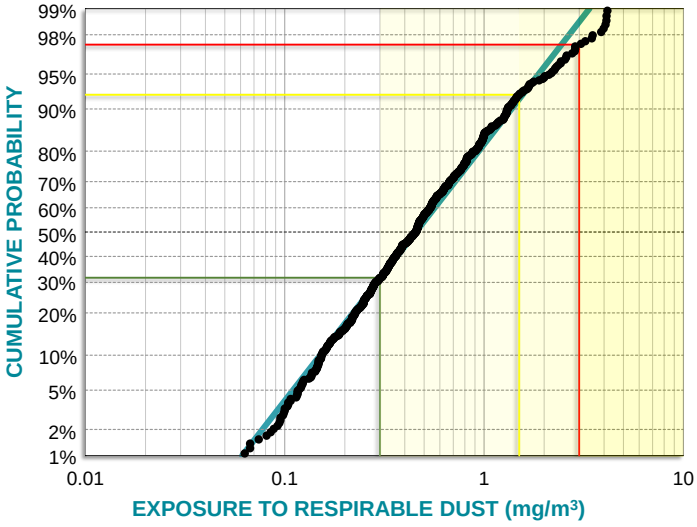


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



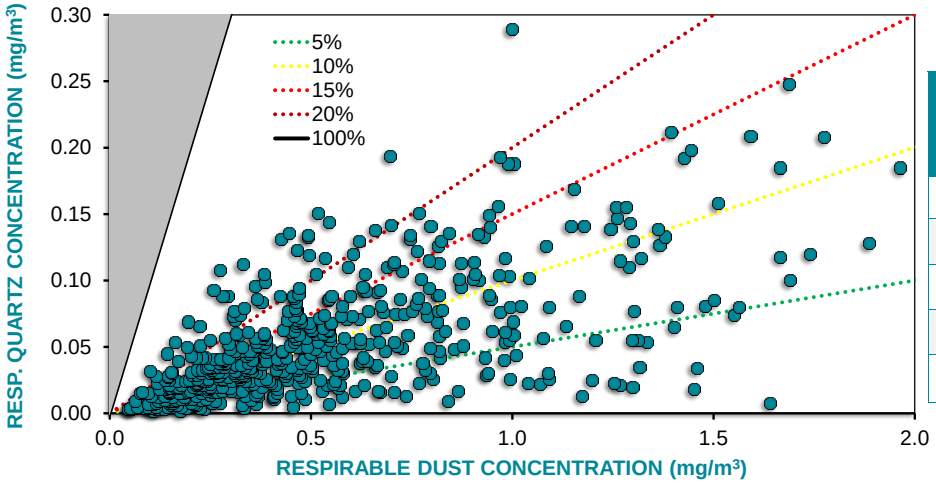
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	82.4%
≤0.05	57.2%
≤0.025	29.1%
≤0.012	11.0%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	97.4%
≤1.5	92.4%
≤0.3	31.7%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	18%
>5% to 10%	34%
>10% to 15%	29%
>15% to 20%	11%
>20%	7%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C9.01 - Management and office work	
C9.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C9.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C9.01.03 - Department foreman	Supervises and organises the equipment, staff and processes of the department. May carry out working tasks in the department (e.g. casting, spraying, etc.).
C9.02 - Composition of the mixture	
C9.02.01 - Slip mixer	Operates a mini-loader to move clay from silo and load it into the dissolvers, where the preparation of a semi-liquid mixture (*slip*) takes place. Corrects the composition by adding the required mineral powders from bags.
C9.03 - Forming by casting	
C9.03.01 - Manual casting operator	Assembles plaster mould for sanitaryware and manually fills it with liquid slip. The mould is first coated on the inside with a layer of talcum powder, then the slip is poured in through a rubber tube. After ware is dried, removes the greenware from the mould and places it on its base for a first drying.
C9.03.02 - Casting machine operator	Operates automatic casting machine for sanitaryware, in which the plaster mould is assembled, coated on the inside with a layer of talcum powder, then the liquid slip is poured in through an automatic adduction system that is controlled during the filling phase. After ware has dried, opens the mould and removes the greenware. In some plants, even the unloading of pieces from the casting line is automated.
C9.03.03 - High-pressure casting machine operator	Operates casting machine for sanitaryware with very high-pressure and speed, in which most of processes are carried out automatically. Resin moulds are clamped, filled with slip, high-pressure is given to form the casting layer in a few minutes, then pressure is reduced and air is used to unload the excess slip. Drying is carried out using air. The mould is opened, clamp released and greenware removed. High-pressure casting technology strongly reduces the formation of casting burrs. In some plants, even the unloading of pieces from the casting line is automated.
C9.03.04 - Plaster mould maker	Makes plaster moulds in which semi-liquid clay (*slip*) is cast for sanitaryware production. Prepares the plaster mixture and pours it on a resin model with the shape to be reproduced. After casting, removes the resulting plaster mould.
C9.04 - Finishing	
C9.04.01 - Ware finisher	Places the workpiece coming from the casting department on a lathe, usually in a suction cabin. Uses scraper and abrasive sponge to remove the casting burrs at the mould junction points and then places the part back on the trolley for transport to the dryer. In high-pressure casting plants, this step is generally not necessary as the technology allows the production of parts with very few casting burrs.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C9.04.02 - Dryer operator	Operates the dryers. Checks the correct execution of the drying process of ceramic sanitaryware controlling its parameters. Loads the sanitaryware on the dryer car and moves it into the dryer. At the end of the drying phase, moves the dryer car to the testing station.
C9.04.03 - Ware testing operator	Places the dried ware on a lathe in a suction cabin. Removes the imperfections using an abrasive sponge. Blows the workpiece with compressed air to remove dust and inspects for fracture lines by brushing the critical parts with oil.
C9.04.04 - Sanitary greenware blower	Cleans sanitary greenware with an air hose, releasing a blast of compressed air on the workpiece. The operation may be carried out when the period of time between two work stages is long enough.
C9.05 - Glazing	
C9.05.01 - Glaze maker	Verifies the characteristics of glaze (usually purchased from specialised companies) and corrects composition to ensure conformance to requirements.
C9.05.02 - Manual glazing operator	Applies a coat of liquid glaze by spraying the workpiece using a hand held spray gun in a water veil spray booth. Places the glazed piece back on the trolley and moves it to the firing department.
C9.05.03 - Glazing robot operator	Operates and controls a glaze spraying robot to apply a coat of liquid glaze on the workpiece. Places the glazed piece back on the trolley and moves it to the firing department.
C9.05.04 - Siphon glazing operator	Applies a coat of liquid glaze by positioning the workpiece on a tilting support, filling it with liquid glaze and emptying it by tipping the support. Places the glazed sanitary siphon back on the trolley and moves it to the firing department.
C9.06 - Decoration	
C9.06.01 - Decal applier	Transfers pictures or printed designs to surfaces by moisture process (*decalcomania*) onto ceramic sanitary fixtures, by hand or using an automated machine. The images are first screen printed on a special paper and then pressed against the ceramic substrate.
C9.07 - Kiln firing	
C9.07.01 - Kiln loading/unloading operator	Prepares the kiln car by manually loading individual workpieces from the spraying department. At the end of the thermal cycle, removes the car from the kiln, places it on a side rail to cool and unloads the fired pieces.
C9.07.02 - Imperfection retouching operator	Uses grinding wheel and brush glaze to remove small imperfections. The workpiece is then fired again in the kiln.
C9.07.03 - Grinding operator	Loads the workpiece (e.g. a washbasin) in a surface grinder machine for sanitary ware, where a grinding cycle is automatically carried out using a numerically controlled grinding wheel. Supervises the process and unloads the ware.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C9.08 - Quality control and laboratory testing	
C9.08.01 - Laboratory technician	Takes glaze and slip samples from the processing plants and performs laboratory examination to determine characteristics of materials (density, thixotropy, specific weight, etc.) for compliance analysis and adjustments of composition.
C9.09 - Warehousing and packaging	
C9.09.01 - Warehouse operator	Examines the finished pieces in order to classify their quality. Operates boxing and palletising systems. Drives forklift to move palletised products.
C9.10 - Various workspaces	
C9.10.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C9.11 - Mechanical and electrical maintenance / cleaning	
C9.11.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C9.11.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

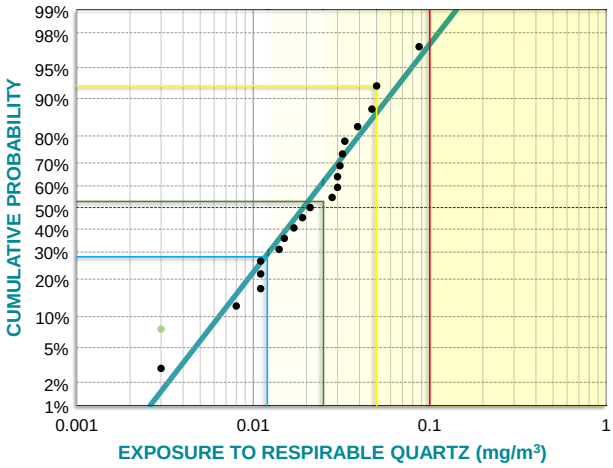
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C9.01.01 - Manager	21	0.019	2.350	>97.1%	92.4%	52.9%	28.1%
C9.02.01 - Slip mixer	13	0.033	1.710	>95.3%	76.2%	44.2%	<4.7%
C9.03.01 - Manual casting operator	109	0.044	1.789	92.8%	59.2%	14.3%	3.8%
C9.03.02 - Casting machine operator	93	0.032	2.187	94.3%	68.8%	33.9%	7.0%
C9.03.03 - High-pressure casting machine operator	7	0.037	1.825	>91.4%	50.0%	21.5%	8.6%
C9.03.04 - Plaster mould maker	6	0.008	2.882		>90.0%	83.7%	56.7%
C9.04.01 - Ware finisher	44	0.065	2.376	60.5%	31.7%	14.4%	5.9%
C9.04.02 - Dryer operator	1	0.031	-	-	-	-	-
C9.04.03 - Ware testing operator	79	0.072	2.616	57.6%	26.0%	16.6%	6.7%
C9.04.04 - Sanitary greenware blower	1	0.020	-	-	-	-	-
C9.05.01 - Glaze maker	7	0.035	1.804	>91.4%	68.9%	36.2%	<8.6%
C9.05.02 - Manual glazing operator	74	0.073	2.321	61.2%	27.8%	6.9%	3.5%
C9.05.03 - Glazing robot operator	15	0.070	2.019	61.7%	41.1%	5.4%	<4.1%
C9.05.04 - Siphon glazing operator	2	0.022	-	-	-	-	-
C9.06.01 - Decal applier	3	0.009	1.712	-	-	-	-
C9.07.01 - Kiln loading/unloading operator	67	0.024	2.890	90.0%	75.7%	54.5%	23.2%
C9.07.02 - Imperfection retouching operator	5	0.060	2.341	-	-	-	-
C9.07.03 - Grinding operator	3	0.041	1.214	-	-	-	-
C9.09.01 - Warehouse operator	32	0.013	2.566	>98.1%	89.5%	77.2%	43.9%
C9.10.01 - Polyvalent worker	19	0.031	1.922	>96.8%	74.0%	39.6%	9.9%
C9.11.01 - Maintenance mechanic / electrician	4	0.021	2.787	-	-	-	-
C9.11.02 - Workplace cleaner	1	0.012*	-	-	-	-	-

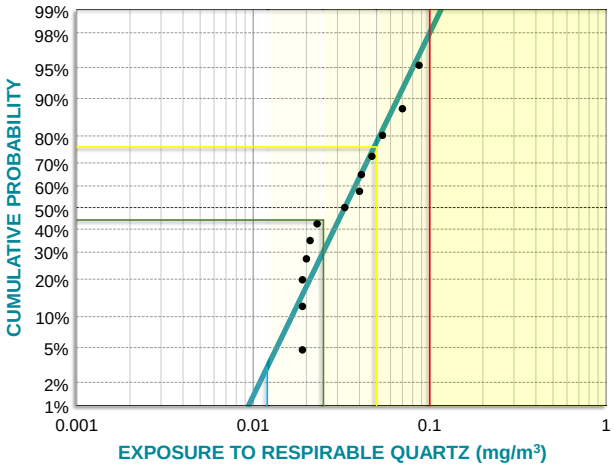
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

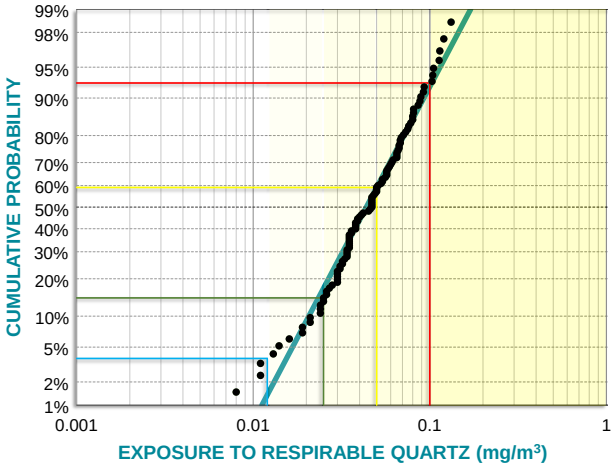
C09.01.01 - Manager



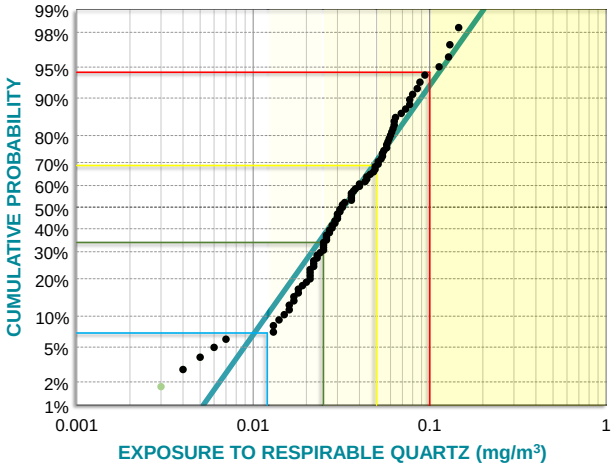
C09.02.01 - Slip mixer



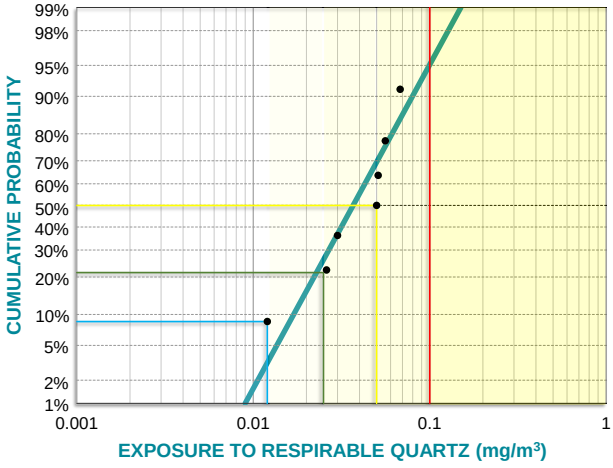
C09.03.01 - Manual casting operator



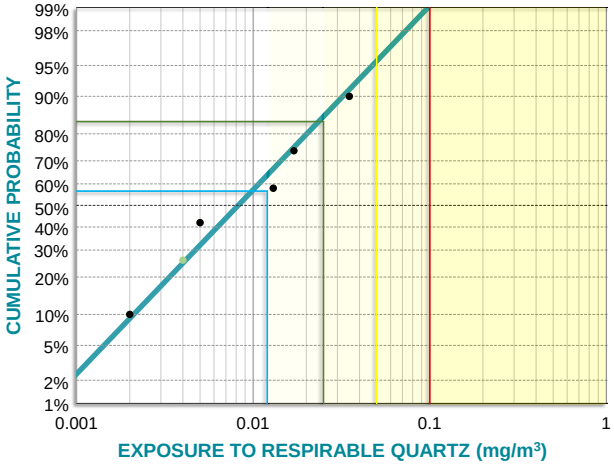
C09.03.02 - Casting machine operator



C09.03.03 - High-pressure casting machine operator

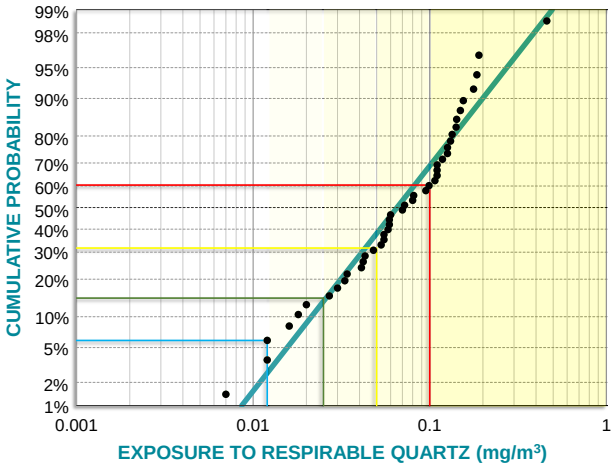


C09.03.04 - Plaster mould maker

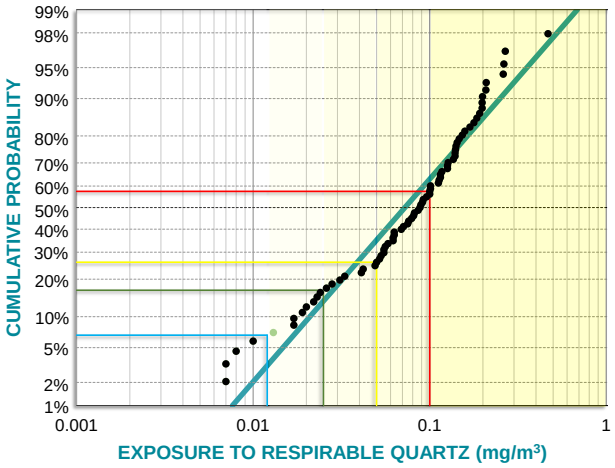


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

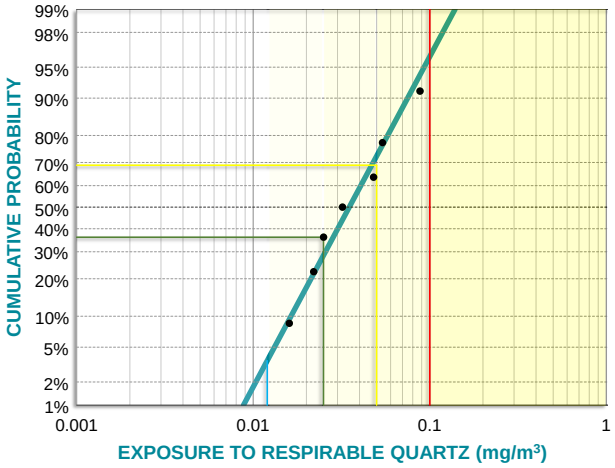
C09.04.01 - Ware finisher



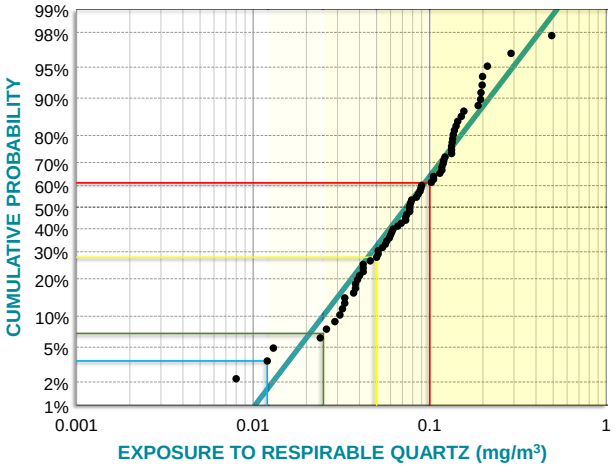
C09.04.03 - Ware testing operator



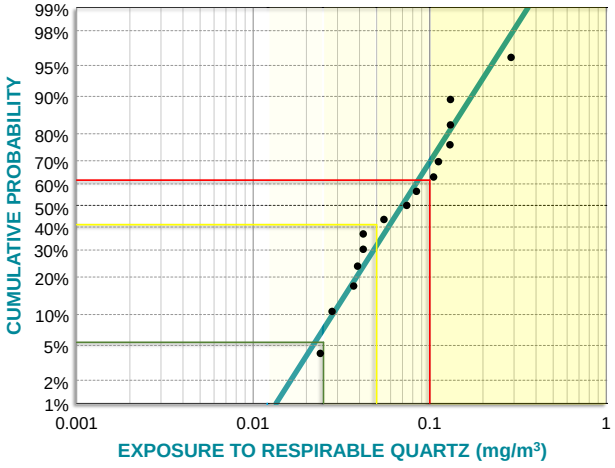
C09.05.01 - Glaze maker



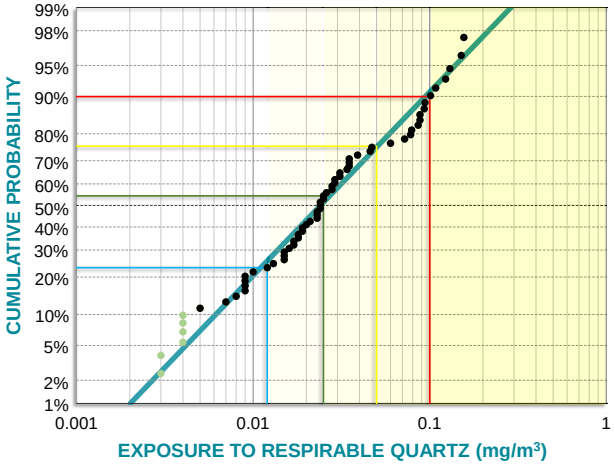
C09.05.02 - Manual glazing operator



C09.05.03 - Glazing robot operator

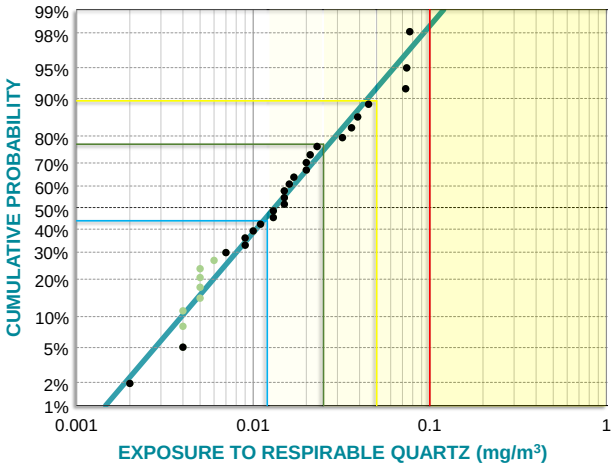


C09.07.01 - Kiln loading/unloading operator

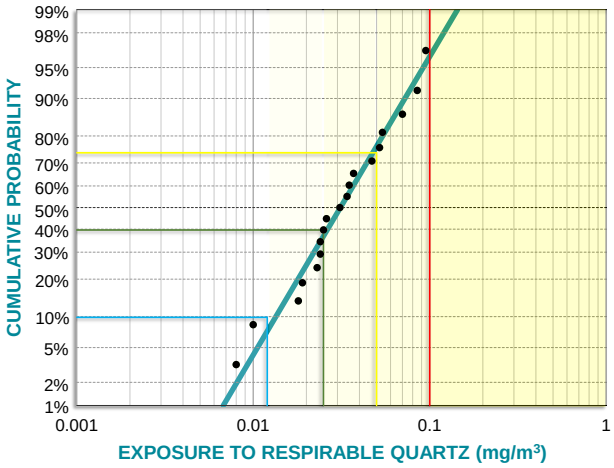


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C09.09.01 - Warehouse operator



C09.10.01 - Polyvalent worker



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C9.01.01 - Manager	24	0.227	2.305	96.8%	95.3%	72.1%
C9.02.01 - Slip mixer	16	0.280	1.728		>96.2%	55.5%
C9.03.01 - Manual casting operator	111	0.586	1.922	98.0%	91.7%	12.9%
C9.03.02 - Casting machine operator	94	0.513	2.044	98.2%	94.0%	23.1%
C9.03.03 - High-pressure casting machine operator	8	0.300	1.618		>92.4%	38.3%
C9.03.04 - Plaster mould maker	7	0.422	2.962		>91.4%	33.7%
C9.04.01 - Ware finisher	44	0.740	2.373	92.4%	80.8%	14.4%
C9.04.02 - Dryer operator	2	0.180	-	-	-	-
C9.04.03 - Ware testing operator	80	0.706	2.505	94.9%	81.6%	18.2%
C9.04.04 - Sanitary greenware blower	1	0.279	-	-	-	-
C9.05.01 - Glaze maker	7	0.250	1.306		>91.4%	65.5%
C9.05.02 - Manual glazing operator	76	0.577	2.309	94.3%	90.9%	15.8%
C9.05.03 - Glazing robot operator	15	0.389	1.701		>95.9%	36.9%
C9.05.04 - Siphon glazing operator	2	0.133	-	-	-	-
C9.06.01 - Decal applier	3	0.343	1.743	-	-	-
C9.07.01 - Kiln loading/unloading operator	69	0.264	2.170	>99.1%	98.4%	61.0%
C9.07.02 - Imperfection retouching operator	5	0.503	2.760	-	-	-
C9.07.03 - Grinding operator	3	0.315	1.268	-	-	-
C9.09.01 - Warehouse operator	32	0.205	1.872		>98.1%	66.7%
C9.10.01 - Polyvalent worker	19	0.309	1.903		>96.8%	55.4%
C9.11.01 - Maintenance mechanic / electrician	4	0.271	2.254	-	-	-
C9.11.02 - Workplace cleaner	1	0.121	-	-	-	-

Working processes

Cements are mixtures of calcium silicates and calcium aluminates and are produced by firing limestone and clay or marl at high temperatures. European standard EN 197-1:2011 defines five types of cement: type I-Portland cement (clinker ≥95%), type II-Portland composite cement (clinker ≥65%), type III-Blast furnace cement, type IV-Pozzolanic cement and type V-Composite cement. The clinker obtained by heating is finely ground and added with gypsum to obtain Portland cement, which is the most common type of cement used as the basic ingredient of concrete in construction; it has a crystalline silica content lower than 0.1%. Crystalline silica content can instead be greater in the blended cement (types II, III, IV and V), from the materials added to the clinker; in fact, the quartz content in these cement types can exceed 1%. Typical work phases in a cement plant are described below.

1. **Mining** – marl (or clay) and limestone are extracted from quarries. The activity includes operations such as drilling of the rock, loading and blasting of mines, loading and transport of extracted material to the stockpile area and then to the crushing plant. This work phase is preferably classified in group B *Mining and quarrying*, but can also be classified here when unpractical to separate it from the other working phase.
2. **Crushing and storage** – the extracted marls and limestones, usually in coarse size, are crushed, loaded on a hopper and handled through conveyor belts or trucks and carried to the raw material storage.
3. **Grinding of crushed material** – crushed materials are finely ground in the raw mills, then the raw meal is stored in silos.
4. **Preparation for the burning** – the material is prepared by dry or semi-dry processes.

   - Dry process (cyclone tower): the raw meal is brought to height and prepared for the burn passing through the cyclone tower, composed of a preheater and pre-calciner system.

   - Semi-dry process (granulators) - the raw meal is carried at a height, moistened with water in a granulator plate, then transported on a carpet and preheated in the *Lepol* grid.
5. **Burning** – the raw meal is loaded in the hopper of a slightly inclined rotary kiln, where it turns into clinker, the basic semi-finished product, a fundamental component of cement.
6. **Drying** – clinker is dried in rotary or static driers and then stored in silos.
7. **Cement grinding** – after the addition of additives (e.g. gypsum) and correctives, the clinker is ground in ball mills, obtaining a powder with grain size lower than 40 µm (*cement*).
8. **Quality control** – samples of cement are taken at regular intervals from the production process and brought to the laboratory for checking the quality requirements.
9. **Packing and shipping** – the cement can be loaded in bulk form on trucks for delivery, or is bagged by a bag filling machine, stacked on pallets and finally shipped by truck to customers.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	64	0.651	2.952	59	0.007	2.578	1.7
STATIC	1	0.215	-	1	0.002	-	0.9

Geometric mean of personal exposure, by region

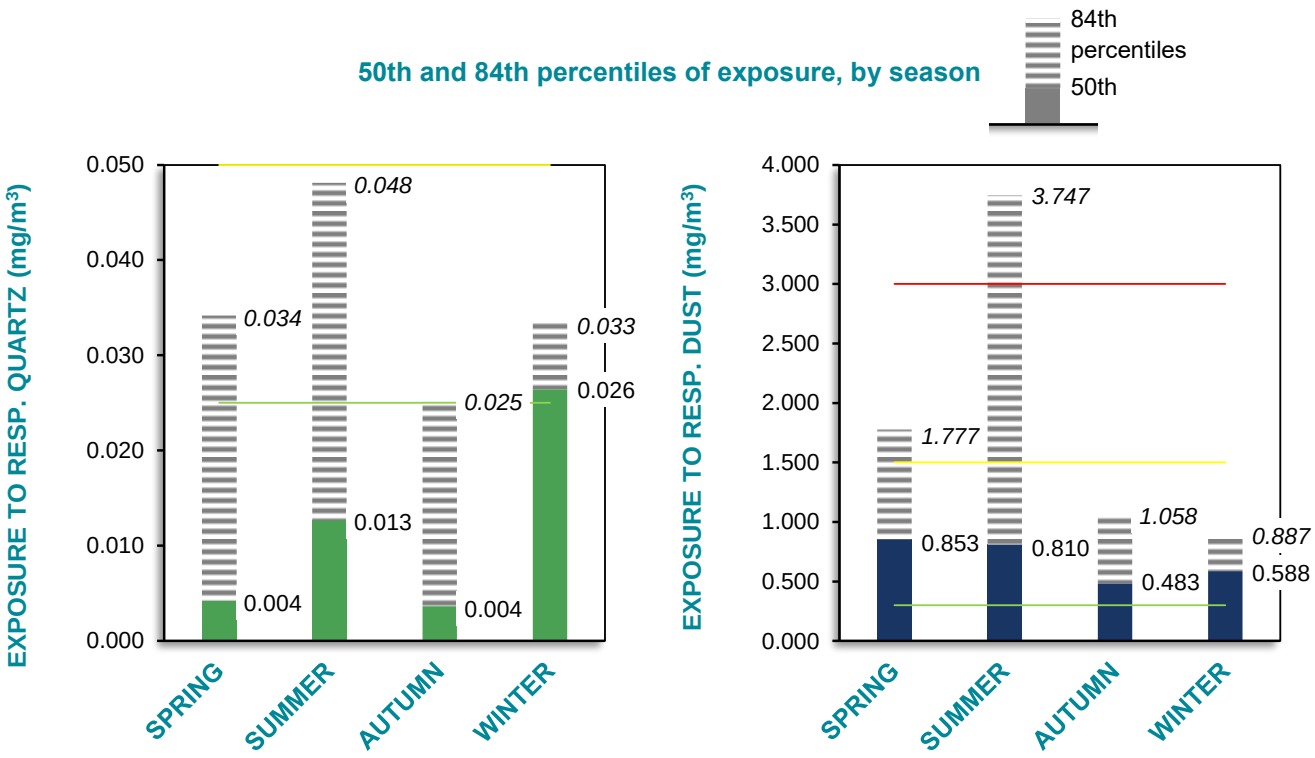
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

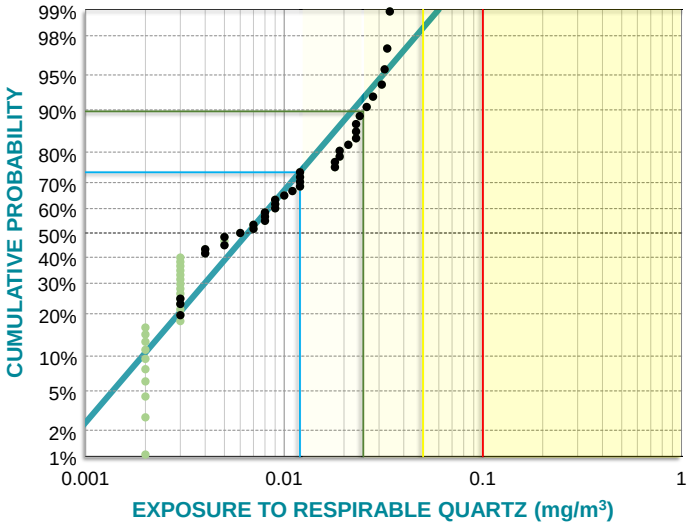
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

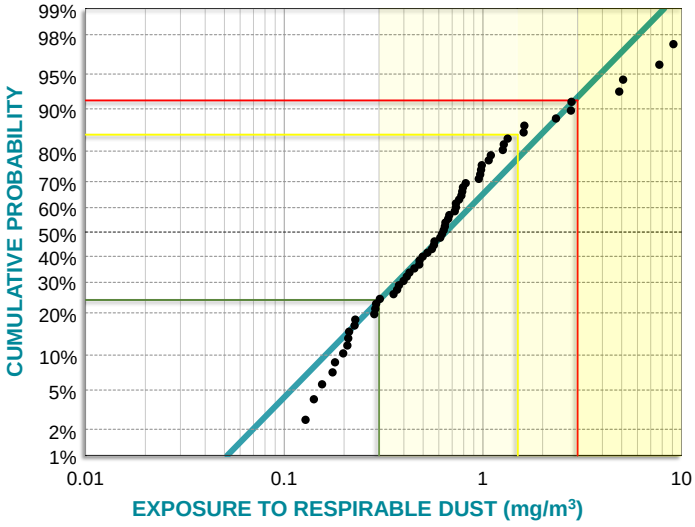


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



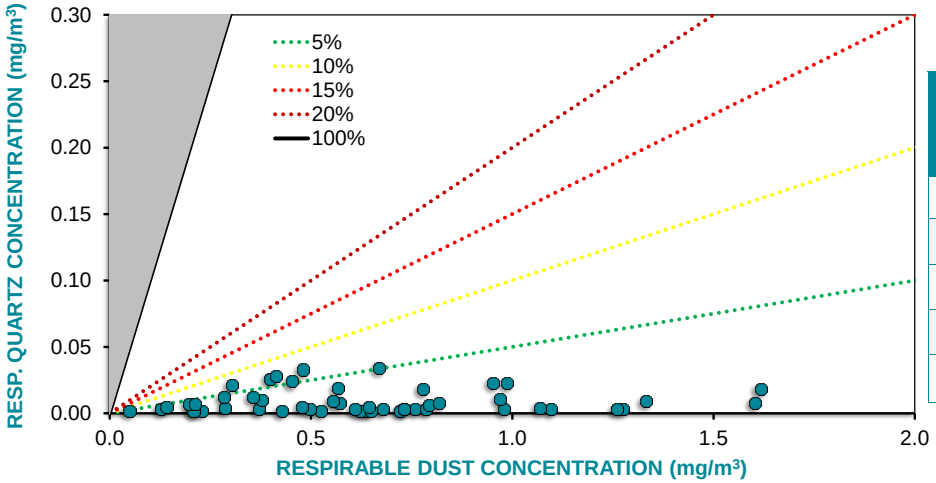
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	-
≤0.05	>98.9%
≤0.025	89.7%
≤0.012	73.6%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	91.5%
≤1.5	84.5%
≤0.3	24.0%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	90%
>5% to 10%	10%
>10% to 15%	0%
>15% to 20%	0%
>20%	0%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C10.01 - Management and office work	
C10.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner, fulfilling both administrative and operating tasks).
C10.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C10.02 - Mining	
C10.02.01 - Miner	Extracts marl and limestone from mine for cement manufacturing. May carry out all the duties at the mine: operates drilling machine and/or power-driven excavating machine (power-shovel, excavator, loader, bulldozer) to move extracted rock and other materials into haul truck; blasts rock (shot firer); assists in various assignments. The job title is better included in B1 *Quarrying of marble, granite and other coherent rocks*, but is included here when it is difficult to separately classify this operator.
C10.03 - Raw materials crushing	
C10.03.01 - Raw material crusher / grinder and screening plant operator	Operates crushing plant to reduce raw materials to suitable size for further processing and mills to grind material. Loads raw materials into hoppers, generally by using loaders. Controls the screening plant. The sieved material is loaded onto a conveyor belt for transport to storehouse / storage silos.
C10.04 - Handling of material in stockyards	
C10.04.01 - Loader / scraper reclaimer operator	Handles raw materials in the storage area. Stores the crushed materials in silos, bins or storage sheds. Removes materials from piles using a scraper reclaimer (the material is usually carried away by rubber belts). The crane operator is not included in this job title.
C10.04.02 - Bridge-crane operator	Operates bridge-crane to move raw materials, coal and clinker to stockpiles or storage areas.
C10.05 - Raw material grinding	
C10.05.01 - Raw material mill operator	Operates raw mill to grind raw materials into a raw mixture. Raw materials and correctives (silica sand) are ground to produce a very fine powder (dry rawmill). Alternatively, raw materials are ground in water to form a slurry which is pumped directly into kiln (wet rawmill). The job title includes the raw material mill assistant.
C10.06 - Homogenisation, preheating and preparation to burning	
C10.06.01 - Cyclone tower operator	Controls the cyclone tower processing. In dry process, raw meal is fed from the top of the tower and drops to the bottom through several cyclones. Each cyclone in the preheater serves as a heat exchanger and a separator and limestone pre-calcination takes place.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C10.06.02 - Granulators and homogenisation system operator	Controls the *Lepol* granulators and homogenisation system. In semi-dry process, raw meal is moistened with water in a granulator plate, then transported on a carpet to *Lepol* grid, where the material is pre-heated. The job title includes both conductor and operator helper.
C10.07 - Burning	
C10.07.01 - Rotary kiln operator	Conducts the cement rotary kilns. In wet process, slurry is fed to the kiln by means of pumps, while in semi-dry process meal is in granular form and in the dry process it is in powder form. The job title includes the kiln operator assistant.
C10.07.02 - Dryer operator	Operates the rotary or static dryers for clinker drying. At the end of the drying phase, the clinker is stored in silos. The job title includes the dryer operator assistant.
C10.08 - Cement grinding	
C10.08.01 - Cement mill operator	Operates ball mill (or roller-press mill, vertical/horizontal roller mill) to grind the cooled clinker blended with additions into a fine powder. The resulting cement is transported pneumatically to silos. The job title includes the cement mill assistant.
C10.09 - Quality control and laboratory testing	
C10.09.01 - Laboratory technician	Determines the carbonate content of the meal in raw material grinding unit by calcimetry analysis. Analyses samples of cement taken at regular intervals after grinding burnt material. Performs laboratory chemical-physical analysis and examination on products for quality assessment.
C10.10 - Handling of materials and products	
C10.10.01 - Truck driver	Drives truck to transport products and materials. The task may include working at the quarry, at the cement plant as well as the delivery to construction sites.
C10.11 - Warehousing and packaging	
C10.11.01 - Silo operator	Tends the loading system that blows bulk cement into the storage silo (pneumatic conveying). Cement is discharged pneumatically from the bottom of silo into tankers and transported by road. Tankers have a blowing system which provide air to transport cement into the silo. Is responsible for silo maintenance and delivery procedures.
C10.11.02 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.
C10.11.03 - Bag filling machine operator	Fills bags with product by operating a bag filling machine. Places an empty bag onto the machine's spout. The machine extracts the cement from the bottom of silos and fills the bag to its proper weight. Then the bag closes automatically and drops to the transfer conveyor. An in-line palletiser enables the stacking of the bags onto pallets.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C10.12 - Mechanical and electrical maintenance / cleaning	
C10.12.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
C10.12.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

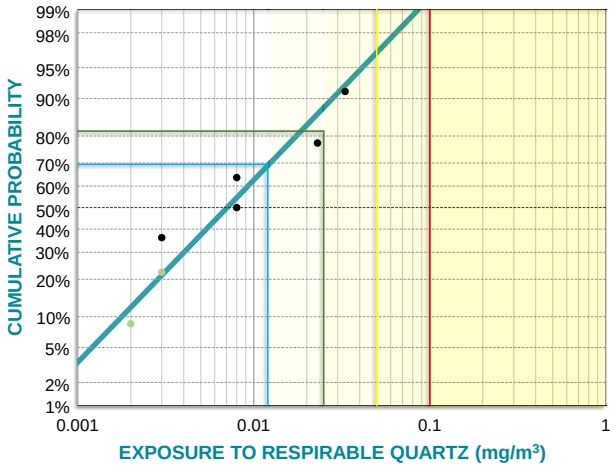
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C10.01.01 - Manager	5	0.006	2.187	-	-	-	-
C10.01.02 - Office worker	1	0.002*	-	-	-	-	-
C10.03.01 - Raw material crusher / grinder and screening plant operator	7	0.007	2.913		>91.4%	81.5%	69.4%
C10.04.01 - Loader / scraper reclaimer operator	3	0.004	1.539	-	-	-	-
C10.04.02 - Bridge-crane operator	4	0.003	1.606	-	-	-	-
C10.05.01 - Raw material mill operator	5	0.006	3.239	-	-	-	-
C10.07.01 - Rotary kiln operator	1	0.002*	-	-	-	-	-
C10.08.01 - Cement mill operator	3	0.006	1.404	-	-	-	-
C10.09.01 - Laboratory technician	2	0.005	-	-	-	-	-
C10.11.01 - Silo operator	3	0.007	2.078	-	-	-	-
C10.11.02 - Warehouse operator	2	0.005	-	-	-	-	-
C10.11.03 - Bag filling machine operator	11	0.010	2.704		>94.4%	80.8%	50.0%
C10.12.01 - Maintenance mechanic / electrician	10	0.009	3.109		>93.9%	77.4%	54.9%
C10.12.02 - Workplace cleaner	2	0.008	-	-	-	-	-

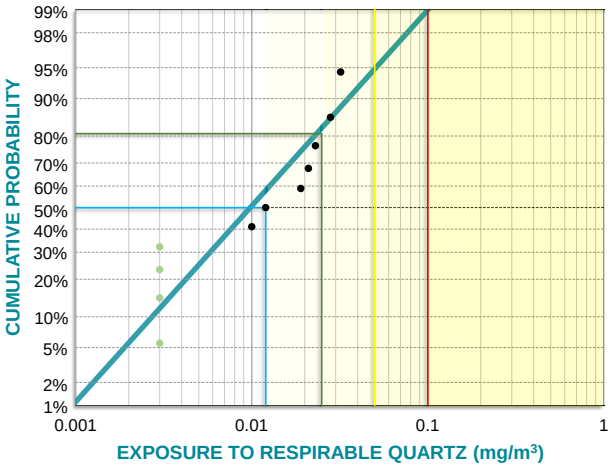
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

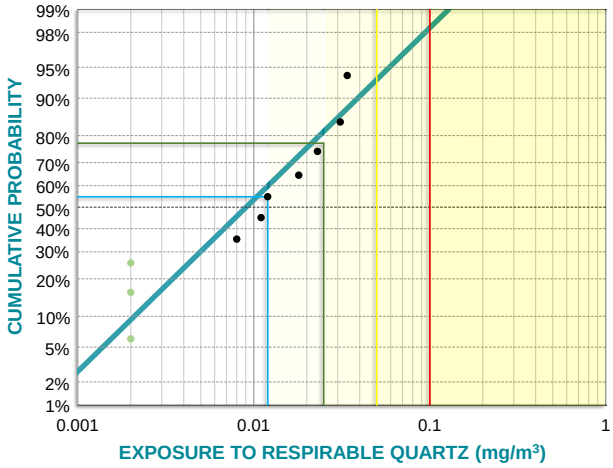
C10.03.01 - Raw material crusher / grinder and screening plant operator



C10.11.03 - Bag filling machine operator



C10.12.01 - Maintenance mechanic / electrician



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C10.01.01 - Manager	5	0.873	4.377	72.3%	60.0%	26.4%
C10.01.02 - Office worker	1	0.228	-	-	-	-
C10.03.01 - Raw material crusher / grinder and screening plant operator	7	0.678	2.083	>91.4%	85.5%	13.5%
C10.04.01 - Loader / scraper reclaimer operator	3	0.646	2.796	-	-	-
C10.04.02 - Bridge-crane operator	5	0.365	1.650	-	-	-
C10.05.01 - Raw material mill operator	6	0.550	1.482		>90.0%	11.2%
C10.07.01 - Rotary kiln operator	1	0.526	-	-	-	-
C10.08.01 - Cement mill operator	4	0.370	3.008	-	-	-
C10.09.01 - Laboratory technician	3	0.136	2.489	-	-	-
C10.11.01 - Silo operator	3	0.530	1.465	-	-	-
C10.11.02 - Warehouse operator	2	0.517	-	-	-	-
C10.11.03 - Bag filling machine operator	11	1.166	3.695	77.8%	70.9%	<5.6%
C10.12.01 - Maintenance mechanic / electrician	10	1.275	3.150	78.6%	63.3%	8.5%
C10.12.02 - Workplace cleaner	3	0.371	1.539	-	-	-

Working processes

Production of concrete

Concrete production takes place in concrete mixing stations, in which a paste of hydraulic binder (cement) and water is mixed with aggregates (sand and natural gravel, or crushed stone or construction waste), with the eventual addition of additives. Concrete mixing plants are often placed close to the aggregate crushing and screening plants, where aggregates of different grain sizes are separated. The aggregates are taken from their storage heaps or silo to the batcher, weighed in a weighing conveyor or hopper and transported to the concrete mixer. Cement, additives and water are also weighed before the mixing with aggregates is carried out in the concrete mixer. The mixture is discharged into concrete mixing trucks and transported to construction or production sites. The main phases of concrete production are listed in summary below.

1. **Raw materials storage** – raw materials for aggregates, such as quarry blocks, gravel, construction waste, are carried by trucks and stored in heaps in the yard of the facility. After crushing and screening, they are again stored in heaps, in silos or bins. Cement and additives are stored in separate silos.
2. **Crushing and screening** – raw materials for aggregates are introduced into the hopper of the crushing plant by mechanical shovel; after grinding, aggregates of different particle sizes are obtained by screening and are transported and stored in the storage yard of the concrete mixing facility.
3. **Concrete mixing and transport** – the ingredients are taken from their storage silos and bins, weighed and conveyed to the concrete mixing plant. Concrete truck mixers approach the mixing plant, where ready-mixed concrete is discharged into the trucks and transported to the job site, mixing during transportation.

Production of reinforced precast concrete elements for construction

The structural elements produced include slabs, beams, columns, etc. Reinforcements usually consist of steel bars cut to size, which are embedded in the concrete to improve strength and durability. Fluid concrete obtained from concrete mixing stations is casted in formworks or dies, after applying a coating of release agents, which allow an easy separation of product. Casted concrete is arranged manually through pestle, or mechanically with the use of vibrators, then follows the setting, hardening and curing. When the concrete has acquired sufficient strength to bear its own weight, the formwork can be removed. The production is carried out in pre-cast production sites, usually outside or in industrial sheds with broad apertures for the transit of mechanical equipment. The reinforced precast concrete elements are later transported to the construction site, where they are lifted into place. The main departments of a facility for the production of reinforced precast concrete elements are summarised below.

1. **Iron unit** – metallic reinforcements for concrete are prepared by cutting, crosscutting and welding of the steel rods and bars.
2. **Concrete cast unit** – concrete is cast in the formwork prepared with embedded steel bars, and then vibrated for compaction. After the concrete has been sufficiently hardened, the formwork is removed.
3. **Warehouse** – storage of finished products is carried out using mechanical equipment, usually in the factory yard outside or under sheds.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	218	0.264	2.355	202	0.005	3.064	2.9
STATIC	12	0.133	2.183	12	0.002	1.550	1.9

CONCRETE PRODUCTS: Manufacture of concrete products for construction purposes and of ready-mixed concrete

Geometric mean of personal exposure, by region

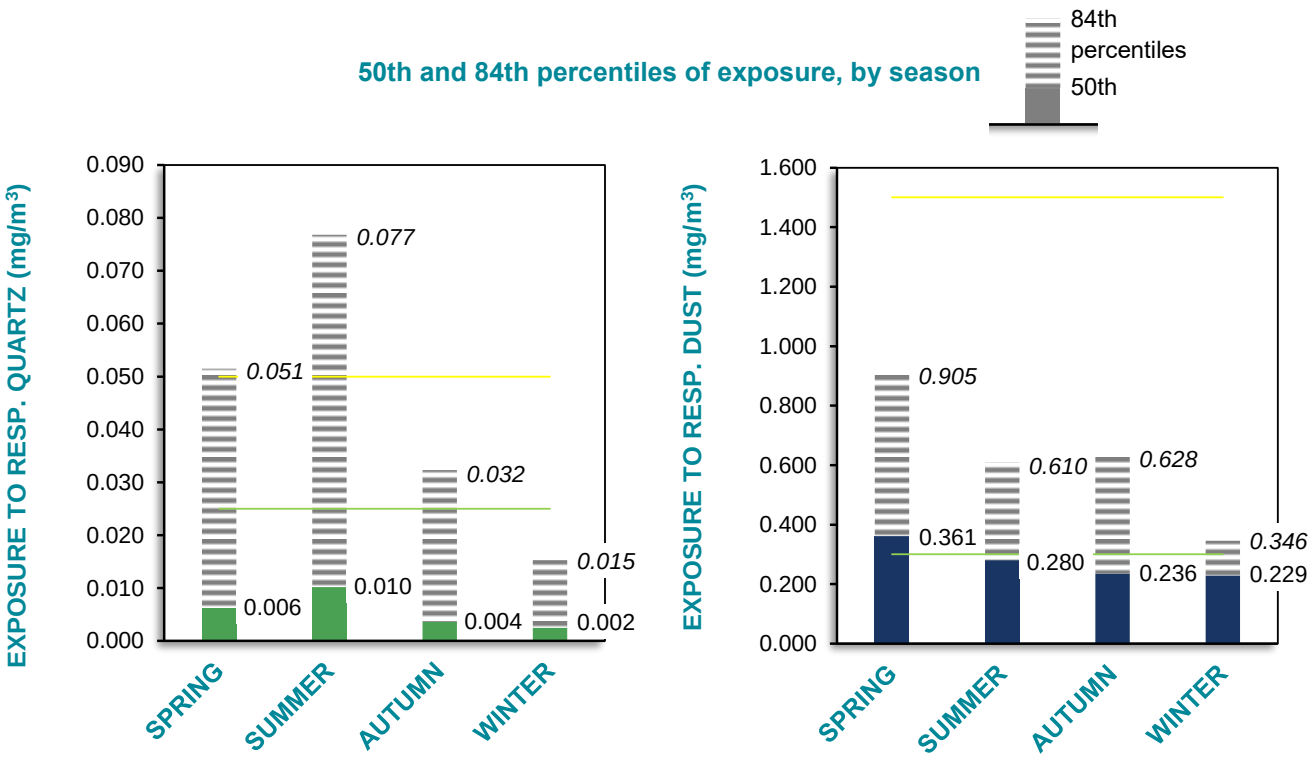
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

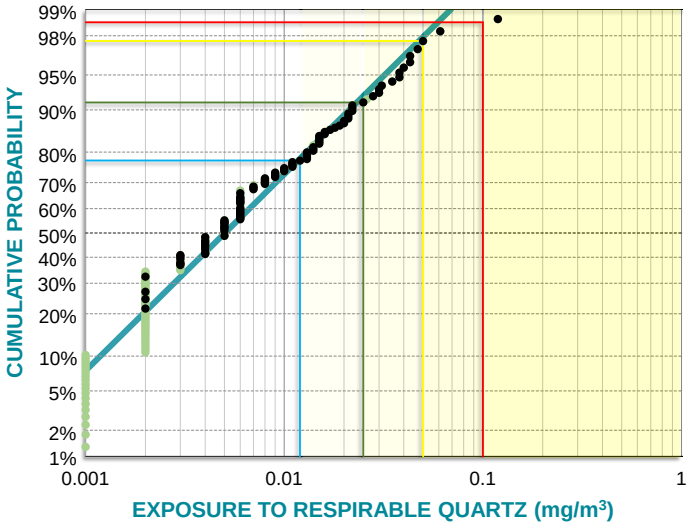
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

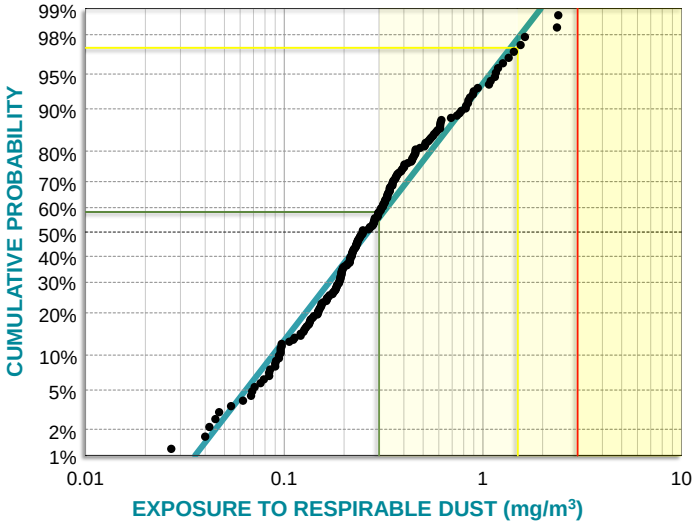


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



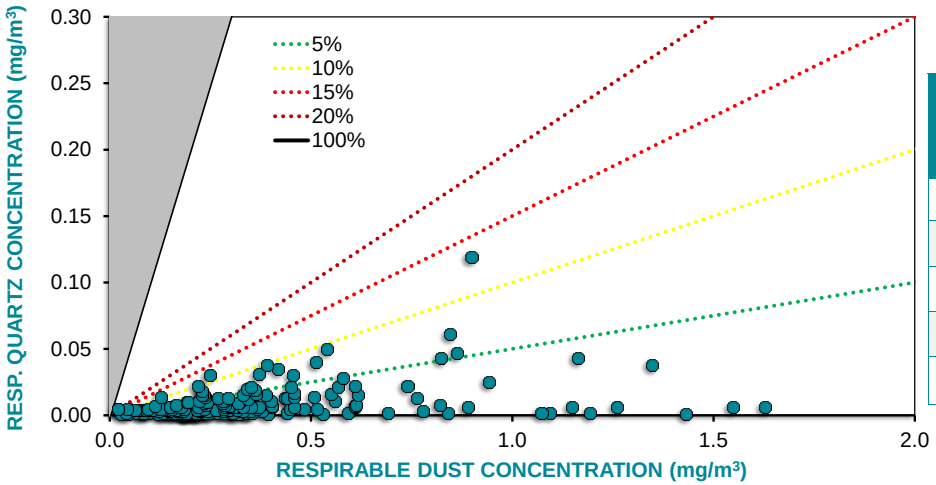
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	98.6%
≤0.05	97.7%
≤0.025	91.3%
≤0.012	77.4%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	99.1%
≤1.5	97.2%
≤0.3	58.2%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	85%
>5% to 10%	11%
>10% to 15%	2%
>15% to 20%	0%
>20%	1%

CONCRETE PRODUCTS: Manufacture of concrete products for construction purposes and of ready-mixed concrete

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C11.01 - Management and office work	
C11.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C11.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C11.02 - Crushing	
C11.02.01 - Crusher / grinder	Operates crushing plant to reduce raw material to suitable size for further processing and mills to grind material. Some concrete factories have a crushing plant for recycling of construction waste.
C11.03 - Concrete batching and mixing	
C11.03.01 - Concrete mixing plant operator	Conducts and controls the batching and mixing concrete plant, including the packaging machine. Usually, operates in a closed cabin using a remote control. May carry out transport of concrete mixture by using a forklift.
C11.03.02 - Concrete mixer truck operator	Drives and operates concrete mixer truck, for the loading at the concrete production plant, the transport to yards as well as concrete casting in moulds for products manufacturing. Operates the concrete distributing vehicle for casting in moulds for precast elements, beam beds/lines, tables for the production of panels, etc.
C11.04 - Precast elements production	
C11.04.01 - Steel fixer	Prepares and inserts iron reinforcement in formworks for concrete or prestressed concrete products. Prepares steel elements and ties them with iron wire to steel electro welded meshes for concrete panels production.
C11.04.02 - Carpenter	Prepares moulds, beam beds/lines, tables for the production of panels, etc., for concrete casting, including their cleaning and the placing of separators.
C11.04.03 - Concrete caster	Casts concrete in formworks, generally using a concrete mixer. Controls concrete vibration and compaction to expel entrapped air from freshly placed concrete. Controls concrete curing, e.g. by live steam at atmospheric pressure or by high-pressure steam in autoclaves or using heating coils embedded near the surface of concrete.
C11.04.04 - Concrete elements production plant operator	Operates automated forming line (moulding press / block moulding machine) for concrete products. Reinforcement cages and iron inserts (produced in-house or by other companies) are delivered to the production line and placed into formwork and shuttering. Mixed concrete is conveyed from the concrete mixing plant to the production line and cast into formwork by an automatic device, possibly compressed and vibrated before being set aside to cure. Finished products are unloaded on pallet. Usually conducts the line from control room.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C11.04.05 - Concrete product demoulding operator	Removes formwork after concrete curing.
C11.04.06 - Special finishing operator	Carries out surface finishing operations such as bush hammering and cutting/splitting of blocks for paving and masonry, drilling and cutting of pre-stressed concrete piles (e.g. by using a bridge saw). May carry out a final wash of concrete products and operations such as grouting, deburring and painting.
C11.05 - Handling of materials and products	
C11.05.01 - Truck driver	Drives trucks to transport aggregates, to be used for production of concrete and other solid materials. The aggregates are generally unloaded at the construction site, e.g. to stockpile or into storage container, such as a silo.
C11.05.02 - Loader operator	Operates mechanical loader or other lifting machine to move aggregates and other materials in storage yard or shed. Feeds the crusher hopper with raw materials. Loads the hopper of the concrete mixing plant with crushed and screened aggregates. Loads trucks and dumpers for transport of aggregates ready for use at the construction site.
C11.05.03 - Bridge-crane / forklift operator	Operates material handling equipment (hand or battery operated pallet truck, reach truck, forklift) to move, pack and store finished products in outside yard or shed. Loads truck for shipping ordered to customers. Operates bridge-crane for picking and storing products and raw materials and loading trucks for transport of concrete to formworks.
C11.06 - Warehousing and packaging	
C11.06.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Operates palletising system for product packaging. Drives forklift to pick up incoming stock or deliver materials to designated areas.
C11.07 - Various workspaces	
C11.07.01 - Polyvalent operator	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C11.08 - Mechanical and electrical maintenance / cleaning	
C11.08.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
C11.08.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

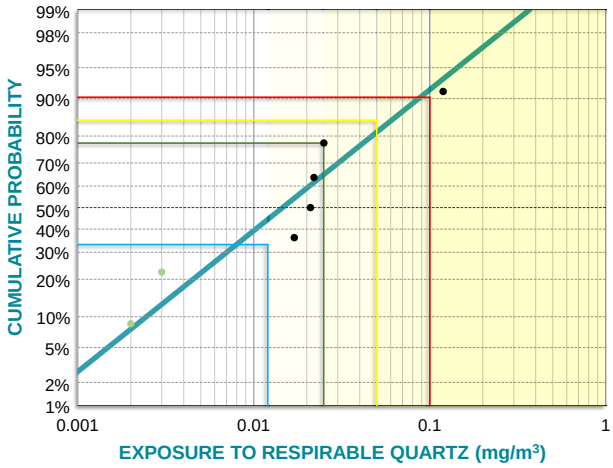
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C11.01.01 - Manager	3	0.003	2.814	-	-	-	-
C11.01.02 - Office worker	1	0.001*	-	-	-	-	-
C11.02.01 - Crusher / grinder	7	0.015	3.985	90.3%	84.8%	77.6%	33.2%
C11.03.01 - Concrete mixing plant operator	35	0.005	2.974		>98.2%	89.1%	75.1%
C11.03.02 - Concrete mixer truck operator	12	0.006	2.039			>94.9%	74.8%
C11.04.01 - Steel fixer	7	0.003	2.239				>91.4%
C11.04.02 - Carpenter	6	0.002*	3.192*			>90.0%	87.3%
C11.04.03 - Concrete caster	11	0.002*	2.260*			>94.4%	94.4%
C11.04.04 - Concrete elements production plant operator	44	0.007	3.950	95.9%	94.2%	83.7%	68.1%
C11.04.05 - Concrete product demoulding operator	4	0.004	1.233	-	-	-	-
C11.04.06 - Special finishing operator	15	0.005	2.686			>95.9%	78.7%
C11.05.01 - Truck driver	7	0.004	1.738				>91.4%
C11.05.02 - Loader operator	14	0.007	3.741	>95.6%	93.3%	71.9%	64.8%
C11.05.03 - Bridge-crane / forklift operator	17	0.005	2.596	>96.4%	96.4%	93.4%	82.4%
C11.06.01 - Warehouse operator	10	0.004*	2.203*			>93.9%	88.4%
C11.07.01 - Polyvalent operator	7	0.005*	2.105*				>91.4%
C11.08.01 - Maintenance mechanic / electrician	2	0.005	-	-	-	-	-

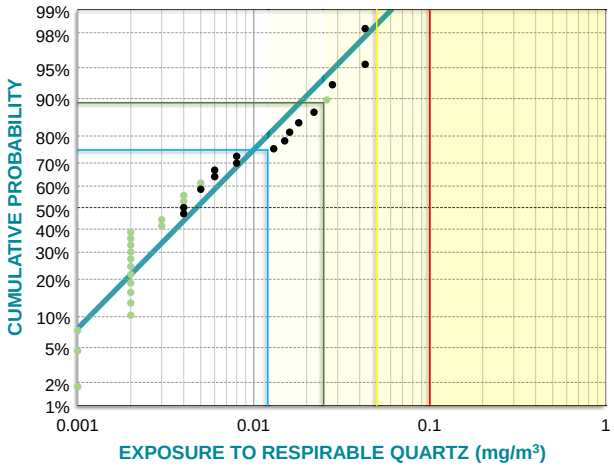
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

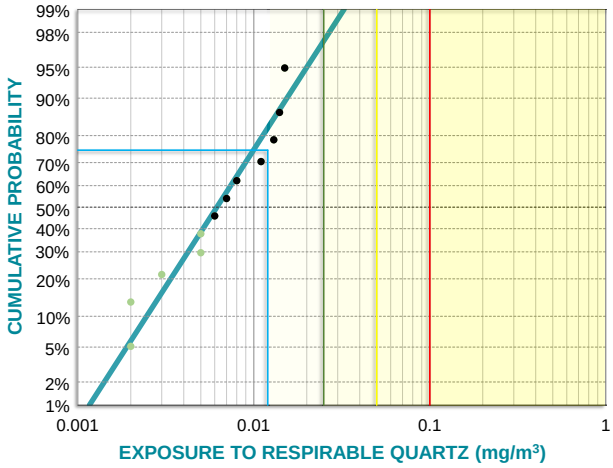
C11.02.01 - Crusher / grinder



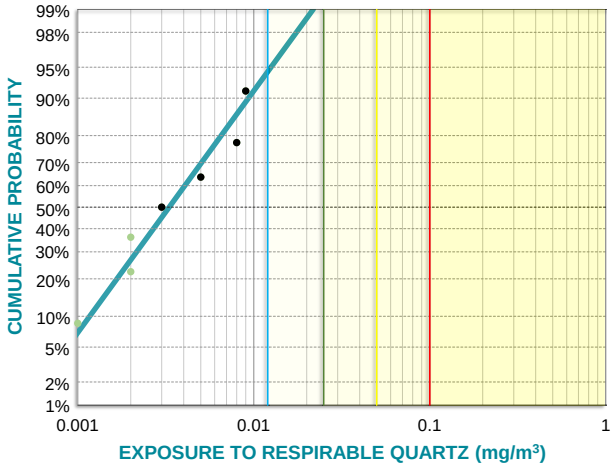
C11.03.01 - Concrete mixing plant operator



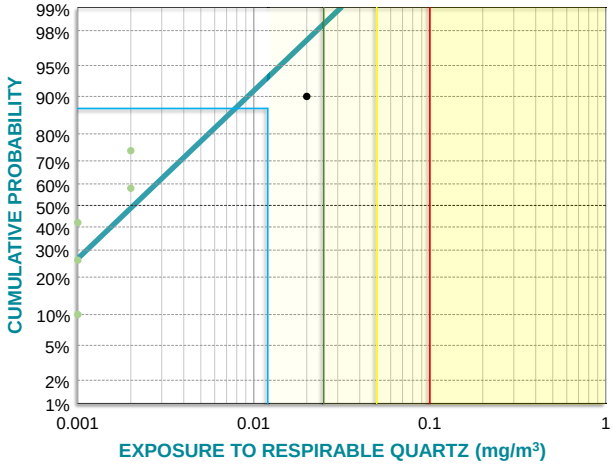
C11.03.02 - Concrete mixer truck operator



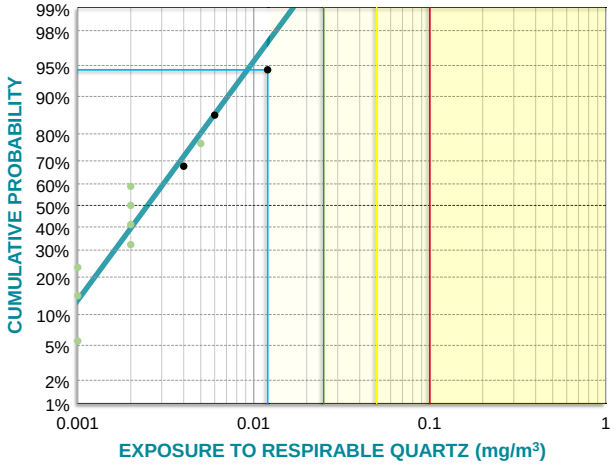
C11.04.01 - Steel fixer



C11.04.02 - Carpenter

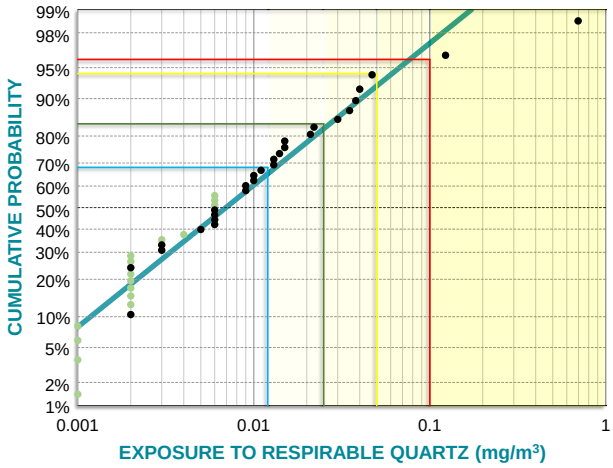


C11.04.03 - Concrete caster

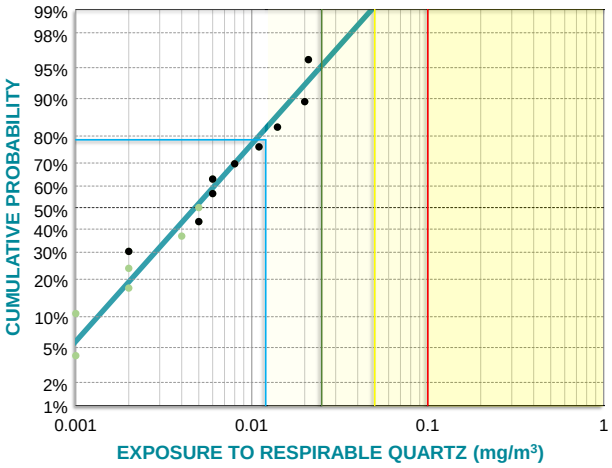


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

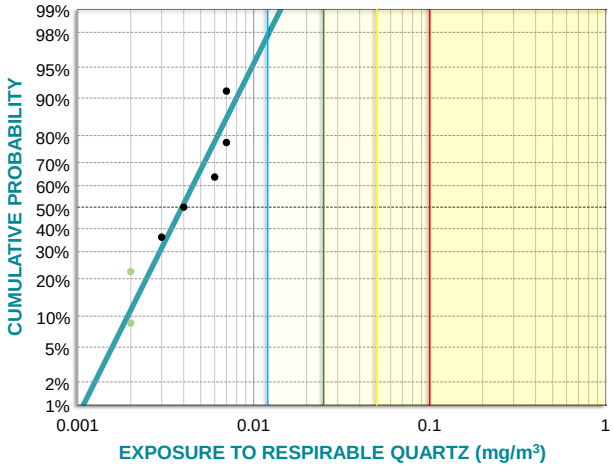
C11.04.04 - Concrete elements production plant operator



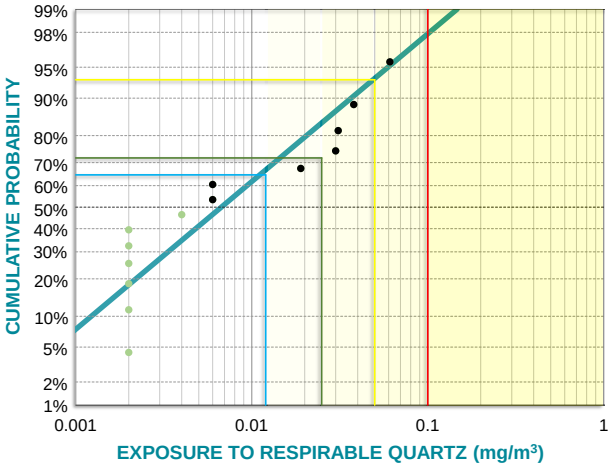
C11.04.06 - Special finishing operator



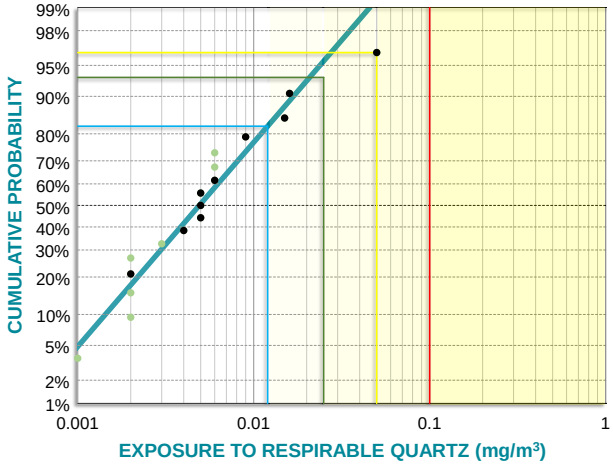
C11.05.01 - Truck driver



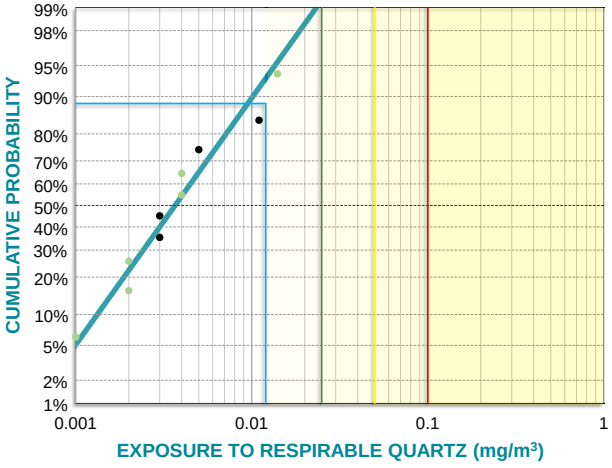
C11.05.02 - Loader operator



C11.05.03 - Bridge-crane / forklift operator

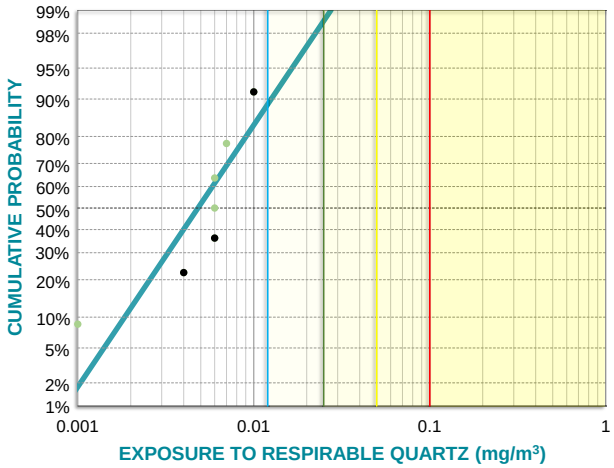


C11.06.01 - Warehouse operator



Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C11.07.01 - Polyvalent operator



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C11.01.01 - Manager	4	0.238	1.682	-	-	-
C11.01.02 - Office worker	1	0.188	-	-	-	-
C11.02.01 - Crusher / grinder	7	0.479	1.705		>91.4%	17.6%
C11.03.01 - Concrete mixing plant operator	40	0.324	2.248	98.2%	96.5%	55.4%
C11.03.02 - Concrete mixer truck operator	12	0.194	3.160		>94.9%	56.6%
C11.04.01 - Steel fixer	7	0.218	1.650		>91.4%	61.7%
C11.04.02 - Carpenter	6	0.192	3.655		>90.0%	68.0%
C11.04.03 - Concrete caster	13	0.193	2.468		>95.3%	71.3%
C11.04.04 - Concrete elements production plant operator	48	0.302	2.384	97.1%	94.8%	55.7%
C11.04.05 - Concrete product demoulding operator	4	0.229	1.685	-	-	-
C11.04.06 - Special finishing operator	17	0.316	2.304	>96.4%	93.6%	48.2%
C11.05.01 - Truck driver	7	0.172	1.448			>91.4%
C11.05.02 - Loader operator	14	0.289	2.692	>95.6%	94.4%	51.1%
C11.05.03 - Bridge-crane / forklift operator	19	0.260	2.273	>96.8%	96.3%	59.9%
C11.06.01 - Warehouse operator	10	0.154	1.637		>93.9%	88.9%
C11.07.01 - Polyvalent operator	7	0.227	2.109		>91.4%	52.4%
C11.08.01 - Maintenance mechanic / electrician	2	0.175	-	-	-	-

Working processes

The cutting, shaping and finishing of stone refers to stone materials extracted in quarries according to the activity classified as B1 *Quarrying of marble, granite and other coherent rocks*. Stone blocks and slabs coming from quarries are processed to obtain semi-finished products such as slabs, strips and small blocks which can then can be further cut and shaped to form finished products such as tiles, slabs, curbs, shingles, stone furnishings, other building components and special products such as blackboards, pool slate table or artistic objects. Stone blocks are often preliminarily processed in the quarry and then transported to the cutting, shaping and finishing premises so that the complete processing in the same warehouse/ industrial unit is unusual. Many companies are specialised in specific processing stages and realise only semi-finished products, which are then sold to other companies which produce finished products ready for the market. Granites and other rocks used in the stonemasonry industry have high quartz content but, due to their value as ornamental stones, cannot be replaced by low quartz content rocks. It should be noted that the commercial terms marble and granite do not match the petrographic definitions, but refer to technical properties of the stone, such as strength, polishability and aesthetic appearance. The following sections describe the main steps in the processing of stones.

1. **Stone handling** – blocks and slabs, coming from the quarry and deposited in the yard of premises, are taken to the processing lines by using a variety of stone handling equipment that may include a bridge crane or other crane, stone block forklift loader, hydraulic jib attachment, vacuum lifter and clamps, wheel loader, dumper, etc. This handling equipment is also used to move stones from the different processing lines and to store and pack finished products in the warehouse at the end of the production cycle.
2. **Slab splitting** – small and medium-size slabs are cut to produce cubes (for paving or curbs for pavement edges) and sliced for tiles with irregular edges, using cube cutting machines, splitting machines, or tilers, depending on the finished product type.
3. **Block cutting** – huge and irregular blocks of stone need to be sawed and squared into more manageable slabs and strips. Smaller blocks, required for successive processing, can also be cut directly from huge blocks. The machinery used includes an automatic water-cooled diamond wire machine, single or multi-blade frames, mono or multi-disc cutter as well as other sawing machines; all processes use water for cooling.
4. **Slabs and strips cutting and trimming** – slabs and strips are cut to meet the required size for final products. Sawing is carried out using a wide variety of machinery including, a mono or multi-blade bridge saw, a banner tile saw, a column cutting machine, a stone lathe machine, disc cutters, a bench saw, a trimming machine, a splitting machine, etc. The automation level of machinery is an important topic for dust exposure assessment since the machine can be operated through manual, semi- or fully-automatic control with robots beginning to replace human workers in some job roles. Water is usually used for automatic cooling as well as to suppress dust. Water jet cutting, a technology working with a high-pressure water blade, is still little used.
5. **Mechanical surface finishing** – this processing carried out on slab and strip surfaces gives the stone its final aesthetic appearance and practical functionality. Finishing operations are usually carried out wet and the machinery can be operated by semi- or fully-automatic control. A list of finishing operations includes the following:

   - mechanical processing: calibration, polishing, profiling, lapping, edging, edge-polishing, bevelling;
   - processing by impact: sandblasting, bush hammering, shot blasting;
   - thermic processing: flaming;
   - chemical processing: resin coating, grouting.

6. **Final finishing by hand** – final products are processed to improve aesthetic and functional aspects using hand tools, often dry, without the use of water for dust suppression. Processes are similar to those described in phase 5: lapping, shaping, drilling, grinding, polishing and sanding of small parts are carried

out by angle grinder, drill and hand stone polisher.

7. **Special processes** – shapeless blocks, slabs and strips, or potsherds can be used to realise special products for floors, tiles, covers, blackboards, pool slate tables and artistic sculptures. Drilling, sorting, splitting by hand or by machine, lathe machining and water jet cutting are operations carried out for special processes.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	1969	0.425	2.521	1904	0.033	3.491	11.6
STATIC	93	0.194	2.815	95	0.015	3.690	12.4

Geometric mean of personal exposure, by region

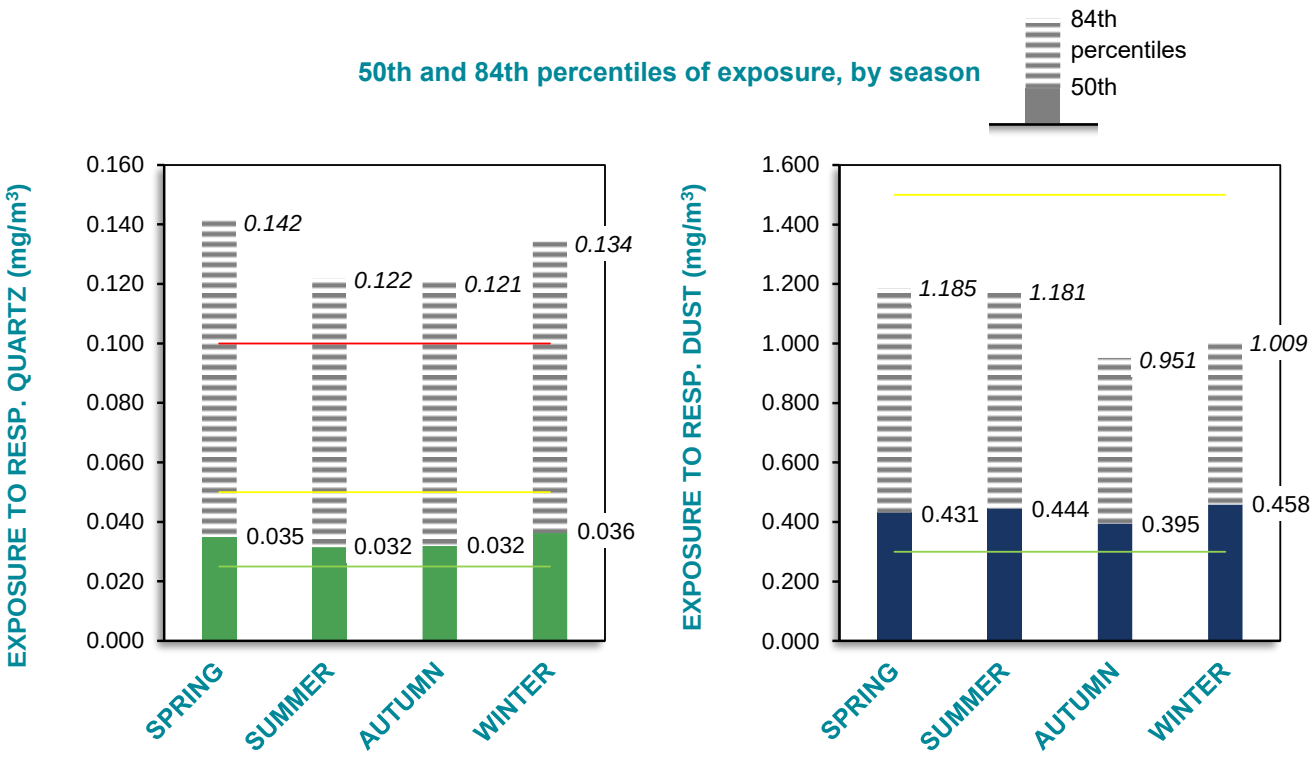
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

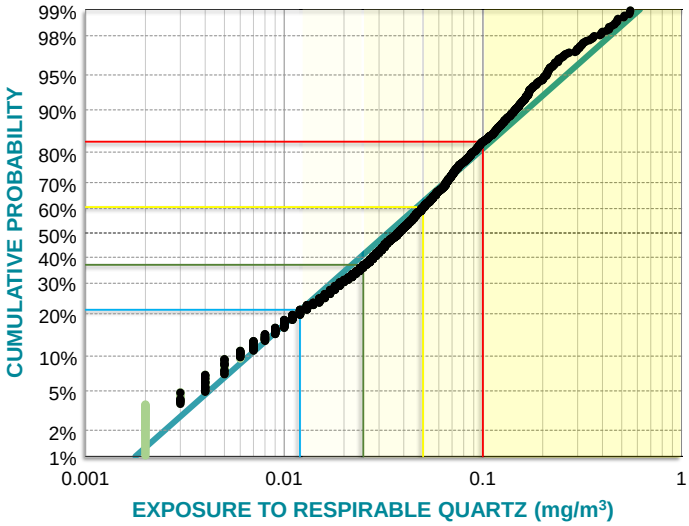
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

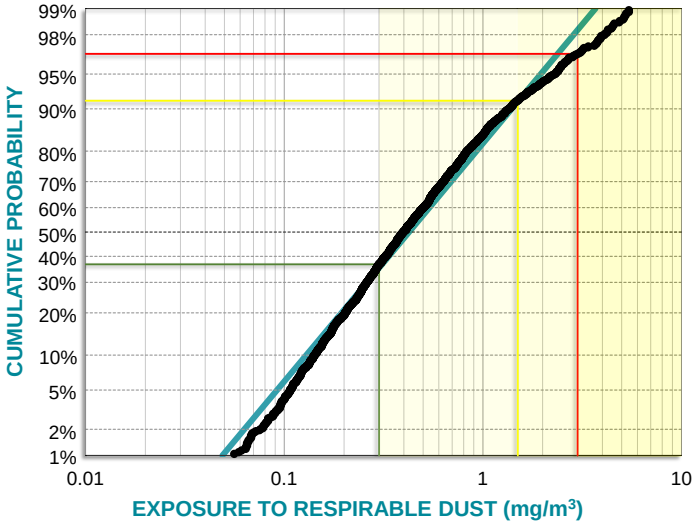


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



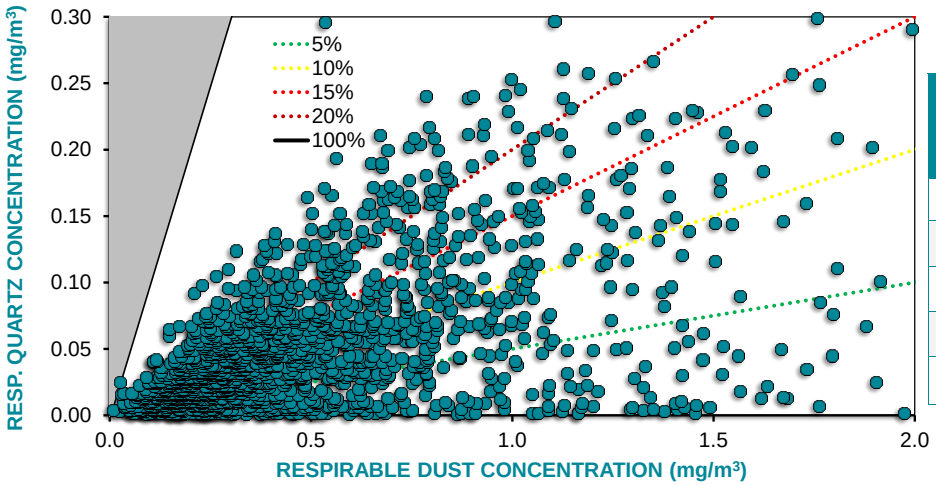
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	82.9%
≤0.05	60.6%
≤0.025	37.0%
≤0.012	21.2%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	96.8%
≤1.5	91.4%
≤0.3	36.8%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	25%
>5% to 10%	24%
>10% to 15%	21%
>15% to 20%	14%
>20%	16%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C12.01 - Management and office work	
C12.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C12.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C12.02 - Block cutting	
C12.02.01 - Quarryman	Extracts granite, limestone or other kinds of stone from quarry. May carry out all the duties at the quarry: operates drilling machine and/or power-driven excavating machine (power-shovel, excavator, loader, bulldozer) to move extracted rock and other materials into haul truck; blasts rock (Shot firer); assists in various assignments. The title is better included in B1 *Quarrying of marble, granite and other coherent rocks*, but is included here when it is difficult to separately classify this operator.
C12.02.02 - Wire block cutting machine operator	Cuts stone blocks using diamond wire cutting machine.
C12.02.03 - Multi-blade frame saw (for blocks) operator	Cuts stone blocks using multi-blade frames for the sawing of slabs, strips or small blocks. Working steps include conveyor arrangement, blade set up, frame control, discharge, frame washing, slabs washing and blade sharpening.
C12.02.04 - Single-blade frame saw (for blocks) operator	Cuts stone blocks using single-blade frames for the sawing of slabs, strips or small blocks.
C12.02.05 - Mono/multi disc cutter (for blocks) operator	Cuts stone blocks using mono or multi-disc block cutter or sawing machine with jumbo disc, for the sawing of slabs, strips or small blocks.
C12.03 - Surface finishing (by machine)	
C12.03.01 - Polishing / bevelling (semi)automatic machine operator	Operates automatic or semi-automatic stone polishing machine or stone edging machine, grinding machine, bevelling machine or edge-polisher.
C12.03.02 - Arm polisher operator	Operates arm polisher (column or wall-mounted, manually operated machine) for polishing or brushing stone slabs. May use manual wet polishing machine.
C12.03.03 - Grouting / resin coating operator	Carries out grouting and resin coating on stone slab by manual or mechanical operations. Carries out resin coating drying in kiln.
C12.03.04 - Bush hammer operator	Uses bush hammer to texturise stone slabs.
C12.03.05 - Flaming operator	Uses flaming machine or manual device to apply high temperature to the surface of stone slab to make it look like natural weathering.
C12.03.06 - Sandblasting operator	Operates sandblasting machine or portable equipment using a high-pressure sand jet (wearing a suitable supplied air respirator) to cut inscriptions and decorative designs on stone. Sandblasting finishes enhance the natural look of stone, making the surface rough and opaque.
C12.03.07 - Planing machine operator	Sets up and operates planing machine to shape, smooth and square the surface of the stone blocks and slabs (dry process).

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C12.03.08 - Finishing operator (general)	Carries out different types of surface special treatment and finishing operations.
C12.04 - Slab cutting and processing	
C12.04.01 - Manually-controlled slab cutting machine operator	Operates manually-controlled machine (mono or multi blade bridge saw, banner tile saw, column cutting machine, stone lathe machine, disc cutters, bench saw, trimming machine, splitting machine) to cut and process stone slabs and small blocks.
C12.04.02 - Semi- or fully-automatic slab cutting machine operator	Operates semi or fully-automatic machinery (mono or multi blade bench saw, stone lathe machine, trimming machine, splitting machine) to cut and trim stone slabs and small blocks.
C12.04.03 - Automatic slab cutting line operator	Operates automatic (cutting, shaping, drilling) line for stone slabs, to realise floor elements, roofing, pool slate tables. The machine is equipped with a control panel, monitor and software, featuring an operator-machine interface.
C12.04.04 - Computerised numerical control lathe machine operator	Operates computerised numerical control lathe machine to process stone slabs.
C12.04.05 - Waterjet slab cutting machine operator	Operates waterjet cutting machine to process stone slabs.
C12.04.06 - Slab cutting machine operator (general)	Operates cutting machine to process stone slabs (cutting/processing machine not specified).
C12.05 - Surface finishing (by hand)	
C12.05.01 - Hand finishing operator	Carries out dry finishing operations (grinding, shaping, drilling, polishing, sanding) on semi-finished stone products through the use of hand tools (angle grinder, drill, manual stone polisher).
C12.06 - Special processing	
C12.06.01 - Stonemason	Carries out manual dry working of hewn stone for floor paving, building components, gravestones, stone inlays, etc. by using mallet and chisel.
C12.06.02 - Stone carver	Carves designs and figures in stone by using mallet and chisel. Employs knowledge of stone-carving techniques and sense of artistry.
C12.06.03 - Stone sorter / splitter	Carries out manual sorting of stone in the quarry or in the workshop. Splits rough dimension stone into smaller units by using mallet and chisel, hammer and wedges and working on a bench equipped with a conveyor belt.
C12.06.04 - Cube cutting machine operator	Uses machine for cube cutting to realise small stone cubes through mechanical splitting. Porphyry cubes are used as paving elements.
C12.06.05 - Tile splitting machine operator	Uses splitting machine to realise tiles and binders with split sides for outdoor paving (e.g. porphyry tiles).
C12.06.06 - Crusher	Operates crushing plant to reduce rock debris.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C12.06.07 - Floor layer and tile setter	Working in the construction site, prepares floor areas and installs marble and other stone flooring materials. Lays stone slabs. Prepares walls, installs marble and other stone tiles or mosaic panels onto walls and floors. Cuts, fits and clads marble and other stone materials.
C12.07 - Handling of materials and products	
C12.07.01 - Truck driver / loader operator	Drives truck or dumper to transport and dump stone blocks and slabs. Operates wheel loader in the factory yard. May lift materials by forklifts, cranes, etc.
C12.07.02 - Forklift operator (processing lines)	Operates lifting equipment (forklift truck, heavy-duty fork positioner or vacuum lifter, hydraulic jib attachment, trolley for slabs attached to the forklift, automatic system, etc.) for moving stone slabs to the processing lines (polishing, flaming, resin coating, etc.) inside the stone slab factory and to the warehouse.
C12.07.03 - Bridge-crane operator (factory yard)	Operates lifting equipment (bridge-crane, stone block forklift loader, heavy-duty forklift, etc.) for moving stone blocks and slabs in the outside yard and to the warehouse. May work together with C12.02 operators, except for block cutting.
C12.08 - Warehousing and packaging	
C12.08.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Operates forklift and/or bridge-crane, pallet truck, packing machines to pick up incoming stock or deliver materials to designated area.
C12.09 - Various workspaces	
C12.09.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C12.10 - Mechanical and electrical maintenance / cleaning	
C12.10.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
C12.10.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C12.01.01 - Manager	37	0.017	3.066	>98.3%	81.2%	58.1%	32.4%
C12.01.02 - Office worker	2	0.002*	-	-	-	-	-
C12.02.02 - Wire block cutting machine operator	3	0.022	1.480	-	-	-	-
C12.02.03 - Multi-blade frame saw (for blocks) operator	100	0.045	2.513	82.7%	46.3%	26.6%	8.6%
C12.02.04 - Single-blade frame saw (for blocks) operator	10	0.012	3.958		>93.9%	54.9%	40.3%
C12.02.05 - Mono/multi disc cutter (for blocks) operator	25	0.017	3.602	90.2%	79.2%	53.1%	38.1%
C12.03.01 - Polishing / bevelling (semi)automatic machine operator	133	0.020	3.602	89.6%	72.8%	53.4%	37.2%
C12.03.02 - Arm polisher operator	17	0.017	3.307	>96.4%	76.2%	55.8%	46.8%
C12.03.03 - Grouting / resin coating operator	5	0.012	7.796	-	-	-	-
C12.03.04 - Bush hammer operator	12	0.071	4.211	59.3%	36.2%	20.3%	13.9%
C12.03.05 - Flaming operator	5	0.023	1.855	-	-	-	-
C12.03.08 - Finishing operator (general)	18	0.009	3.161	95.6%	91.6%	78.1%	65.3%
C12.04.01 - Manually-controlled slab cutting machine operator	264	0.028	3.250	89.5%	66.1%	40.7%	25.6%
C12.04.02 - Semi- or fully-automatic slab cutting machine operator	64	0.021	3.780	86.8%	73.8%	50.0%	35.2%
C12.04.03 - Automatic slab cutting line operator	18	0.026	2.271	>96.6%	68.7%	44.7%	17.8%
C12.04.04 - Computerised numerical control lathe machine operator	18	0.020	2.426	91.9%	86.0%	61.0%	32.1%
C12.04.05 - Waterjet slab cutting machine operator	6	0.017	1.950	>90.0%	89.7%	77.0%	42.0%
C12.04.06 - Slab cutting machine operator (general)	53	0.025	3.187	90.7%	74.1%	48.1%	26.6%
C12.05.01 - Hand finishing operator	244	0.046	5.003	67.2%	50.6%	34.6%	22.4%
C12.06.01 - Stonemason	12	0.112	4.976	51.5%	39.0%	14.3%	7.5%
C12.06.02 - Stone carver	1	0.003*	-	-	-	-	-
C12.06.03 - Stone sorter / splitter	380	0.048	2.291	81.1%	51.4%	18.8%	5.7%
C12.06.04 - Cube cutting machine operator	136	0.056	2.797	71.2%	40.8%	18.1%	7.1%
C12.06.05 - Tile splitting machine operator	93	0.060	2.424	67.5%	38.2%	18.4%	2.4%
C12.06.06 - Crusher	12	0.078	2.196	54.4%	28.5%	10.0%	<5.1%
C12.06.07 - Floor layer and tile setter	3	0.030	2.609	-	-	-	-

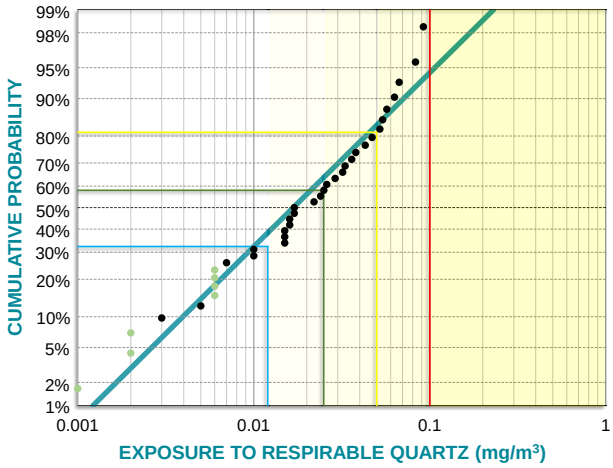
* more than half of the measurements are <LOQ

Exposure to respirable quartz, by job title

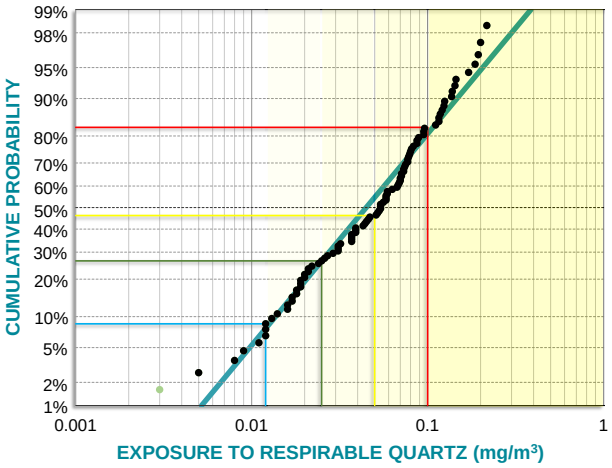
Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C12.07.01 - Truck driver / loader operator	100	0.020	2.628	97.0%	83.9%	54.5%	26.6%
C12.07.02 - Forklift operator (processing lines)	16	0.011	4.855	95.2%	77.7%	59.2%	50.9%
C12.07.03 - Bridge-crane operator (factory yard)	22	0.016	3.639	92.9%	87.2%	69.7%	41.0%
C12.08.01 - Warehouse operator	28	0.023	3.624	89.1%	63.5%	44.7%	29.3%
C12.09.01 - Polyvalent worker	58	0.017	3.234	94.3%	81.8%	62.9%	44.0%
C12.10.01 - Maintenance mechanic / electrician	9	0.015	5.950	84.2%	70.3%	62.8%	39.2%

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

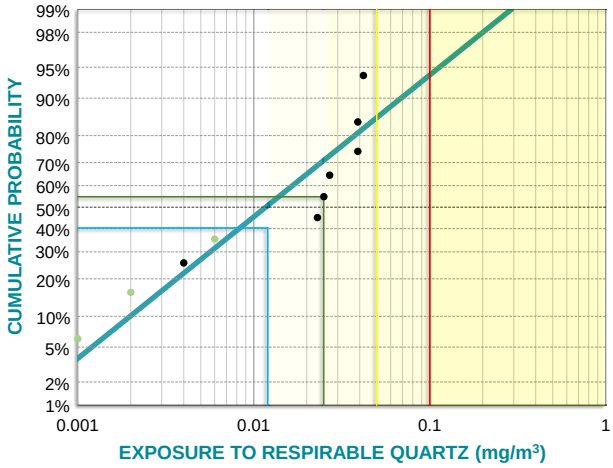
C12.01.01 - Manager



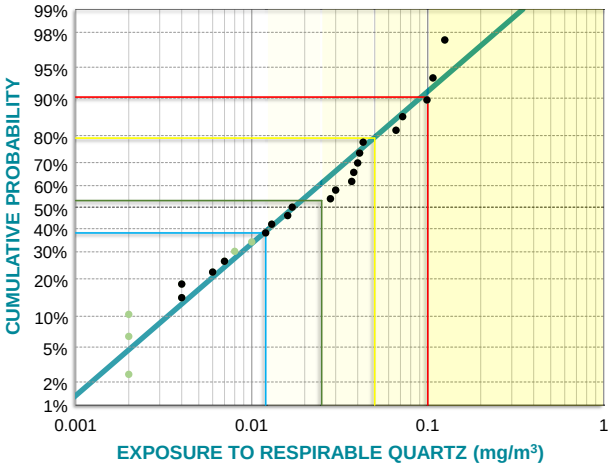
C12.02.03 - Multi-blade frame saw (for blocks) operator



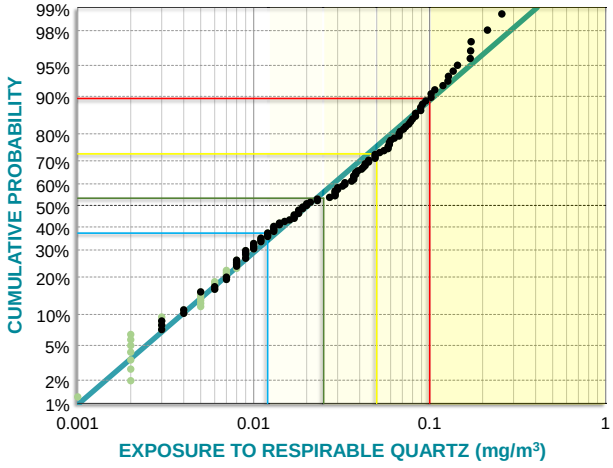
C12.02.04 - Single-blade frame saw (for blocks) operator



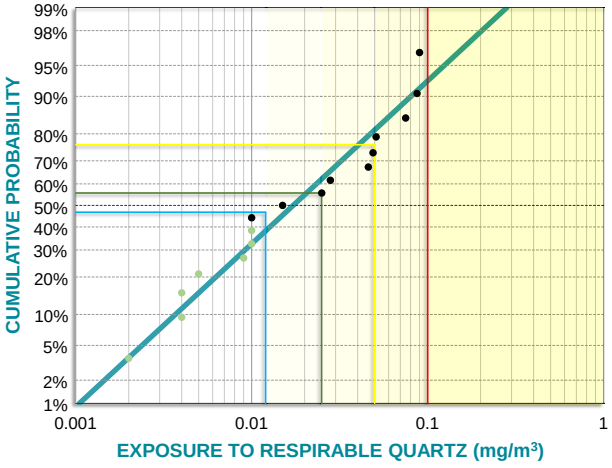
C12.02.05 - Mono/multi disc cutter (for blocks) operator



C12.03.01 - Polishing / bevelling (semi)automatic machine operator

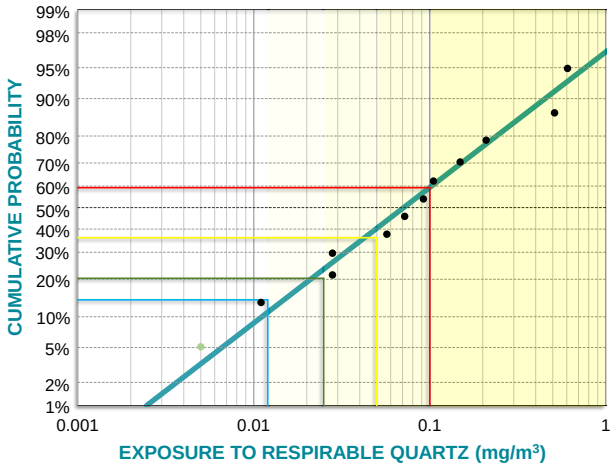


C12.03.02 - Arm polisher operator

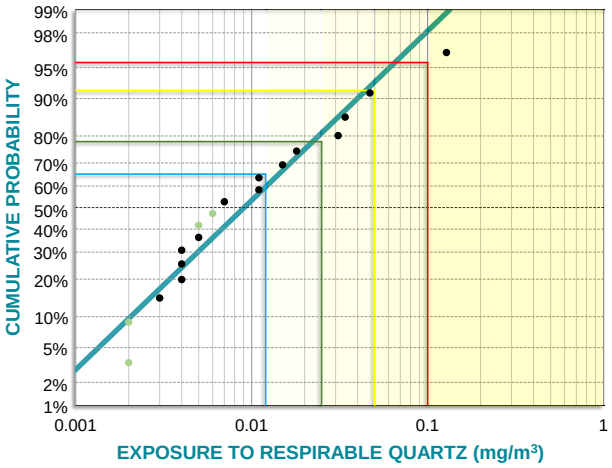


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

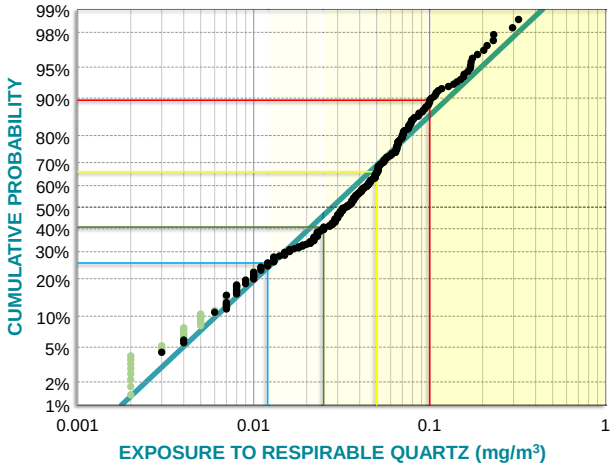
C12.03.04 - Bush hammer operator



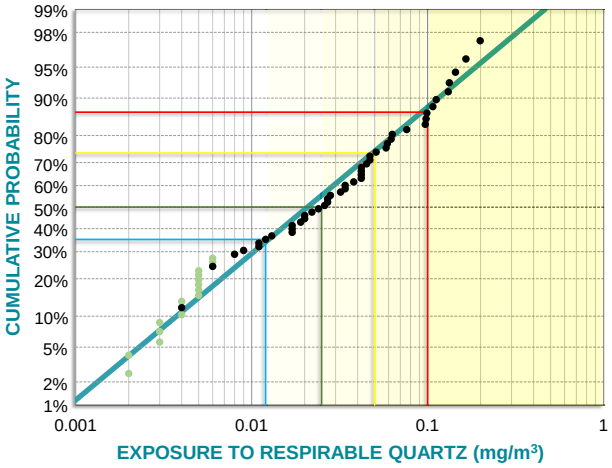
C12.03.08 - Finishing operator (general)



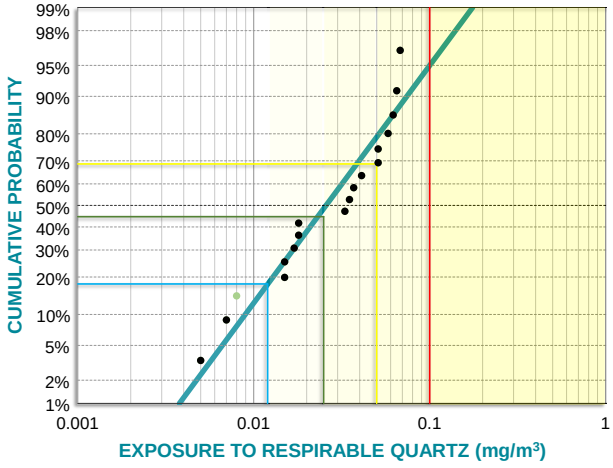
C12.04.01 - Manually-controlled slab cutting machine operator



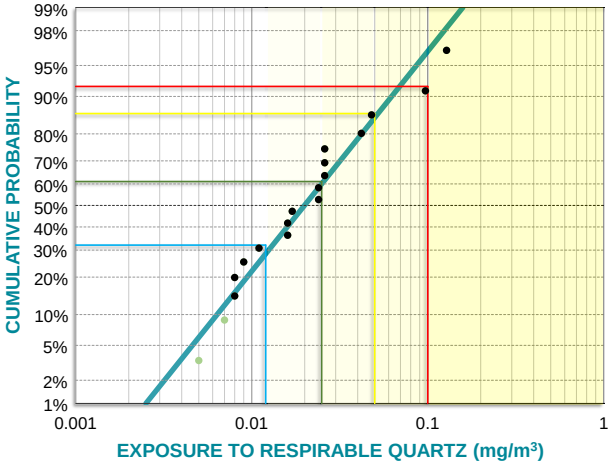
C12.04.02 - Semi- or fully-automatic slab cutting machine operator



C12.04.03 - Automatic slab cutting line operator

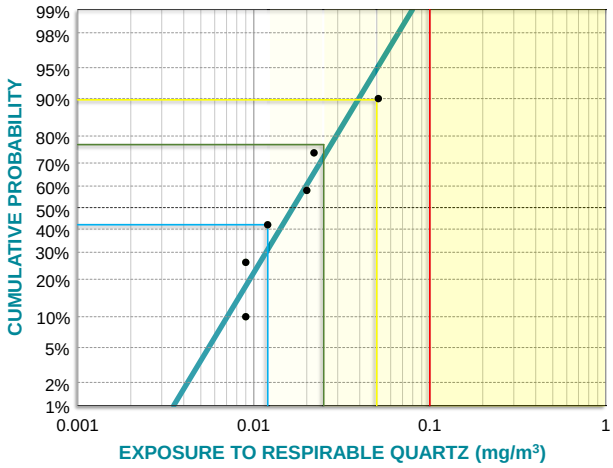


C12.04.04 - Computerised numerical control lathe machine operator

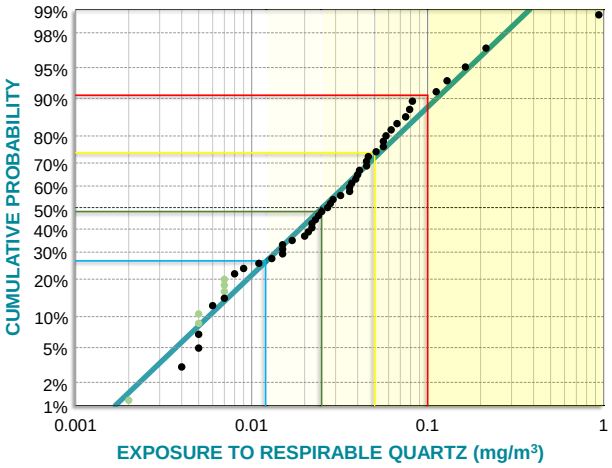


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

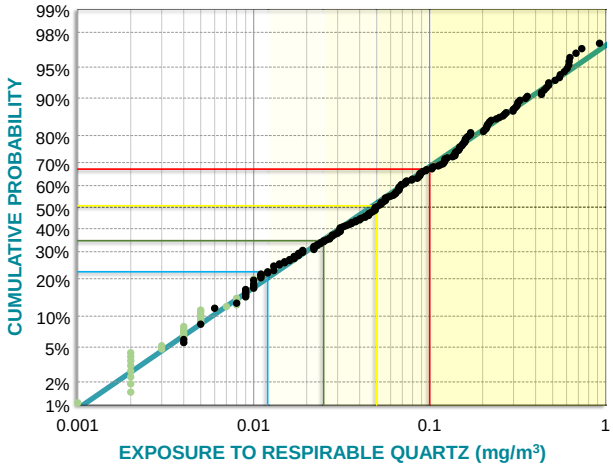
C12.04.05 - Waterjet slab cutting machine operator



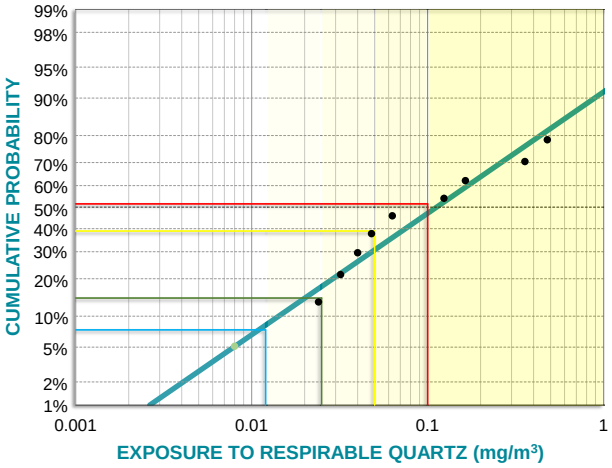
C12.04.06 - Slab cutting machine operator (general)



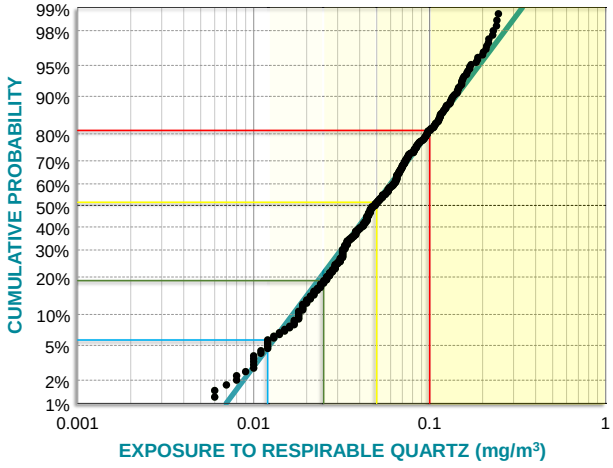
C12.05.01 - Hand finishing operator



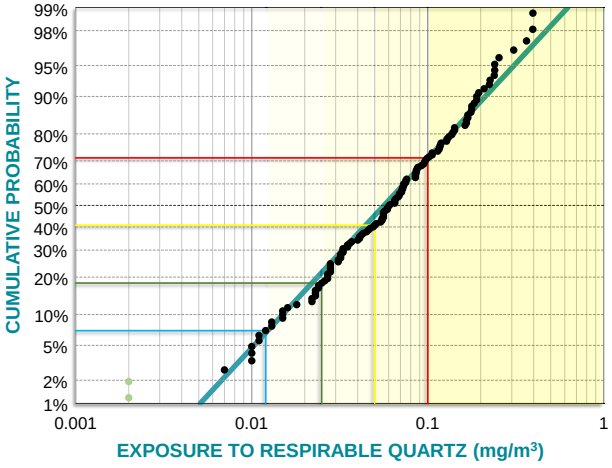
C12.06.01 - Stonemason



C12.06.03 - Stone sorter / splitter

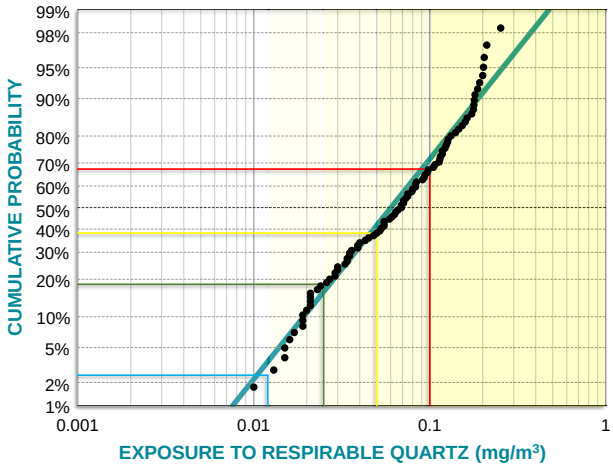


C12.06.04 - Cube cutting machine operator

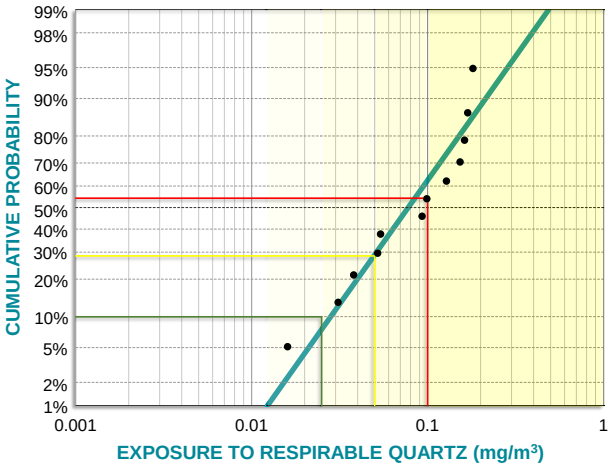


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

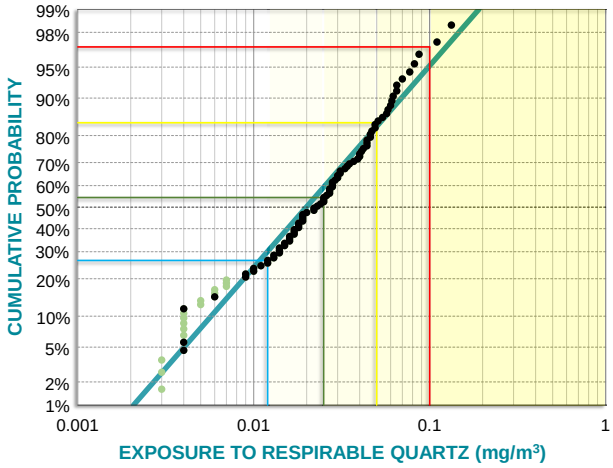
C12.06.05 - Tile splitting machine operator



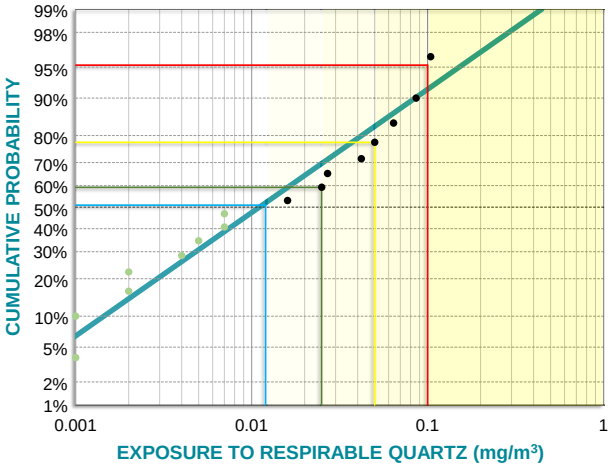
C12.06.06 - Crusher



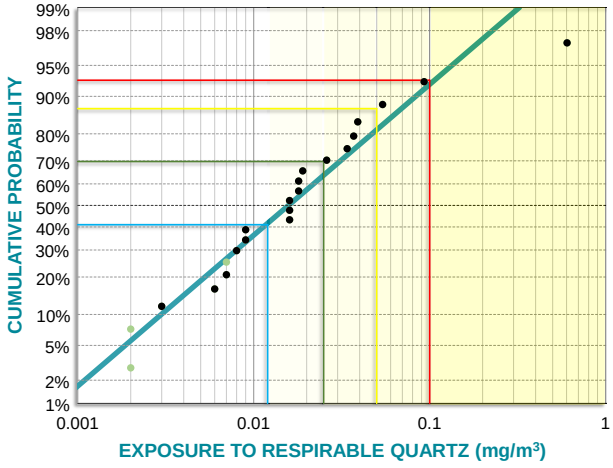
C12.07.01 - Truck driver / loader operator



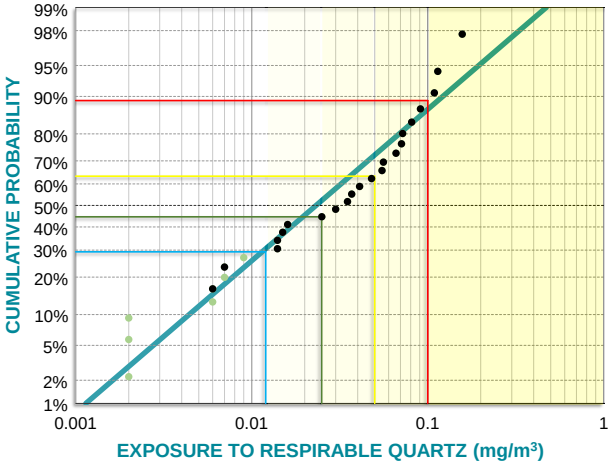
C12.07.02 - Forklift operator (processing lines)



C12.07.03 - Bridge-crane operator (factory yard)

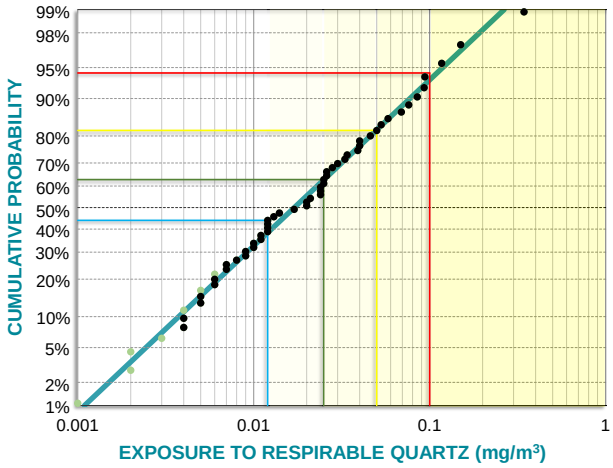


C12.08.01 - Warehouse operator

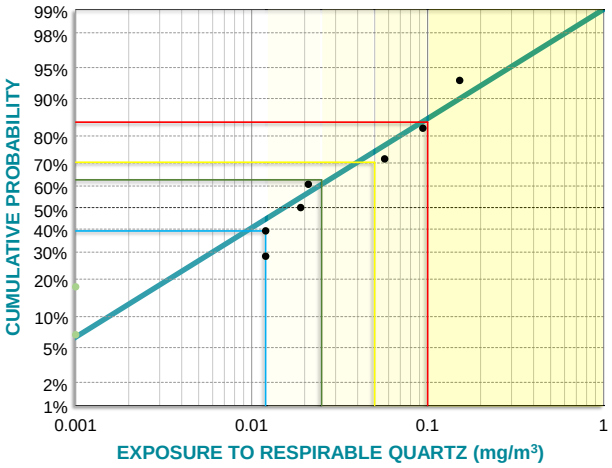


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C12.09.01 - Polyvalent worker



C12.10.01 - Maintenance mechanic / electrician



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C12.01.01 - Manager	46	0.215	2.198		>98.6%	74.3%
C12.01.02 - Office worker	2	0.144	-	-	-	-
C12.02.02 - Wire block cutting machine operator	4	0.217	1.762	-	-	-
C12.02.03 - Multi-blade frame saw (for blocks) operator	102	0.453	2.124	>99.4%	97.4%	28.5%
C12.02.04 - Single-blade frame saw (for blocks) operator	11	0.472	3.310	89.7%	85.6%	34.1%
C12.02.05 - Mono/multi disc cutter (for blocks) operator	26	0.450	2.482	96.5%	91.9%	41.9%
C12.03.01 - Polishing / bevelling (semi)automatic machine operator	136	0.437	2.525	94.2%	90.7%	33.9%
C12.03.02 - Arm polisher operator	17	0.526	1.775		>96.4%	16.1%
C12.03.03 - Grouting / resin coating operator	7	0.205	3.164		>91.4%	60.1%
C12.03.04 - Bush hammer operator	12	1.080	2.290	89.4%	65.7%	6.5%
C12.03.05 - Flaming operator	6	0.283	2.192		>90.0%	42.0%
C12.03.08 - Finishing operator (general)	18	0.342	2.071	>96.6%	95.3%	41.2%
C12.04.01 - Manually-controlled slab cutting machine operator	269	0.414	2.191	99.0%	95.9%	31.6%
C12.04.02 - Semi- or fully-automatic slab cutting machine operator	69	0.459	2.848	93.1%	86.2%	40.5%
C12.04.03 - Automatic slab cutting line operator	20	0.342	1.944		>96.9%	44.5%
C12.04.04 - Computerised numerical control lathe machine operator	20	0.167	1.958		>96.9%	87.7%
C12.04.05 - Waterjet slab cutting machine operator	6	0.361	2.586		>90.0%	44.5%
C12.04.06 - Slab cutting machine operator (general)	53	0.489	2.535	95.6%	86.0%	30.3%
C12.05.01 - Hand finishing operator	247	1.048	2.896	84.2%	62.4%	12.4%
C12.06.01 - Stonemason	13	0.727	3.640	84.0%	63.3%	30.3%
C12.06.02 - Stone carver	2	0.233	-	-	-	-
C12.06.03 - Stone sorter / splitter	378	0.383	1.953	>99.8%	98.4%	35.9%
C12.06.04 - Cube cutting machine operator	147	0.378	2.235	>99.6%	95.4%	42.4%
C12.06.05 - Tile splitting machine operator	98	0.393	1.939	>99.4%	98.3%	33.3%
C12.06.06 - Crusher	12	0.513	2.785		>94.9%	12.3%
C12.06.07 - Floor layer and tile setter	4	0.229	1.601	-	-	-

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C12.07.01 - Truck driver / loader operator	109	0.200	1.968		>99.4%	74.8%
C12.07.02 - Forklift operator (processing lines)	16	0.288	1.884		>96.2%	44.6%
C12.07.03 - Bridge-crane operator (factory yard)	22	0.268	2.353	96.7%	95.2%	62.7%
C12.08.01 - Warehouse operator	28	0.351	2.260	>97.8%	96.0%	38.8%
C12.09.01 - Polyvalent worker	59	0.286	2.323	>98.9%	94.9%	55.1%
C12.10.01 - Maintenance mechanic / electrician	10	0.378	1.672		>93.9%	34.5%

Working processes

Powders of abrasive grains are manufactured by crushing and sizing natural or synthetic abrasives and then used by other abrasives manufacturers to make products such as abrasive belts, rolls and cloths for manual finishing operations or to be used in sanding machines. Abrasive pastes and emulsions are used for cleaning and polishing with manual, mechanical or robotised processing. Sintered abrasives are used in a number of abrasive wheel applications for deburring, grinding, sharpening, etc. The most commonly used abrasive materials are artificial corundum, silicon carbide (*carborundum*) or boron carbide, which generally make up about 80% of the mass of the finished product. Synthetic diamond, garnet and quartz are used in smaller quantities. A production cycle of rigid abrasive tools is briefly described below.

1. **Storage of raw materials** – mainly represented by silicon carbide and artificial corundum, as well as by water, ceramic binders (kaolin, quartz, clays of different types, sodium and potassium feldspar minerals) and/or synthetic resin binders (commonly phenolic resin).
2. **Mixing** – the raw materials are dosed and poured in a rotating bowl mixer, with the addition of binders (to enhance the cohesion of the mixture), then the particles are classified in a vibrating screen system.
3. **Pressing** – the mixture is placed in steel moulds and pressed in a hydraulic press to obtain blocks of the desired shape.
4. **Raw finishing** – is carried out on part of the blocks produced (while the others are sent directly to the baking ovens) and is generally comprised of a series of mechanical processing, such as flattening and grinding.
5. **Hot-working** – in case of ceramic binder abrasives, consisting of kaolin, quartz, feldspar and glass agglomerates, the material is fired in a high-temperature oven, while synthetic resin binder abrasives are hardened in the oven.
6. **Quality control** – by checking the modulus of elasticity, the hardness and the specific weight.
7. **Reduction to size and rectification** – may be carried out on blocks that have not undergone the previous finishing.
8. **Final check, storing, packing and shipping** – after a final check, the products are packed and stored in the warehouse and eventually loaded on a truck for delivery.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	9	0.123	2.430	4	0.020	1.741	10.6
STATIC	-	-	-	-	-	-	-

Geometric mean of personal exposure, by region

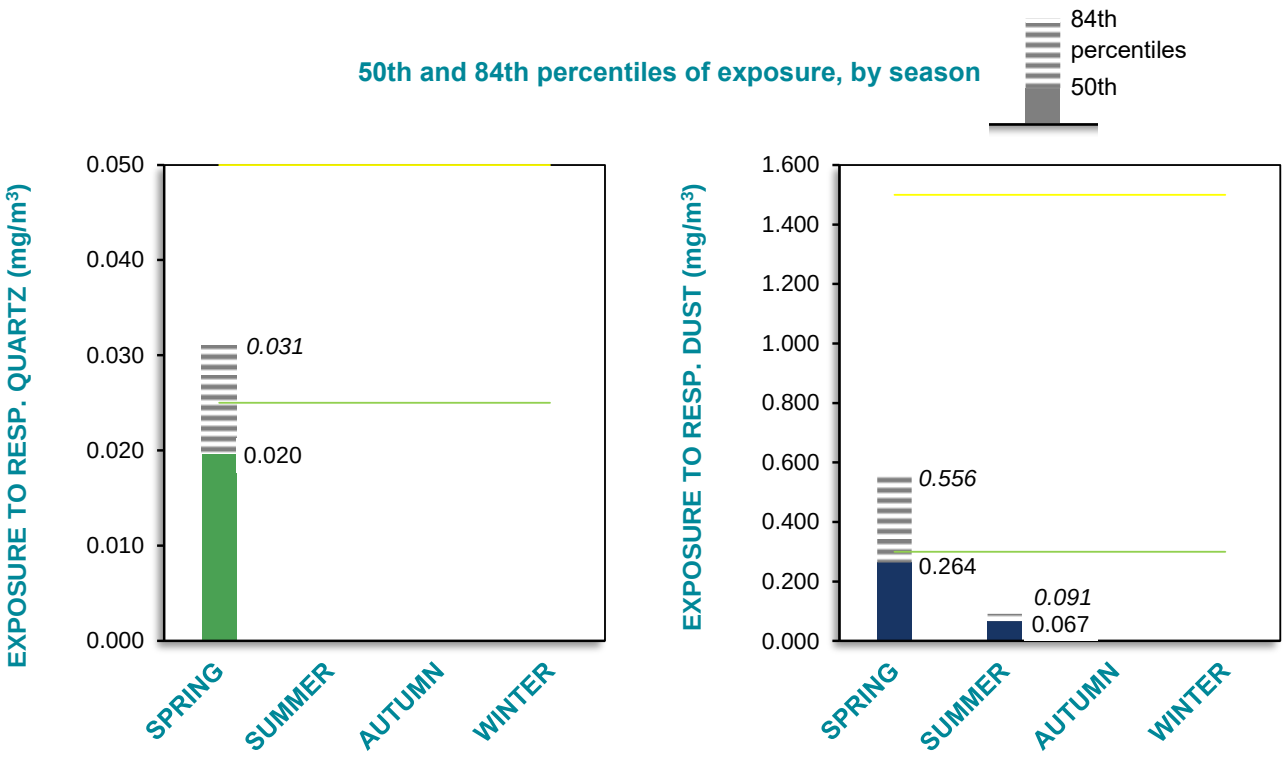
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

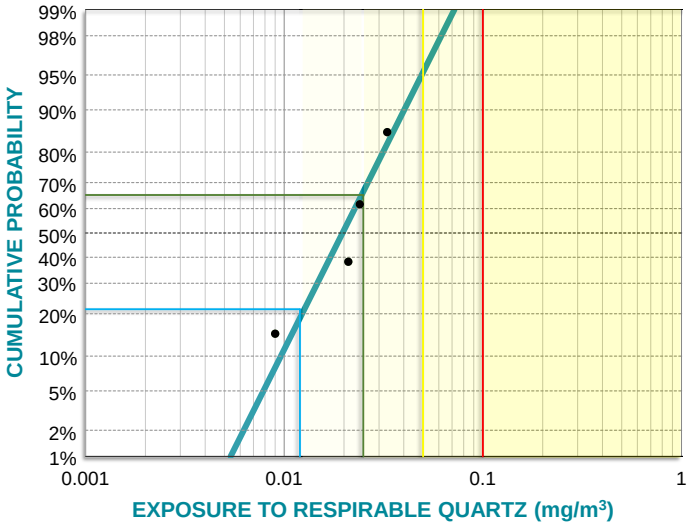
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

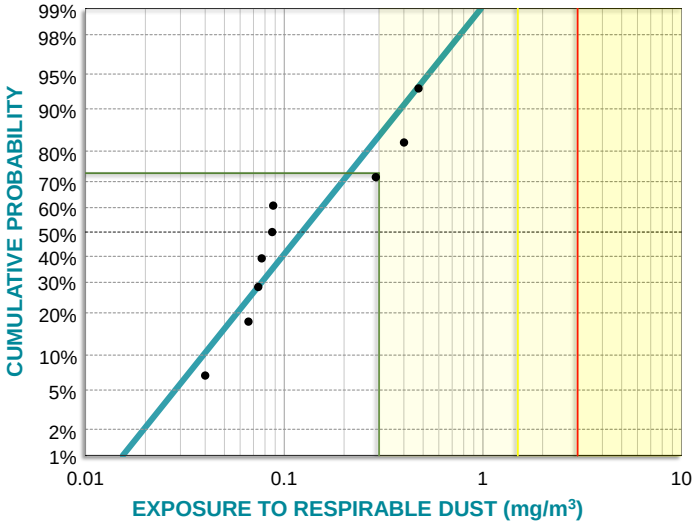


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



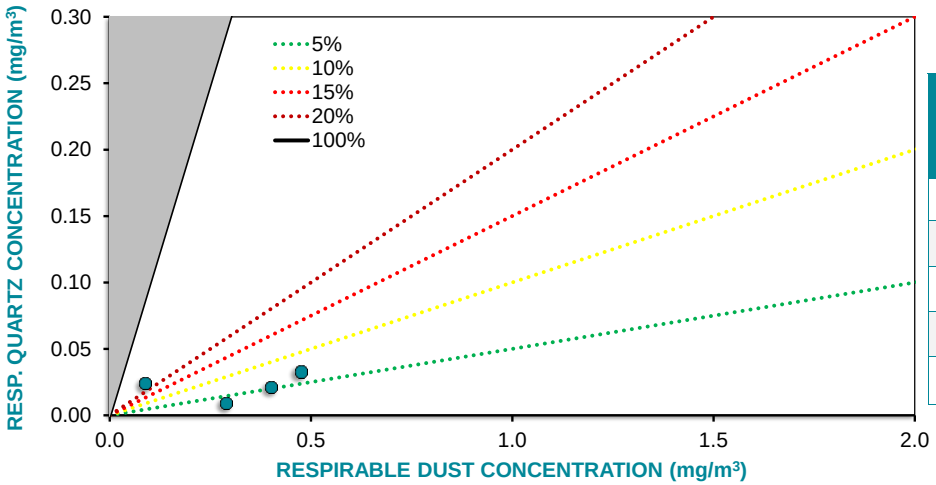
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	-
≤0.05	>85.3%
≤0.025	65.4%
≤0.012	21.3%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	-
≤1.5	>93.2%
≤0.3	73.0%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	25%
>5% to 10%	50%
>10% to 15%	0%
>15% to 20%	0%
>20%	25%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C13.01 - Management and office work	
C13.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C13.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C13.02 - Composition of the mixture	
C13.02.01 - Weigher and mixer	Breaks sacks or bags with raw materials (magnesium sulphate, silicon carbide, magnesium chloride and ground quartz). Weighs raw materials to ensure conformance to requirements. Loads the material in the mixing machine in which water recalled by a hydraulic system is added. The mixture obtained is then poured into moulds to make grinding or polishing compounds.
C13.03 - Coated abrasive production	
C13.03.01 - Coated abrasive machine operator	Operates and controls the machine for the production of coated abrasive on flexible backing (so called *sandpaper*, but with organic or synthetic abrasive; aluminium oxide and silicon carbide are the most common abrasive minerals). Layers of adhesive hold the abrasive mineral to the backing.
C13.04 - Grinding wheels and abrasive segments production	
C13.04.01 - Moulding press operator	Operates hydraulic press for grinding wheels and abrasive segments production. Fills mould with a paste of mixed abrasive compound (based on silicon carbide and corundum, with addition of suitable binders). Puts mould in press, starts and operates press. Withdraws and transfers the shaped abrasive products on a trolley. Generally, does not stand in a fixed position but moves as needed along the production line.
C13.05 - Finishing	
C13.05.01 - Turner / grinder for abrasive wheels	Carries out the finishing, dressing, turning, levelling and grinding of abrasive wheels.
C13.06 - Kiln firing	
C13.06.01 - Kiln loading/unloading operator	Operates (tunnel, shuttle) kiln for abrasive products. Loads the kiln car with the green abrasives and introduces it into the kiln. After the firing is completed, unloads the products and stacks them on pallets in the warehouse.
C13.07 - Warehousing and packaging	
C13.07.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Examines, sorts, packages and records data of finished products. Drives forklift to pick up incoming stock or deliver materials to designated areas.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C13.08 - Mechanical and electrical maintenance / cleaning	
C13.08.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C13.08.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C13.01.01 - Manager	2	0.028	-	-	-	-	-
C13.02.01 - Weigher and mixer	1	0.021	-	-	-	-	-
C13.04.01 - Moulding press operator	-	-	-	-	-	-	-
C13.05.01 - Turner / grinder for abrasive wheels	-	-	-	-	-	-	-
C13.06.01 - Kiln loading/unloading operator	1	0.009	-	-	-	-	-

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C13.01.01 - Manager	3	0.154	2.652	-	-	-
C13.02.01 - Weigher and mixer	1	0.401	-	-	-	-
C13.04.01 - Moulding press operator	2	0.071	1.115	-	-	-
C13.05.01 - Turner / grinder for abrasive wheels	2	0.054	-	-	-	-
C13.06.01 - Kiln loading/unloading operator	1	0.289	-	-	-	-

Working processes

Cores are models used in foundries to create internal cavities in the casting, preventing molten metal from filling a designed part of the casting. Cores are made of refractory materials, such as silica sand coated with resin, or mixtures of sand and resin, using a core-box that reproduces the negative of the core itself. Cores are designed to break down only after the cooling and so it is for this reason binders that burn off during solidification are used. The cores can be produced in the core department of a foundry (in this case, their production is included in C16 *Foundries*) or the same activity is carried out by a specialised company, in which case the sand core production is classified here. The production cycle is described as follows.

1. **Raw materials storage** – materials are unloaded in containers, boxes and silos in storage areas. Materials are then conveyed to the mixer, which in the older plants is fed manually by a worker.
2. **Pattern and core-boxes making** – the patterns are made of wood or metal (works of carpentry or removal performed with machine tools); seldom, gypsum, cement, or synthetic resin is used. Core boxes in materials such as wood and iron are common.
3. **Core making** – three main methods are used:

   - Manual moulding: the core-box is filled manually with sand together with resin and a catalyst, using a mixer, then compacted and flattened. A gagger can be put inside the core to keep the core in position. After hardening, the two parts of the core-box are opened and the core is extracted.

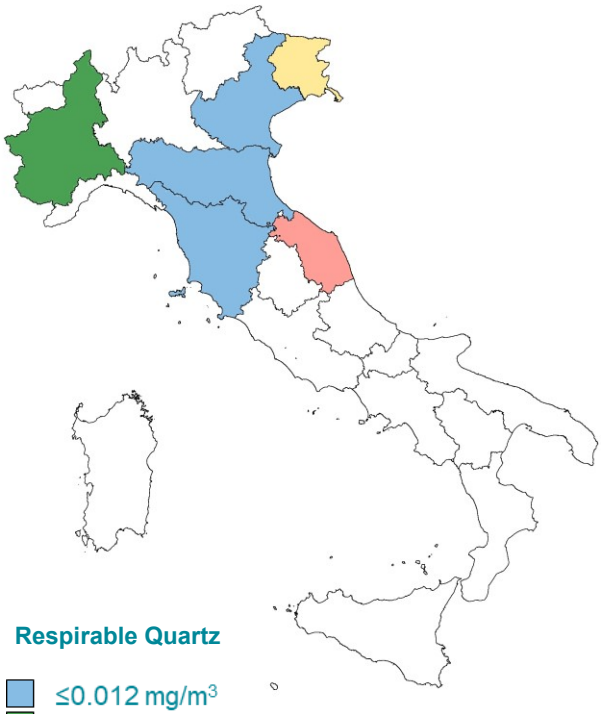
   - Cold-box (or *Ashland*) method, with automatic core shooters: the sand mixed with a resin binder is forced into the core-box by compressed air. Hardening is achieved by blowing the cores with a gas catalyst and then an ejector extracts the cores.

   - Shell-moulding (or *hot-box*) method, with core-blowers: sand grains are coated with a thermosetting resin; the sand is blown inside the heated core-box. The chemical coating creates the bonding when heated, resulting in the core hardening; after that, the core is extracted from the box by an ejector.
4. **Handling (materials and products)** – the cores are placed into trays and boxes and moved by hand or using forklifts and pallet trucks.
5. **Core finishing** – by hand using files, sandpaper and other tools; segmented cores are assembled with hot glue.
6. **Core varnishing** – some kinds of cores need to be covered with a refractory coating. The preferred technique is to dip the core in the coating. Usually, a drying phase follows.
7. **Storing, packing and shipping** – the finished product is placed on trays and then stored in the warehouse, in open storage boxes, or packed in cardboard/polystyrene boxes. Eventually, the products are loaded on a truck for delivery.

Geometric mean and geometric standard deviation values of exposure measurements

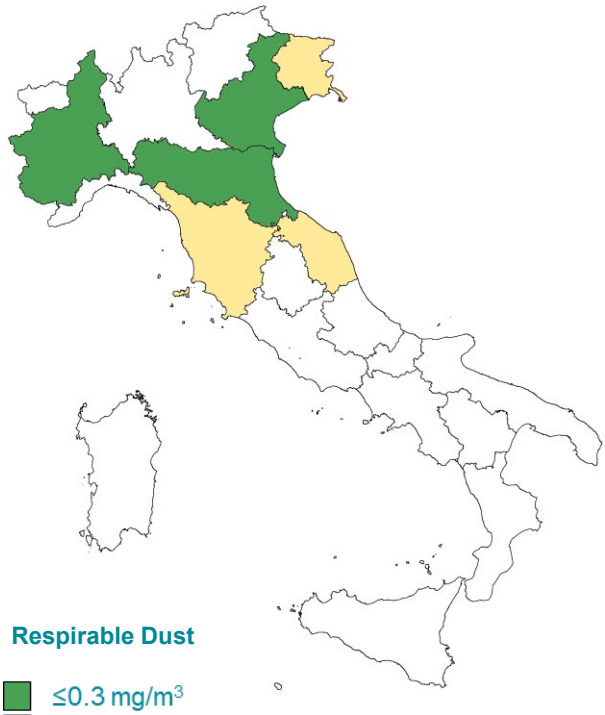
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	140	0.213	2.362	123	0.014	3.774	10.5
STATIC	5	0.114	1.575	5	0.010	2.080	9.0

Geometric mean of personal exposure, by region



Respirable Quartz

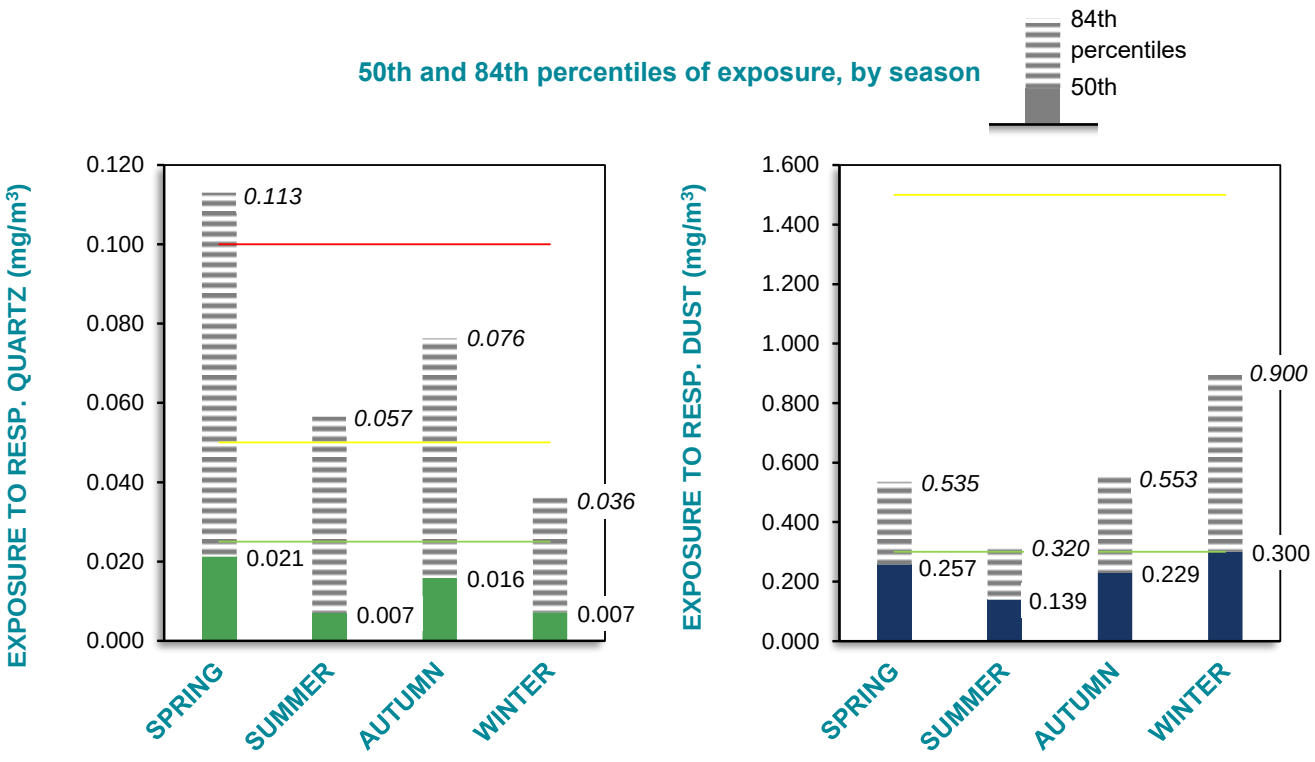
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



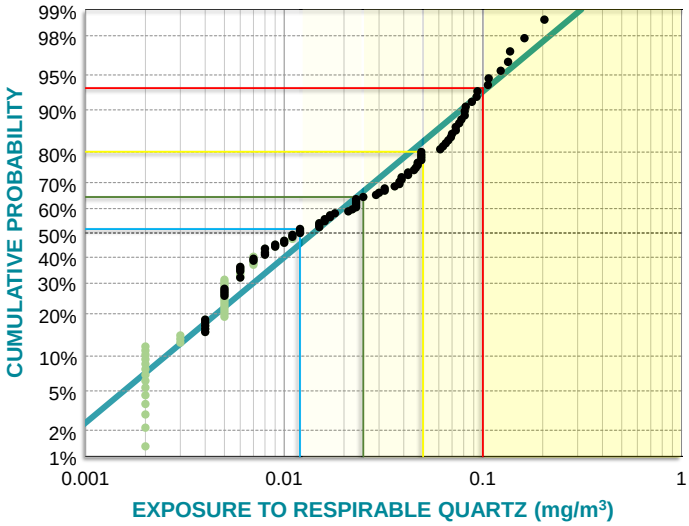
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

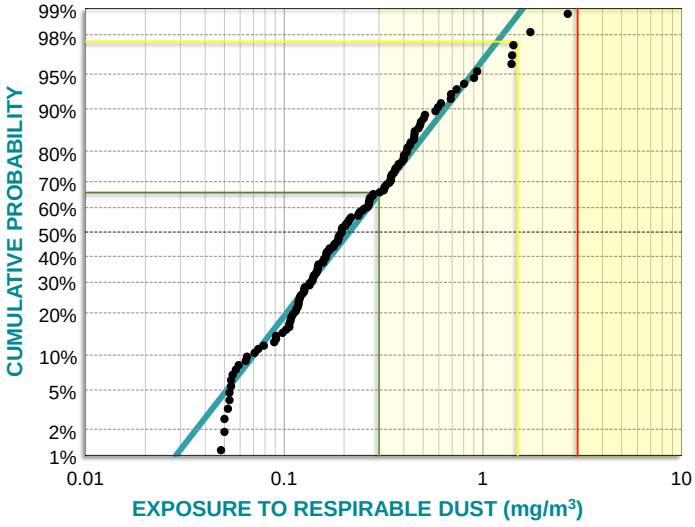


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



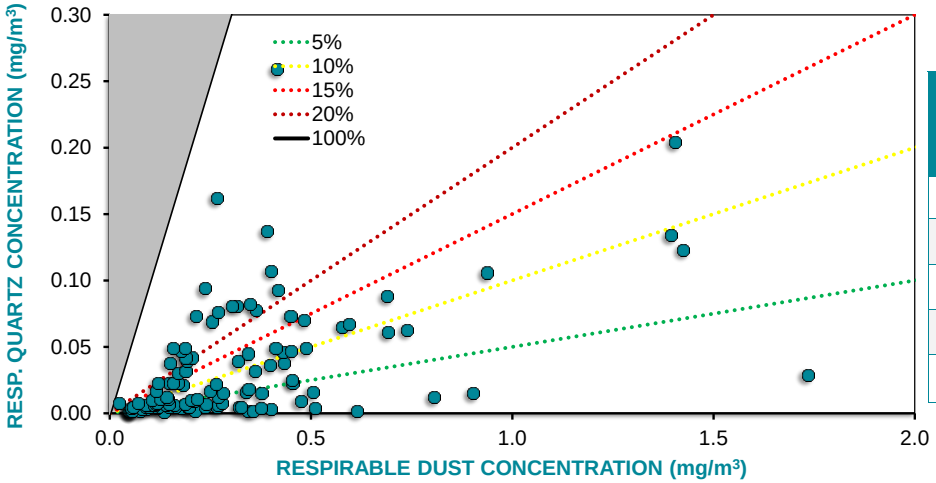
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	93.4%
≤0.05	80.1%
≤0.025	64.6%
≤0.012	51.6%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	99.1%
≤1.5	97.6%
≤0.3	65.9%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	43%
>5% to 10%	23%
>10% to 15%	12%
>15% to 20%	5%
>20%	17%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C14.01 - Management and office work	
C14.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C14.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C14.02 - Core making	
C14.02.01 - Mixer	Loads the automatic (kneading) mixing machine, controlling the mixture of sand, catalyst, resin and aggregate. If necessary, carries the mixture to the core maker by wheelbarrow.
C14.02.02 - Hand core maker	Prepares sand-cores by hand. Takes the mixture of sand, catalyst, resin and aggregate from a bucket and forces it into specially shaped hollow forms.
C14.02.03 - Semi-mechanised core making operator	Prepares sand-cores by using a machine that fills the specially shaped hollow forms with the mixture of sand, catalyst, resin and aggregate, then smooths it by hand.
C14.02.04 - Cold-box core-shooting machine operator	Operates cold-box core-shooting machine at room temperature (Ashland process), where phenolic resin and polyurethane are used as the binder, producing a flowable sand mix that is shot into the core box. Clamps core box into the machine; withdraws core from core box. May carry out finishing (with files or vibratory tumbler) and painting of cores. Cleans the core box. Carries out the tooling of machine components.
C14.02.05 - Hot-box core-shooting machine (shell-moulding) operator	Operates hot core-shooting machine, where a phenolic resin-coated sand, coated with a silicone release agent, is shot into a mould at about 270°C; the melting of the resin binds the sand grains and forms a solid shell (shell moulding process). Clamps core box into the machine; withdraws core from core box. May carry out finishing (with files or vibratory tumbler) and painting of cores. Cleans the core box. Carries out the tooling of machine components.
C14.02.06 - Core-shooting machine tool assembler	Fits and assembles core-shooting machine parts and components according to specifications for products.
C14.02.07 - Sand core finishing / deburring operator	Carries out manual finishing of sand cores with files. May perform the gluing of the parts making up the sand core.
C14.02.08 - Core painting operator	Applies water-based with dipping or brush painting over core surfaces to be treated.
C14.02.09 - Dryer operator	Operates the sand core dryers. Loads the cores on trays and places them in the dryer. At the end of the drying phase, moves them to storage and unloads the cores.

Contarp 2016 classification

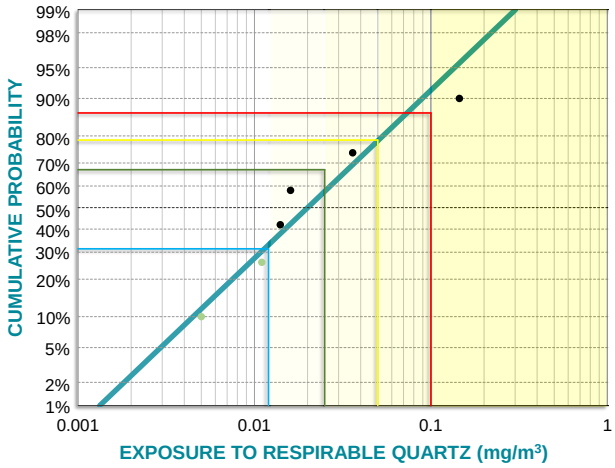
WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C14.03 - Pattern making	
C14.03.01 - Pattern maker	Makes patterns (models) of cores and moulds used to reproduce the object. The pattern can be made of wood, metal, plaster, concrete or synthetic resin. Finishes the pattern, if required.
C14.04 - Handling of materials and products	
C14.04.01 - Forklift operator	Operates material handling equipment (hand or battery operated pallet truck, reach truck, forklift) to move, pack and store raw materials and finished products.
C14.05 - Warehousing and packaging	
C14.05.01 - Warehouse operator	Handles duties pertaining to the processing, organising, packaging and shipping of materials, equipment and other items that are sent to warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.
C14.06 - Various workspaces	
C14.06.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C14.07 - Mechanical and electrical maintenance / cleaning	
C14.07.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C14.07.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

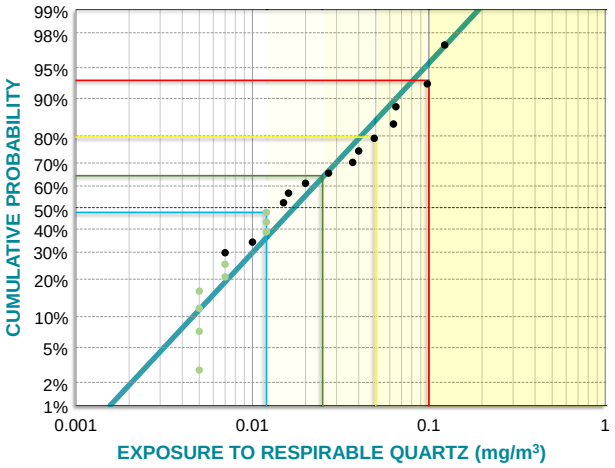
Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C14.02.01 - C16.05.01 - Mixer	6	0.020	3.189	86.7%	78.6%	67.2%	31.4%
C14.02.02 - Hand core maker	22	0.017	2.796	93.2%	79.6%	64.6%	47.8%
C14.02.03 - C16.05.03 - Semi-mechanised core making operator	41	0.019	3.746	93.7%	78.5%	62.1%	25.8%
C14.02.04 - C16.05.04 - Cold-box core-shooting machine operator	77	0.022	3.097	93.0%	76.1%	57.1%	28.0%
C14.02.05 - C16.05.05 - Hot-box core-shooting machine (shell-moulding) operator	33	0.008	2.483		>98.1%	84.7%	68.0%
C14.02.06 - C16.05.06 - Core-shooting machine tool assembler	5	0.020	2.032	-	-	-	-
C14.02.07 - C16.05.07 - Sand core finishing / deburring operator	24	0.013	5.183	83.8%	77.0%	62.8%	47.9%
C14.02.08 - C16.05.08 - Core painting operator	8	0.008	3.162	>92.4%	90.5%	85.6%	56.1%
C14.03.01 - C16.06.01 - Pattern maker	13	0.018	2.637	>95.3%	83.1%	58.6%	40.8%
C14.04.01 - Forklift operator	4	0.005	3.282	-	-	-	-
C14.05.01 - Warehouse operator	2	0.008	-	-	-	-	-
C14.06.01 - Polyvalent worker	1	0.006	-	-	-	-	-
C14.07.01 - Maintenance mechanic / electrician	1	0.073	-	-	-	-	-

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

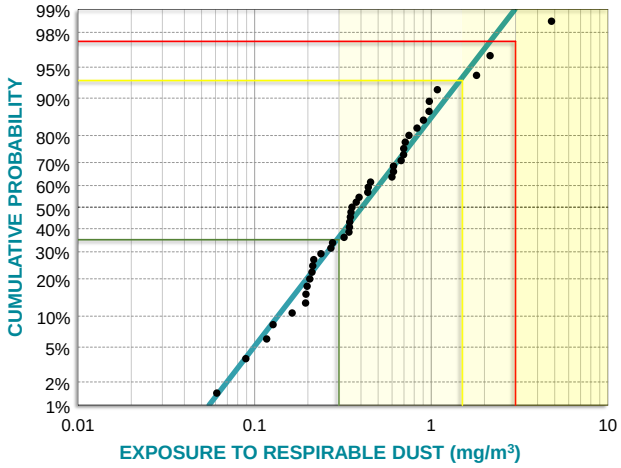
C14.02.01 - C16.05.01 - Mixer



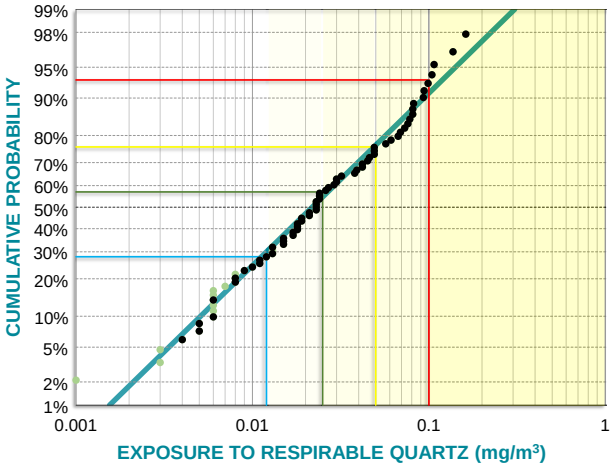
C14.02.02 - C16.05.02 - Hand core maker



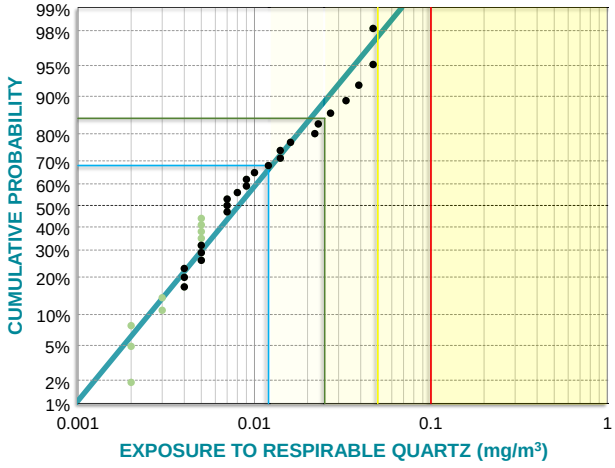
C14.02.03 - C16.05.03 - Semi-mechanised core making operator



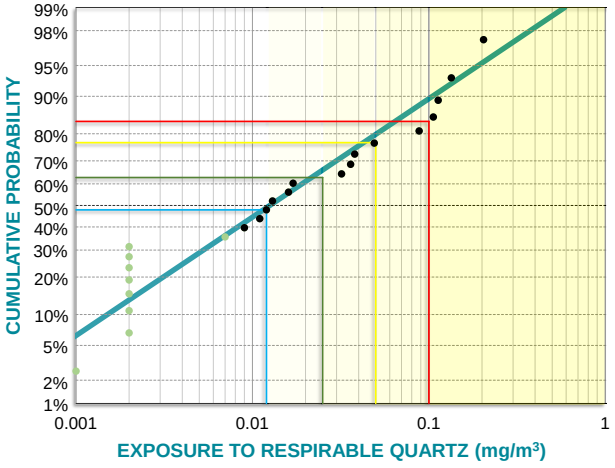
C14.02.04 - C16.05.04 - Cold-box core-shooting machine operator



C14.02.05 - C16.05.05 - Hot-box core-shooting machine (shell-moulding) operator

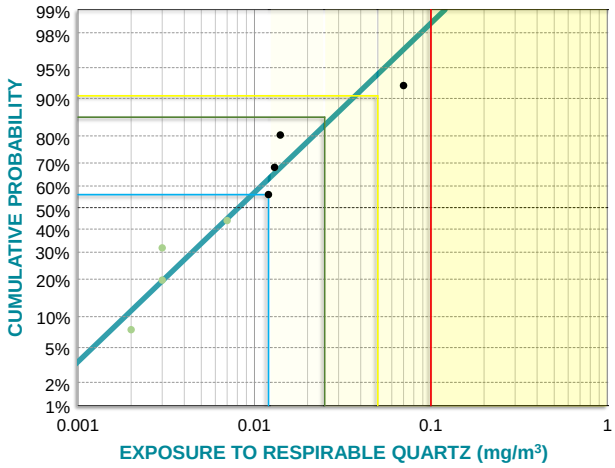


C14.02.07 - C16.05.07 - Sand core finishing / deburring operator

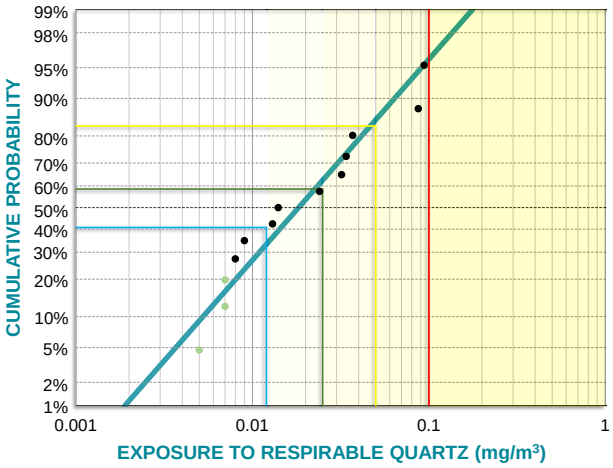


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C14.02.08 - C16.05.08 - Core painting operator



C14.03.01 - C16.06.01 - Pattern maker



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C14.02.01 - C16.05.01 - Mixer	6	0.231	1.350		>90.0%	80.8%
C14.02.02 - C16.05.02 - Hand core maker	23	0.351	2.626	96.4%	93.3%	43.5%
C14.02.03 - C16.05.03 - Semi-mechanised core making operator	43	0.406	2.346	97.4%	93.2%	35.1%
C14.02.04 - C16.05.04 - Cold-box core-shooting machine operator	83	0.188	1.878		>99.2%	70.0%
C14.02.05 - C16.05.05 - Hot-box core-shooting machine (shell-moulding) operator	38	0.171	2.193		>98.4%	73.7%
C14.02.06 - C16.05.06 - Core-shooting machine tool assembler	5	0.443	1.390	-	-	-
C14.02.07 - C16.05.07 - Sand core finishing / deburring operator	24	0.250	3.277	>97.4%	93.9%	53.8%
C14.02.08 - C16.05.08 - Core painting operator	9	0.226	2.082		>93.2%	55.4%
C14.03.01 - C16.06.01 - Pattern maker	14	0.324	1.601		>95.6%	40.6%
C14.04.01 - Forklift operator	4	0.474	3.042	-	-	-
C14.05.01 - Warehouse operator	3	0.127	1.139	-	-	-
C14.06.01 - Polyvalent worker	1	0.268	-	-	-	-
C14.07.01 - Maintenance mechanic / electrician	3	0.154	1.345	-	-	-

Working processes

This industry deals with the production of iron, ferrous alloys (iron content higher than 50%) such as pig iron (2-6% in carbon) obtained from smelting iron ore or from scrap iron, steel (up to 1.8% in carbon) and other iron alloys. Iron and steel plants produce semi-finished products (ingots, slabs, billets, blooms, wire rods) that need further processing before being processed into finished goods. The source for exposure to RCS is given by the quartz contained in raw materials (e.g., quartz content in coal is usually 3-6% and even higher contents are found in ferrous ores), especially affecting the workers involved in cleaning operations and particularly those carried out in the holds of ships. The technological cycle in a large iron and steel plant can be divided into the following four processing areas.

1. **Primary stockyards** – ore and coal are unloaded from a ship's cargo hold to quays in the port terminal facility and taken to the primary stockyards. Stockpiles are formed using stackers along the length of a conveyor and reclaimers to retrieve the material when required. In this area, the coal preparation plant and the coke production and screening plants are located. Materials are crushed and sorted and the fines are agglomerated. In this area, the dry distillation of coal produces metallurgical coke.
2. **Cast iron area** – It includes the blast furnace and auxiliary plants. In the blast furnace, the mixture of metallic ore, coke and flux (limestone) is transformed into liquid metal by the produced heat from the combustion of coke with pre-heated air. The process produces cast iron and slag, which are cast separately.
3. **Steel area** – cast iron is converted into steel (lowering the carbon content of the alloy and changing it into low-carbon steel) by blowing air through the molten iron, reducing carbon and other elements contents and removing impurities. This process is carried out in L-D converters, where oxygen is blown through a lance into the liquid cast iron, oxidising carbon, silicon, manganese and phosphorous. At the end of this operation, the liquid steel is poured into the steel ladle, where it can undergo further processing by the addiction of iron alloys that give specific properties to the steel. In the continuous casting process, the liquid steel is poured from a ladle into a tundish and then into an ingot mould, which is cooled by water. The cooling of the ingot mould produces the solidification of the ingot outer layer (skin). The solidification is then completed by a jet of water droplets that cools the surface of the strand during its downward movement through a series of rolls. Afterwards, when the centre is completely solid, the semi-finished product is cut by an ox-cutting machine into slabs at the wanted length and sent to the stock.
4. **Lamination area** – the semi-finished product (slabs) produced in the steel area is sent to a heated soaking furnace and then passed through a hot-rolling mill, to reduce and make a uniform thickness, after which it is ready for the market. Coils produced from the hot rolling mill can be sent to cold rolling mills to produce a more refined surface with improved mechanical properties. The coils sent to the coating line may undergo an intermediate treatment of annealing to restore some of the ductility. Pipes can also be produced in this area, as helical (from hot-rolled coils) or longitudinal (from steel plates) welded pipes, or by Electric Resistance Welding (ERW); in the latter case, a current is passed between the two edges of a cold steel sheet, heating the steel to form a bond without the use of welding filler material.

Geometric mean and geometric standard deviation values of exposure measurements

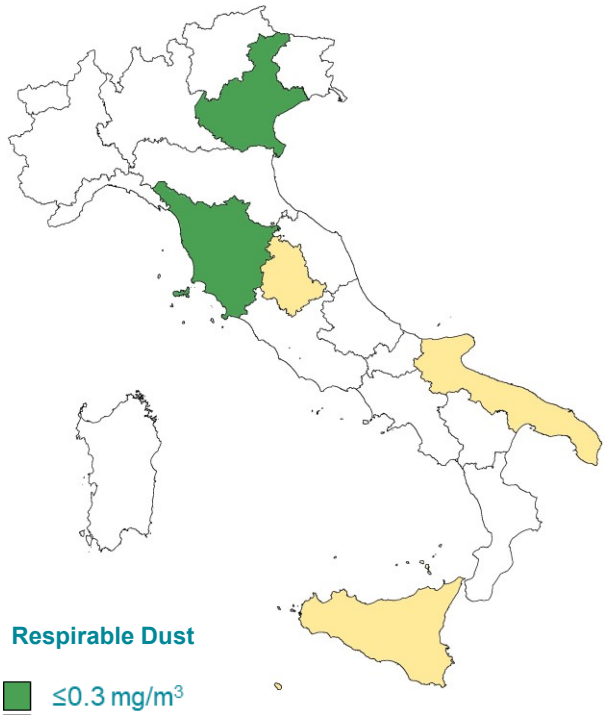
	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	524	0.425	2.538	523	0.007	2.374	2.2
STATIC	9	0.561	2.948	9	0.005	3.134	2.4

IRON AND STEEL INDUSTRY: Manufacture of basic iron and steel and of ferro-alloys

Geometric mean of personal exposure, by region

Respirable Quartz

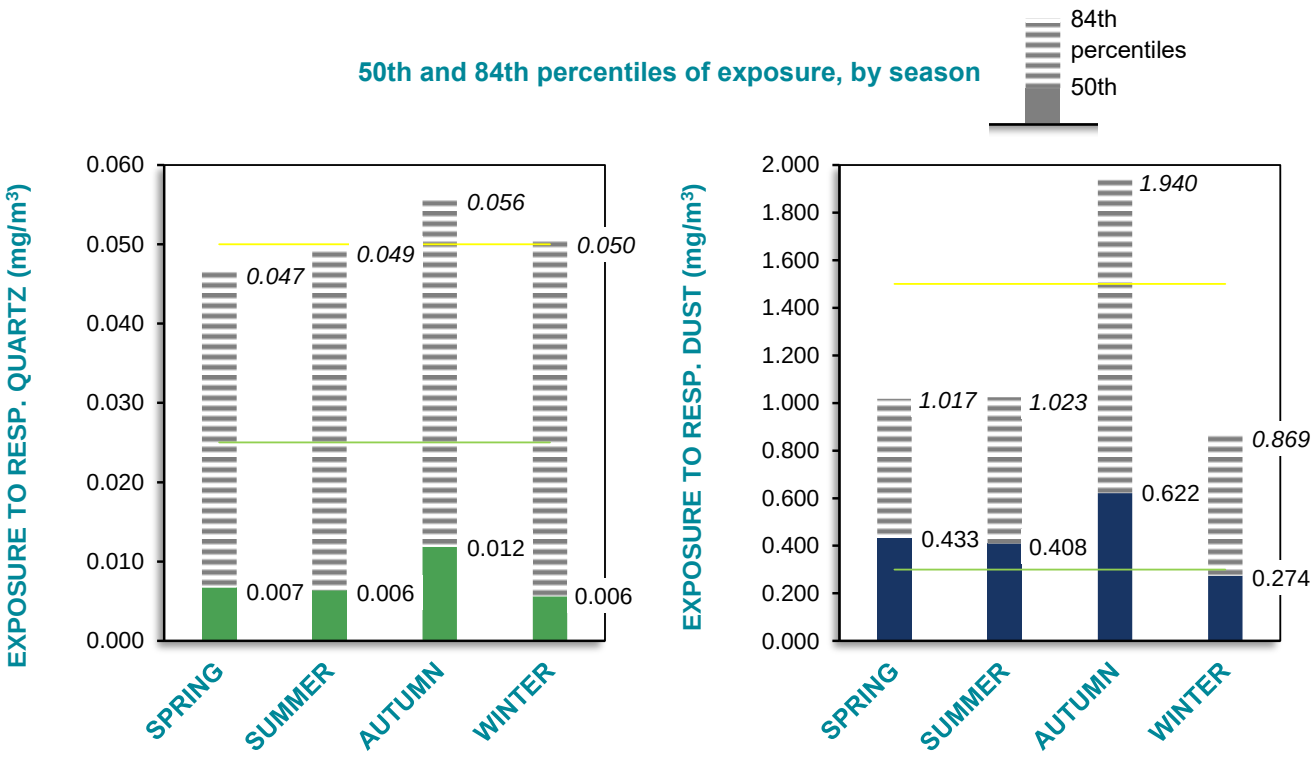
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



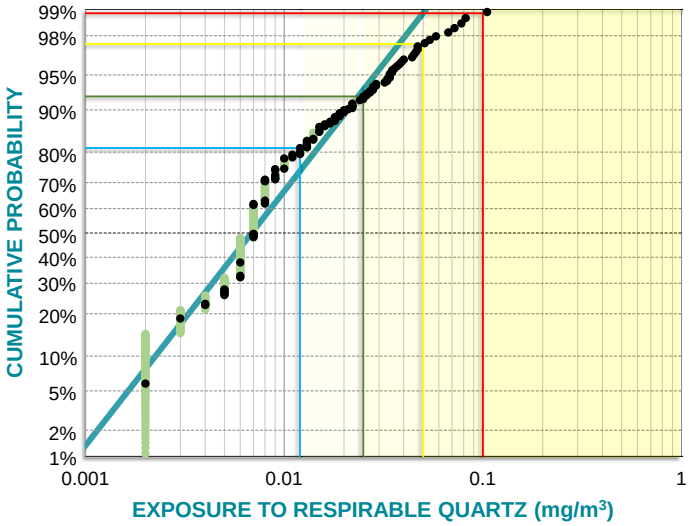
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

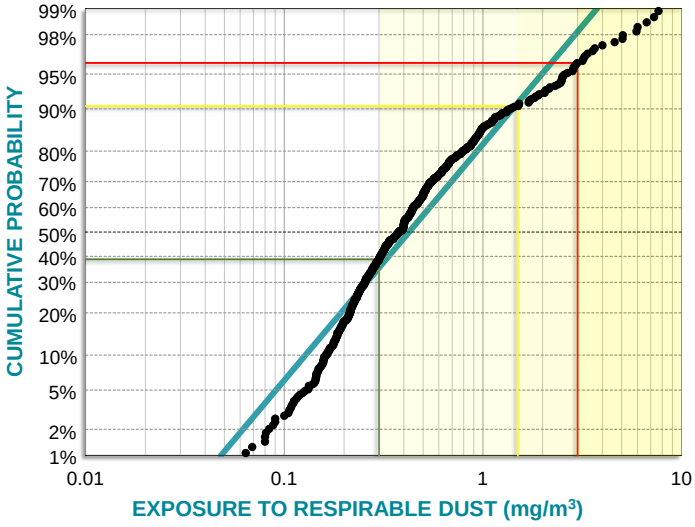


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



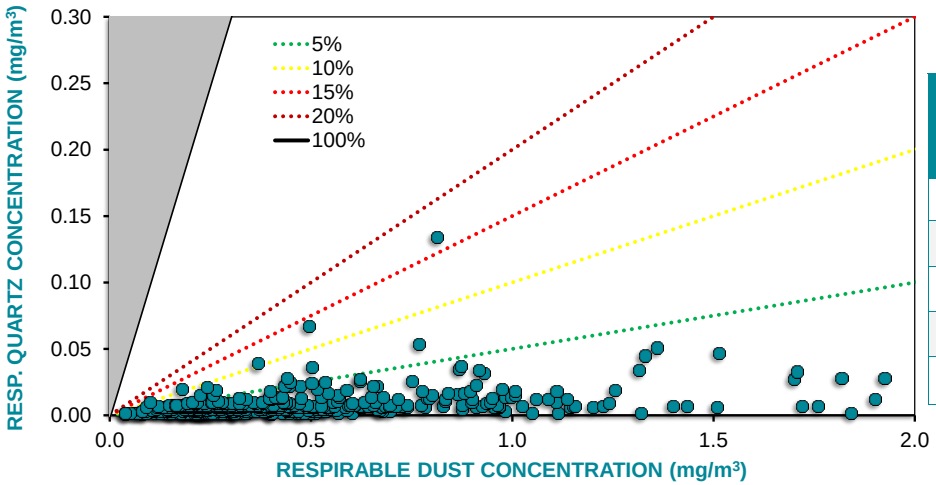
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	98.9%
≤0.05	97.5%
≤0.025	92.2%
≤0.012	81.2%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	96.1%
≤1.5	90.5%
≤0.3	38.8%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	96%
>5% to 10%	3%
>10% to 15%	1%
>15% to 20%	0%
>20%	0%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.01 - Management and office work	
C15.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C15.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C15.02 - Port terminal facility	
C15.02.01 - Unloading foreman (Port terminal facility)	Supervises and directs workers engaged in the loading and unloading of the ships. Organises workers on the quay, in ship's cargo holds and in offices.
C15.02.02 - Crane operator (Port terminal facility)	Operates crane for loading and unloading bulk carrier ships, working in a cab on the crane. The crane lifts the ore from the ship's cargo holds and moves it into a hopper, from where a conveyor belt carries the ore to the mineral stocks. Performs small maintenance tasks.
C15.02.03 - Signaller (Port terminal facility)	Controls the loading and unloading operations according to the operative procedures. Helps the shift foreman organise the tasks of external workers. Performs small repair tasks and cooperates with other workers which carry out the job, both on the ship and on the plants.
C15.02.04 - Longshore worker (Port terminal facility)	Operates lifting equipment (cranes and forklift trucks) in the ship's cargo holds for loading and unloading from the ships onto the quay. Attaches slings and lifting chains to cargo.
C15.02.05 - Hold cleaning operator (Port terminal facility)	Finishes the discharge of ore and coal from the holds. Reaches the bottom of the hold, when the grabs and bulldozers cannot discharge any remaining material, removing the residue by using hammer drills and manual equipment. Cleans the holds to prevent contamination of the next cargo. Cleans piers, dry docks and other working areas.
C15.02.06 - Slinger (Port terminal facility)	Assembles rigging to lift and move the semi-finished steel products to be loaded on the ships. Operates on the quay.
C15.03 - Primary stockyards (ore, coal)	
C15.03.01 - Stacker-reclaimer machine operator (Primary stockyards)	Operates the stacker-reclaimer machine for stockpile reclaiming, from a remote control station. The material (ore, coal) is taken up by the bucket wheel, transported by the reversible belt conveyor, dumped into the central chute and transferred onto a discharging stockpile conveyor. On the floor, clears away the material stuck under the bucket wheel during the loading operations using a shovel and pick. Carries out controls and small repair tasks.
C15.03.02 - Reclaimer machine operator (Primary stockyards)	Operates the reclaimer machine (on the floor or in a cab) to reclaim materials stacked in the stockyard. The reclaimer works on a rail track and the material (ore, coal) is taken up by the bucket wheel.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.03.03 - Stacker machine operator (Primary stockyards)	Operates the stacker machine (on the floor or in a cab) to stack materials (ore, coal) in the stockyard. The stacker moves on a rail between the stockpiles in the yard.
C15.03.04 - Foreman (Primary stockyards)	Manages and directs the operators in the primary stockyards and slag stockyard, cooperating in their duties. Inspects the plants. Supervises the cleaning operations. Carries out minor manual cleaning tasks by using shovel, hook and water jets.
C15.03.05 - Foreman, cleaning workings (Primary stockyards)	Organises the cleaning working groups and controls all the cleaning operations in primary stockyards and slag stockyard. Performs minor cleaning tasks by using a lance, shovel, hook, water jet or pneumatic hammer.
C15.03.06 - Conveyors manual cleaning operator (Primary stockyards)	Cleans conveyors and other machinery, utensils and equipment in primary stockyard and slag stockyard, by using a hand lance, shovel, hook, water–jet and pneumatic hammer.
C15.03.07 - Conveyors cleaning machine operator (Primary stockyards)	Removes the material accumulated under the conveyor belts in primary stockyard and slag stockyard, by using mechanical means (telescopic handler, power shovel, truck dumper, etc.). Cleans the working areas.
C15.03.08 - Cleaning water systems operator (Primary stockyards)	Cleans the machinery in primary stockyard and slag stockyard by using a drain-cleaning truck (water jet). Cleans the stacker and reclaimer machines by using water cannons and hydrants.
C15.04 - Metallurgical coke production – Coal and coke treatment: coal preparation plant	
C15.04.01 - Manual cleaning operator (Coal preparation plant)	Operates the cleaning of the coal preparation plant by using hand tools (shovel and hook). Operates scheduled and on demand cleaning in the department.
C15.04.02 - Cleaning machine operator (Coal preparation plant)	Operates the cleaning of the coal preparation plant by using machines (compact excavator, power shovel, etc.). Operates scheduled and on demand cleaning in the department.
C15.04.03 - Maintenance mechanic / electrician (Coal preparation plant)	Maintains and repairs machines in the coal preparation plant (mills, screens, hoppers, conveyors belts, fans, silos, dust removers, etc.) by using spanners, hydraulic pumps, a lift truck, an oxygen gas torch, a welding machine, etc. Carries out maintenance tasks on the electrical components of the equipment by using testers, spanners, screwdrivers, vacuum cleaner, etc.
C15.04.04 - Running operator (Coal preparation plant)	Controls the operations and the processing equipment (conveyor belts, vibrofeeders, crushers, dispensers, screens, fans, hoppers, fire prevention systems) in the assigned area. Reports any malfunctions to the shift foreman. Controls the efficiency of the plant from the push-button panel. Takes routine samples of coal and settling tank water at a set frequency.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.05 - Metallurgical coke production – Coke production plant (batteries)	
C15.05.01 - Cleaning machine operator (Coke production plant)	Operates the cleaning of the coke wharf and of roads in the department.
C15.05.02 - Walkway cleaning operator (Coke production plant)	Operates the cleaning of the walkways. When the hot coke is dumped into the quenching car, quenches the coke spilled from the car by a jet of water.
C15.05.03 - Oven charger (Coke production plant)	Operates the charging car (or larry car) for transporting a charge of pre-heated coal along the top of a battery of coke ovens and charges the coke ovens. Handles the temporary hampering of the charging hole and gas pipe of the coke oven, when the charged coal reaches the oven top clogging it. Operates the de-dusting system (pulse jet compressor) on the coal tower.
C15.05.04 - Oven dauber (Coke production plant)	Seals the charge lid of the coke oven by application of lute material. Cleans the deck over the coke oven.
C15.05.05 - Cokeside car operator (Coke production plant)	Operates the cokeside car (after the doors of coke oven have been opened) to guide the discharged coke from the oven to the quenching car on the coke wharf. Performs maintenance work of the quenching car locomotive.
C15.05.06 - Ceramic welder for oven repairing (Coke production plant)	Performs ceramic welding for hot repairs of the coke oven walls (bricks) to prevent leaks from the oven chamber, caused by cracks and spalls.
C15.05.07 - Mortar pump operator for oven repairing (Coke production plant)	Pumps or injects refractory mortar into cracks for the repairing of refractory brickwork panels of the coke oven.
C15.05.08 - Ceramic rope sealing operator for oven repairing (Coke production plant)	Performs repair works to the coke ovens, sealing the gaps between metal carpentry and refractory masonry by using ceramic rope seal.
C15.05.09 - Guniting operator for oven repairing (Coke production plant)	Sprays refractory mortar by using a spray gun (*guniting*) to seal cracks inside the coke ovens.
C15.05.10 - Guniting operator for charging holes repairing (Coke production plant)	Sprays refractory mortar by using a spray gun (*guniting*) to repair the refractory linings of the charging holes of the coke ovens.
C15.05.11 - Charging hole lid replacement operator (Coke production plant)	Performs maintenance operations that include the replacing of the charging hole lid of coke ovens.
C15.05.12 - Oven wall restoration operator (Coke production plant)	Repairs the damaged chamber of the coke oven by dismantling, removing and replacing the brick walls.
C15.05.13 - Caulker operator for oven pipes (Coke production plant)	Performs caulking operations for repairing the pipe that connects the coke oven chamber to the atmosphere. Caulking repairing includes ceramic rope sealing, refractory masonry and refractory mortar sealing.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.05.14 - Oven deck maintenance operator (Coke production plant)	Operates the maintenance of the oven deck, included the dismantling and replacement of the floor, by refractory masonry.
C15.05.15 - Maintenance electrician (Coke production plant)	Carries out maintenance tasks on the electric components of equipment (switchboards, line cords, switches, etc.) and machines operating in the coke production plant. The job title includes both foreman / maintenance manager and other workers.
C15.05.16 - Maintenance mechanic (Coke production plant)	Maintains and repairs machines (charging car, leveller bar, coke guide, quenching car, locomotive, etc) in the coke production plant (lubrication, hydraulic control units, conveyors, pumps, compressors, rail tracks, extractor hoods, etc.). The job title includes both foreman / maintenance manager and other workers.
C15.05.17 - Mechanical maintenance technician (Coke production plant)	Controls the process operations, checks how the required tasks are executed and makes a report on the work activity.
C15.06 - Metallurgical coke production – Coal and coke treatment: coke screening plant	
C15.06.01 - Manual cleaning operator (Coke screening plant)	Operates the cleaning of the coke screening plant by using hand tools (shovel and hook). Operates scheduled and on demand cleaning in the department.
C15.06.02 - Cleaning machine operator (Coke screening plant)	Operates the cleaning of the coke screening plant by using machines (compact excavator, power shovel, etc.). Operates scheduled and on demand cleaning in the department.
C15.06.03 - Maintenance mechanic / electrician (Coke screening plant)	Maintains and repairs machines in the coke screening plant (mills, screens, hoppers, conveyors belts, fans, silos, dust removers, etc.) by using spanners, hydraulic pumps, a lift truck, an oxygen gas torch, a welding machine, etc. Carries out maintenance tasks on the electric components of equipment by the use of tester, spanners, screwdrivers, vacuum cleaner, etc. The job title includes both foreman / maintenance manager and other workers.
C15.06.04 - Running operator (Coke screening plant)	Controls the operations and the processing equipment (conveyor belts, vibrators, crushers, dispensers, stacker-reclaimer machines, screens, fans, hoppers, fire prevention systems) in the assigned area. Reports any malfunctions to the shift foreman. Controls the efficiency of the plant from the push-button panel. Takes routine samples of coal from the conveyor belts. Operates the stacker-reclaimer machine in the coke stockpile. Operates the quenching of the coke still burning on the coke wharf by using a hydrant, before the coke is sent to the screening plant.
C15.07 - Agglomeration	
C15.07.01 - Running operator (Homogenising plant)	Inspects and verifies the running conditions of machines. Operates mechanical vehicles, belt conveyors and remote controlled machines (stakers and reclaimers) of the homogenising plant.

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WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.07.02 - Running operator (Agglomeration plant)	Inspects and verifies the running conditions of machines and equipment, including coke crushing, agglomeration machine, hot screening, cold screening, impellers, secondary electro filters, conveyor belts. Takes samples. Performs small cleaning tasks, related to machine function, by shovel, hook and water jet. Performs routine maintenance tasks on the agglomeration machine. Cleans the primary and secondary electro filters and discharges the removed powders.
C15.07.03 - Shift supervisor (Homogenising and agglomeration plants)	Supervises and organises the working activities in the homogenising and agglomeration plants. Inspects the plants. Occasionally may supervise the discharge of the powders removed from the primary and secondary electro filters.
C15.07.04 - Foreman (Homogenising and agglomeration plants)	Organises the workers engaged in the homogenising and agglomeration plants. Carries out the office operation of the department. Supervises the cleaning operations and carries out small maintenance tasks. Operates some handling on the plants. Carries out the discharge of the powders removed from the primary and secondary electro filters.
C15.07.05 - Maintenance mechanic (Agglomeration department)	Maintains and repairs (carpentry, welding, lubrication, testing and calibration in restarting operations) machines in the plants by using oxygen gas torch, a welding machine, a grinder, a cross-cut saw, a drill, etc. Carries out maintenance tasks on the safety and cleaning equipment. Performs lubrication and repair on mechanical parts of the primary and secondary electro filters and minor painting jobs.
C15.07.06 - Maintenance electrician (Agglomeration department)	Carries out maintenance tasks on the electric components of equipment and electric cabins of the plants.
C15.07.07 - Manual cleaning operator (Homogenising plant)	Operates the manual cleaning in the homogenising plant remote controlled machines included (stackers and reclaimers).
C15.07.08 - Manual cleaning operator (Agglomeration plant)	Operates the manual cleaning in the agglomeration plant (coke crushing, agglomeration machine, hot and cold screening, impellers, secondary electro filters, conveyor belts). Carries out the discharge of the powders removed from the primary and secondary electro-filters.
C15.07.09 - Cleaning machine operator (Homogenising plant)	Operates the cleaning in the homogenising plant by using machines (compact excavator, power shovel, truck dumper, etc.).
C15.07.10 - Cleaning machine operator (Agglomeration plant)	Operates the cleaning in the agglomeration plant by using auxiliary machines (compact excavator, power shovel, lifting equipment, drain-cleaning truck, etc.).
C15.07.11 - Foreman, cleaning workings (Homogenising and agglomeration plants)	Organises the cleaning working groups and controls the cleaning operations carried out manually and by mechanical means. Performs minor cleaning tasks. Carries out the discharge of the powders removed from the primary and secondary electro filters and minor painting jobs.

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WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.08 - Blast furnace	
C15.08.01 - Shift supervisor (Blast furnace)	Supervises and organises the working activities in the blast furnace department. Controls the running parameters of the casting process. Inspects and checks the equipment of the plant (control cabin, tuyeres floor, casting field, cowper stoves, stock house, gas network, top of the blast furnace).
C15.08.02 - Technician (Blast furnace)	Controls the casting and handles any anomalies.
C15.08.03 - Cooling operator (Blast furnace)	Inspects the plant. May use the power hammer during the blast furnace stop. Makes repairs on the tuyeres floor and cooling system.
C15.08.04 - Caster (Blast furnace)	Checks the casting process and conducts the tapping and tap hole drilling machines through radio control. Operates power hammer, crane and excavator when the blast furnace has been stopped. Makes repair services during the blast furnace stop.
C15.08.05 - Torpedo ladle car operator (Blast furnace)	Conducts the torpedo ladle car used to transport liquid iron from blast furnace to steel converter.
C15.08.06 - Stock-house operator (Blast furnace)	Checks the transport of raw materials from primary stockyards and coke production plant to the silos of the stock house and then to the blast furnace stock house. Controls the filling of the silos of the stock house and the hoppers from a control cabin.
C15.08.07 - Stock-house silo operator (Blast furnace)	Tends the loading system of storage silos, checking the filling level in hoppers and silos, operating from the ground floor of the stock house. Makes small repairs in the blast furnace stock house.
C15.08.08 - Mechanical maintenance operator (Blast furnace)	Maintains and repairs structures and equipment (blast furnace, dust remover, fossil injection system) in the blast furnace and stock house. Performs welding and cutting operations using the welding torch.
C15.08.09 - Maintenance electrician (Blast furnace)	Operates maintenance tasks on the electric components of equipment and electric cabins of the plants (pyrometers, tuyeres floor, casting field, cowper stoves, stock house, gas network, blast furnace, slag granulation tanks, electric cabins, compressor room, turbines and motor vehicles).
C15.09 - Steel refining plant	
C15.09.01 - AOD running operator (Steel refining plant)	Controls the steel refining Argon Oxygen Decarburisation (AOD) process from a control room. Takes samples of molten metal and temperature measurements. Operates the tilt drives to rotate the converter vessel around its own axis for refilling and emptying of molten metal.
C15.09.02 - ASEA ladle furnace running operator (Steel refining plant)	Controls the steel vacuum refining process (ASEA ladle furnace), which requires the heating of the molten metal and a further addiction of ferro-alloys. Operates from an open control room.

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WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.10 - Continuous casting plant	
C15.10.01 - Running operator (Continuous casting plant)	Controls the casting process from a control room.
C15.10.02 - Casting floor operator (Continuous casting plant)	Operates the distribution of coating powders into ingot mould and basket. Carries out the cleaning of casting floor. Takes temperature measurements on molten steel. Performs small maintenance tasks.
C15.10.03 - Ladle crane operator (Continuous casting plant)	Operates ladle crane transporting hot metal from the converter furnace to the casting plant. Pours the exothermic powder from the bags into the ladle.
C15.11 - Refractory maintenance	
C15.11.01 - Bricklayer (Refractory maintenance)	Assesses the wear level of the ladle lining. Carries out the hot maintenance of the critical areas in the ladle. Cleans the plate with a jet of compressed air and removes the concrete by using a hammer and chisel (the operation usually takes a short time, 30-40 minutes). Restores the refractory lining of the gate and of the ladle shroud.
C15.11.02 - Ladle maintenance inspector (Refractory maintenance)	Supervises the demolition and restoring of refractory lining of tundishes, ladles, converters and furnaces. Compiles reports in the office.
C15.11.03 - Ladle liner (Refractory maintenance)	Rebuilds the ladle refractory multilayer lining, made of a working brick lining which is in contact with the molten metal and slag, a safety brick lining, an insulated shell and a metallic shell on the outside. Removes scraps by manual equipment, carries out brick laying and cutting, refractory mortar preparation and application on the upper edge between carpentry and bricks.
C15.11.04 - Power shovel operator for ladle lining demolition (Refractory maintenance)	Operates the partial or total demolition of ladle and converter refractory linings by using a power shovel equipped with a demolition hammer.
C15.11.05 - Tundish liner (Refractory maintenance)	Rebuilds the sprayed mortar refractory lining of tundishes. Operates the transport of tundish to the cooling area by using a bridge-crane and its overbanking in a closed box. Operates the demolition of the shroud and the preparation and application of refractory mortar on the bottom and walls of the tunsdish.
C15.11.06 - Converter liner (Refractory maintenance)	Rebuilds the converter brick lining, consisting of refractory crashed bed materials and refractory bricks applied on the vessel walls (double layer: wear and safety). Removes debris, handles materials, applies the refractory crashed materials on the bottom, cuts to proper size and applies the bricks on the wall.
C15.11.07 - Melting furnace liner (Refractory maintenance)	Restores the refractory lining of the melting furnace chamber. Applies and compacts the fire clay on the bottom of the melting furnace. Removes the demolition debris. Rebuilds, lifts and places the taphole into the chamber. Distributes and compacts the refractory crashed materials on the bottom. Cuts and applies refractory bricks (wear layer and safety layer).
C15.11.08 - Power shovel operator for furnace chamber lining demolition (Refractory maintenance)	Operates the demolition of the refractory lining melting furnace chamber by using a mini power shovel equipped with a demolition hammer. The operator works in a fully enclosed cab with heat and air conditioning, while a dry-fog system for dust suppression is used in the furnace chamber, inside which the mini power shovel operates.

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WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C15.11.09 - Fibre lining maintainer (Refractory maintenance)	Replaces the fibre lining of heat treatment furnaces, furnace doors, ladle lids, burner screens and melting furnace edges. Makes the repairs on the plant or moves the parts to a closed box, equipped with an absolute filter. Handles and assembles materials and products. Removes fibre modules. Cleans carpentry surfaces. Performs coating repairs with refractory cement. Cleans the working area and worker overalls using vacuum cleaner.
C15.11.10 - Jackhammer operator for pusher furnace demolition (Refractory maintenance)	Operates the demolition of the pusher furnace, working inside the furnace using a hand-held demolition hammer.
C15.12 - Scrap stockyard	
C15.12.01 - Shift supervisor (Scrap stockyard)	Supervises and organises the working activities in the scrap stockyard. Checks the materials, the tests on the weights and packaging of the baskets.
C15.12.02 - Bridge-crane / polyp-grab operator (Scrap stockyard)	Operates lifting equipment (crane, bridge-crane, polyp-grabs for excavator) to move metal scraps from the open pits into cast baskets.
C15.12.03 - Ferro-alloy batching plant operator (Scrap stockyard)	Controls the ferro-alloy batching plant from a control room. The required iron alloys are weighed and added to the ladle to correct the chemical characteristics of the iron to be cast.
C15.12.04 - Electric furnace operator (Scrap stockyard)	Operates the electric furnace from a control room. Prepares the scrap metal charge recipes for the baskets and sends them to bridge-crane / polyp-grab operators.
C15.12.05 - Basket car driver (Scrap stockyard)	Drives the car for basket transport to the bridge-crane for metal scrap filling, then to the ferro-alloy batching plant where iron alloys are added and finally to the electric furnace. May also carry empty or full ladles from the furnace to the continuous casting plant.
C15.13 - Masonry	
C15.13.01 - Masonry foreman	Organises the workers engaged in masonry. Makes inspections to determine the work to be done and to check the safety conditions of the plants. Supervises the operations carried out by the workers. Carries out the office operation of the activity.
C15.13.02 - Bridge-crane for demolished material / stripping operator	Operates bridge-crane for loading and unloading of tundishes and ladles for refractory lining demolition. Operates the deferrisation of rubble from demolished refractory material and transport on vehicles. Occasionally operates a mechanical loader to transport the residue of the casting process removed from the tundishes and refractory materials, plastic, wooden debris and waste, to the dump site.
C15.13.03 - Power-driven machinery operator for demolished material transport	Operates power-driven machines: locomotive for ladle; mechanical loader for the removed residue of casting process and for plastic, wooden debris and waste; tractor for worn hand lances and carpentries to be restored (bells, snorkel, impeller); truck dumper. Operates power-shovel equipped with demolition hammer to carry out demolition of refractory materials. Performs small maintenance repairs on the assigned mechanical means.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C15.01.01 - Manager	2	0.001*	-	-	-	-	-
C15.02.02 - Crane operator (Port terminal facility)	21	0.003*	1.704*			>97.1%	96.0%
C15.02.03 - Signaller (Port terminal facility)	11	0.003*	1.605*				>94.4%
C15.02.04 - Longshore worker (Port terminal facility)	8	0.003*	2.006*			>92.4%	91.2%
C15.02.05 - Hold cleaning operator (Port terminal facility)	29	0.010	2.684	>97.9%	97.7%	75.7%	53.4%
C15.02.06 - Slinger (Port terminal facility)	1	0.002*	-	-	-	-	-
C15.03.01 - Stacker-reclaimer machine operator (Primary stockyards)	7	0.003*	1.888*				>91.4%
C15.03.02 - Reclaimer machine operator (Primary stockyards)	3	0.002*	2.681*	-	-	-	-
C15.03.03 - Stacker machine operator (Primary stockyards)	1	-	-	-	-	-	-
C15.03.04 - Foreman (Primary stockyards)	6	0.003*	1.775*				>90.0%
C15.03.05 - Foreman, cleaning workings (Primary stockyards)	2	0.003	-	-	-	-	-
C15.03.06 - Conveyors manual cleaning operator (Primary stockyards)	8	0.003*	1.900*				>92.4%
C15.03.07 - Conveyors cleaning machine operator (Primary stockyards)	23	0.005*	2.361*		>97.3%	96.6%	84.4%
C15.03.08 - Cleaning water systems operator (Primary stockyards)	11	0.008	3.168		>94.4%	82.7%	53.5%
C15.04.01 - Manual cleaning operator (Coal preparation plant)	50	0.006	2.438	98.5%	97.1%	93.5%	85.6%
C15.04.02 - Cleaning machine operator (Coal preparation plant)	3	0.006	2.475	-	-	-	-
C15.04.03 - Maintenance mechanic / electrician (Coal preparation plant)	31	0.013	2.918	91.2%	86.1%	72.4%	64.0%
C15.04.04 - Running operator (Coal preparation plant)	8	0.008	2.150		>92.4%	87.8%	80.3%
C15.05.01 - Cleaning machine operator (Coke production plant)	1	0.011*	-	-	-	-	-
C15.05.02 - Walkway cleaning operator (Coke production plant)	7	0.006*	1.232*				>91.4%
C15.05.03 - Oven charger (Coke production plant)	4	0.007*	1.125*	-	-	-	-
C15.05.04 - Oven dauber (Coke production plant)	4	0.010*	1.482*	-	-	-	-

* more than half of the measurements are <LOQ

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C15.05.05 - Cokeside car operator (Coke production plant)	1	0.006*	-	-	-	-	-
C15.05.06 - Ceramic welder for oven repairing (Coke production plant)	6	0.009*	1.819*		>90.0%	88.8%	79.0%
C15.05.07 - Mortar pump operator for oven repairing (Coke production plant)	4	0.006*	-	-	-	-	-
C15.05.08 - Ceramic rope sealing operator for oven repairing (Coke production plant)	6	0.007*	1.127*				>90.0%
C15.05.09 - Guniting operator for oven repairing (Coke production plant)	3	0.010*	1.381*	-	-	-	-
C15.05.10 - Guniting operator for charging holes repairing (Coke production plant)	10	0.006*	1.144*				>93.9%
C15.05.11 - Charging hole lid replacement operator (Coke production plant)	3	0.007*	1.080*	-	-	-	-
C15.05.12 - Oven wall restoration operator (Coke production plant)	2	0.009*	-	-	-	-	-
C15.05.13 - Caulker operator for oven pipes (Coke production plant)	6	0.006*	1.000*				>90.0%
C15.05.14 - Oven deck maintenance operator (Coke production plant)	7	0.028*	5.891*	74.6%	66.8%	60.0%	53.6%
C15.05.15 - Maintenance electrician (Coke production plant)	7	0.008*	1.158*				>91.4%
C15.05.16 - Maintenance mechanic (Coke production plant)	8	0.007*	1.195*				>92.4%
C15.05.17 - Mechanical maintenance technician (Coke production plant)	2	0.006*	-	-	-	-	-
C15.06.01 - Manual cleaning operator (Coke screening plant)	2	0.005*	-	-	-	-	-
C15.06.02 - Cleaning machine operator (Coke screening plant)	6	0.007*	3.043*	>90.0%	89.2%	84.8%	79.0%
C15.06.03 - Maintenance mechanic / electrician (Coke screening plant)	1	0.007*	-	-	-	-	-
C15.07.01 - Running operator (Homogenising plant)	5	0.010*	1.862*	-	-	-	-
C15.07.02 - Running operator (Agglomeration plant)	7	0.010*	2.120*		>91.4%	76.6%	69.5%
C15.07.03 - Shift supervisor (Homogenising and agglomeration plants)	3	0.007*	1.155*	-	-	-	-
C15.07.04 - Foreman (Homogenising and agglomeration plants)	3	0.007*	1.300*	-	-	-	-

* more than half of the measurements are <LOQ

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C15.07.05 - Maintenance mechanic (Agglomeration department)	13	0.006*	2.280*		>95.3%	93.1%	89.5%
C15.07.06 - Maintenance electrician (Agglomeration department)	6	0.007*	1.071*				>90.0%
C15.07.07 - Manual cleaning operator (Homogenising plant)	4	0.015*	2.992*	-	-	-	-
C15.07.08 - Manual cleaning operator (Agglomeration plant)	11	0.015*	1.539*	>94.4%	94.1%	89.8%	11.1%
C15.07.09 - Cleaning machine operator (Homogenising plant)	3	0.013*	1.093*	-	-	-	-
C15.07.10 - Cleaning machine operator (Agglomeration plant)	5	0.015*	1.469*	-	-	-	-
C15.07.11 - Foreman, cleaning workings (Homogenising and agglomeration plants)	3	0.034	2.370	-	-	-	-
C15.08.01 - Shift supervisor (Blast furnace)	1	0.006*	-	-	-	-	-
C15.08.02 - Technician (Blast furnace)	2	0.003*	-	-	-	-	-
C15.08.03 - Cooling operator (Blast furnace)	5	0.007*	1.180*	-	-	-	-
C15.08.04 - Caster (Blast furnace)	12	0.007*	1.113*				>94.9%
C15.08.05 - Torpedo ladle car operator (Blast furnace)	2	0.006*	-	-	-	-	-
C15.08.06 - Stock-house operator (Blast furnace)	1	0.002*	-	-	-	-	-
C15.08.08 - Mechanical maintenance operator (Blast furnace)	14	0.005*	1.752*				>95.6%
C15.08.09 - Maintenance electrician (Blast furnace)	6	0.006*	2.384*		>90.0%	88.8%	81.2%
C15.09.01 - AOD running operator (Steel refining plant)	11	0.005*	1.504*			>94.4%	92.5%
C15.09.02 - ASEA ladle furnace running operator (Steel refining plant)	2	0.021	-	-	-	-	-
C15.10.01 - Running operator (Continuous casting plant)	5	0.006*	1.533*				
C15.10.02 - Casting floor operator (Continuous casting plant)	8	0.010*	1.831*		>92.4%	89.0%	62.5%
C15.10.03 - Ladle crane operator (Continuous casting plant)	5	0.007*	1.155*	-	-	-	-
C15.11.01 - Bricklayer (Refractory maintenance)	3	0.008*	1.197*	-	-	-	-
C15.11.02 - Ladle maintenance inspector (Refractory maintenance)	7	0.008*	1.585*			>91.4%	81.8%

* more than half of the measurements are <LOQ

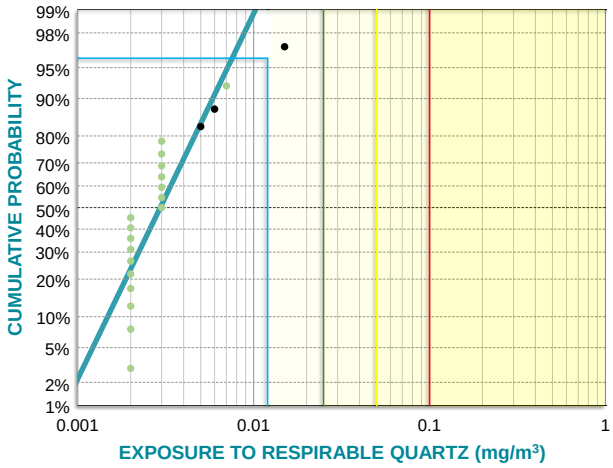
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C15.11.03 - Ladle liner (Refractory maintenance)	7	0.009*	1.461*	-	-	-	>91.4%
C15.11.04 - Power shovel operator for ladle lining demolition (Refractory maintenance)	4	0.016	1.709	-	-	-	-
C15.11.05 - Tundish liner (Refractory maintenance)	11	0.009	2.179		>94.4%	94.4%	56.2%
C15.11.06 - Converter liner (Refractory maintenance)	10	0.009	2.016		>93.9%	90.0%	74.4%
C15.11.07 - Melting furnace liner (Refractory maintenance)	5	0.023*	2.234*	-	-	-	-
C15.11.08 - Power shovel operator for furnace chamber lining demolition (Refractory maintenance)	1	0.038	-	-	-	-	-
C15.11.09 - Fibre lining maintainer (Refractory maintenance)	8	0.005*	2.004*			>92.4%	80.3%
C15.11.10 - Jackhammer operator for pusher furnace demolition (Refractory maintenance)	2	0.002*	-	-	-	-	-
C15.12.05 - Basket car driver (Scrap stockyard)	1	0.009	-	-	-	-	-
C15.13.01 - Masonry foreman	2	0.005	-	-	-	-	-
C15.13.02 - Bridge-crane for demolished material / stripping operator	2	0.002*	-	-	-	-	-
C15.13.03 - Power-driven machinery operator for demolished material transport	8	0.003*	1.651*				>92.4%

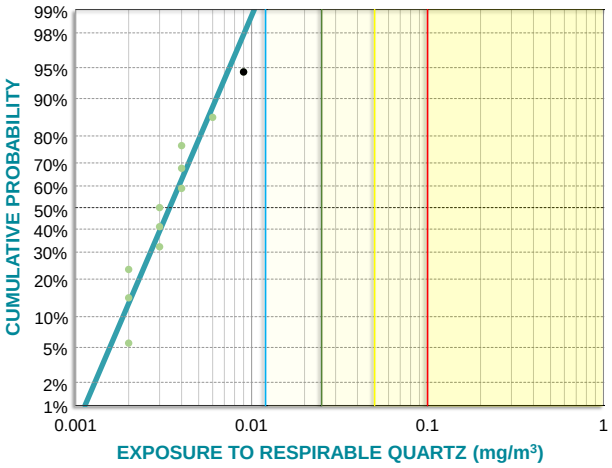
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

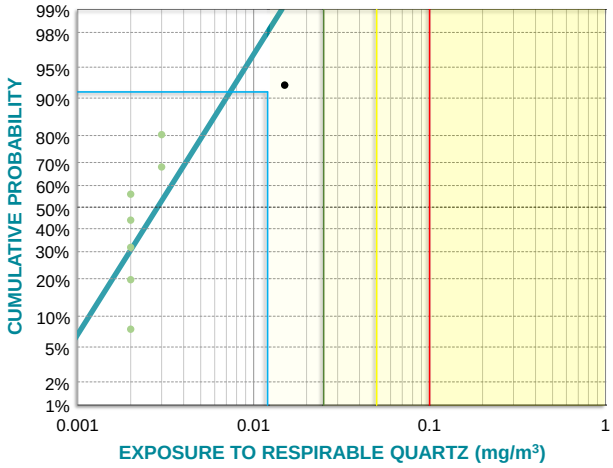
C15.02.02 - Crane operator (Port terminal facility)



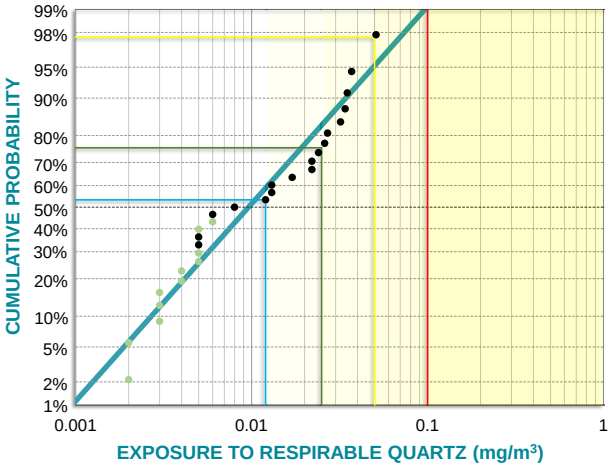
C15.02.03 - Signaller (Port terminal facility)



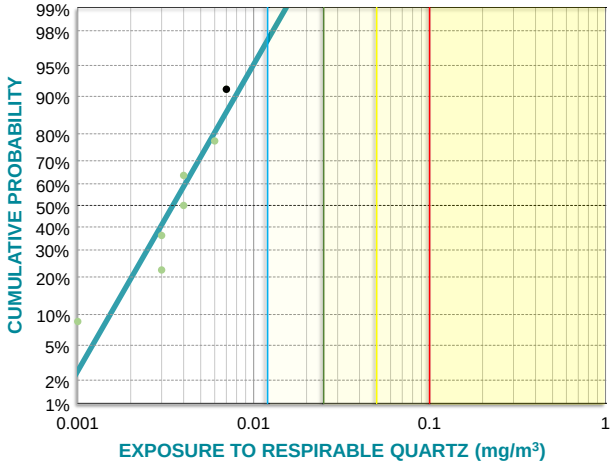
C15.02.04 - Longshore worker (Port terminal facility)



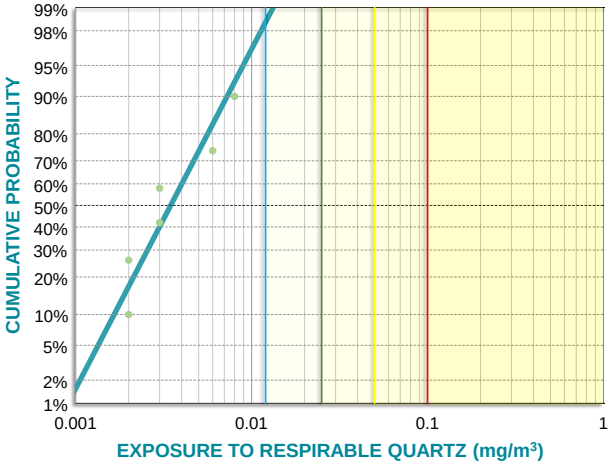
C15.02.05 - Hold cleaning operator (Port terminal facility)



C15.03.01 - Stacker-reclaimer machine operator (Primary stockyards)

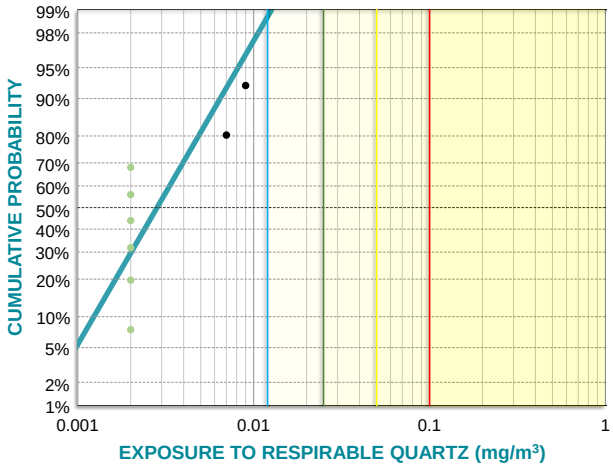


C15.03.04 - Foreman (Primary stockyards)

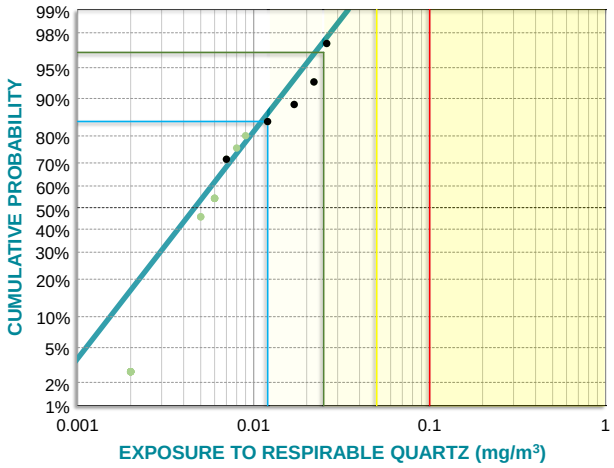


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

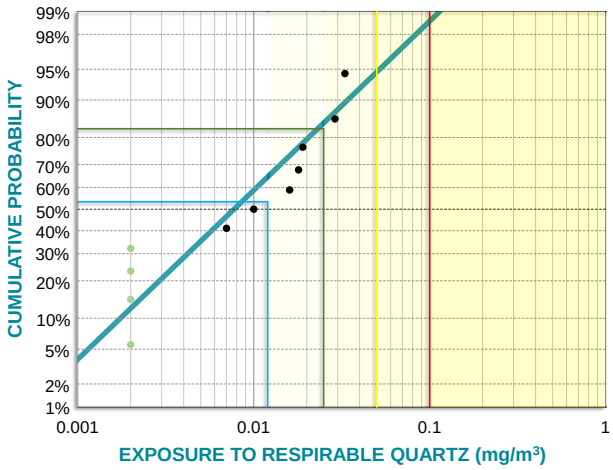
C15.03.06 - Conveyors manual cleaning operator (Primary stockyards)



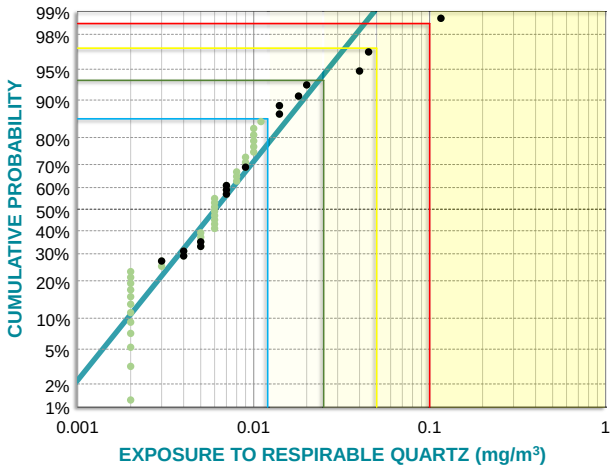
C15.03.07 - Conveyors cleaning machine operator (Primary stockyards)



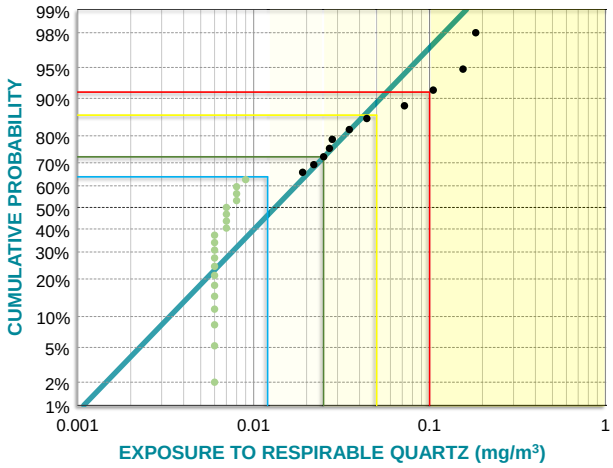
C15.03.08 - Cleaning water systems operator (Primary stockyards)



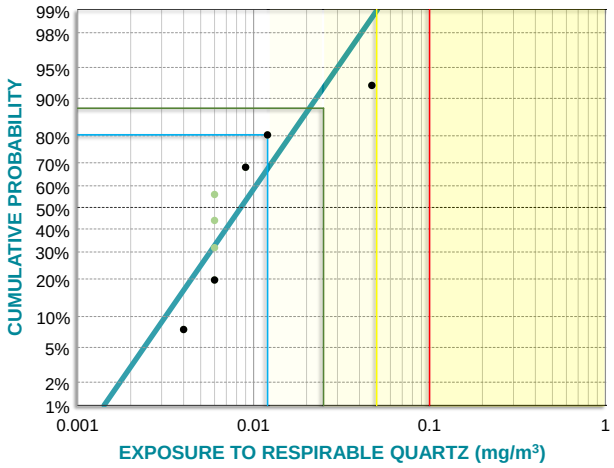
C15.04.01 - Manual cleaning operator (Coal preparation plant)



C15.04.03 - Maintenance mechanic / electrician (Coal preparation plant)

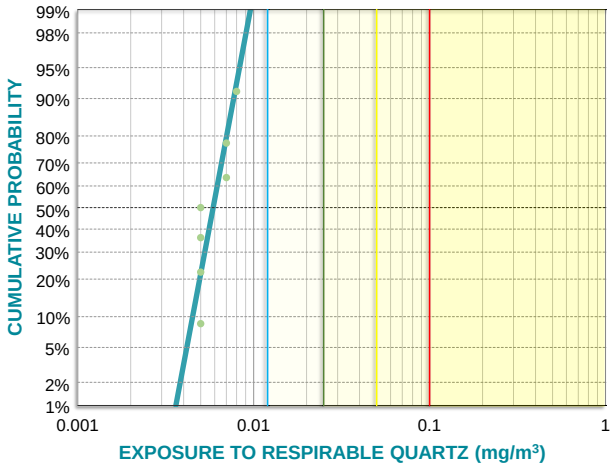


C15.04.04 - Running operator (Coal preparation plant)

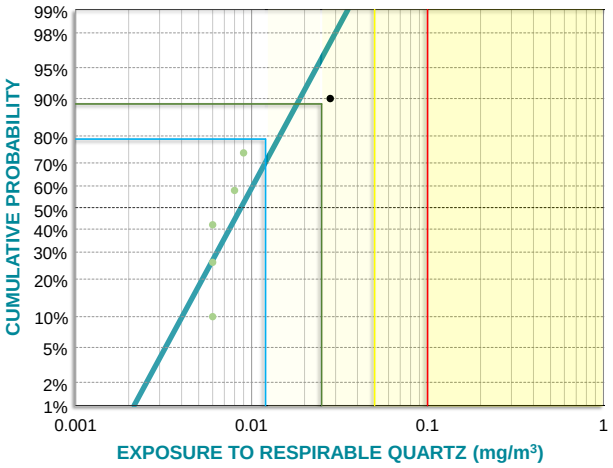


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

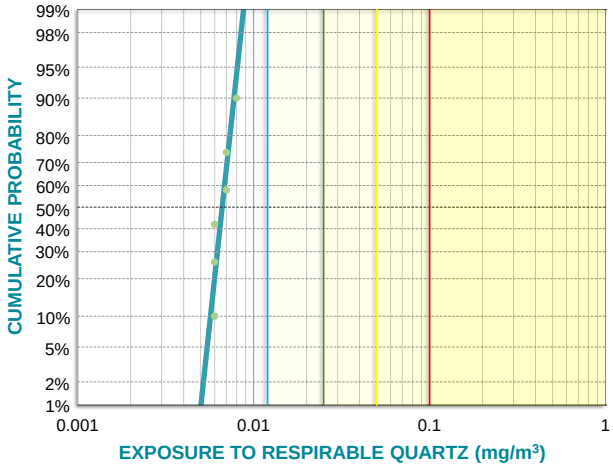
C15.05.02 - Walkway cleaning operator (Coke production plant)



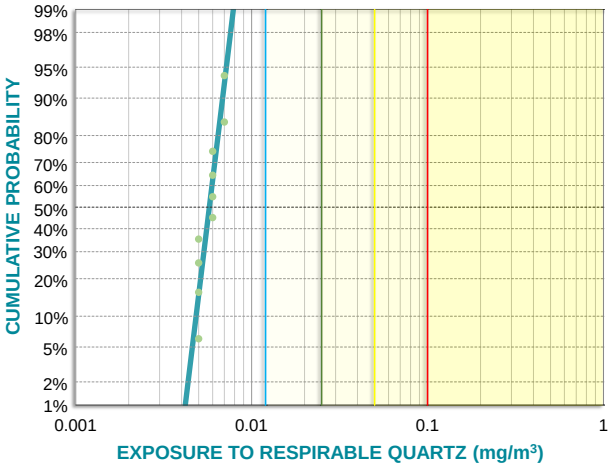
C15.05.06 - Ceramic welder for oven repairing (Coke production plant)



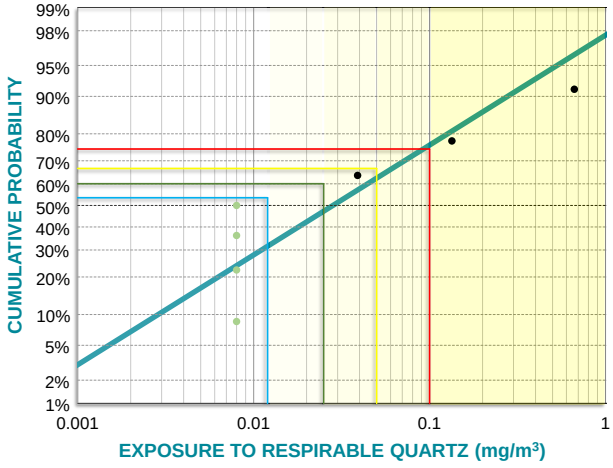
C15.05.08 - Ceramic rope sealing operator for oven repairing (Coke production plant)



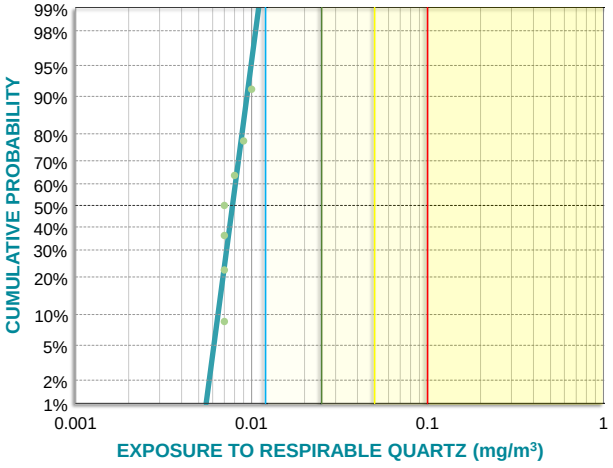
C15.05.10 - Guniting operator for charging holes repairing (Coke production plant)



C15.05.14 - Oven deck maintenance operator (Coke production plant)

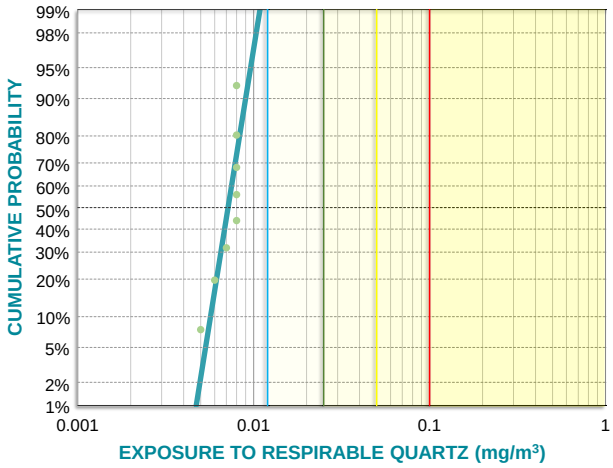


C15.05.15 - Maintenance electrician (Coke production plant)

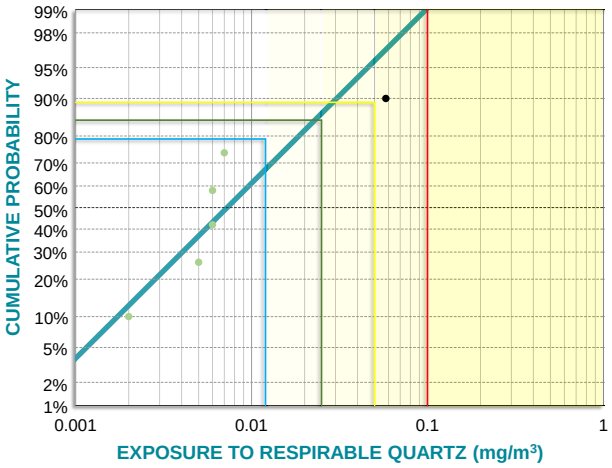


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

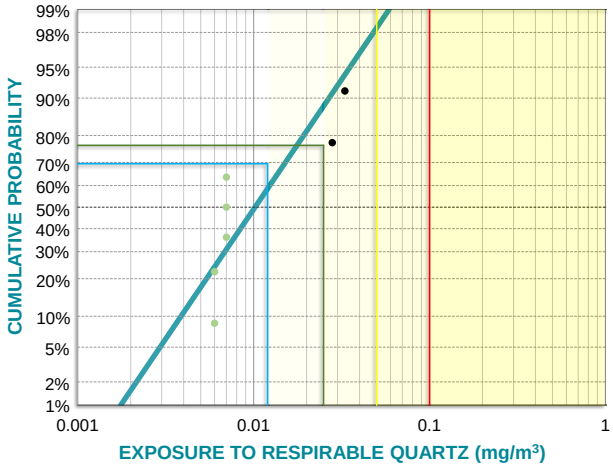
C15.05.16 - Maintenance mechanic (Coke production plant)



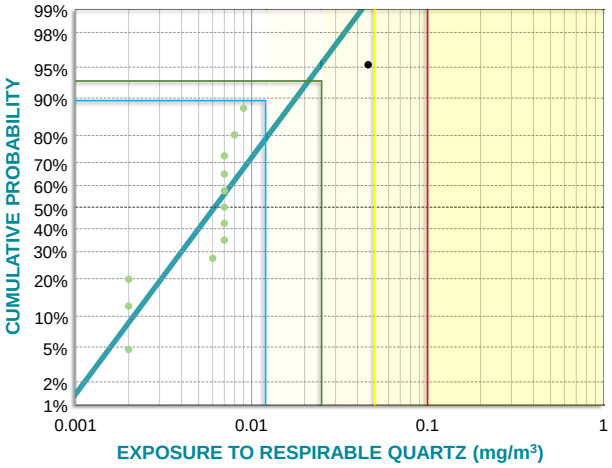
C15.06.02 - Cleaning machine operator (Coke screening plant)



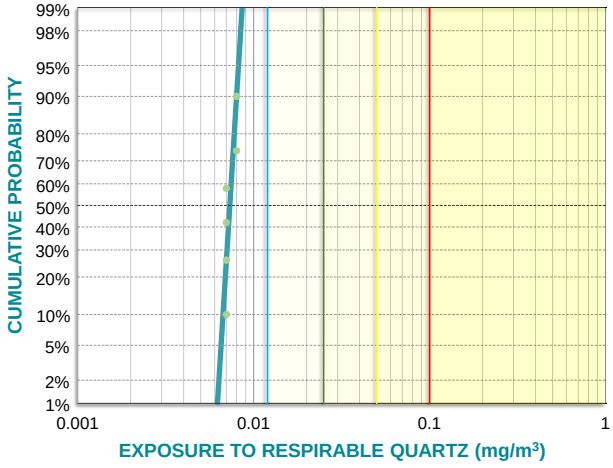
C15.07.02 - Running operator (Agglomeration plant)



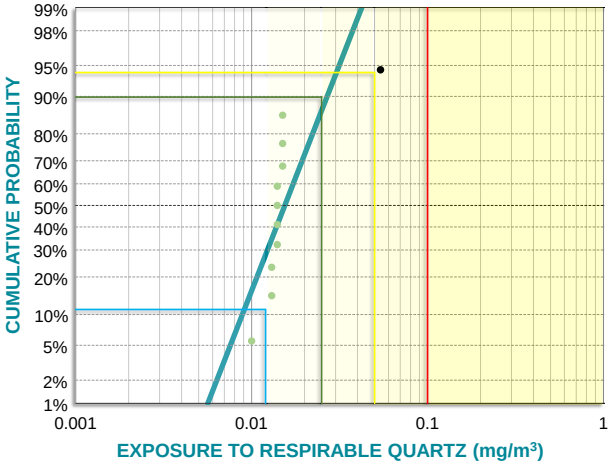
C15.07.05 - Maintenance mechanic (Agglomeration department)



C15.07.06 - Maintenance electrician (Agglomeration department)

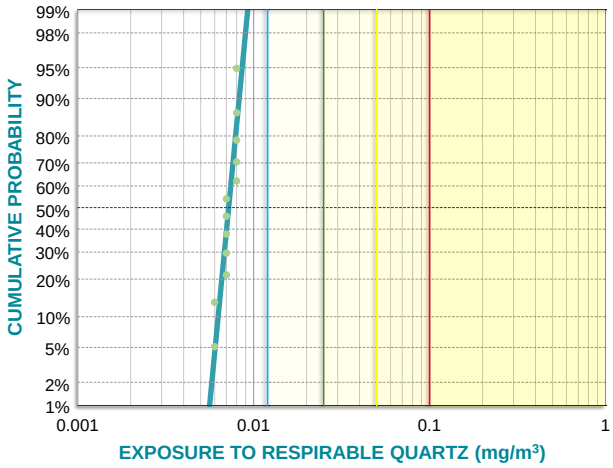


C15.07.08 - Manual cleaning operator (Agglomeration plant)

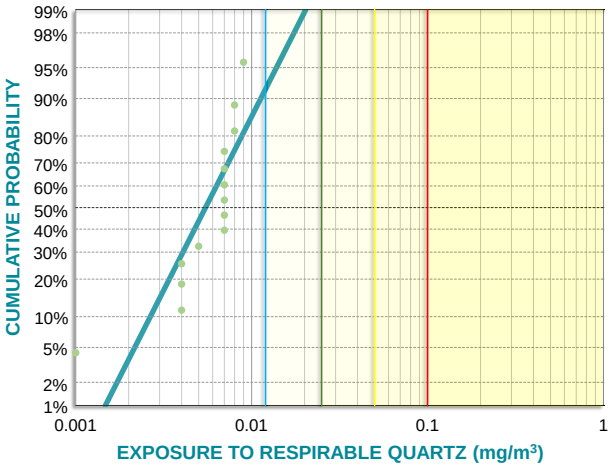


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

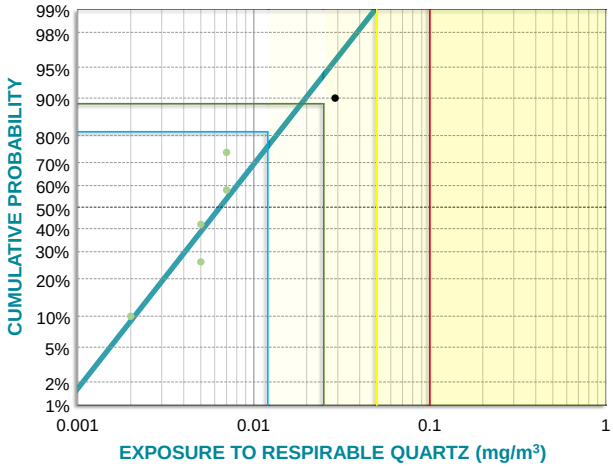
C15.08.04 - Caster (Blast furnace)



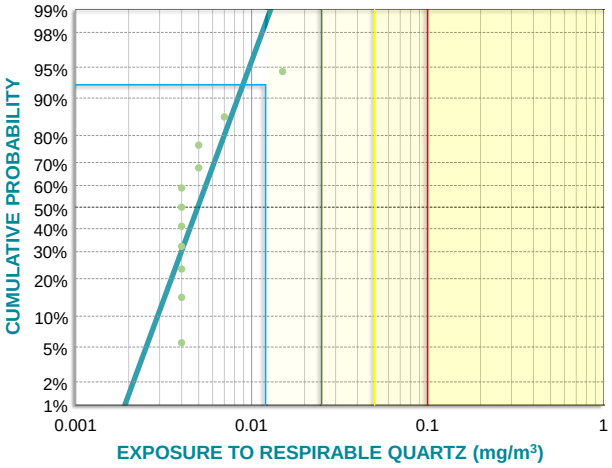
C15.08.08 - Mechanical maintenance operator (Blast furnace)



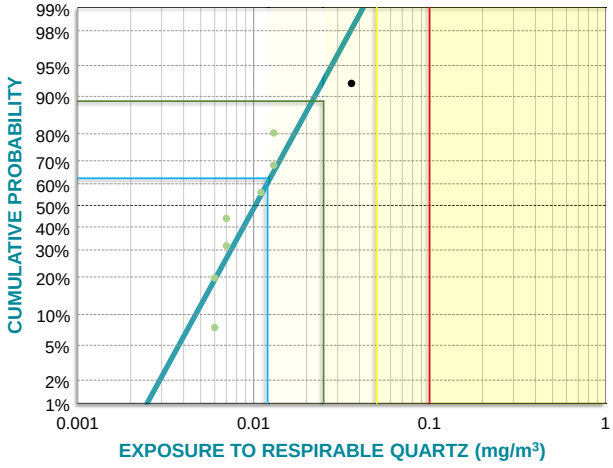
C15.08.09 - Maintenance electrician (Blast furnace)



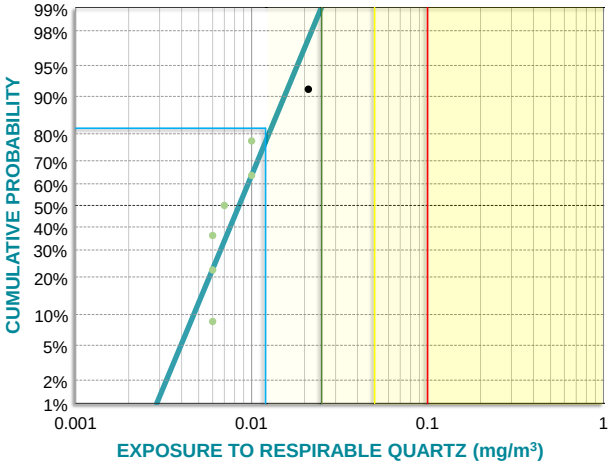
C15.09.01 - AOD running operator (Steel refining plant)



C15.10.02 - Casting floor operator (Continuous casting plant)

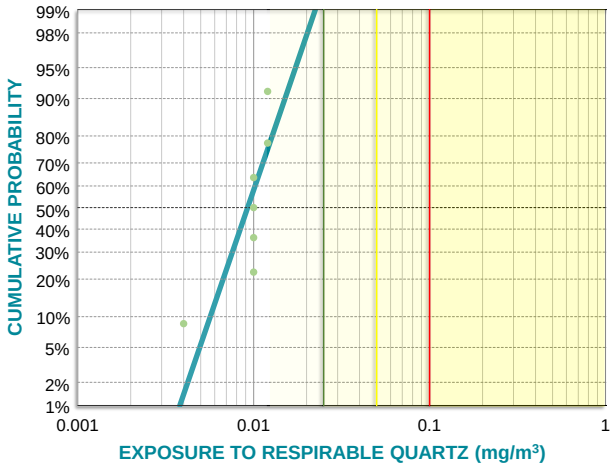


C15.11.02 - Ladle maintenance inspector (Refractory maintenance)

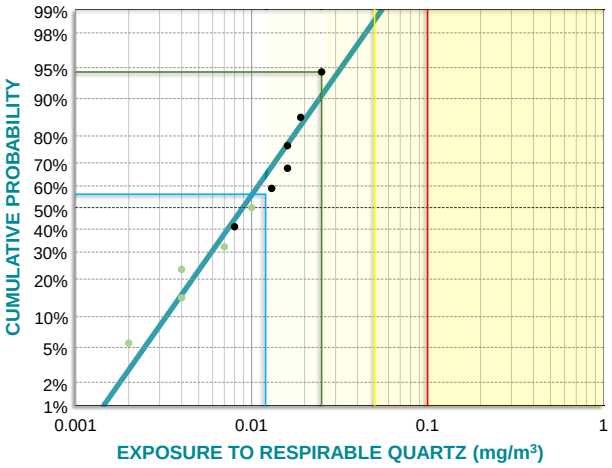


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

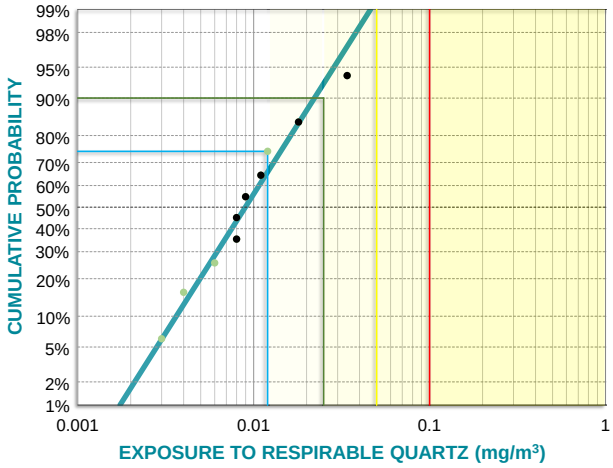
C15.11.03 - Ladle liner (Refractory maintenance)



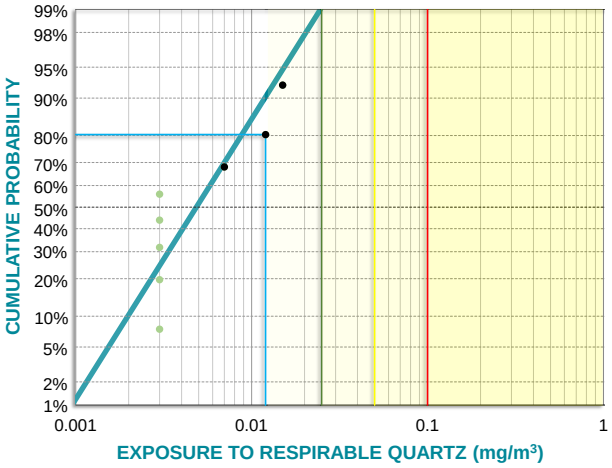
C15.11.05 - Tundish liner (Refractory maintenance)



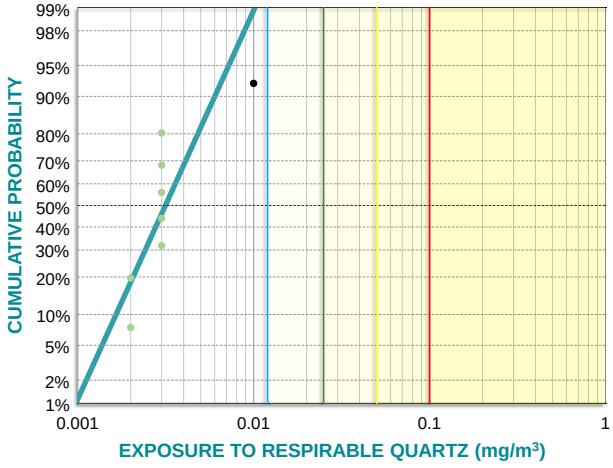
C15.11.06 - Converter liner (Refractory maintenance)



C15.11.09 - Fibre lining maintainer (Refractory maintenance)



C15.13.03 - Power-driven machinery operator for demolished material transport



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C15.01.01 - Manager	2	0.139	-	-	-	-
C15.02.02 - Crane operator (Port terminal facility)	21	0.270	2.067	>97.1%	95.8%	64.1%
C15.02.03 - Signaller (Port terminal facility)	11	0.215	1.252		>94.4%	90.4%
C15.02.04 - Longshore worker (Port terminal facility)	8	0.142	2.065		>92.4%	83.5%
C15.02.05 - Hold cleaning operator (Port terminal facility)	29	0.506	1.605		>97.9%	11.8%
C15.02.06 - Slinger (Port terminal facility)	1	0.090	-	-	-	-
C15.03.01 - Stacker-reclaimer machine operator (Primary stockyards)	7	0.365	1.394		>91.4%	21.1%
C15.03.02 - Reclaimer machine operator (Primary stockyards)	3	0.183	4.226	-	-	-
C15.03.03 - Stacker machine operator (Primary stockyards)	1	0.289	-	-	-	-
C15.03.04 - Foreman (Primary stockyards)	6	0.230	1.441		>90%	69.5%
C15.03.05 - Foreman, cleaning workings (Primary stockyards)	2	0.316	-	-	-	-
C15.03.06 - Conveyors manual cleaning operator (Primary stockyards)	8	0.368	1.529		>92.4%	35.2%
C15.03.07 - Conveyors cleaning machine operator (Primary stockyards)	23	0.323	1.532		>97.3%	49.3%
C15.03.08 - Cleaning water systems operator (Primary stockyards)	11	0.776	3.019	88.1%	79.8%	21.6%
C15.04.01 - Manual cleaning operator (Coal preparation plant)	50	0.441	2.152	95.0%	93.1%	36.4%
C15.04.02 - Cleaning machine operator (Coal preparation plant)	3	0.616	2.998	-	-	-
C15.04.03 - Maintenance mechanic / electrician (Coal preparation plant)	31	0.726	3.537	85.2%	76.8%	25.0%
C15.04.04 - Running operator (Coal preparation plant)	8	0.542	2.208	>92.4%	87.0%	24.1%
C15.05.01 - Cleaning machine operator (Coke production plant)	1	0.269	-	-	-	-
C15.05.02 - Walkway cleaning operator (Coke production plant)	7	0.249	1.427		>91.4%	62.2%
C15.05.03 - Oven charger (Coke production plant)	4	0.397	2.361	-	-	-
C15.05.04 - Oven dauber (Coke production plant)	4	0.426	1.597	-	-	-

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C15.05.05 - Cokeside car operator (Coke production plant)	1	0.290	-	-	-	-
C15.05.06 - Ceramic welder for oven repairing (Coke production plant)	6	0.445	3.013	>90.0%	82.1%	45.8%
C15.05.07 - Mortar pump operator for oven repairing (Coke production plant)	4	0.377	1.295	-	-	-
C15.05.08 - Ceramic rope sealing operator for oven repairing (Coke production plant)	6	0.234	1.232		>90.0%	84.8%
C15.05.09 - Guniting operator for oven repairing (Coke production plant)	3	0.573	1.373	-	-	-
C15.05.10 - Guniting operator for charging holes repairing (Coke production plant)	10	0.313	1.305		>93.9%	45.1%
C15.05.11 - Charging hole lid replacement operator (Coke production plant)	3	0.376	1.724	-	-	-
C15.05.12 - Oven wall restoration operator (Coke production plant)	2	0.235	-	-	-	-
C15.05.13 - Caulker operator for oven pipes (Coke production plant)	6	0.452	1.928	>90.0%	89.9%	29.8%
C15.05.14 - Oven deck maintenance operator (Coke production plant)	7	0.473	1.852	>91.4%	91.2%	8.6%
C15.05.15 - Maintenance electrician (Coke production plant)	7	0.301	1.350		>91.4%	66.8%
C15.05.16 - Maintenance mechanic (Coke production plant)	8	0.315	1.568		>92.4%	38.2%
C15.05.17 - Mechanical maintenance technician (Coke production plant)	2	0.188	-	-	-	-
C15.06.01 - Manual cleaning operator (Coke screening plant)	3	1.194	30.553	-	-	-
C15.06.02 - Cleaning machine operator (Coke screening plant)	6	0.374	2.622	>90.0%	87.0%	40.9%
C15.06.03 - Maintenance mechanic / electrician (Coke screening plant)	1	0.312	-	-	-	-
C15.07.01 - Running operator (Homogenising plant)	5	0.731	1.689	-	-	-
C15.07.02 - Running operator (Agglomeration plant)	7	0.926	2.037	>91.4%	61.4%	10.2%
C15.07.03 - Shift supervisor (Homogenising and agglomeration plants)	3	0.151	1.283	-	-	-
C15.07.04 - Foreman (Homogenising and agglomeration plants)	3	0.188	2.215	-	-	-

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C15.07.05 - Maintenance mechanic (Agglomeration department)	13	0.373	4.867	88.4%	77.8%	38.7%
C15.07.06 - Maintenance electrician (Agglomeration department)	6	0.446	2.962		>90.0%	46.4%
C15.07.07 - Manual cleaning operator (Homogenising plant)	4	1.471	2.747	-	-	-
C15.07.08 - Manual cleaning operator (Agglomeration plant)	11	1.248	2.069	82.4%	62.5%	<5.6%
C15.07.09 - Cleaning machine operator (Homogenising plant)	3	0.980	1.169	-	-	-
C15.07.10 - Cleaning machine operator (Agglomeration plant)	5	1.260	2.121	-	-	-
C15.07.11 - Foreman, cleaning workings (Homogenising and agglomeration plants)	3	0.675	2.024	-	-	-
C15.08.01 - Shift supervisor (Blast furnace)	1	0.156	-	-	-	-
C15.08.02 - Technician (Blast furnace)	2	0.218	-	-	-	-
C15.08.03 - Cooling operator (Blast furnace)	5	0.246	1.392	-	-	-
C15.08.04 - Caster (Blast furnace)	12	0.371	1.623		>94.9%	39.9%
C15.08.05 - Torpedo ladle car operator (Blast furnace)	2	0.294	-	-	-	-
C15.08.06 - Stock-house operator (Blast furnace)	1	0.335	-	-	-	-
C15.08.08 - Mechanical maintenance operator (Blast furnace)	14	0.326	2.706	94.9%	87.2%	58.8%
C15.08.09 - Maintenance electrician (Blast furnace)	6	0.611	2.951	88.5%	80.8%	32.2%
C15.09.01 - AOD running operator (Steel refining plant)	11	0.199	1.779		>94.4%	77.4%
C15.09.02 - ASEA ladle furnace running operator (Steel refining plant)	2	0.644	-	-	-	-
C15.10.01 - Running operator (Continuous casting plant)	5	0.251	1.170	-	-	-
C15.10.02 - Casting floor operator (Continuous casting plant)	8	0.546	1.934	>92.4%	88.9%	9.2%
C15.10.03 - Ladle crane operator (Continuous casting plant)	5	0.223	1.600	-	-	-
C15.11.01 - Bricklayer (Refractory maintenance)	3	0.453	1.691	-	-	-
C15.11.02 - Ladle maintenance inspector (Refractory maintenance)	7	0.253	1.779		>91.4%	69.2%

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C15.11.03 - Ladle liner (Refractory maintenance)	7	0.734	1.453		>91.4%	<8.6%
C15.11.04 - Power shovel operator for ladle lining demolition (Refractory maintenance)	4	0.554	1.522	-	-	-
C15.11.05 - Tundish liner (Refractory maintenance)	11	1.783	2.924	61.6%	45.4%	7.0%
C15.11.06 - Converter liner (Refractory maintenance)	10	0.772	2.302	>93.9%	70.6%	<6.1%
C15.11.07 - Melting furnace liner (Refractory maintenance)	5	1.015	2.668	-	-	-
C15.11.08 - Power shovel operator for furnace chamber lining demolition (Refractory maintenance)	1	3.999	-	-	-	-
C15.11.09 - Fibre lining maintainer (Refractory maintenance)	8	0.437	1.588		>92.4%	21.9%
C15.11.10 - Jackhammer operator for pusher furnace demolition (Refractory maintenance)	2	1.176	-	-	-	-
C15.12.05 - Basket car driver (Scrap stockyard)	1	0.361	-	-	-	-
C15.13.01 - Masonry foreman	2	0.118	-	-	-	-
C15.13.02 - Bridge-crane for demolished material / stripping operator	2	0.149	-	-	-	-
C15.13.03 - Power-driven machinery operator for demolished material transport	8	0.191	1.949		>92.4%	70.2%

Working processes

In foundries, also called second melting foundries, the metal ingots, slabs, billets, etc., coming from primary metallurgical industry (classified in C15 *Iron and steel industry*), or metal scraps recovered from waste, are remolten and the liquid metal is poured into moulds, where it solidifies and cools. Casting processes can be classified into three main types:

- green sand castings;
- shell mould castings;
- die castings.

The main differences are described below.

- Type of mould – in shell moulding and die casting, the liquid metal is poured into a metal mould that can be reused. Conversely, in green sand foundries the mould, made using *green* sands (mainly silica sands), can be used only once. Therefore, the green sand foundries are of greatest interest as far as exposure to RCS is concerned.
- Type of metal to be melted – in ferrous metal foundries (cast iron and steel) the mould is made of sand. In non-ferrous metal foundries (aluminium, brass, zamak) shell moulding and die casting technologies prevail.
- Operating temperature – in green sand foundries, the melting temperature of cast iron is about 1200°C and about 1400°C for steel, while a lower temperature (500-1000°C) is required in shell moulding and die casting foundries.

1. **Storage of raw materials, chemicals and patterns** – metal ingots, slabs, billets, etc., are unloaded and arranged in the appropriate spaces. Chemical products (slagging materials, correctives), moulding green sand and cores sand are stored in silos.
2. **Pattern preparation** – the casting pattern, that is a reproduction of the desired final product to be cast, can be made from wood, metal, synthetic resins, wax or expanded polymeric material. Depending on the type of pattern, different works are carried out, such as carpentry or removal works performed with machine tools, or polymer material moulding.
3. **Moulding, core production and green sand preparation**

   - Green sand recovery and preparation – the green sand is prepared in the green sand plant, operated from a cabin, using a mixture of silica sand, bentonite and black mineral. The green sand is conveyed, through a system of conveyor belts, to the hoppers of the moulding plant and poured into metal frames (moulding box, flasks).

   - Moulding (manual or mechanical) – in most plants, sand moulding is carried out in an automated manner, using machines that press the casting pattern in the sand previously packed into a moulding box. The mould cavity reproduces the inverse of the external shape of the piece to be made. To allow the extraction of the pattern from the mould, the mould is divided into two parts (a lower *drag* and upper *cope*).

   - Core production – cores are used when the casting to be made has internal cavities. Cores are the models of the casting internal cavities and are made in the core department, using silica sand, precoated with resins, or a mixture of sands and resins. The separate phase constitutes activity C14 Foundry sand cores.

   - Core assembling – positioning the cores into the mould is performed by hand or automatically by machine.
4. **Metal melting and treatment** – the charges made of metal slabs and additives (fluxes) are loaded into the furnace by a crane. The molten metal is discharged in holding electric furnaces, where drossing-off agents or inoculants are added to refine and adjust the melt chemistry in order to obtain the desired grade of mechanical properties.

5. **Pouring** – the molten metal is transferred from the furnace to a secondary holding furnace utilising ladles and overhead cranes and then from here it is poured into the moulds.

6. **Furnace and ladle repair** – vibratable refractories (Al oxides, Al silicates and crystalline silica) line the inside of furnaces and ladles. A Man-Made Mineral Fibre (MMMF) layer can be present between refractory and metal shell. Damaged or worn parts are removed and a new lining is placed.

7. **Shakeout, decoring, gates and risers removal** – after the liquid metal has been poured into the moulds, they are left to cool. After cooling, the moulds are conveyed to the vibration table, where they are crumbled separating the castings from the sand. After that, sprues, risers, gates and runners must be removed using cutting tools/machines.

8. **Finishing processes** – different operations may be carried out on different types of end-products (see also C17 *Treatment of metals*).

   - Sand blasting/shot blasting – after removing the cast from the mould, cutting gates and risers, the piece is cleaned and polished by sand blasting (using compressed air to shoot an abrasive media like quartz sand against the product) or shot blasting (using a mechanical device to propel an abrasive media like steel balls on the product by centrifugal force).

   - Deburring – the small imperfections (burrs) remaining on the castings are removed.

   - Heat treatments and other processes – some castings need to be heat treated in the furnace to achieve the designed mechanical properties. Surface processing such as grinding, drilling, boring or turning can follow.

   - Painting – some castings are powder coated by applying an organic film to the surface or by cataphoresis: an epoxy or acrylic resin is evenly deposited onto the metal surface.

   - Testing and inspection – visual inspection, magnetic particle inspection, pressure test and radiographic inspection are some of the tests used to inspect the products.

9. **Storing, packing and shipping** – the products are packed and stored in the warehouse and eventually loaded on a truck for delivery.

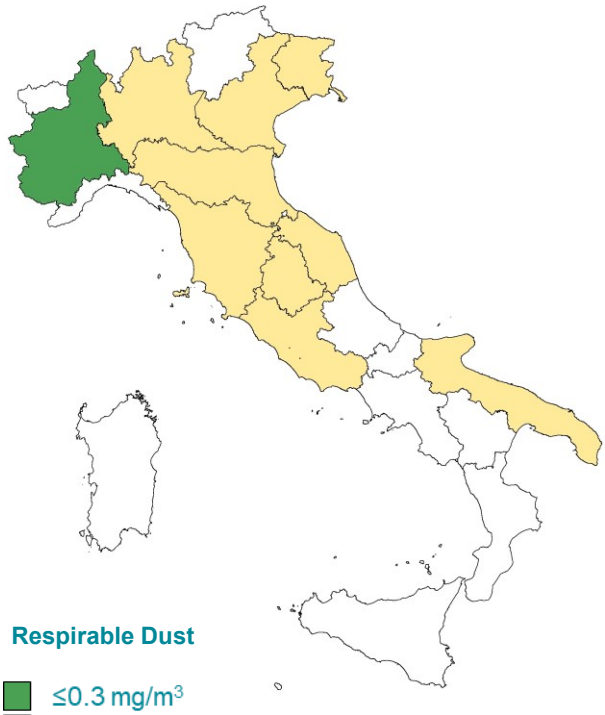
Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	880	0.463	2.963	853	0.024	3.415	8.3
STATIC	13	0.231	2.167	13	0.019	1.896	12.1

Geometric mean of personal exposure, by region

Respirable Quartz

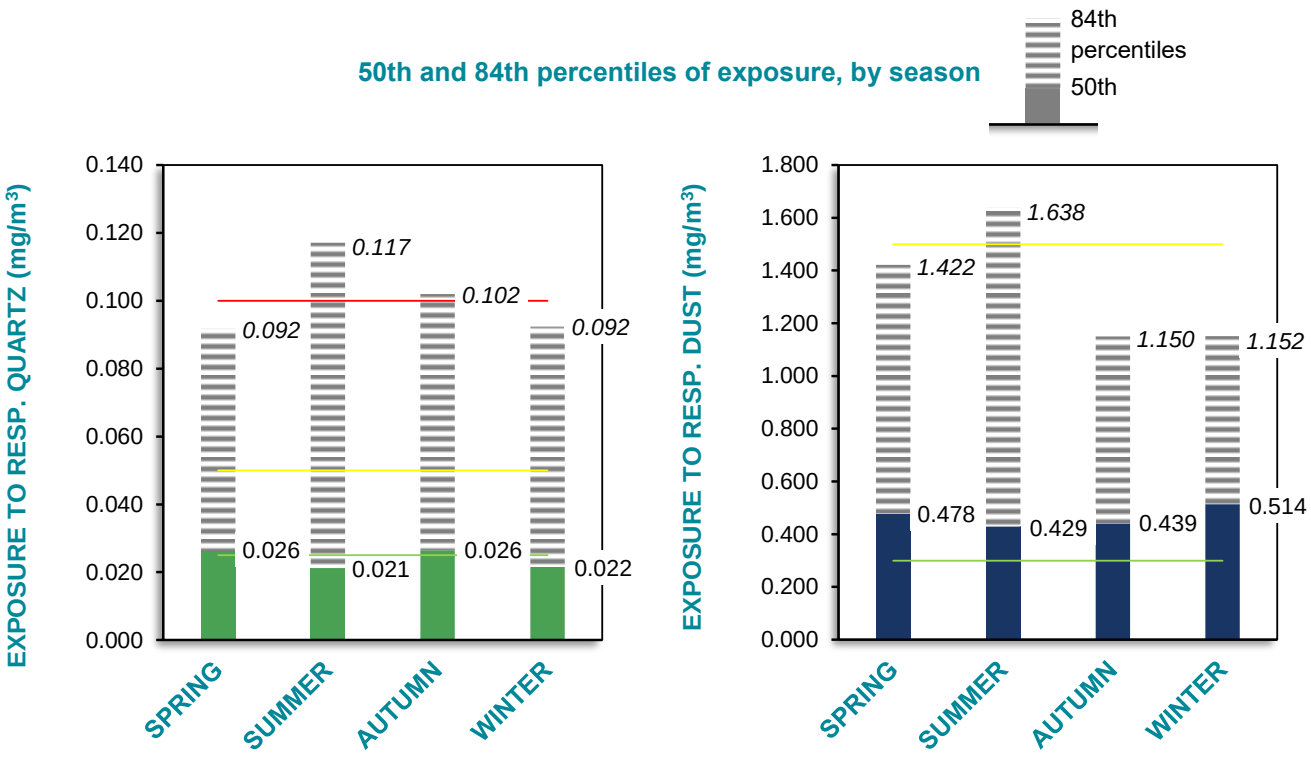
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



Respirable Dust

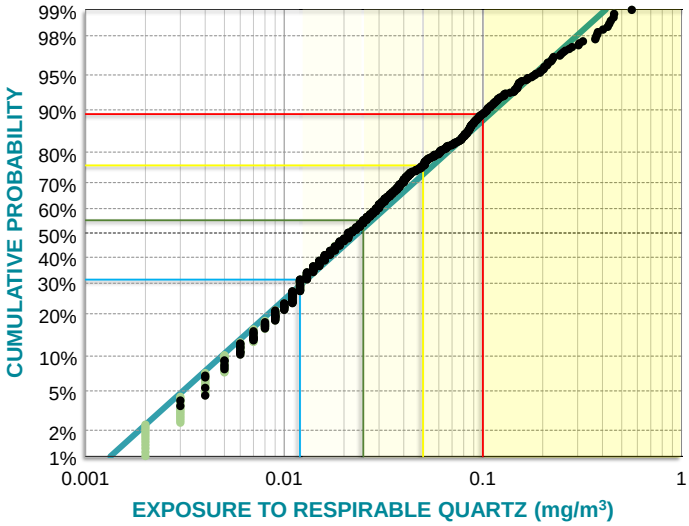
- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season



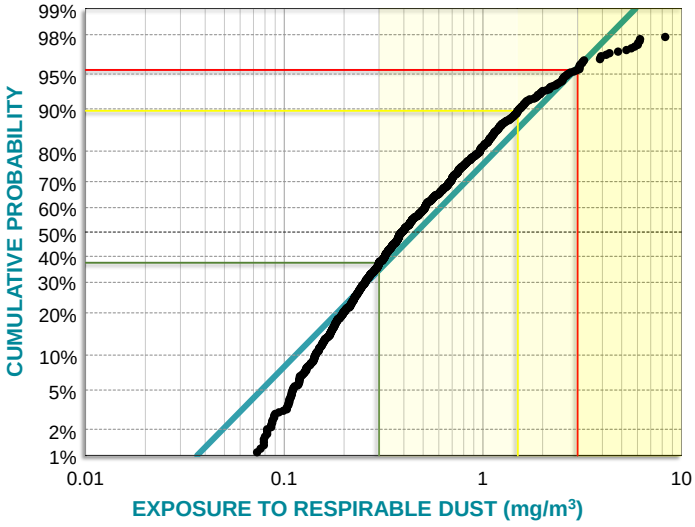
FOUNDRIES: Casting of iron, steel, light metals and non-ferrous metals – Manufacture of machinery and equipment (electrical equipment, motors, generators, turbines, valves, etc.), transport equipment (and accessories) and other metal products

Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



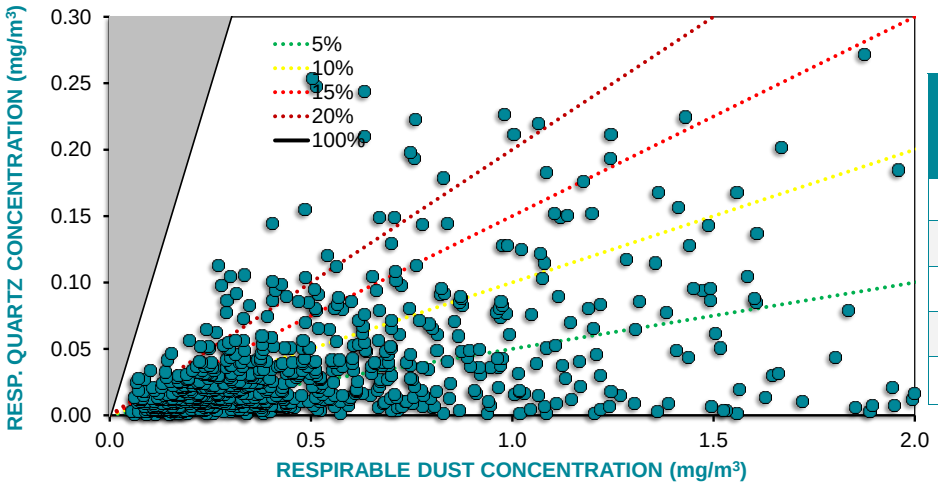
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	89.2%
≤0.05	75.9%
≤0.025	55.3%
≤0.012	31.4%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	95.4%
≤1.5	89.7%
≤0.3	37.4%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	42%
>5% to 10%	30%
>10% to 15%	15%
>15% to 20%	6%
>20%	8%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C16.01 - Management and office work	
C16.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C16.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C16.02 - Handling of raw materials	
C16.02.01 - Raw material crane/forklift operator	Operates crane, bridge-crane or bulldozer to unload incoming raw materials. Pours raw material into hoppers. Loads silos by means of forklift truck.
C16.03 - Preparation of green sand	
C16.03.01 - Green sand plant operator	Loads and controls the green sand plant, usually from a control cabin. Cleans, uniformly sized, high quality silica sand with minor ingredient additives such as bentonite clay, water and sea coal used in foundry casting processes. May also control the plant for reclaiming (sieving, regeneration, mulling, disintegration or aeration) used green sand before it can be reintroduced into the casting process. May carry out laboratory tests on green sand samples.
C16.03.02 - Crusher	Operates crushing plant to reduce raw material to suitable size for further processing.
C16.04 - Mould making and core assembling	
C16.04.01 - Hand mould maker	Forms sand moulds by hand. Moulds may be prepared in mould boxes (flasks) or in pits of the foundry (for large-sized castings). Assembles pattern (made in the shape of the desired part) into the flask. Fills the flask with foundry sand and rams it by hand and using hand tools (e.g. pneumatic pestle).
C16.04.02 - Semi-automatic moulding machine operator	Operates semi-automatic moulding machine to form sand moulds, generally made in two parts. Assembles flask and pattern into the moulding machine. Controls the mixer that feeds with foundry sand the moulding machine, filling the flask. Operates the machine that compacts sand in a flask to form mould. May fit and assemble moulding machine parts and components according to specifications.
C16.04.03 - Automatic moulding machine operator	Operates fully automated moulding machine to form sand moulds, generally made in two parts. The machine automatically fills the flask with foundry sand from the mixer, then squeezes the sand against a pattern plate, making an impression of the part to be cast in each of the two mould halves. May fit and assemble moulding machine parts and components according to specifications.
C16.04.04 - Moulding press operator	Controls press for making sand moulds in automatic moulding lines. After moulding, cleans pattern and checks, repairs and finishes moulds. May fit and assemble moulding line parts and components according to specifications.
C16.04.05 - Core setter	Positions cores in drag of sand mould. Examines cores for defects before mould is closed. If needed, uses compressed air to clean cores. May fit and assemble moulding line parts and components according to specifications.

FOUNDRIES: Casting of iron, steel, light metals and non-ferrous metals – Manufacture of machinery and equipment (electrical equipment, motors, generators, turbines, valves, etc.), transport equipment (and accessories) and other metal products

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C16.04.06 - Moulding line tool assembler	Fits and assembles moulding line parts and components according to specifications for products. Places pattern and plate into flask for moulding. Repairs parts and components.
C16.05 - Core making	
C16.05.01 - Mixer	Loads the automatic (kneading) mixing machine, controlling the mixture of sand, catalyst, resin and aggregate. If necessary, carries the mixture to the core maker by wheelbarrow.
C16.05.02 - Hand core maker	Prepares sand-cores by hand. Takes the mixture of sand, catalyst, resin and aggregate from a bucket and forces it into specially shaped hollow forms.
C16.05.03 - Semi-mechanised core making operator	Prepares sand-cores by using a machine that fills the specially shaped hollow forms with the mixture of sand, catalyst, resin and aggregate, then smooths it by hand.
C16.05.04 - Cold-box core-shooting machine operator	Operates cold-box core-shooting machine at room temperature (Ashland process), where phenolic resin and polyurethane are used as the binder, producing a flowable sand mixture that is shot into the core box. Clamps core box into the machine; withdraws core from core box. May carry out finishing (with files or vibratory tumbler) and painting of cores. Cleans the core box. Carries out tooling of machine components.
C16.05.05 - Hot-box core-shooting (shell-moulding) machine operator	Operates hot core-shooting machine, where a phenolic resin-coated sand is shot into a mould, coated with a silicone release agent, at about 270°C; the melting of the resin binds the sand grains and forms a solid shell (shell moulding process). Clamps core box into the machine; withdraws core from core box. May carry out finishing (with files or vibratory tumbler) and painting of cores. Cleans the core box. Carries out tooling of machine components.
C16.05.06 - Core-shooting machine tool assembler	Fits and assembles core-shooting machine parts and components according to specifications for products.
C16.05.07 - Sand core finishing / deburring operator	Carries out manual finishing of sand cores with files. May perform the gluing of the parts making up the sand core.
C16.05.08 - Core painting operator	Applies water-based paint by dipping or brush painting over core surfaces to be treated.
C16.05.09 - Dryer operator	Operates the sand core dryers. Loads the cores on trays and places them in the dryer. At the end of the drying phase, moves them to storage and unloads the cores.
C16.06 - Pattern making	
C16.06.01 - Pattern maker	Makes patterns (models) of cores and moulds used to reproduce the object. The pattern can be made of wood, metal, plaster, concrete or synthetic resin. Finishes the pattern, if required.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C16.07 - Melting and pouring - Furnace and ladle maintenance	
C16.07.01 - Furnace charge / ladle crane operator	Operates hoist or ladle crane for charging metal into furnace. Controls (crucible, cupola or electric-arc) furnace to melt metal prior to casting. Removes and transports molten metal in ladle. May use a forklift to move crucibles or receptacles of molten metal.
C16.07.02 - Furnace operator	Operates and controls furnaces used to heat the metal and holding furnaces.
C16.07.03 - Metal pourer (by hand)	Manually moves the ladle with molten metal from furnace to work station. Tilts ladle or opens pouring spout to pour metal into moulds producing metal casting. Typically works in small handicraft workshops.
C16.07.04 - Metal pourer / ladle crane operator	Operates hoist or ladle crane for moving the ladle with molten metal from melting or holding furnace to work station. Tilts ladle or opens pouring spout by moving levers to pour metal into moulds, producing metal casting.
C16.07.05 - Metal pouring by remote operator	Operates hoist or ladle crane for moving the ladle with molten metal from melting or holding furnace to work station. Operates via remote control from a cabin, operating a lever for tilting ladle or opening pouring spout to pour metal into moulds, producing metal casting.
C16.07.06 - Molten metal quality control technician	Carries out sampling of molten metal and send the samples to laboratory for analysis to test the required quality standards.
C16.07.07 - Melting furnace / ladle liner	Restores the refractory lining of the melting furnace chamber, dismantling it by demolition hammer. Moves lining debris to the mill, using forklift, to reduce their size. Uses the refractory crushed materials mixed with electrolyte paste to reline the crucible.
C16.07.08 - Furnace cupola liner	Repairs and rebuilds lining of furnace cupola. Mixes sand, clay and other refractory materials and applies mixture, using trowels and other hand tools, to burned areas in brick lining of cupola. Replaces brick linings and relines cupola with new firebrick, using bricklayer's tools. May use a hand-held demolition hammer.
C16.07.09 - Refinement operator	Operates the refining process (fire-refining by selective oxidation, electrolytic or chemical refining) to remove the last small amounts of impurities and elements from the molten metal in order to avoid casting defects.
C16.08 - Shakeout and decoring	
C16.08.01 - Manual shakeout operator	Manually opens the flasks and removes the casting from the mould by means of brushes, chisel and scraper (in handcraft and artistic workshops). Performs unmoulding of bigger castings using hammer and chisel or a chipping hammer.
C16.08.02 - Semi-manual shakeout operator	Operates bridge-crane or hoist to move the castings from the cooling area to the shakeout agitation/vibration table (open-air or closed cabin) that vigorously shakes as unflasked moulds are dropped onto it. Puts the castings in boxes/trolleys for transporting and further operations. Sets the used flasks apart for next re-use.
C16.08.03 - Automatic shakeout operator	Uses a remote operated robot, from a control room, to move the castings from the cooling area to the shakeout agitation/vibration table (open-air or closed cabin) that vigorously shakes as unflasked moulds are dropped onto it. Castings are loaded on boxes/trolleys for transporting and further operations, while used flasks are set apart for the next re-use.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C16.08.04 - Semi-automatic decoring machine operator	Operates semi-automatic machine for decoring or de-sanding castings (manual loading/unloading of pieces). The machine removes sand core, core residues and adhering sand by hammering, vibrating and turning.
C16.08.05 - Automatic decoring machine operator	Operates fully automated machine for decoring or de-sanding castings (robot loading and unloading). The machine removes sand core, core residues and adhering sand by hammering, vibrating and turning.
C16.09 - Gates and risers removal	
C16.09.01 - Degating operator	Removes (cuts) gates and risers. Depending on the casting size and materials may use hand hammering (chisel), machine (band saw, grinder, pneumatic chisel, etc.) or oxy-acetylene or oxy-methane torch.
C16.10 - Finishing: sandblasting and shotblasting	
C16.10.01 - Hand-held sandblasting gun operator	Operates open air sandblasting or works inside a confined, controlled and clean blast room. Uses a portable sandblast tank equipped with air compressor. Operates a hand-held nozzle to direct the abrasive quartz sand toward the work piece surface to remove burrs, scale and rust. Wears a suit of protective clothing and air respirator.
C16.10.02 - Cabinet sandblasting (manual) operator	Operates a sandblasting cabinet inside which the workpiece is placed in a turntable and moved by the operator using special rubber gloves. The cabinet is equipped with blast guns to propel abrasive quartz sand under high-pressure against the workpiece to remove burrs, scale and rust. Starts/stops the blast using a foot pedal.
C16.10.03 - Automatic sandblasting machine operator	Operates automatic sandblasting machine. Workpieces are placed in an isolated blasting chamber and a controlled stream of abrasive quartz sand are propelled towards them from multiple blast nozzles to remove burrs, scale and rust. Controls the completely automated process from a command console.
C16.10.04 - Hand-held shotblasting gun operator	Operates open air shotblasting or works inside a confined, controlled and clean blast room. Uses a portable sandblast tank equipped with air compressor. Operates a hand-held nozzle to direct the abrasive material (e.g. cut wire shot, steel shot, corundum) towards the work piece surface to remove burrs, scale and rust. Wears a suit of protective clothing and an air respirator.
C16.10.05 - Cabinet shotblasting (manual) operator	Operates a shotblasting cabinet inside which workpiece is placed in a turntable and moved by the operator using special rubber gloves. The cabinet is equipped with blast guns to propel abrasive material (e.g. cut wire shot, steel shot, corundum) under high-pressure against the workpiece to remove burrs, scale and rust. Starts/stops the blast using a foot pedal.
C16.10.06 - Automatic shotblasting machine operator	Operates automatic shotblasting machine. Workpieces are placed in an isolated blasting chamber and controlled streams of abrasive material (e.g. cut wire shot, steel shot, corundum) are propelled towards them from multiple blast nozzles to remove burrs, scale and rust. Controls the completely automated process from a command console.
C16.10.07 - Sandblasted casting quality control technician	Assesses the quality and sorts the sand/shot blasted castings.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C16.11 - Other metal finishing processing	
C16.11.01 - Deburring / grinding finisher	Removes surface residue from castings, preparing the pieces for further finishing. Manually scrapes parts with file or wire brush and deburrs parts using a portable grinder, pneumatic chisel, chipping hammer or deburring machine.
C16.11.02 - Cutting finisher	Carries out cutting finishing operations on metal workpieces using hand tools (angle grinder).
C16.11.03 - Gouging finisher	Carries out mechanical (grinding, hand milling, routing or chipping) or thermal (oxy-fuel gas or air carbon-arc) gouging for removing material in connection with welding or casting.
C16.11.04 - Welder	Operates welding equipment such as oxy acetylene welder, plasma arc welder and laser-assisted arc welder to join metal components.
C16.11.05 - Flattening finisher	Flattens sheets, bars, etc. using an hydraulic, mechanical or abrasive machine.
C16.11.06 - Polishing finisher	Removes excess metal and surface defects, creating a smooth and shiny surface, using a powered polishing wheel, belt or other polishing techniques.
C16.11.07 - Shot peening operator	Operates the shot peening or micro peening system to treat metal parts in order to increase their fatigue resistance. The machine shoots the metal surface with a controlled spray of micro-bead (round metallic, glass or ceramic particles) shots at very high speed.
C16.11.08 - Turning and boring finisher	Operates a lathe for shaping metal castings. In a lathe the workpiece is held, rotated and cut by a non-rotary tool bit. The cutting action can generate both external surfaces (by turning) and internal holes (by boring). Carries out assembling of pieces.
C16.11.09 - Cast painting operator	Paints castings to prevent corrosion by spray painting, dipping painting, electro galvanising, hot dip galvanising or by applying electrophoretic coating for iron and steel castings parts. The painting process is generally automated; the operator loads/unloads castings and operates the painting plant. May also carry out vitrification using resins, e.g. on the interior walls of tanks.
C16.11.10 - Heat treatment operator	Operates the heat treatment furnace. Loads pieces into the furnace, unloads and checks the pieces after the required series of thermal cycles have been performed. A combination of heat treatment techniques (e.g. annealing, solution treatment, precipitation treatment, quenching, etc.) may be used in order to increase the strength of the metal or to achieve other required properties without changing the product shape.
C16.11.11 - Treated casting quality control technician	Carries out visual examination and instrumental tests (magnetoscopic, X-ray and pressure tests) for product quality assessment.
C16.12 - Handling of castings	
C16.12.01 - Casting crane operator	Operates crane, hoist, forklift and conveyor as mechanical handling devices for lifting and transferring castings in the foundry departments.

FOUNDRIES: Casting of iron, steel, light metals and non-ferrous metals – Manufacture of machinery and equipment (electrical equipment, motors, generators, turbines, valves, etc.), transport equipment (and accessories) and other metal products

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C16.12.02 - Charging-crane operator	Attaches loads (especially large castings) to hoisting attachments, such as hooks and slings, prior to operating bridge-crane.
C16.12.03 - Bridge-crane / forklift operator	Operates material handling equipment (forklift, lift truck, bridge-crane or other carrying equipment) to move and store materials and finished products.
C16.13 - Warehousing and packaging	
C16.13.01 - Warehouse operator	Handles duties pertaining to the processing, organising, packing and shipping of materials, equipment and other items that are sent to the warehouse or the storage yard. Drives a forklift to pick up incoming stock or deliver materials to designated area.
C16.14 - Various workspaces	
C16.14.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C16.15 - Mechanical and electrical maintenance / cleaning	
C16.15.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C16.15.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C16.01.01 - Manager	7	0.010	1.910		>91.4%	88.2%	77.6%
C16.02.01 - Raw material crane/forklift operator	5	0.013	3.231	-	-	-	-
C16.03.01 - Green sand plant operator	11	0.014	2.328	>94.4%	86.6%	80.2%	58.9%
C16.03.02 - Crusher	2	0.050	-	-	-	-	-
C16.04.01 - Hand mould maker	38	0.021	3.318	89.5%	74.8%	59.2%	35.6%
C16.04.02 - Semi-automatic moulding machine operator	32	0.015	2.378	97.4%	95.7%	76.4%	42.2%
C16.04.03 - Automatic moulding machine operator	38	0.035	2.730	91.3%	58.7%	36.4%	17.3%
C16.04.04 - Moulding press operator	23	0.014	1.774		>97.3%	79.1%	47.2%
C16.04.05 - Core setter	80	0.024	2.656	92.6%	78.9%	51.3%	25.7%
C16.04.06 - Moulding line tool assembler	3	0.035	3.255	-	-	-	-
The results of the exposure measurements for the job titles included in work phases (departments) *C16.05 - Core making* and *C16.06 - Pattern making* are given in the section *C14 Foundry sand cores*.							
C16.07.01 - Furnace charge / ladle crane operator	18	0.025	2.893	87.5%	74.7%	58.7%	27.3%
C16.07.02 - Furnace operator	38	0.031	4.603	79.4%	63.0%	42.6%	25.2%
C16.07.03 - Metal pourer (by hand)	13	0.018	1.901	>95.3%	91.9%	63.9%	42.5%
C16.07.04 - Metal pourer / ladle crane operator	41	0.024	2.929	89.9%	74.0%	48.9%	23.3%
C16.07.05 - Metal pouring by remote operator	12	0.023	2.208	>94.9%	88.9%	47.3%	30.8%
C16.07.06 - Molten metal quality control technician	2	0.013	-	-	-	-	-
C16.07.07 - Melting furnace / ladle liner	10	0.013*	2.802*	92.4%	86.9%	77.5%	64.6%
C16.07.08 - Furnace cupola liner	9	0.208	4.728	42.6%	26.1%	<6.8%	
C16.08.01 - Manual shakeout operator	8	0.016	4.404	>92.4%	66.6%	56.1%	36.8%
C16.08.02 - Semi-manual shakeout operator	21	0.027	2.684	87.3%	78.7%	43.9%	20.3%
C16.08.03 - Automatic shakeout operator	10	0.041	2.955	63.2%	54.2%	32.2%	17.0%
C16.08.04 - Semi-automatic decoring machine operator	7	0.025	2.155	>91.4%	83.7%	47.3%	18.7%
C16.09.01 - Degating operator	66	0.044	4.044	68.3%	52.1%	37.2%	22.1%

* more than half of the measurements are <LOQ

FOUNDRIES: Casting of iron, steel, light metals and non-ferrous metals – Manufacture of machinery and equipment (electrical equipment, motors, generators, turbines, valves, etc.), transport equipment (and accessories) and other metal products

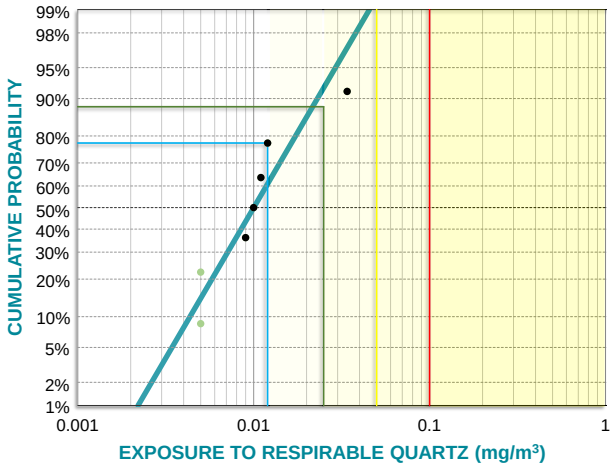
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
The results of the exposure measurements for the job titles included in work phases (departments) *C16.10 - Finishing: sandblasting and shotblasting* and *C16.11 - Other metal finishing processing* are given in the section *C17 Treatment of metals*.							
C16.12.01 - Casting crane operator	12	0.012	2.589	>94.9%	91.3%	81.7%	43.0%
C16.12.03 - Bridge-crane / forklift operator	23	0.025	2.086	>97.3%	88.9%	45.7%	15.6%
C16.13.01 - Warehouse operator	2	0.006*	-	-	-	-	-
C16.14.01 - Polyvalent worker	11	0.014	2.764	>94.4%	85.0%	72.8%	52.1%
C16.15.01 - Maintenance mechanic / electrician	17	0.013	2.406	>96.4%	95.3%	67.4%	44.2%
C16.15.02 - Workplace cleaner	6	0.016	2.367		>90.0%	76.2%	22.6%

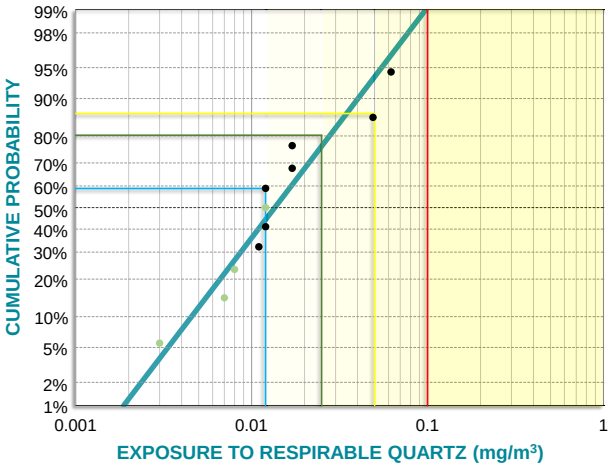
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

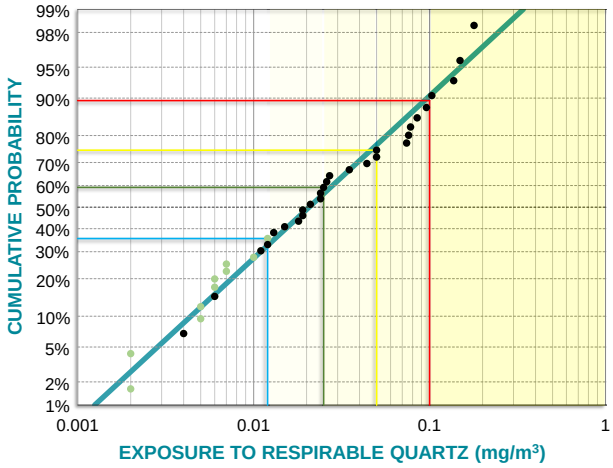
C16.01.01 - Manager



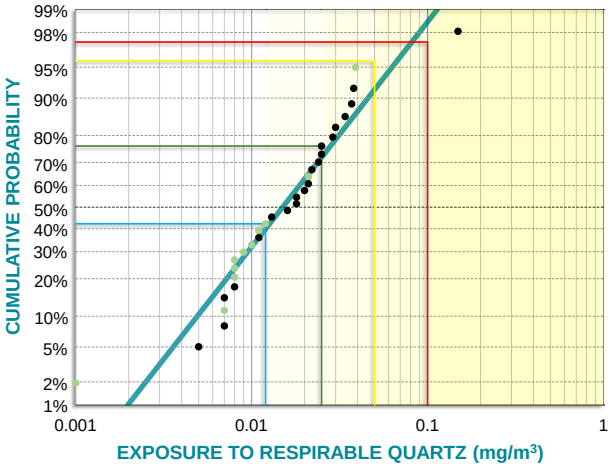
C16.03.01 - Green sand plant operator



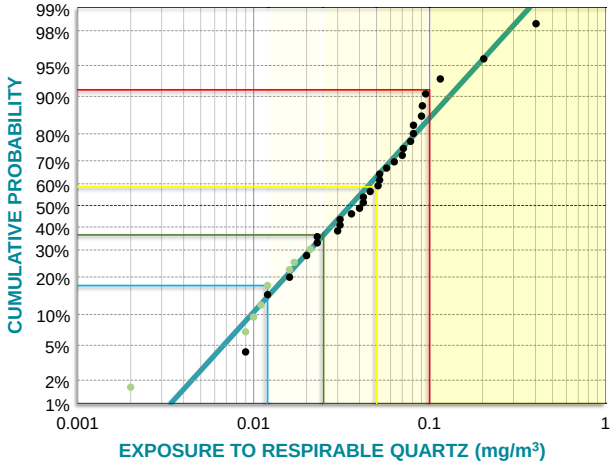
C16.04.01 - Hand mould maker



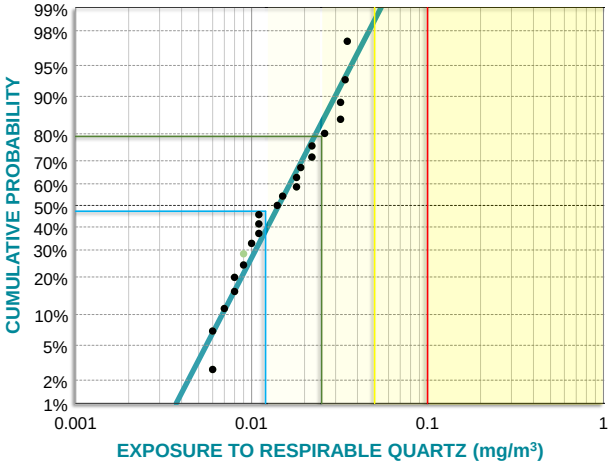
C16.04.02 - Semi-automatic moulding machine operator



C16.04.03 - Automatic moulding machine operator

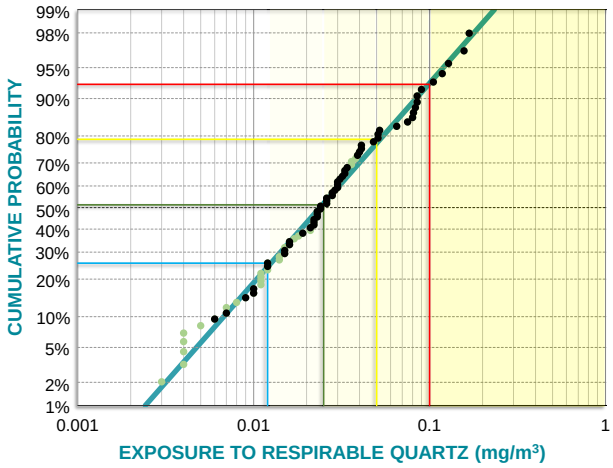


C16.04.04 - Moulding press operator

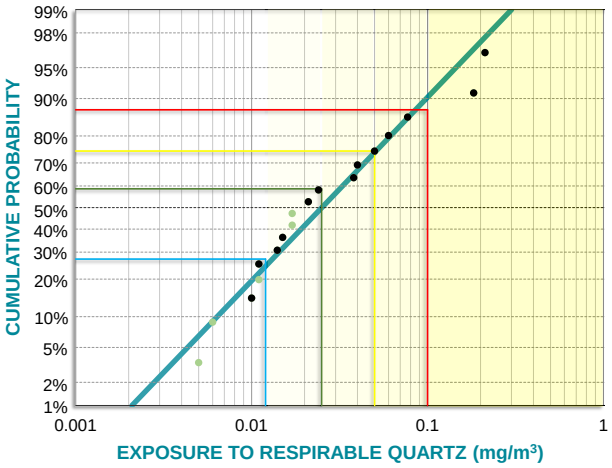


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

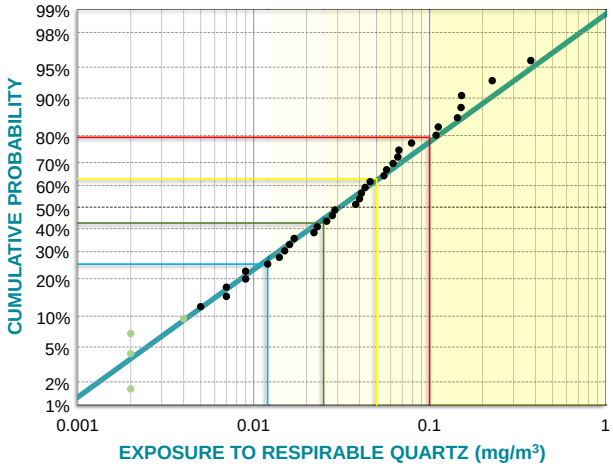
C16.04.05 - Core setter



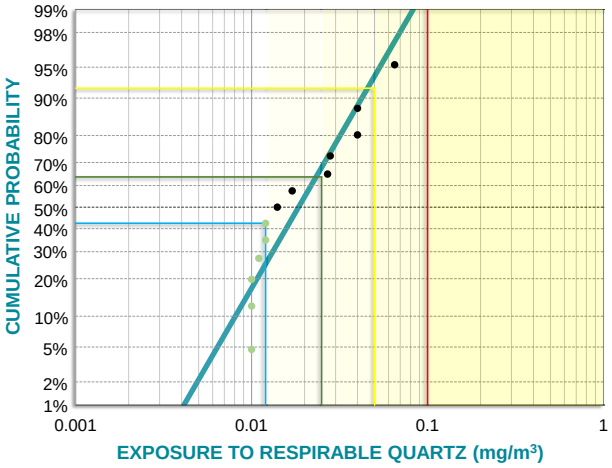
C16.07.01 - Furnace charge / ladle crane operator



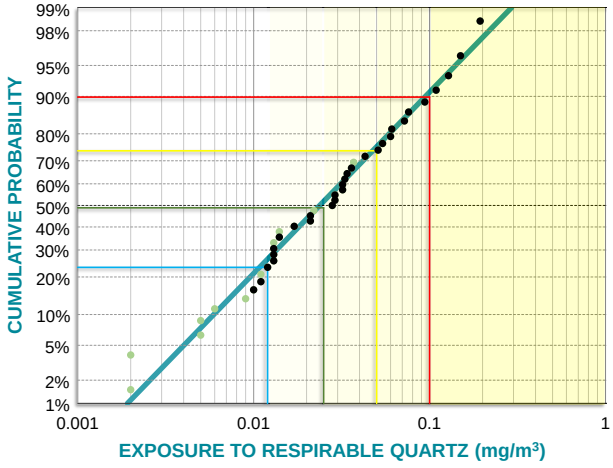
C16.07.02 - Furnace operator



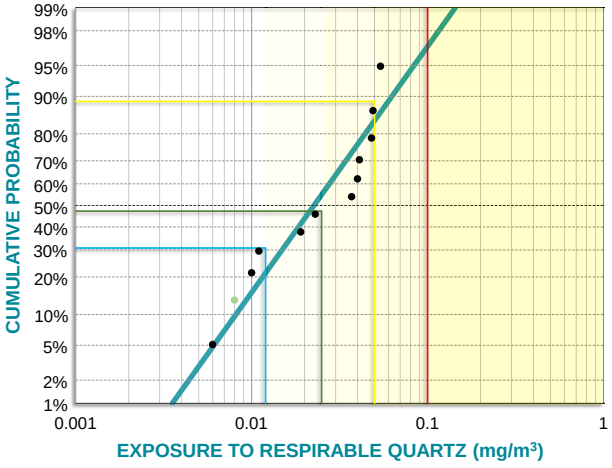
C16.07.03 - Metal pourer (by hand)



C16.07.04 - Metal pourer / ladle crane operator

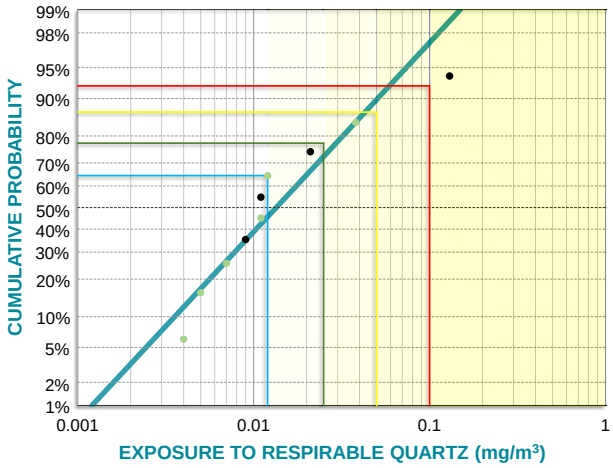


C16.07.05 - Metal pouring by remote operator

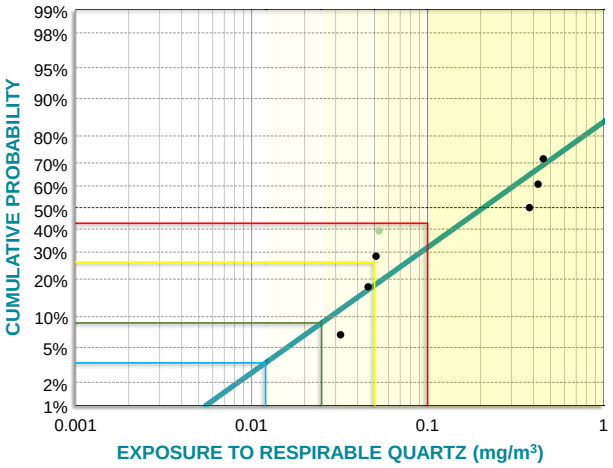


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

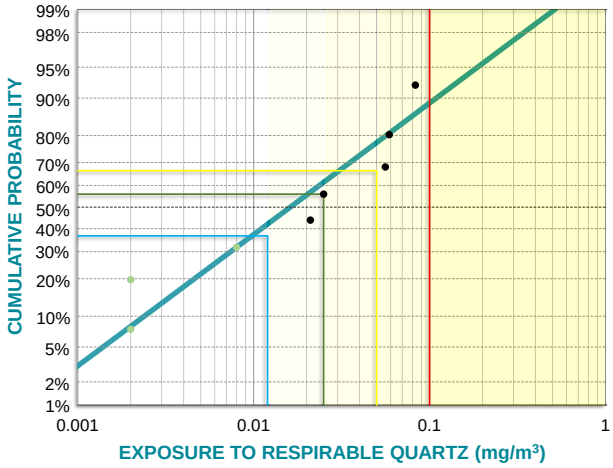
C16.07.07 - Melting furnace / ladle liner



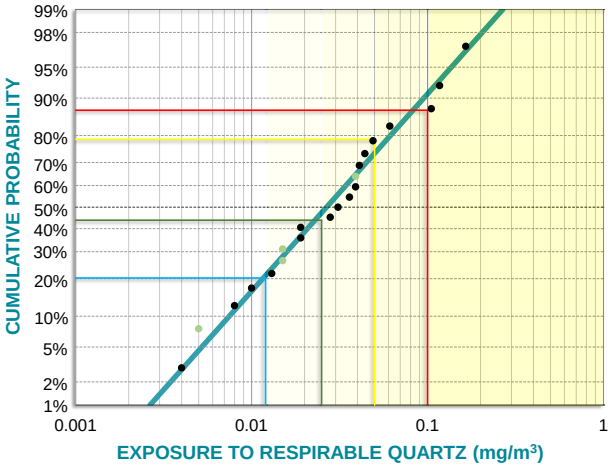
C16.07.08 - Furnace cupola liner



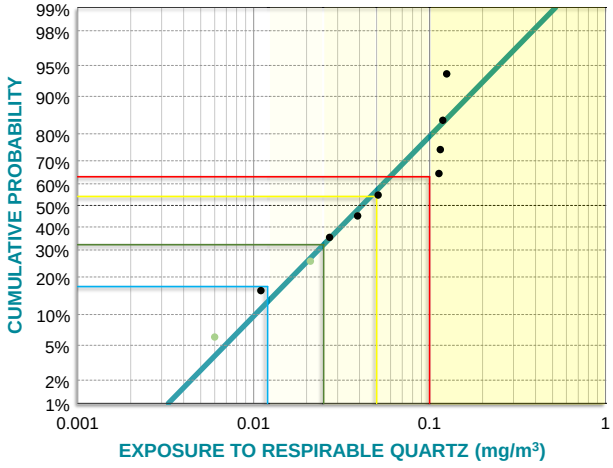
C16.08.01 - Manual shakeout operator



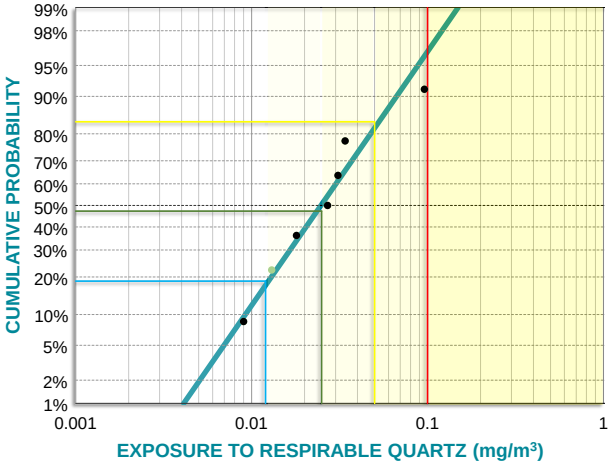
C16.08.02 - Semi-manual shakeout operator



C16.08.03 - Automatic shakeout operator



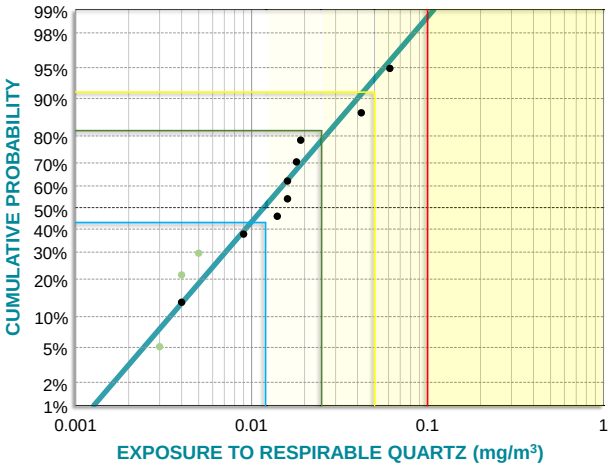
C16.08.04 - Semi-automatic decoring machine operator



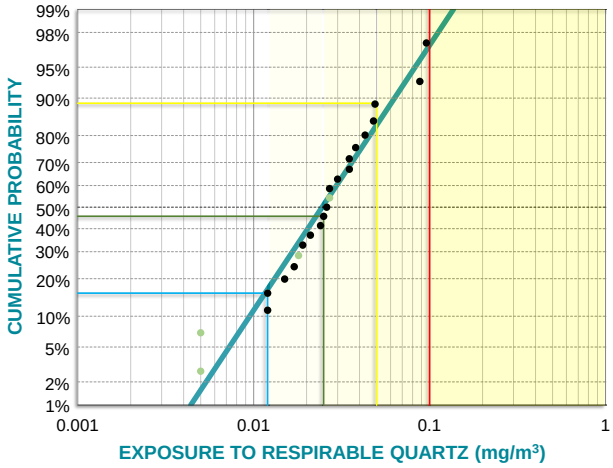
Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C16.09.01 - Degating operator

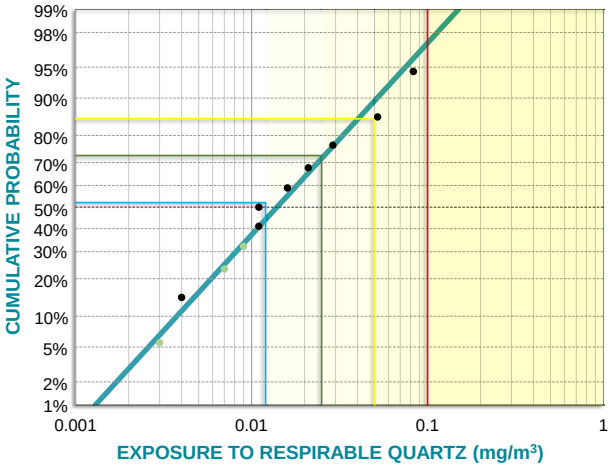
C16.12.01 - Casting crane operator



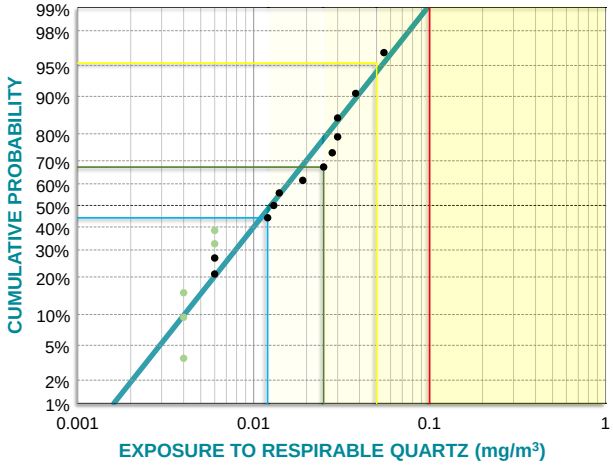
C16.12.03 - Bridge-crane / forklift operator



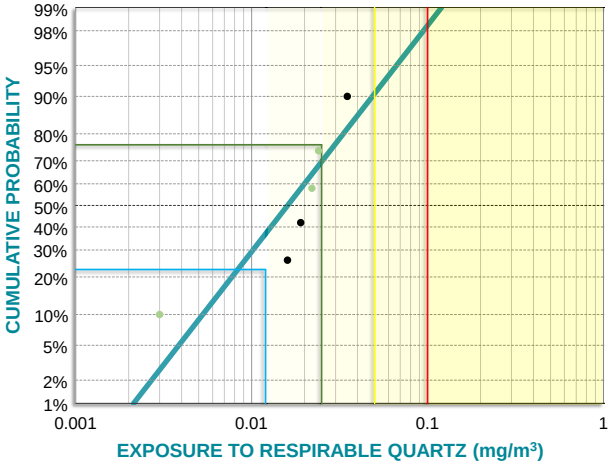
C16.14.01 - Polyvalent worker



C16.15.01 - Maintenance mechanic / electrician



C16.15.02 - Workplace cleaner



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C16.01.01 - Manager	6	0.181	1.652		>90.0%	87.2%
C16.02.01 - Raw material crane/forklift operator	5	0.328	2.207	-	-	-
C16.03.01 - Green sand plant operator	11	0.305	1.442		>94.4%	41.4%
C16.03.02 - Crusher	2	0.527	-	-	-	-
C16.04.01 - Hand mould maker	39	0.582	2.053	>98.4%	93.5%	22.3%
C16.04.02 - Semi-automatic moulding machine operator	34	0.271	2.494	>98.2%	92.0%	64.1%
C16.04.03 - Automatic moulding machine operator	40	0.487	2.165	97.3%	94.0%	32.5%
C16.04.04 - Moulding press operator	23	0.399	1.667		>97.3%	24.1%
C16.04.05 - Core setter	81	0.395	2.179	99.0%	92.5%	40.2%
C16.04.06 - Moulding line tool assembler	3	0.374	1.425	-	-	-
The results of the exposure measurements for the job titles included in work phases (departments) *C16.05 - Core making* and *C16.06 - Pattern making* are given in the section *C14 Foundry sand cores*.						
C16.07.01 - Furnace charge / ladle crane operator	18	0.449	2.474	>96.6%	89.7%	42.0%
C16.07.02 - Furnace operator	40	0.581	2.789	96.1%	93.5%	29.4%
C16.07.03 - Metal pourer (by hand)	13	0.525	2.760	>95.3%	85.2%	19.1%
C16.07.04 - Metal pourer / ladle crane operator	41	0.401	2.360	98.2%	90.7%	41.4%
C16.07.05 - Metal pouring by remote operator	12	0.376	1.726		>94.9%	20.5%
C16.07.06 - Molten metal quality control technician	2	0.144	-	-	-	-
C16.07.07 - Melting furnace / ladle liner	11	0.433	2.993	91.7%	87.6%	43.2%
C16.07.08 - Furnace cupola liner	9	2.301	5.715	52.6%	43.4%	15.7%
C16.08.01 - Manual shakeout operator	9	0.373	2.175		>93.2%	39.9%
C16.08.02 - Semi-manual shakeout operator	21	0.530	2.645	96.0%	83.7%	26.7%
C16.08.03 - Automatic shakeout operator	11	0.505	2.212	>94.4%	90.1%	27.5%
C16.08.04 - Semi-automatic decoring machine operator	7	0.412	2.083		>91.4%	50.5%
C16.09.01 - Degating operator	67	0.547	2.596	95.8%	88.8%	27.8%

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
The results of the exposure measurements for the job titles included in work phases (departments) *C16.10 - Finishing: sandblasting and shotblasting* and *C16.11 - Other metal finishing processing* are given in the section *C17 Treatment of metals*.						
C16.12.01 - Casting crane operator	12	0.321	1.893		>94.9%	54.6%
C16.12.03 - Bridge-crane / forklift operator	23	0.431	2.167	>97.3%	96.5%	31.3%
C16.13.01 - Warehouse operator	2	0.313	-	-	-	-
C16.14.01 - Polyvalent worker	11	0.309	2.457		>94.4%	45.1%
C16.15.01 - Maintenance mechanic / electrician	17	0.220	1.855		>96.4%	79.0%
C16.15.02 - Workplace cleaner	6	0.443	1.904		>90.0%	30.6%

Working processes

Metal refining and coating techniques are used to improve the characteristics of a product, such as hardness, impact strength, wear resistance, corrosion resistance and outward appearance, in order to achieve duration and inhibit oxidation. Specialised manufacturers can focus on coating and refining treatments, but some of them are often carried out directly within the foundry (in this case they are classified under C16 *Foundries*). Below is a list of the main types of refining/coating treatments.

1. **Mechanical treatments**

Cold plastic deformation of sheet metal allows manufacturers to obtain a wide variety of products, which often can be used without other treatments. The most common treatments can be carried out manually or through the use of Computer Numerical Control (CNC) machinery or robot, as follows:

- Shearing/stamping and punching: these processes force the sheet between two shaped cutting edges (punch/moving blade and die/fixed blade) to obtain a shear that reproduces the shape of the cutting edges. The difference between the two processes is in the product: in punching, the cut-out represents a scrap while in stamping the cut portion is the product.

- Forming/bending: is the plastic deformation to obtain elements with open or closed sections along their length in a straight line. It is accomplished by using presses or roll brakes (mechanical, pneumatic or hydraulic).

- Bending: is a process that uses a roll bender to obtain cylindrical or conic shapes, by bending the sheet metal between three rollers that force a plastic (usually cold) deformation of the sheet in a circular arc. Subsequent passages in the rollers enable this to obtain the desired curvature.

- Extrusion: in this process a ram, powered by a horizontal hydraulic press, pushes a metal blank to pass through a die, giving the object the desired shape.

- Deep drawing: this cold forming process is used to obtain cups or hollow pieces from sheet metal, by using specially adapted dies, often in a sequence.

Manufacturing by hot working is used to obtain products of given shape and dimensions by deformation of a semi-finished product (ingot, billet, etc.) since the heated material offers optimal ductility; it is usually followed by machining of the product. Depending on the kind of procedure used, the manufacturing processes are defined as open-die or impression-die forging, moulding or electro-forming.

- Open-die or impression-die forging: is a method to obtain products by repeated compressions (using hammers or presses) at a temperature that allows it to achieve a good plasticity at hot temperature and also a homogenous fine structure at a cool temperature. The process starts from the ingot, which is cold cut as needed, followed by heating of the piece in a muffle furnace and subsequent operations of threading, upsetting, rounding, rolling, extrusion, etc. Forging is used to obtain coarse pieces, usually of a large size, for a single piece or a low number of items.

- Moulding: is a manufacturing process in which the product is obtained by applying pressure on a heated shot of metal held between two closed moulds: the shape of the enclosed space defines the shape of the product. The final shape can be obtained in one or more steps. Pressure is applied from a press (constant pressure) or a hammer (impact pressure).

- Electro-moulding: is a moulding process where electric current heats the material (usually by induction) until it acquires the desired ductility and is pressed in a mould.

- Welding: is a technique used to join two or more metal parts. Different methods of welding can be used, such as heat (oxyacetylene torch, metal transfer arc and shielded metal arc), resistance (spot, seam) and pressure (friction, ultrasound). In soldering/brazing, a different molten metal (solder) is used to join the pieces, which are not melted in the process.

- Thermal cutting: is a technique that allows fast cuts even in conditions where mechanical cutting of metal could be difficult or impossible. The cutting process can be manual, automated or semi-automated.

Different techniques include oxyfuel torch cutting, powder cutting, oxy-arc cutting, plasma arc cutting and laser cutting.

- Surface cleaning treatments: sandblasting and shot blasting are techniques that use a high-pressure jet of abrasive blasting materials (silica sand, metal slags, steel grit, garnet or others) to smooth a surface or remove contaminants. The equipment used can be portable and with a hand-held nozzle and the pressurised fluid can be air (dry blasting) or water (wet blasting). Standard dry blasting can cause dispersion of abrasive dust, while in dry vacuum blasting the equipment can recapture and reuse the abrasive material. Shot peening is the cold processing of the material surface, hammering it with a controlled jet of beads (metallic, glass, ceramic, etc.) or cut wire shots, which cleans the surface but also relieves stress and boosts resistance.

- Finishing processes – within this broad definition there are many types of surface refining processes, like grinding, degating, machining, polishing, lapping, sharpening, brushing, tumbling, etc.

2. **Painting / coating**

Different types of painting techniques are available: powder coating (powder sprayed by nozzles in a charged electrostatic field), liquid spray painting (in a spray booth) or painting by immersion (electrodeposition painting). The painted pieces are cured/dried in an oven.

3. **Heat treatments**

Metal microcrystalline structure can be manipulated by the use of heating/cooling cycles, sometimes with the use of chemicals and provides a way to modify properties such as hardness, strength, toughness, ductility and elasticity. Physical heat treatments include different kinds of reheating (e.g., heating beyond critical temperature, maintaining in temperature, low cooling while in the critical interval, cooling to ambient temperature) and quenching (heating above critical interval, then fast cooling). Isothermal annealing or quenching is a process to obtain alloys with high hardness and low cracking, but also reduced toughness. Thermochemical treatments (e.g. carburisation, carbonitriding, nitriding or boriding) allow the diffusion of alloying elements in the material surface, usually to change its hardness.

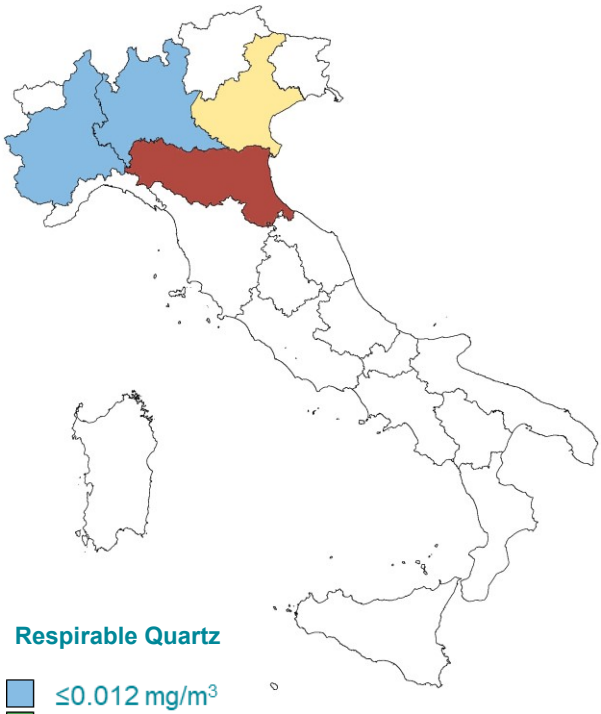
4. **Galvanic treatments**

Galvanic treatments are used to improve resistance against chemicals (corrosion) or mechanical attacks and to achieve a better aesthetic of the finished product. Electroplating is achieved by electrodeposition of one or more metal on a substrate, in a plating bath. Examples of possible plating include copper, nickel, chrome, zinc, silver, gold, brass, cadmium, etc. Another galvanic treatment is the anodic oxidisation of aluminium.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	52	1.656	4.916	52	0.045	5.832	4.8
STATIC	2	1.139	-	2	0.007	-	1.0

Geometric mean of personal exposure, by region



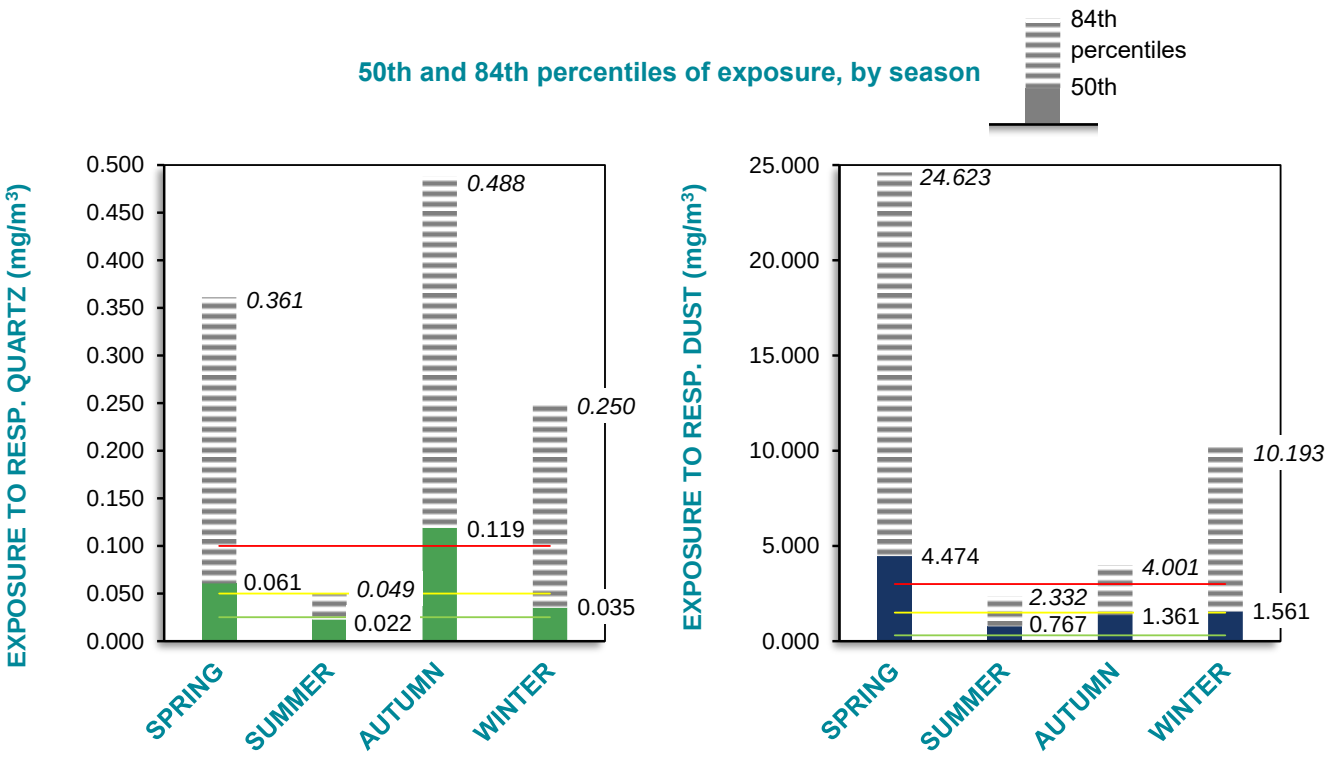
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

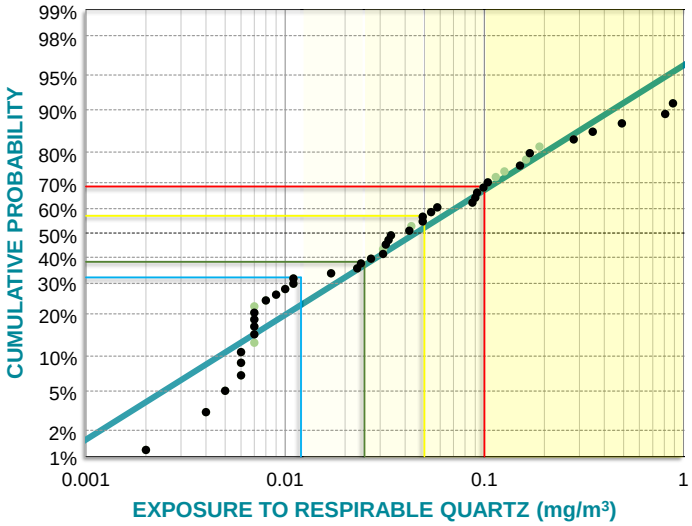
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

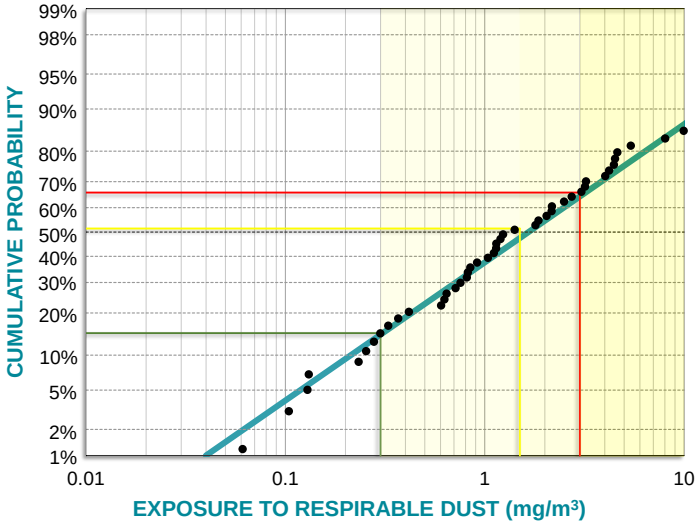


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



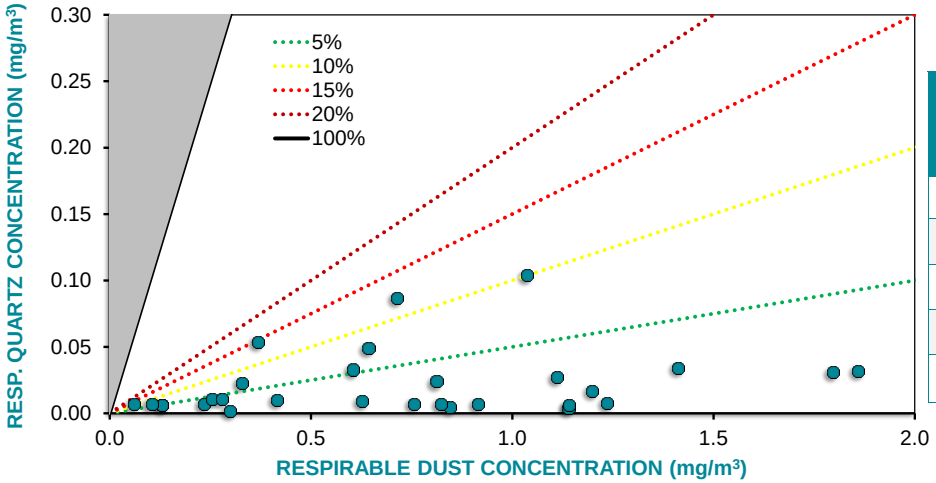
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	68.6%
≤0.05	57.1%
≤0.025	38.2%
≤0.012	32.2%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	66.0%
≤1.5	51.4%
≤0.3	14.7%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	63%
>5% to 10%	21%
>10% to 15%	12%
>15% to 20%	4%
>20%	0%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C17.01 - Management and office work	
C17.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C17.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C17.02 - Finishing: sandblasting and shotblasting	
C17.02.01 - Hand-held sandblasting gun operator	Operates open air sandblasting or works inside a confined, controlled and clean blast room. Uses a portable sandblast tank equipped with air compressor. Operates a hand-held nozzle to direct the abrasive quartz sand towards the surface of the workpiece to remove burrs, scale and rust. Wears a suit of protective clothing and air respirator.
C17.02.02 - Cabinet sandblasting (manual) operator	Operates a sandblasting cabinet inside which workpiece is placed in a turntable and moved by the operator using special rubber gloves. The cabinet is equipped with blast guns to propel abrasive quartz sand under high-pressure against the workpiece to remove burrs, scale and rust. Starts/stops the blast using a foot pedal.
C17.02.03 - Automatic sandblasting machine operator	Operates automatic sandblasting machine. Workpieces are placed in an isolated blasting chamber and controlled streams of abrasive quartz sand are propelled towards them from multiple blast nozzles to remove burrs, scale and rust. Controls the completely automated process from a command console.
C17.02.04 - Hand-held shotblasting gun operator	Operates open air shotblasting or works inside a confined, controlled and clean blast room. Uses a portable sandblast tank equipped with air compressor. Operates a hand-held nozzle to direct the abrasive material (e.g. cut wire shot, steel shot, corundum) towards the work piece surface to remove burrs, scale and rust. Wears a suit of protective clothing and air respirator.
C17.02.05 - Cabinet shotblasting (manual) operator	Operates a shotblasting cabinet inside which workpiece is placed in a turntable and moved by the operator using special rubber gloves. The cabinet is equipped with blast guns to propel abrasive material (e.g. cut wire shot, steel shot, corundum) under high-pressure against the workpiece to remove burrs, scale and rust. Starts/stops the blast using a foot pedal.
C17.02.06 - Automatic shotblasting machine operator	Operates automatic shotblasting machine. Workpieces are placed in an isolated blasting chamber and controlled streams of abrasive material (e.g. cut wire shot, steel shot, corundum) are propelled towards them from multiple blast nozzles to remove burrs, scale and rust. Controls the completely automated process from a command console.
C17.02.07 - Sandblasted casting quality control technician	Assesses the quality and sorts the sand/shot blasted castings.
C17.03 - Other metal finishing processing	
C17.03.01 - Deburring / grinding finisher	Removes surface residues from castings and prepares the pieces for further finishing. Manually scrapes parts with file or wire brush and deburrs parts using a portable grinder, pneumatic chisel, chipping hammer or deburring machine.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C17.03.02 - Cutting finisher	Carries out cutting finishing operations on metal workpieces using hand tools (angle grinder).
C17.03.03 - Gouging finisher	Carries out mechanical (grinding, hand milling, routing or chipping) or thermal (oxy-fuel gas or air carbon-arc) gouging for removing material in connection with welding or casting.
C17.03.04 - Welder	Operates welding equipment such as an oxy acetylene welder, plasma arc welder or laser-assisted arc welder to join metal components.
C17.03.05 - Flattening finisher	Flattens sheets, bars, etc. using a hydraulic, mechanical or abrasive machine.
C17.03.06 - Polishing finisher	Removes excess metal and surface defects creating a smooth and shiny surface using powered polishing wheel or belt or other polishing technique.
C17.03.07 - Shot peening operator	Operates shot peening or micro peening system to treat metal parts in order to increase their fatigue resistance. The machine shoots the metal surface with a controlled spray of micro-bead (round metallic, glass or ceramic particles) shots at very high speed.
C17.03.08 - Turning and boring finisher	Operates a lathe for shaping metal castings. In a lathe the workpiece is held, rotated and cut by a non-rotary tool bit. The cutting action can generate both external surfaces (by turning) and internal holes (by boring). Carries out assembling of pieces.
C17.03.09 - Cast painting operator	Paints castings to prevent corrosion by spray painting, dipping painting, electro galvanising, hot dip galvanising or by applying electrophoretic coating for iron and steel castings parts. The electrophoresis process ensures a uniform deposit of an epoxy or acrylic resin on the metal surface. The painting process is generally automated; the operator loads/unloads castings and operates the painting plant. May also carry out vitrification using resins, e.g. on the interior walls of the tanks.
C17.03.10 - Heat treatments operator	Operates the heat treatment furnace. Loads pieces into the furnace; unloads and controls the pieces after the required series of thermal cycles has been performed. A combination of heat treatment techniques (e.g. annealing, solution treatment, precipitation treatment, quenching, etc.) may be used in order to increase the strength of metal or achieve other required properties without changing the product shape.
C17.03.11 - Treated casting quality control technician	Carries out visual examination and instrumental tests (magnetoscopic, X-ray and pressure tests) for product quality assessment.
C17.04 - Handling of materials and products	
C17.04.01 - Bridge-crane / forklift operator	Operates material handling equipment (forklift, lift truck, bridge-crane or other carrying equipment) to move and store materials and finished products.
C17.05 - Warehousing and packaging	
C17.05.01 - Warehouse operator	Handles duties pertaining to the processing organising, packing and shipping of materials, equipment and other items that are sent to the warehouse or storage yard. Drives forklift to pick up incoming stock or deliver materials to designated area.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C17.06 - Various workspaces	
C17.06.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.
C17.07 - Mechanical and electrical maintenance / cleaning	
C17.07.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in the factory departments. The job title includes both foreman / maintenance manager and other workers.
C17.07.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

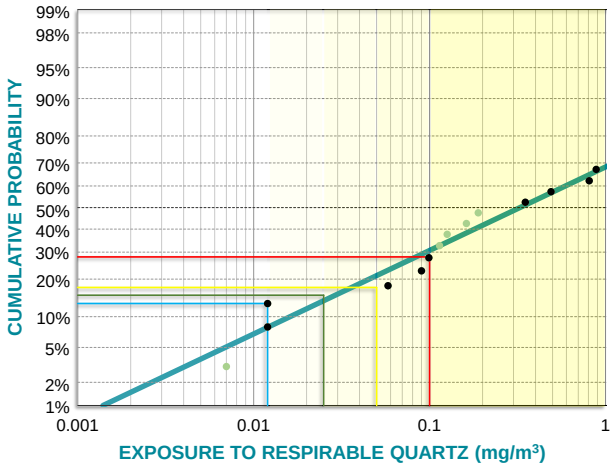
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C17.01.02 - Office worker	1	0.002	-	-	-	-	-
C17.02.01 - C16.10.01 - Hand-held sandblasting gun operator	20	0.326	10.307	28.1%	17.4%	15.1%	13.0%
C17.02.02 - C16.10.02 - Cabinet sandblasting (manual) operator	11	0.020	2.776	>94.4%	80.7%	50.0%	39.6%
C17.02.03 - C16.10.03 - Automatic sandblasting machine operator	22	0.059	3.417	54.6%	44.7%	24.6%	11.8%
C17.02.04 - C16.10.04 - Hand-held shotblasting gun operator	1	0.004*	-	-	-	-	-
C17.02.05 - C16.10.05 - Cabinet shotblasting (manual) operator	4	0.019	3.548	-	-	-	-
C17.02.06 - C16.10.06 - Automatic shotblasting machine operator	27	0.025	3.110	93.7%	65.4%	53.7%	31.7%
C17.02.07 - C16.10.07 - Sandblasted casting quality control technician	5	0.021	5.230	-	-	-	-
C17.03.01 - C16.11.01 - Deburring / grinding finisher	71	0.020	3.630	89.2%	74.7%	57.7%	38.8%
C17.03.02 - C16.11.02 - Cutting finisher	6	0.022	2.057		>90.0%	44.3%	30.4%
C17.03.03 - C16.11.03 - Gouging finisher	4	0.065	5.416	-	-	-	-
C17.03.04 - C16.11.04 - Welder	13	0.008	1.735			>95.3%	65.1%
C17.03.05 - C16.11.05 - Flattening finisher	1	0.004*	-	-	-	-	-
C17.03.06 - C16.11.06 - Polishing finisher	6	0.006	1.542				>90.0%
C17.03.07 - C16.11.07 - Shot peening operator	3	0.021*	2.631*	-	-	-	-
C17.03.08 - C16.11.08 - Turning and boring finisher	5	0.019	1.502	-	-	-	-
C17.03.09 - C16.11.09 - Cast painting operator	13	0.056	2.627	70.3%	48.7%	23.6%	5.5%
C17.03.11 - C16.11.11 - Treated casting quality control technician	12	0.037	1.604	>94.9%	68.4%	17.9%	<5.1%
C17.06.01 - Polyvalent worker	1	0.049	-	-	-	-	-

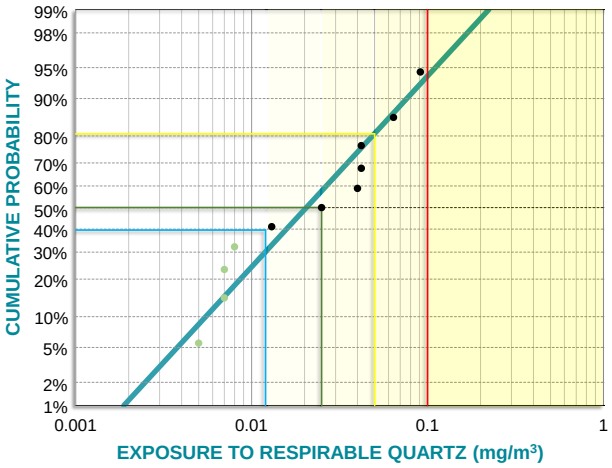
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

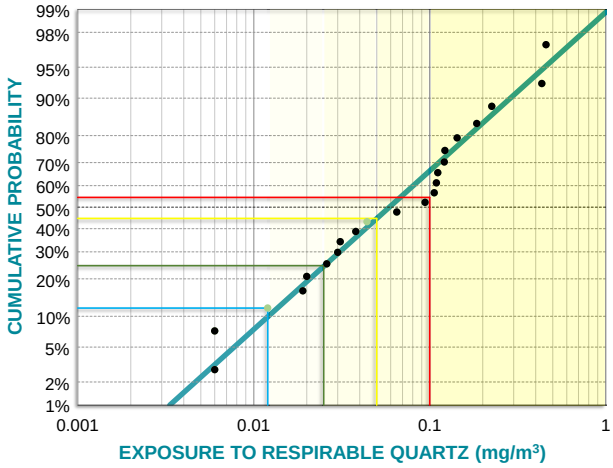
C17.02.01 - C16.10.01 - Hand-held sandblasting gun operator



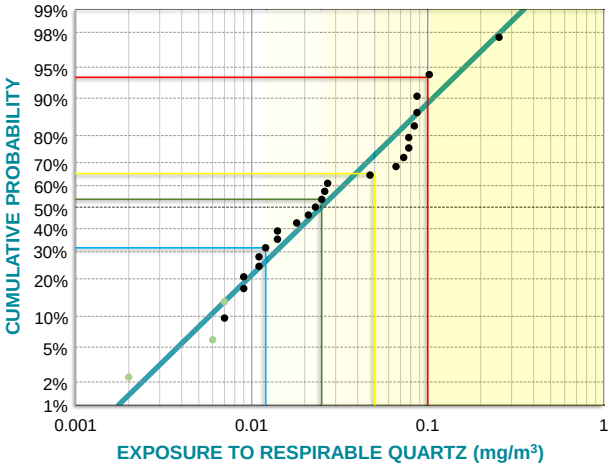
C17.02.02 - C16.10.02 - Cabinet sandblasting (manual) operator



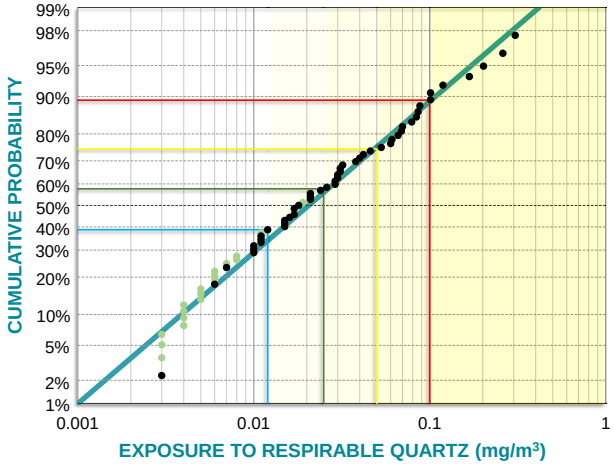
C17.02.03 - C16.10.03 - Automatic sandblasting machine operator



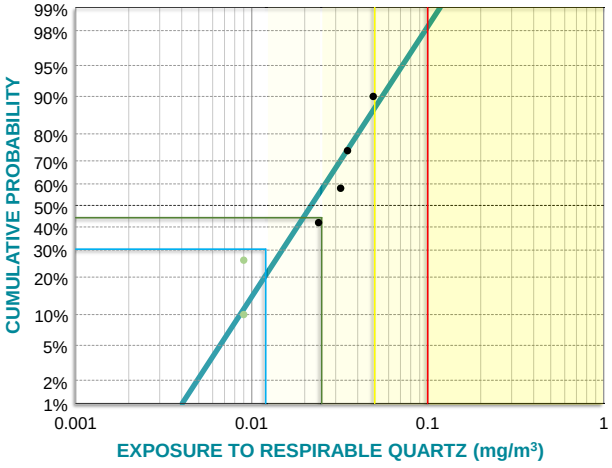
C17.02.06 - C16.10.06 - Automatic shotblasting machine operator



C17.03.01 - C16.11.01 - Deburring / grinding finisher

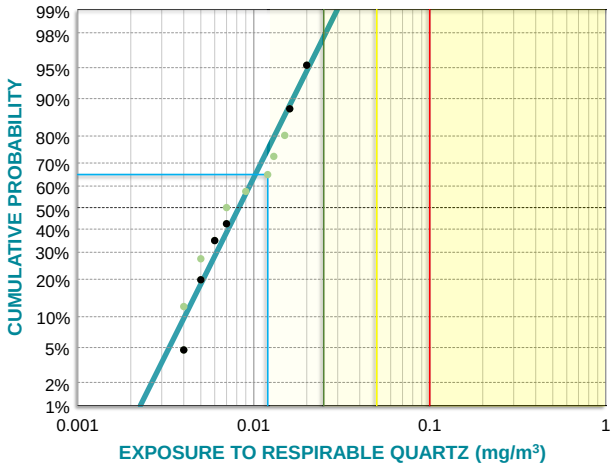


C17.03.02 - C16.11.02 - Cutting finisher

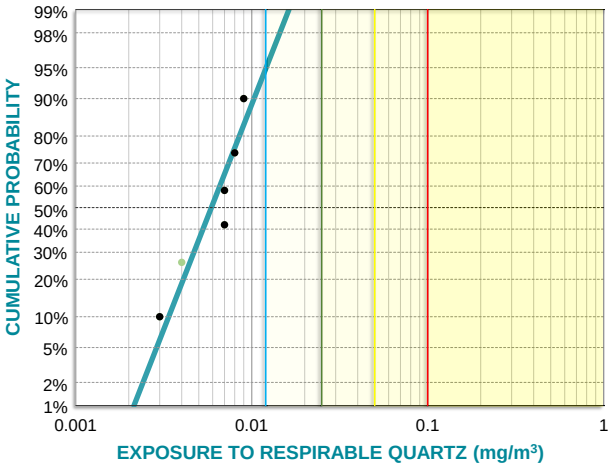


Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

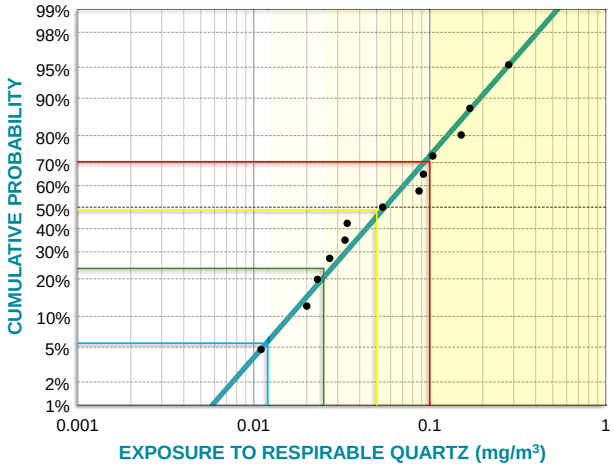
C17.03.04 - C16.11.04 - Welder



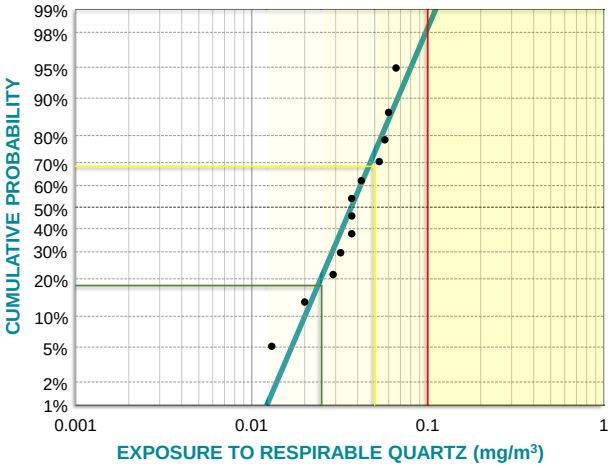
C17.03.06 - C16.11.06 - Polishing finisher



C17.03.09 - C16.11.09 - Cast painting operator



C17.03.11 - C16.11.11 - Treated casting quality control technician



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C17.01.02 - Office worker	1	0.299	-	-	-	-
C17.02.01 - C16.10.01 - Hand-held sandblasting gun operator	25	11.207	7.290	21.6%	13.4%	6.0%
C17.02.02 - C16.10.02 - Cabinet sandblasting (manual) operator	12	0.403	2.297		>90.0%	34.8%
C17.02.03 - C16.10.03 - Automatic sandblasting machine operator	22	0.582	3.169	92.5%	79.5%	43.4%
C17.02.04 - C16.10.04 - Hand-held shotblasting gun operator	1	1.530	-	-	-	-
C17.02.05 - C16.10.05 - Cabinet shotblasting (manual) operator	4	0.390	2.293	-	-	-
C17.02.06 - C16.10.06 - Automatic shotblasting machine operator	27	0.335	2.096		>97.7%	51.8%
C17.02.07 - C16.10.07 - Sandblasted casting quality control technician	5	0.191	2.342	-	-	-
C17.03.01 - C16.11.01 - Deburring / grinding finisher	72	0.708	2.820	93.0%	71.3%	23.0%
C17.03.02 - C16.11.02 - Cutting finisher	6	0.931	3.593	73.1%	54.6%	21.0%
C17.03.03 - C16.11.03 - Gouging finisher	11	12.043	2.511	9.4%	<5.6%	
C17.03.04 - C16.11.04 - Welder	13	0.846	2.010	94.7%	81.3%	<4.7%
C17.03.05 - C16.11.05 - Flattening finisher	1	0.376	-	-	-	-
C17.03.06 - C16.11.06 - Polishing finisher	7	0.379	2.895		>91.4%	42.8%
C17.03.07 - C16.11.07 - Shot peening operator	3	1.264	8.703	-	-	-
C17.03.08 - C16.11.08 - Turning and boring finisher	5	0.349	1.535	-	-	-
C17.03.09 - C16.11.09 - Cast painting operator	13	0.946	2.657	84.5%	66.4%	15.4%
C17.03.11 - C16.11.11 - Treated casting quality control technician	12	0.376	1.480		>94.9%	32.8%
C17.06.01 - Polyvalent worker	1	0.643	-	-	-	-

Working processes

Ovens and furnaces are used in many productions for heating, cooking, burning or smelting materials and their characteristics depend on the task they are assigned. Metal alloy melting furnaces include a variety of types, heated with solid fuel, electric current as well as gas burners and their operating temperatures depend on the composition of the alloy to be melted. In foundries, the most frequently used furnaces are cupola furnaces, heated by coke, those which use induction technology with alternating electric currents, crucible furnaces, reverberatory furnaces, heated by oil or gas burners (e.g. to melt secondary aluminium scrap) and electric arc furnaces used to reduce iron from iron ore and to make steel. The open-hearth furnace is used in some steel plants to burn excess carbon and other impurities out of cast iron, producing steel. In the brick and tile industry, a continuous moving ware kiln (tunnel kiln) is commonly used for firing clay products loaded on kiln cars. The Hoffmann kiln, a continuous moving fire kiln in which the clay products are stacked in rooms, was widely used in the past for the production of bricks and some factories still use it today. Shuttle intermittent kilns and muffles, fuelled by natural gas or electricity, are widely used in ceramics production (sanitary ware, pottery, tableware and ornamental articles); ceramic fibre blankets are generally used for the thermal insulation lining of the kiln chamber. Crystalline silica may be present in refractory materials used for the thermal insulation of furnaces. Therefore, exposure to RCS may occur in the installation and removal of refractories and Refractory Ceramic Fibre (RCF) from furnaces. Although RCF does not contain CS as produced, devitrification of silica and formation of cristobalite may occur due to the high operating temperature. Given the variety of ovens and furnace types in industrial applications, the working cycles can be quite different. The typical phases of the manufacturing process of a gas-fired melting kiln are listed below.

1. **Bearing structure and chamber walls assembly** – the metal framework of the bearing structure of the kiln, which encases the chamber body, is assembled, then the wall panels are mounted.
2. **Thermal insulation of the chamber** – one or more layers of the refractory or thermal-insulating materials are installed on the bottom and walls of the kiln chamber. When the kiln floor must bear the weight of the kiln car loaded with the clay products, refractory bricks are used as hot face lining, laying on refractory mortar and a second layer of refractory bricks generally resting on a bedding mortar made of cement mixed with expanded clay and vermiculite.
3. **Thermal insulation of the crucible** – can be achieved using cement mortars and refractory bricks, mineral wool and mats.
4. **Metal structure painting** – is usually carried out in dedicated areas, separated from the other working places and equipped with an air extractor.
5. **Finishing** – is carried out on some installation details of the electric and hydraulic components and on control, command and safety devices installed on the furnaces.
6. **Burner assembly** – includes the operations of flame calibration and final testing, sometimes carried out by external contractors.

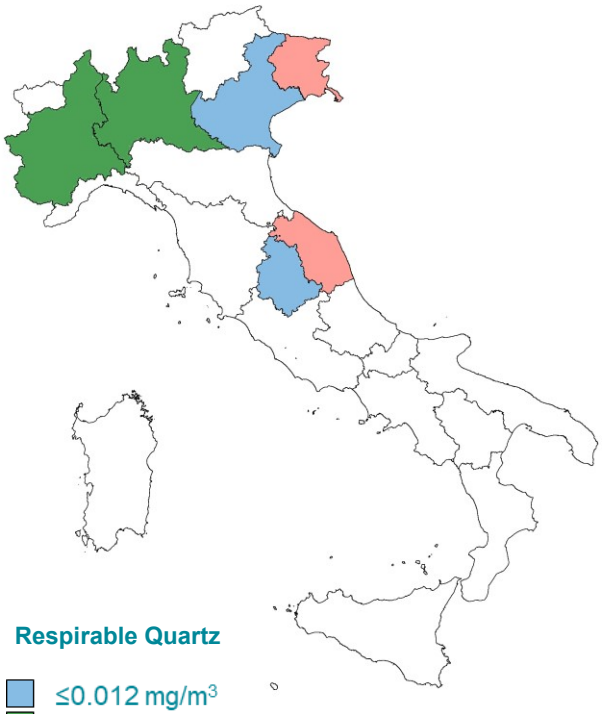
This activity includes the installation, repair and maintenance of process furnaces and other heating equipment.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	15	0.353	3.676	15	0.017	2.943	8.3
STATIC	1	0.036	-	1	0.002	-	5.6

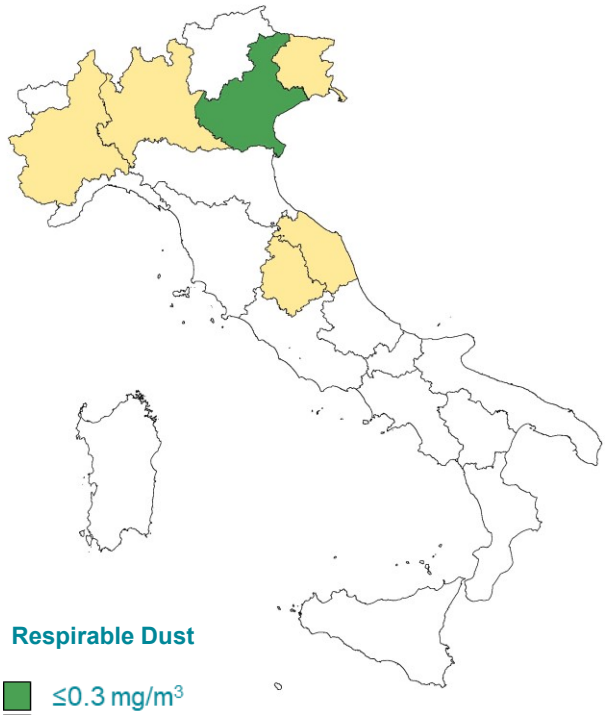
OVENS AND FURNACES: Manufacture, repair and maintenance of ovens and furnaces

Geometric mean of personal exposure, by region



Respirable Quartz

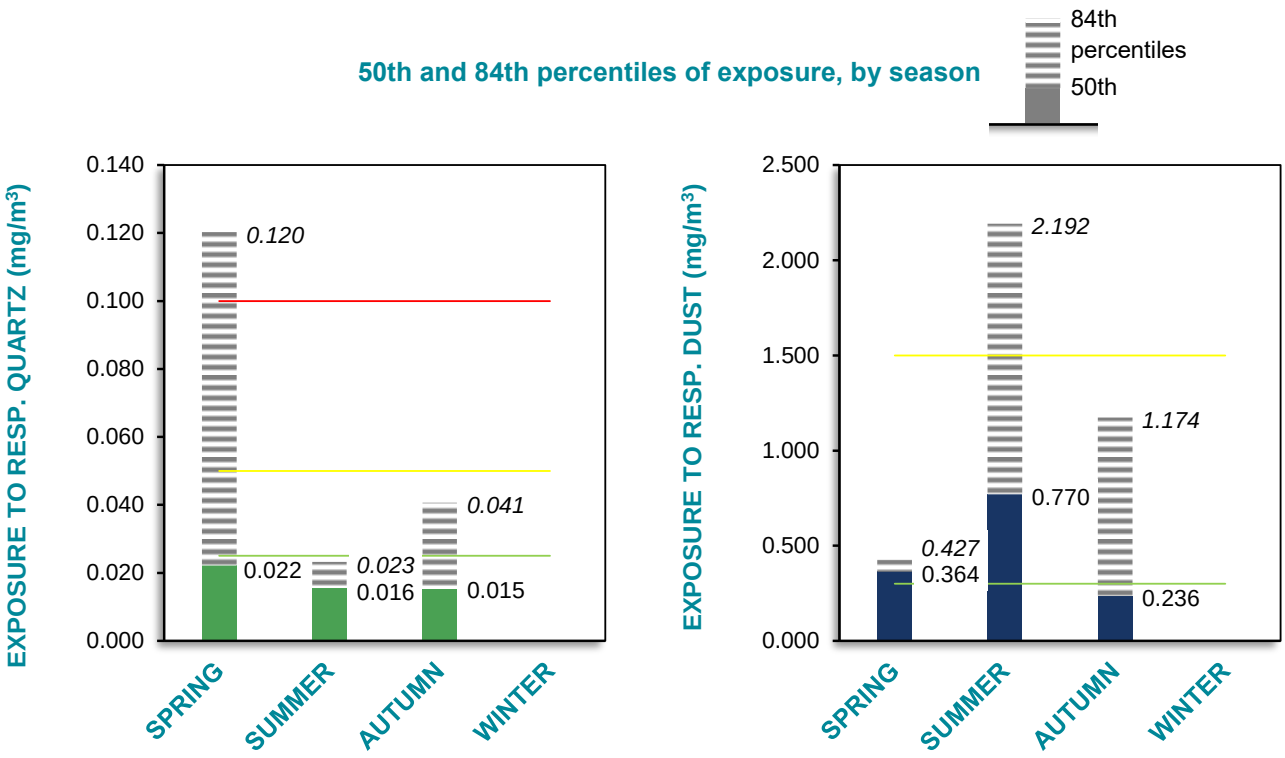
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



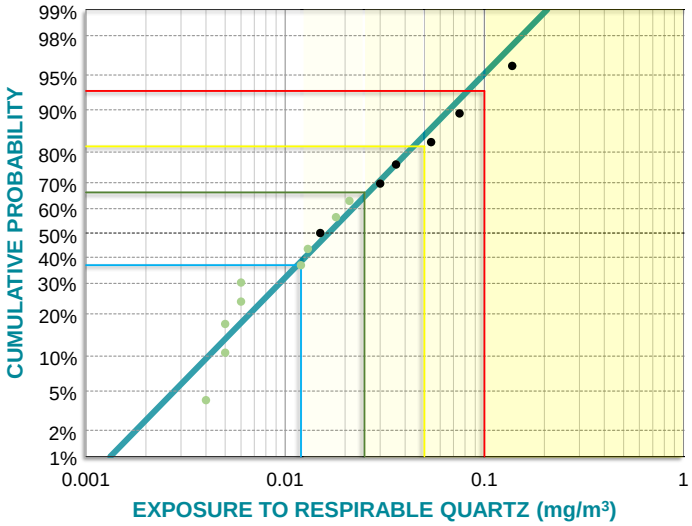
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

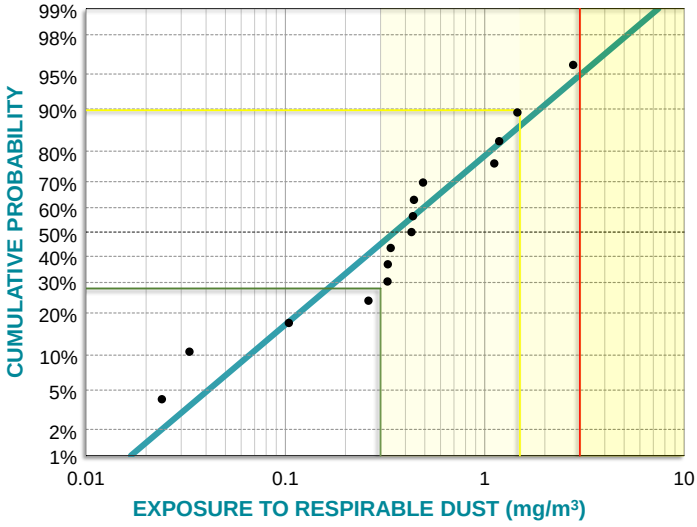


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



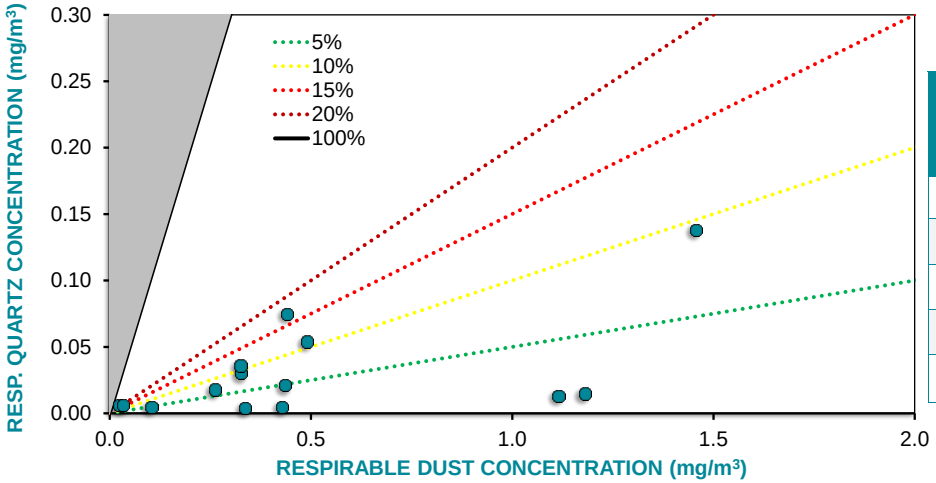
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	93.0%
≤0.05	81.6%
≤0.025	66.4%
≤0.012	36.9%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	>95.9%
≤1.5	89.8%
≤0.3	27.8%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	40%
>5% to 10%	27%
>10% to 15%	13%
>15% to 20%	13%
>20%	7%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C18.01 - Management and office work	
C18.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C18.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C18.02 - Bearing structure assembling	
C18.02.01 - Mechanical assembly fitter	Carries out the mechanical fitting and assembly of the bearing structure of ovens and furnaces.
C18.03 - Insulation	
C18.03.01 - Insulation operator	Carries out the insulation of furnaces. Applies insulating materials such as cement mortars and refractory bricks, mineral wool, fibreglass mats, etc. Performs the cutting of refractory bricks and the pleating and cutting of ceramic fibre mats.
C18.04 - Painting	
C18.04.01 - Painting operator	Carries out the painting of the metallic structure of ovens and furnaces.
C18.05 - Hydraulic components and burners installation	
C18.05.01 - Hydraulic components and burners installer	Installs hydraulic components and command and safety devices. Installs and regulates ovens and furnace burner units, performing flame calibration and final test.
C18.06 - Electric components assembling	
C18.06.01 - Electrician	Installs the electric components of ovens and furnaces.
C18.07 - Demolition and rebuilding	
C18.07.01 - Jackhammer operator for insulation demolition	Operates the demolition of the furnace insulation. The task includes the use of a hand-held demolition hammer.
C18.07.02 - Rebuilding operator	Rebuilds the insulation and other parts of the furnace.
C18.07.03 - Refractory bricklayer	Constructs or repairs furnaces, electric furnaces and open-hearth (Martin Siemens) furnaces. Lays firebrick and refractory tile to build, rebuild, reline or patch furnaces. Removes burned or damaged brick using a jackhammer. Spreads fire-clay mortar over brick with a trowel and lays brick in place. The tasks performed are similar to those of F1.02.01 *Oven / refractory bricklayer* in construction.
C18.08 - Handling of materials and products	
C18.08.01 - Bridge-crane / forklift operator	Operates material handling equipment (forklift, lift truck, bridge-crane or other carrying equipment) to move and store materials and finished products.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C18.09 - Mechanical and electrical maintenance / cleaning	
C18.09.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and in factory departments. The job title includes both foreman / maintenance manager and other workers.
C18.09.02 - Workplace cleaner	Keeps working areas and courtyards in clean and in an orderly condition, performing sweeping, vacuum cleaning and washing of floors. May use scrubbers, sweepers and manual cleaning equipment.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C18.01.01 - Manager	2	0.005*	-	-	-	-	-
C18.01.02 - Office worker	1	0.006*	-	-	-	-	-
C18.02.01 - Mechanical assembly fitter	1	0.036	-	-	-	-	-
C18.03.01 - Insulation operator	3	0.017	4.340	-	-	-	-
C18.07.01 - Jackhammer operator for insulation demolition	4	0.016*	1.304*	-	-	-	-
C18.07.02 - Rebuilding operator	2	0.086	-	-	-	-	-
C18.07.03 - Refractory bricklayer	2	0.012	-	-	-	-	-

* more than half of the measurements are <LOQ

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C18.01.01 - Manager	2	0.101	-	-	-	-
C18.01.02 - Office worker	1	0.033	-	-	-	-
C18.02.01 - Mechanical assembly fitter	1	0.325	-	-	-	-
C18.03.01 - Insulation operator	3	0.560	1.934	-	-	-
C18.07.01 - Jackhammer operator for insulation demolition	4	0.770	2.843	-	-	-
C18.07.02 - Rebuilding operator	2	0.845	-	-	-	-
C18.07.03 - Refractory bricklayer	2	0.184	-	-	-	-

Working processes

Gold is a relatively soft metal, easily workable, but also easily bent, so that it is necessary to transform it into gold alloys with other metals (e.g. silver, palladium or copper). Processing is based on hot (forging, casting and stamping) and cold (sheet metal drawing) techniques. Casting is the most common procedure in the case of alloys of several metals. After melting, the liquid metals are poured into special containers and processed in hydraulic presses to obtain ingots or medals. A processing technique for the production of gold objects consists in the **lost wax micro-casting**, described below. The so-called *plaster* used in this process is made of 20%-30% gypsum and 70-80% of quartz and cristobalite.

1. **Metal model making** – the model of the object is created by an artist using a non-precious metal.
2. **Rubber mould making** – a castable and vulcanisable rubber mould (with venting channels), which is the negative of the model, is achieved by mixing the fluid components.
3. **Wax pattern making** – molten wax is injected into the rubber mould, left to cool and harden and removed from the mould; the operation is repeated a number of times, obtaining many wax patterns with the same shape of the original model. Each wax pattern is then finished to correct any imperfection.
4. **Plaster pouring** – clusters of the wax patterns are mounted on a tree-like structure and then they are inserted in a metal flask, into which fluid heat-resistant plaster is poured and then left to solidify. Plaster is prepared by blending gypsum, quartz and cristobalite powders in a hand-loaded mixer.
5. **Wax removal** – the metal flask is heated in a kiln at about 100°C, so that the wax melts and drains out of the plaster investments by gravity, through the venting channels, leaving spaces with the negative shape of the original model.
6. **Molten metal pouring** – precious metal is melted and poured into the plaster investments, filling the space left by the wax.
7. **Plaster removal** – after cooling, the plaster investments are removed leaving the precious pieces free.
6. **Objects finishing** – carried out by polishing, scrubbing or other processing.

Polishing of metal objects (gold, silver, aluminium, brass, etc.) – the edges/irregularities are removed by rubbing the object surfaces with an abrasive paste, some of which contain even more than 40% quartz.

Recovery and refining of precious metals - Various types of processing waste contain precious metals (gold, platinum, palladium, rhodium, etc.) that can be recovered. Examples of such waste include goldsmith scrap, slag, crucibles, exhausted catalysts from the chemical and pharmaceutical industries, electronic waste and dental waste. The recovered metal is subjected to refinement, to increase its concentration. The technologies used for the recovery of metals with high added value from waste are basically of two types:

1. **Heat treatment** – pyrometallurgical process involving melting/oxidation in a converter-furnace and scorification of most of the metals present in small quantities.
2. **Wet treatment** – hydrometallurgical process, which includes chemical-physical liquid-phase treatments: leaching, solvent or supercritical fluids extraction, reverse osmosis, nano-filtration, ultrafiltration, ion exchange, adsorption on coal or other materials, electrochemical methods, etc.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	79	0.310	2.872	72	0.023	3.029	10.5
STATIC	39	0.094	1.723	39	0.004	2.925	6.6

Geometric mean of personal exposure, by region

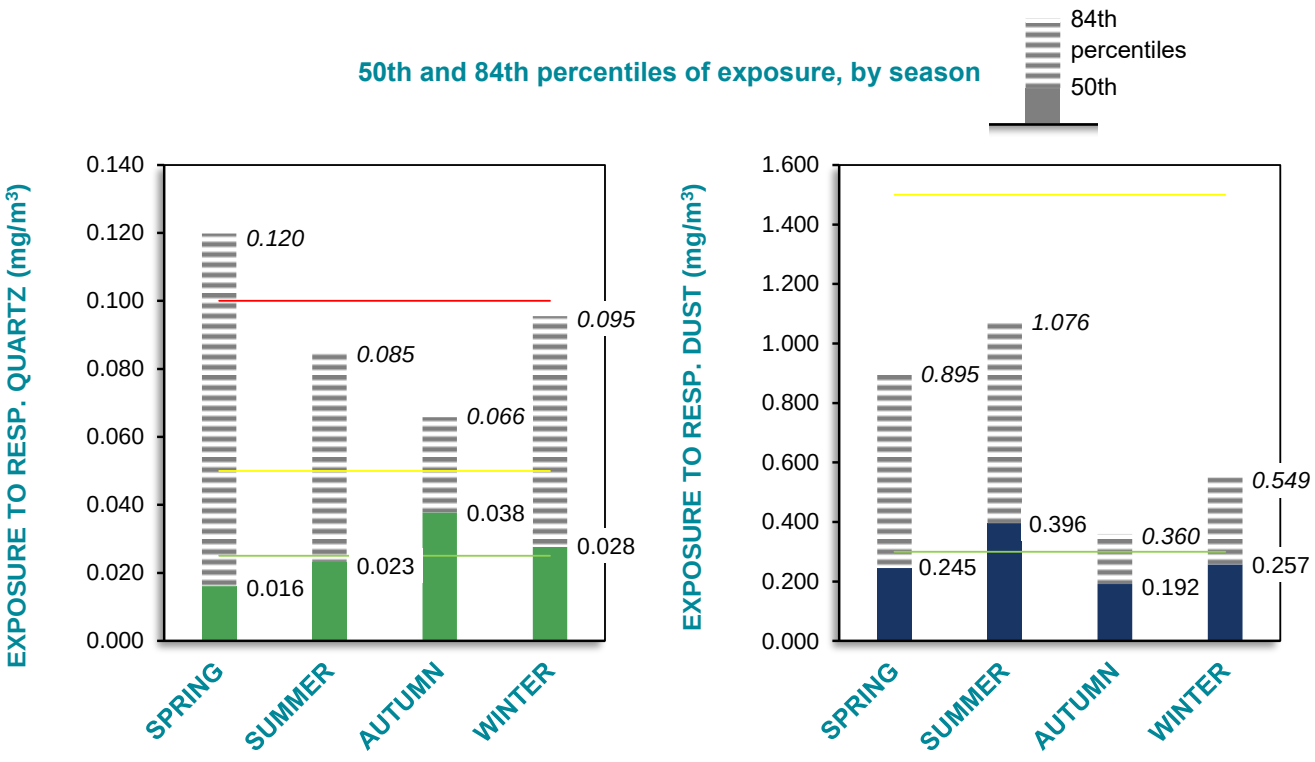
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

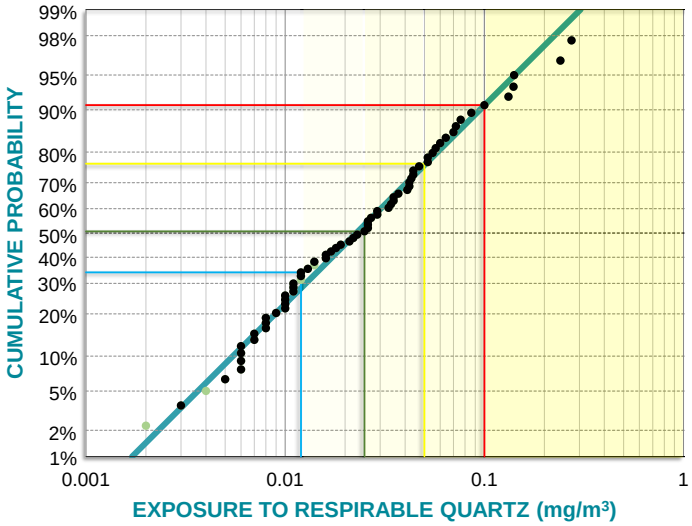
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

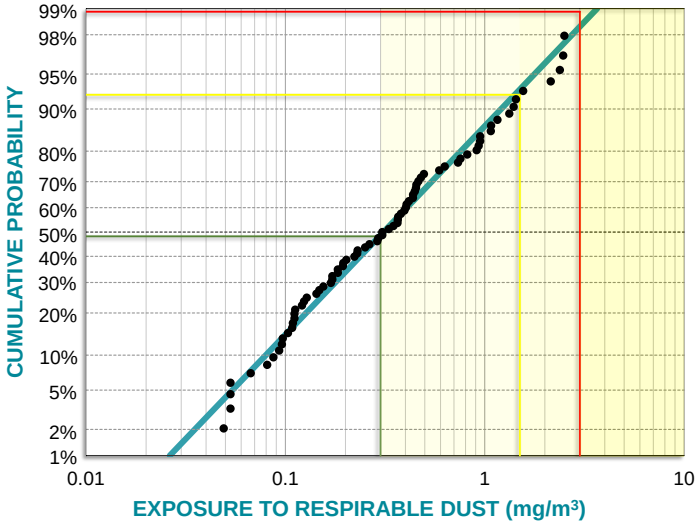


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



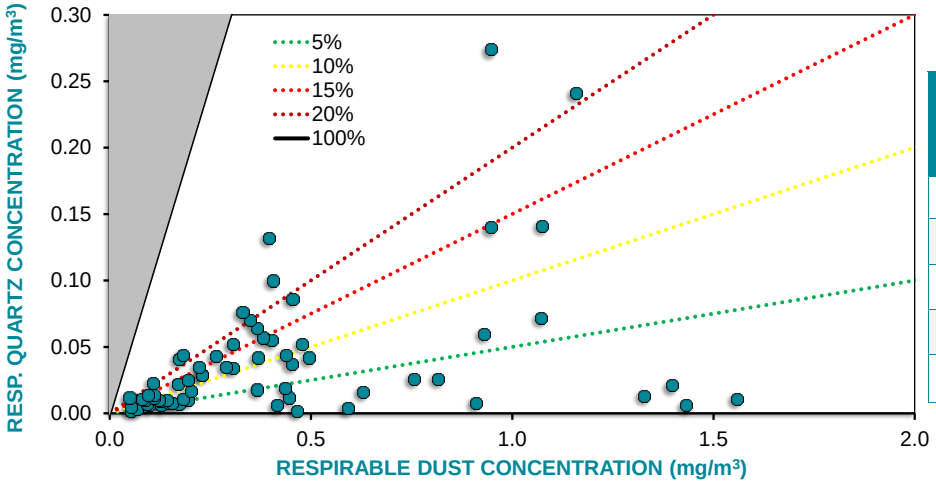
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	90.8%
≤0.05	76.5%
≤0.025	50.7%
≤0.012	34.1%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	98.9%
≤1.5	92.3%
≤0.3	48.2%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	33%
>5% to 10%	19%
>10% to 15%	25%
>15% to 20%	8%
>20%	14%

Contarp 2016 classification

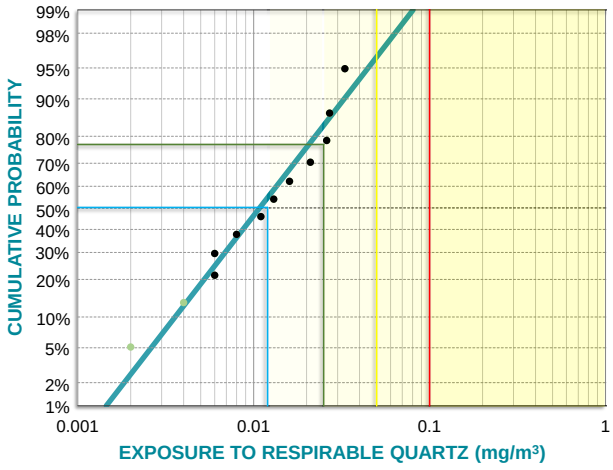
WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C19.01 - Polishing of metal objects	
C19.01.01 - Silver polisher	Smooths and polishes metal (silver) objects by rubbing the surface with abrasive paste (often with high quartz content).
C19.02 - Lost wax micro-casting for the production of gold and silver objects	
C19.02.01 - Plaster mixer	Loads the mixing machine for the production of quartz-rich plaster. Carries out the operation by hand in a room usually isolated from the rest of the factory. The plaster is later used accordingly with the lost wax micro-casting processing technique for the production of gold objects.
C19.03 - Recovery and refining of precious metals	
C19.03.01 - Metal ashes mill operator	Operates ball mill to grind the ashes that contain precious metals. The powders obtained are sampled and weighed, transferred to sealed containers and stored in the ash warehouse.
C19.03.02 - Metal waste furnace operator	Operates the furnace used to incinerate the goldsmith's waste powders, for the recovery of precious metals.
C19.03.03 - Metal ashes mixer	Collects the containers with metal wastes (ashes) from the warehouse and pours the ashes into the mixing machine, then adds flux materials and hydroxides. In the next phase, the mixed material is melted in a rotary kiln and precious metals recovered.

Exposure to respirable quartz, by job title

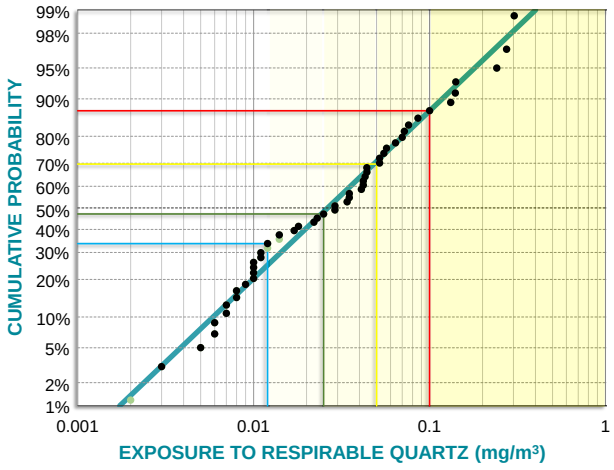
Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
C19.01.01 - Silver polisher	12	0.011	2.359		>94.9%	77.2%	50.2%
C19.02.01 - Plaster mixer	52	0.026	3.201	87.3%	69.7%	47.1%	33.7%
C19.03.01 - Metal ashes mill operator	3	0.017	1.478	-	-	-	-
C19.03.02 - Metal waste furnace operator	1	0.047	-	-	-	-	-
C19.03.03 - Metal ashes mixer	4	0.032	1.638	-	-	-	-

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

C19.01.01 - Silver polisher



C19.02.01 - Plaster mixer



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
C19.01.01 - Silver polisher	14	0.846	2.088	>95.6%	78.6%	11.9%
C19.02.01 - Plaster mixer	57	0.206	2.329		>98.9%	63.4%
C19.03.01 - Metal ashes mill operator	3	1.533	2.940	-	-	-
C19.03.02 - Metal waste furnace operator	1	2.143	-	-	-	-
C19.03.03 - Metal ashes mixer	4	0.610	1.458	-	-	-

Working processes

Medical supplies productions that may involve exposure to crystalline silica dust include:

- production of eyewear;
- manufacture and repair of dental prostheses.

In the dental laboratories, the prosthesis models of casts of dentures are finished by using abrasives that may contain CS (but the production of abrasive pastes is classified in C13 *Abrasives*). However, this activity has not yet been monitored during the INAIL investigations and is not covered further in this report.

The Italian eyewear production involves companies that carry out the complete production and smaller companies specialised in one or more work phases. The production cycle of metal frame eyewear begins with the manufacture of the small parts (e.g. noses, bridges, temples, front bars, etc.) by pressing or casting. Metal frames are created from metal wires shaped inside a reeling machine. The front can be welded by hand to the other metal components. After the pieces are assembled, the frame is cleaned and polished (tumbling) and coloured with paints or by a galvanic and protective treatment. Exposure to RCS can occur in a few steps in the production cycle. The polishing of metal surfaces is carried out by using abrasive pastes that can be made of quartz sand. Glass lenses can be ground to their final form by using quartz emery as abrasive in a rotating cup-shaped tool; fine smoothing of lens surfaces is obtained with a polishing tool covered with a thin layer of abrasive. The manufacture of small parts by the lost-wax casting process may also involve exposure to silica dust, in fact silica glass is often used in making the refractory slurry, but sometimes quartz is used instead of glass. The lost-wax casting process is carried out as follows:

1. **Model making** – the original model of the metal part is handmade or 3D printed.
2. **Wax injection die making** – represents a negative image of the model and is generally made in aluminium or steel.
3. **Wax pattern making** – molten wax is injected into the metal die to produce a wax pattern, which is a faithful copy of the part to be produced; the operation is repeated obtaining many wax patterns.
4. **Ceramic moulds coating** – patterns are processed individually or assembled into clusters on a tree-like structure and then inserted in a metal flask. Investment shells are obtained by manually or automatically dipping the wax pattern clusters into a ceramic slurry bath, which leaves a coating layer. The excess slurry is then drained off and the ceramic shells are stuccoed and allowed to dry and harden. The operation is repeated until the shells reach the required thickness (final coat). The slurry is prepared by adding the (quartz) refractory powder to a binder liquid, in a mixer or a rotating tank for stirring.
5. **Wax removal** – the flask is heated in a kiln, the wax melts and drains out of the ceramic shells through venting holes, leaving spaces with the negative shape of the original model.
6. **Melting and casting** – the ceramic moulds are inserted in a chamber, fired to remove moisture and preheated; the metal alloy is melted in a furnace and poured into the hot ceramic moulds, filling the cavities.
7. **Ceramic mould removal** – after cooling, the ceramic mould is destroyed, e.g. by abrasive or water blasting, or by dissolving it, leaving the pieces free.
8. **Objects finishing** – by sandblasting (e.g. by using silica sand), polishing, scrubbing or other processing.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	4	0.116	1.300	4	0.007	1.811	6.3
STATIC	-	-	-	-	-	-	-

MEDICAL AND DENTAL INSTRUMENTS: Manufacture of medical and dental instruments

Geometric mean of personal exposure, by region

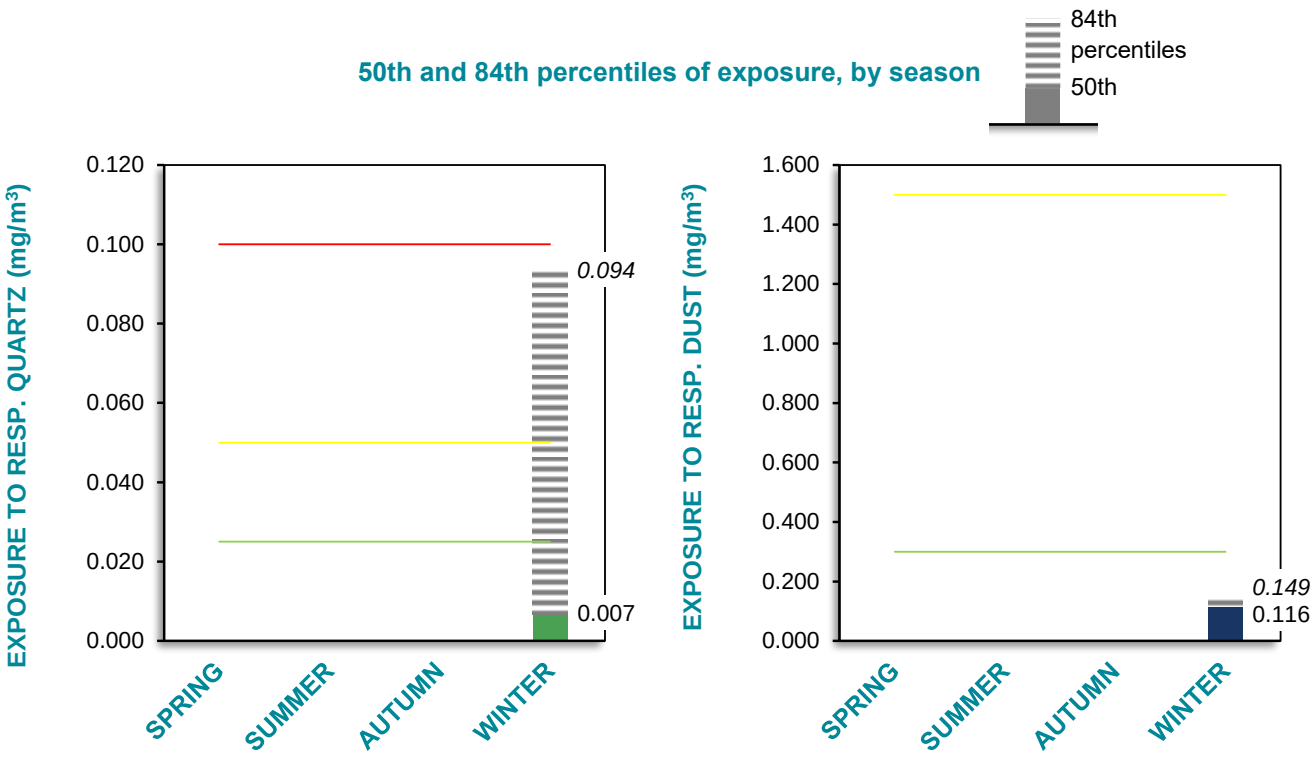
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

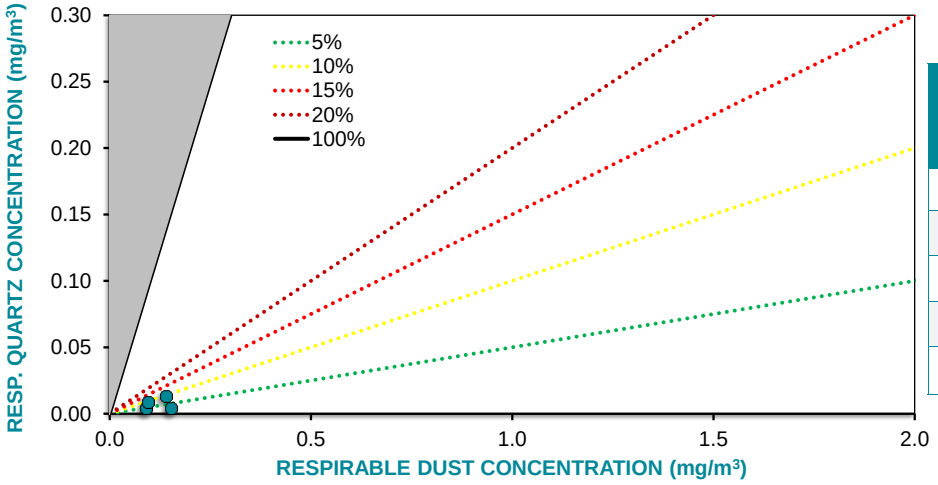
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season



Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	50%
>5% to 10%	50%
>10% to 15%	0%
>15% to 20%	0%
>20%	0%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C20.01 - Management and office work	
C20.01.01 - Manager	Carries out the management and/or operational functions involving production department coordination and control (e.g. head of production unit, lab manager and supervisor). In small companies, these tasks are often handled by the company holder (partner or owner fulfilling both administrative and operating tasks).
C20.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the production departments.
C20.02 - Eyewear production - Mechanical processing	
C20.02.01 - Eyewear production - Rim forming operator	Carries out the mechanical machining of the rim forming. Bends the metal structure of the frame to the desired shape by making the meniscus, milling and welding the metal. Carries out the welding of noses and snouts and the cutting of tubes.
C20.02.02 - Eyewear production - Frame surface finisher	Carries out the cleaning and polishing of frames by sandblasting, tumbling and wheel cleaning before moving on to the decoration phase. Polishes metal surfaces using abrasive pastes (which may contain quartz) for cleaning objects. Tumbling is usually sufficient for plastic frames.
C20.03 - Eyewear production - Frame surface decoration	
C20.03.01 - Eyewear production - Galvanic colouring operator	Carries out colouring of metal frames using a galvanic and protective treatment, after pickling, washing and drying of the surfaces to be treated.
C20.03.02 - Eyewear production - Enamelling / painting operator	Carries out colouring of eyewear frames by applying enamels and paints.
C20.03.03 - Eyewear production - Laser engraver	Decorates eyewear frame with engraved logo and letters by operating a laser engraving machine.
C20.03.04 - Eyewear production - Pad printing operator	Carries out colouring of eyewear frames by pad printing (tampography), transferring a 2-D image from a cliché via a silicone pad onto the 3-D substrate.
C20.04 - Eyewear production - Processing of small parts: lost-wax investment casting process	
C20.04.01 - Eyewear production - Wax model maker	Makes the wax model of the object ready to be reproduced in series.
C20.04.02 - Eyewear production - Plaster mixer	Prepares the plaster that is later cast into the metal cylinder where clusters of wax models are placed. Loads the mixing machine by hand, taking the gypsum from bags. The job title includes the attendant. Operates in a room isolated from the other departments.
C20.04.03 - Eyewear production - Small parts surface finisher	Carries out the finishing of the small parts that, before being coloured, are brushed, cleaned and polished by sandblasting, tumbling or polishing on a brush wheel.
C20.05 - Eyewear production - Assembly	
C20.05.01 - Eyewear production - Drilling and screwing operator	Carries out drilling and screwing for eyewear assembly.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C20.05.02 - Eyewear production - Temples and nose bridge assembler	Assembles temples and nose bridge on the eyewear.
C20.05.03 - Eyewear production - Lenses milling and mounting operator	Carries out milling and mounting of lenses in frames.
C20.05.04 - Eyewear production - Rhinestone and accessories applier	Applies rhinestone decorations and accessories on eyewear frames.
C20.05.05 - Eyewear production - Frame front assembler	Assembles the eyewear frame front.
C20.06 - Eyewear production - Finishing, quality control and packaging	
C20.06.01 - Eyewear production - Nose pads assembler	Assembles the nose pads on the eyewear.
C20.06.02 - Eyewear production - Quality control technician	Examines frame parts and completed frames of eyeglass for conformity to specifications and product quality assessment.
C20.06.03 - Eyewear production - Packaging operator	Packages the finished product, making it ready for sale or distribution. May use machines to prepare and move manufactured products.
C20.07 - Eyewear production - Lens processing	
C20.07.01 - Eyewear production – Lens grinding and polishing operator	Carries out finishing of lens surface in three steps: roughing, grinding and polishing with hard materials and fine powders.
C20.07.02 - Eyewear production – Lens cutting and shaping operator	Carries out the cutting and shaping of lens by using lens cutting and shaping machines.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C20.04.01 - Eyewear production - Wax model maker	1	0.004*	-	-	-	-	-
C20.04.02 - Eyewear production - Plaster mixer	1	0.009	-	-	-	-	-
C20.04.03 - Eyewear production - Small parts surface finisher	2	0.007	-	-	-	-	-

* more than half of the measurements are <LOQ

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C20.04.01 - Eyewear production - Wax model maker	1	0.152	-	-	-	-
C20.04.02 - Eyewear production - Plaster mixer	1	0.096	-	-	-	-
C20.04.03 - Eyewear production - Small parts surface finisher	2	0.112	-	-	-	-

Working processes

Sandblasting of fabrics is a technique consisting of a mechanical and abrasive process applied to denim garments (jeans, skirts, dresses or jackets), which partially removes and damages the original pigmentation in order to make the fabric more appealing, acquiring a faded and worn look. Sandblasting is carried out using a nozzle operating under high pressure (4 to 8 bars) propelling sand against parts of denim clothing, until the desired effects of fading and ageing are obtained. Such treatment is generally applied with pure quartz sand. Impacting the fabric, quartz grains go through comminution, producing a micrometric dust. The sandblasting treatment is described below.

1. **Positioning of garment on desk** – the clothing is placed on the working bench and fixed with spring clamps.
2. **Sandblasting** – the sandblasting operator propels a jet of sand against each piece of clothing; the sand is withdrawn from a container by compressed air, using a nozzle under pressure. After being treated, the clothing is removed from the working bench.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	6	0.624	3.066	6	0.009	6.659	2.2
STATIC	-	-	-	-	-	-	-

DENIM SANDBLASTING: Alteration of clothing: denim sandblasting

Geometric mean of personal exposure, by region

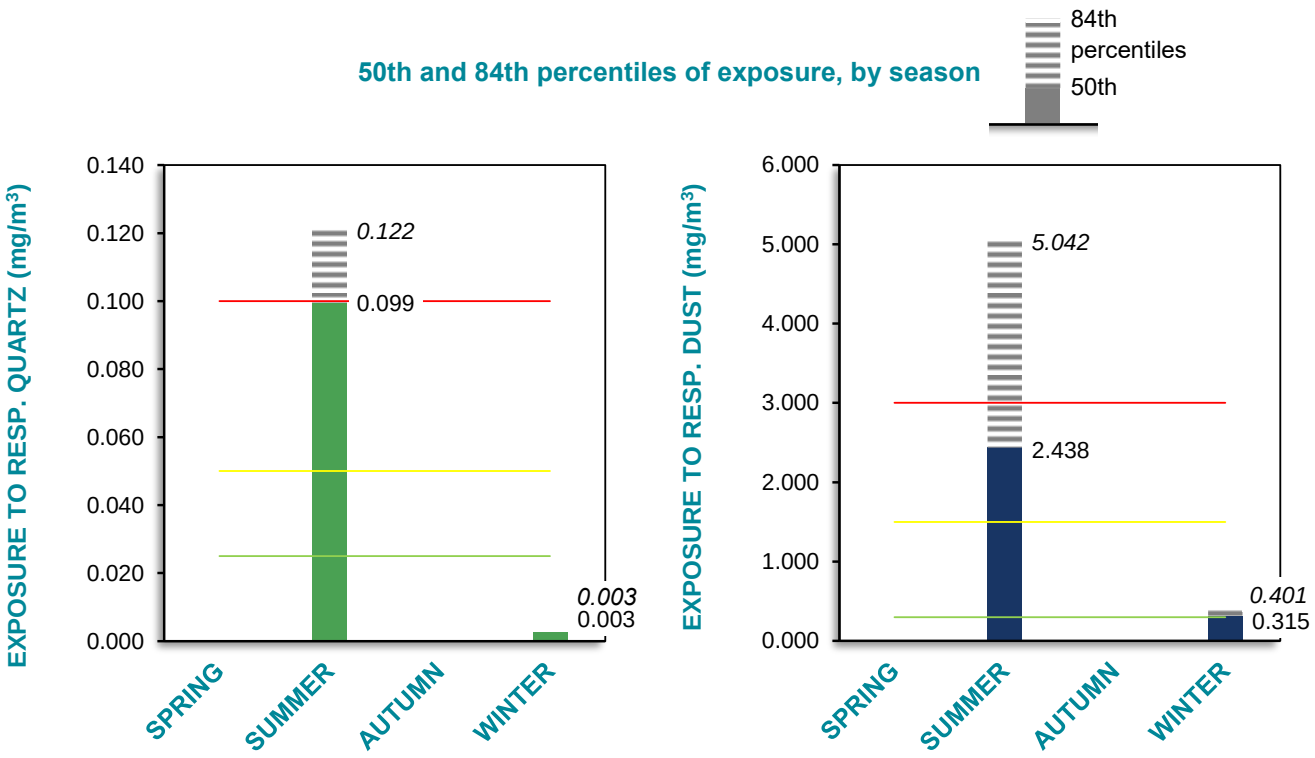
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

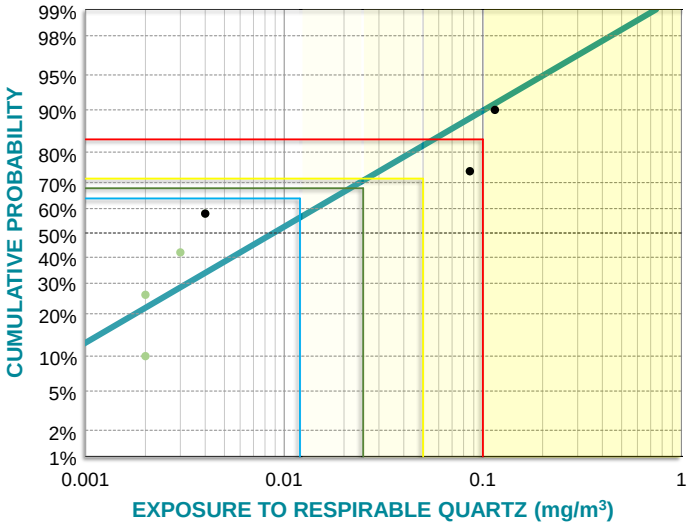
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

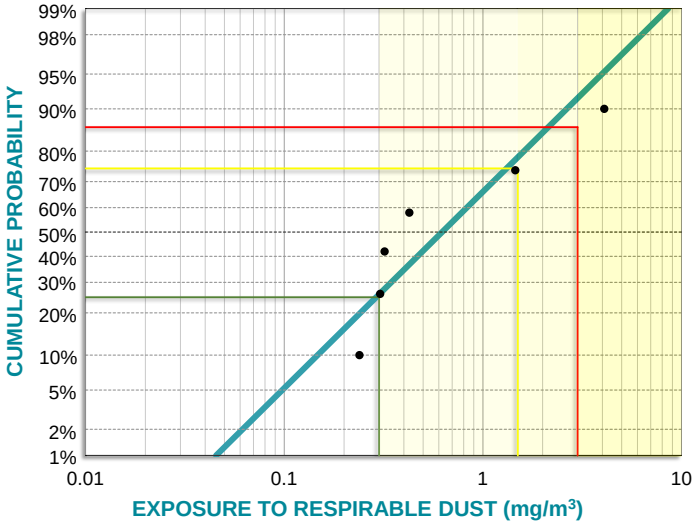


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



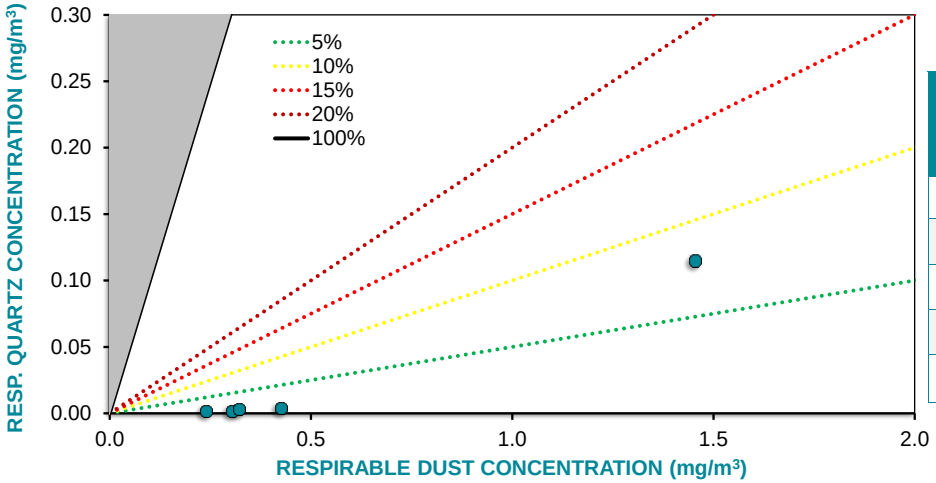
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	83.5%
≤0.05	71.4%
≤0.025	67.9%
≤0.012	64.1%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	86.2%
≤1.5	74.6%
≤0.3	24.9%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	83%
>5% to 10%	17%
>10% to 15%	0%
>15% to 20%	0%
>20%	0%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
C21.01 - Sandblasting	
C21.01.01 - Sandblasting operator	Sprays a jet of sand on textile fabrics (trousers, jackets, shirts, etc.) to obtain artificial ageing effect. Fills the storage tank with quartz sand. Uses a lance connected to the tank to propel sand under high-pressure against the clothing (placed on the workbench by the assistant). Wears a suitable supplied air respirator. The workbench is equipped with dust extraction system.
C21.01.02 - Sandblasting assistant	Prepares clothing (trousers, jackets, shirts, etc.) for sandblasting. Fills the storage tank with quartz sand. Arranges clothing on the workbench, equipped with dust extraction system. Removes clothing after treatment. Wears a suitable supplied air respirator.

Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
C21.01.01 - Sandblasting operator	3	0.007*	8.772*	-	-	-	-
C21.01.02 - Sandblasting assistant	3	0.011	7.593	-	-	-	-

* more than half of the measurements are <LOQ

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
C21.01.01 - Sandblasting operator	3	0.667	4.825	-	-	-
C21.01.02 - Sandblasting assistant	3	0.583	2.236	-	-	-

Working processes

Construction is a broad sector of activities, concerning a very high number of both large and small companies. A list of construction trades will follow here according to the national collective bargaining agreement (2012) for the construction of Small and Medium-sized Enterprises (SMEs) in Italy.

1. **Construction of buildings** – residential, industrial, commercial, agricultural buildings construction; monumental masonry, tanks, chimneys and heating plants installation. Typical activities included in this group are excavation for foundations, reinforcements, scaffolding, wood and steel structural work, structures settling and dismantling, building materials loading and unloading, concrete, brick, wood and steelwork maintenance (also with prefab elements). Also included are finishing and completion in the following activities:

   - Building construction.

   - Plastering, painting, varnishing, gilding, silvering and similar. Sandblasting is excluded from this group and classified in F4 *Sandblasting for building exteriors*.

   - Decoration and lining with different materials; wallpaper hanging.

   - Concrete and other materials paving, preparation and deposition of sealing coats (asphalt, bitumen, felt, board, etc.) with an optional insulation layer underneath. Sandblasting is not included (see F4 *Sandblasting for building exteriors*).

   - Lightning rods, bells, statues, crosses, clocks and aerials setting.

   - Masonry works to set up plants, machinery and other equipment in buildings.

   - Industrial plant varnishing.

   - Walls and monument dusting, scraping and cleaning.

   - Concrete or brick masonry demolition, wood or metal carpentry dismantling.

   - Removal and demolition materials containing asbestos and other toxic substances; other materials masonry demolition, removal and reclamation.

   - Restoration and repair of residential, industrial, commercial, agricultural buildings and monumental masonry.

2. **Construction of water projects** – construction, maintenance, repair and demolition of the following works:

   - Reclamation works, river defence and hydraulic engineering works and flood protection works.

   - Water systems, pipelines (gas and oil), sewer, cesspool, septic tank, etc.

   - Tanks for any kind of fluids.

   - Waterways, industrial and agricultural canals and hydroelectric plant work.

   - Harbours (also inland, lake or river) and maritime works (also lake and lagoon).

   Water well drilling is not included in this group, see F2 *Tunnel construction, conventional excavation*.

3. **Earthmoving and borrow pits excavation**

   - Excavation, digging, levelling and preparation for sports arenas, landing sites, parks and gardens, embankments, etc. Road paving digging for pipelines and other works.

   - Aggregates and clay quarries – their life is related to the connected building site and their activities.

   Permanent quarry sites not included, otherwise classified in B *Mining and quarrying*.

4. **Construction of roads and bridges** – construction, maintenance, repair and demolition of the following works:

   - Roads and motorways, railways and tramways.

   - Cable transport (cable car, cable railway, chairlift, ropeway, etc.).

   - Bridges and viaducts.

   Tunnel (and other underground structures) construction, excavation, lining, finishing and maintenance is not included here. See F2 *Tunnel construction, conventional excavation* and F3 *Tunnel construction, mechanical excavation*.

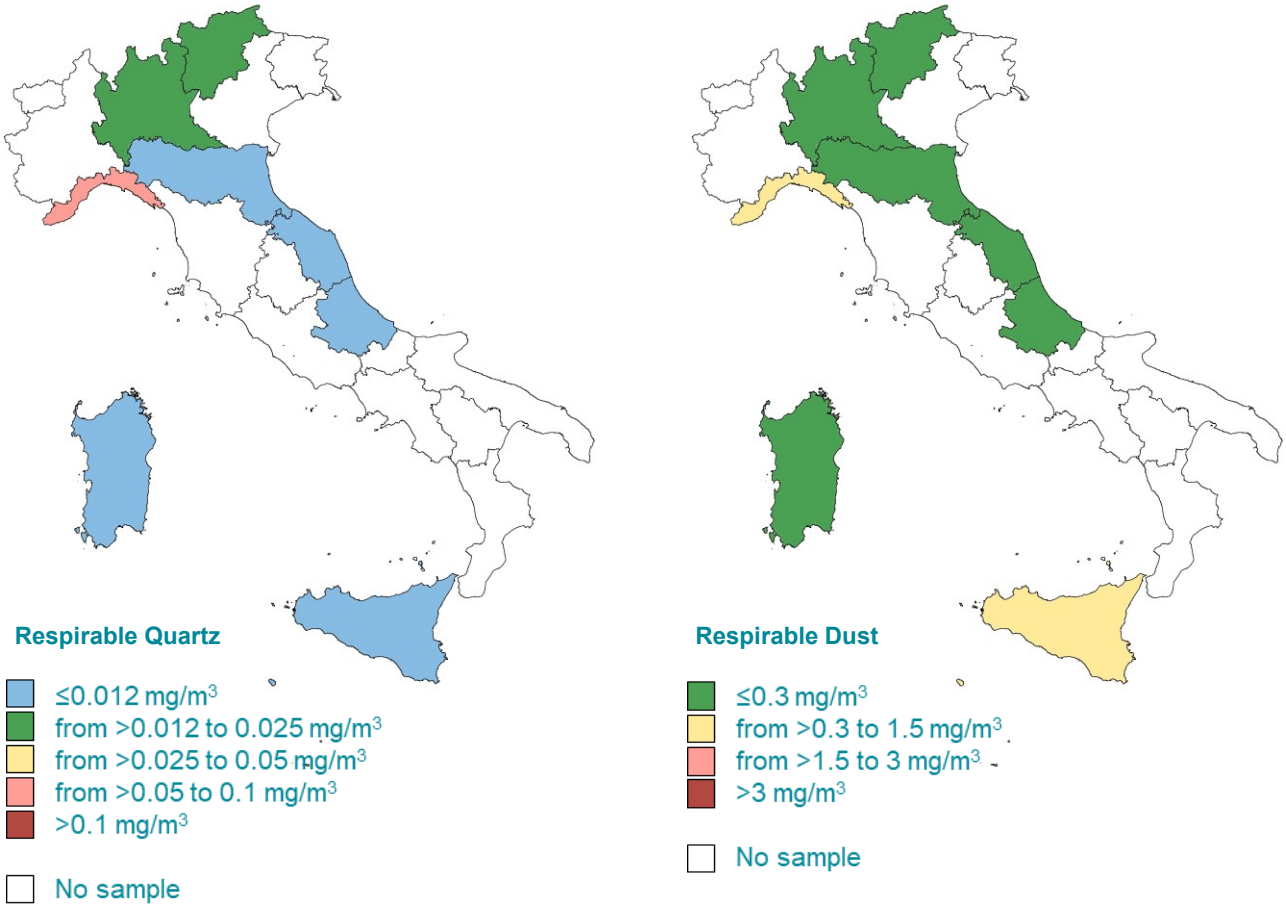
5. **Construction of power lines** – pylons, poles and similar supports setting, site preparation with digging, trenches and masonry works, road paving rebuilding, construction of aerial and underground distribution lines for electricity and telecommunications, television antenna support structures installation.

6. **Ready-mix concrete production and distribution** – this activity is included here only if produced on site, otherwise is classified in C11 *Concrete products*.

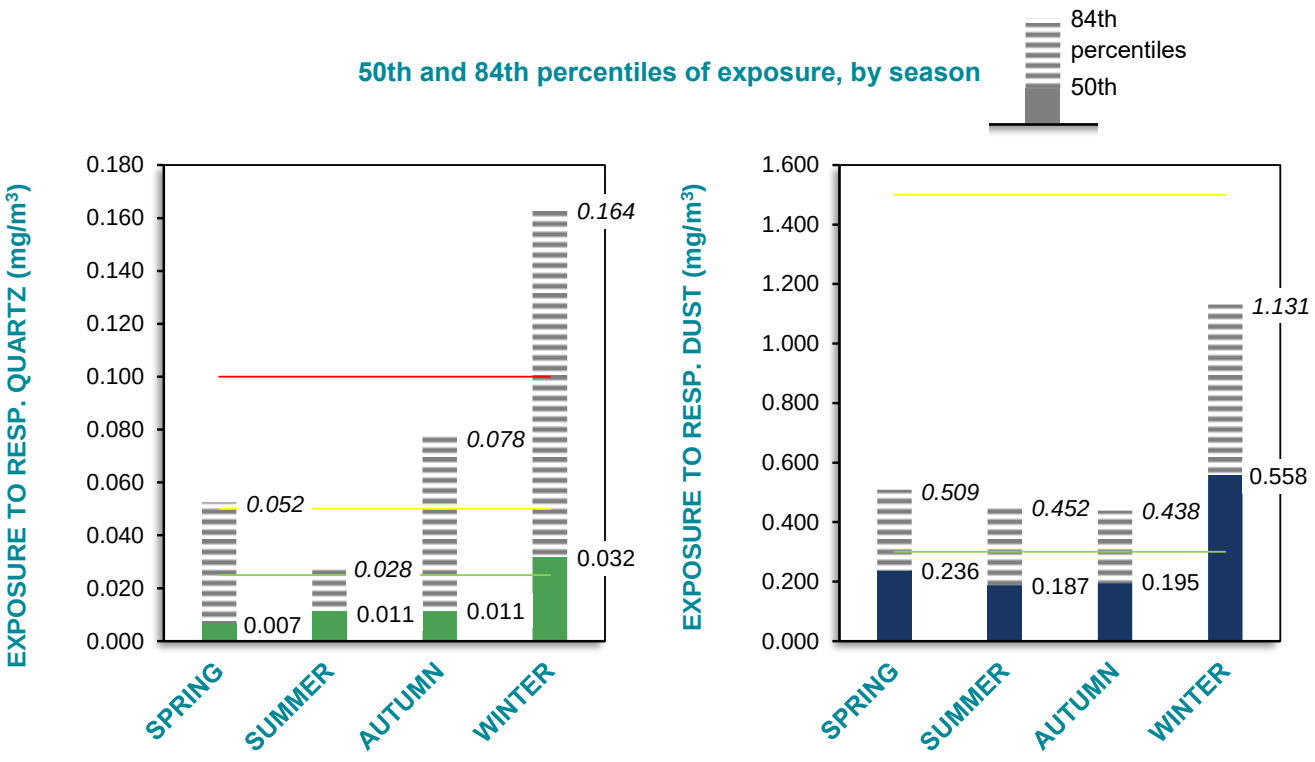
Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	119	0.209	2.332	106	0.011	2.941	7.0
STATIC	4	0.256	1.401	4	0.005	3.552	2.6

Geometric mean of personal exposure, by region

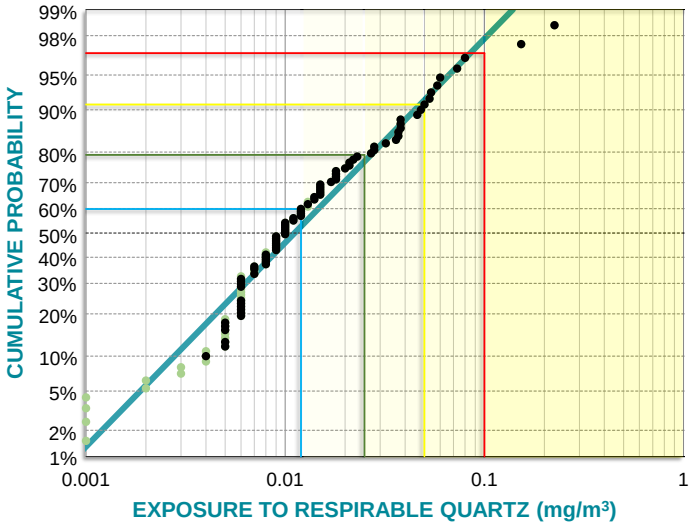


50th and 84th percentiles of exposure, by season



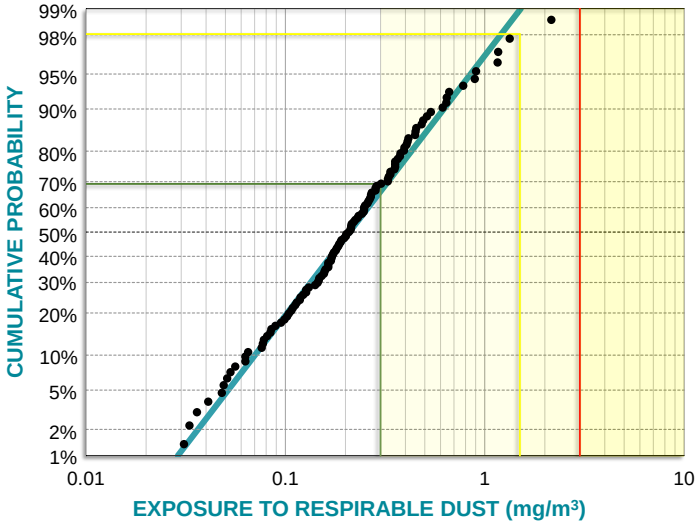
CONSTRUCTION: Construction of buildings - Civil engineering - Construction of roads - Asphalt paving of roads - Demolition and site preparation - Installation of machinery and systems

Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



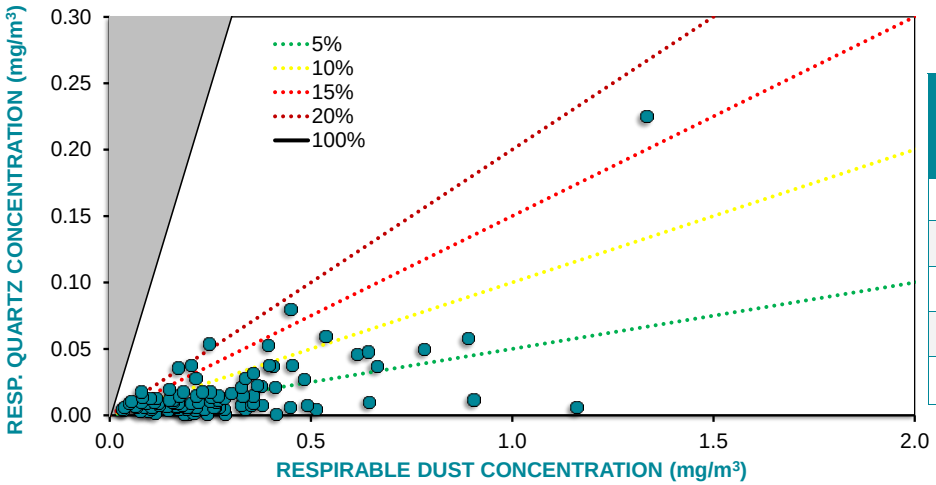
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	96.9%
≤0.05	90.9%
≤0.025	79.2%
≤0.012	59.9%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	99.3%
≤1.5	98.0%
≤0.3	69.2%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	46%
>5% to 10%	33%
>10% to 15%	10%
>15% to 20%	6%
>20%	5%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F1.01 - Management and office work	
F1.01.01 - Construction site manager	Carries out the management and/or operational functions involving responsibility, coordination and control of construction site activities. The role and duties require professional skills to carry out research and planning activities too. The job may be performed by the general foreman or site supervisor.
F1.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the construction site.
F1.01.03 - Senior technical assistant	Coordinates the activities of workers in the construction site and organises the materials required to complete the job. Oversees day-to-day construction activities on the sites assigned.
F1.01.04 - Construction foreman	Is in charge and directs the construction crew and is responsible for organising construction works on site. Generally, the role is assumed by an experienced construction worker.
F1.02 - Building and related trades workers, including maintenance operators and skilled demolition workers	
F1.02.01 - Oven / refractory bricklayer	Constructs or repairs kilns, ovens, smokestacks, furnaces, converters and refractories. Lays firebrick and refractory tiles to build, rebuild, reline or patch furnaces. Removes burned or damaged brick using a jackhammer. Spreads fire-clay mortar over brick with a trowel and lays brick in place.
F1.02.02 - Bricklayer	Lays bricks, pre-cut stones and other types of building blocks in mortar to construct and repair walls, partitions, arches and other structures.
F1.02.03 - Concrete placer	Makes concrete and cement mixing. Casts concrete. Makes forms for moulding concrete. Constructs and repairs reinforced concrete floors, walls and other concrete structures. Makes shuttering or assembles prefabricated forms for moulding concrete. Finishes and smooths surfaces of concrete structures.
F1.02.04 - Demolition worker	Operates equipment to demolish or repair masonry and reinforced concrete structures. Dismantles slabs, walls, coatings, floors, roofs. Handles debris to temporary storage.
F1.02.05 - Prefabricated construction elements assembler	Assembles and disassembles shaped mould, installs plasterboards, sets up and joints shaped elements. Carries out on site assembly of shaped elements as main or secondary beams, trusses, cornices, etc. for the construction of civil and industrial buildings, bridges, viaducts or other special building work.
F1.02.06 - Construction scaffolder	Puts up temporary metal or wooden scaffolding and platforms on building sites and removes them when work is completed. Erects and fixes slings, suspended scaffolds, scaffold service and cradles. May specialise in metal or wood and be designated accordingly.
F1.02.07 - Railway equipment worker	Operates heavy equipment to tamp, clean and redistribute ballast, clean tracks and grade and level ballast on railroad tracks. Tightens loose bolts and adjusts blades. Installs and repairs railroad track on specified territory of railroad. The job title includes the tasks of ballast cleaning machine operator, ballast regulator operator; tamping machine operator and track broom operator.
F1.02.08 - Floor layer and finisher	Prepares floor areas, installs flooring materials, maintains and repairs marble, concrete glass and mosaic flooring. Lays stone slabs. Grinds, polishes and finishes floors.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F1.02.09 - Tile setter	Prepares walls, installs tiles onto walls and floors, maintains and repairs walls and other surfaces with tiles or mosaic panels. Cuts, fits and clads marble; lays mosaic panels; sets up glass cladding.
F1.02.10 - Hardwood / resilient floor layer	Prepares floor areas, installs flooring materials, maintains and repairs hardwood floors (wood, parquet, hardwood, timber floor layer) and prefabricated tiles or rolls of flooring materials such as linoleum, vinyl, rubber or cork to serve as floor covering.
F1.02.11 - Plasterer	Applies decorative and protective coverings of plaster, cement or similar materials to the interior walls and ceilings and to exteriors of buildings to produce a finished surface.
F1.02.12 - Construction painter / decorator	Prepares paint and surfaces for painting. Applies coats of paint, varnish, stain, enamel or lacquer to decorate and protect interior or exterior surfaces, trimmings and fixtures of buildings and other structures using brushes, spray gun or paint rollers and with cloth, brush, sponge or fingers to create special effects. Simulates wood grain, marble, brick or tile effects. Applies horizontal signs in road works. The job title includes the tasks of painter, interior finish painter, simulator of marble and wood, house lacquerer, road sign painter, gilder ornamental painter and decorator painter.
F1.03 - Concrete production and concrete operators	
F1.03.01 - Concrete mixing plant operator	Conducts and controls the batching and mixing concrete plant in construction sites.
F1.03.02 - Concrete mixer truck operator	Drives and operates concrete mixer truck for concrete casting in construction sites. May run and control concrete mixer and pump for concrete casting.
F1.03.03 - Cable steel fixer	Inserts steel cables or wires to reinforce concrete structures.
F1.03.04 - Carpenter	Constructs composite trusses, ribs or formwork for special reinforcements in wood or iron and for reinforced concrete works. Cuts, shapes, assembles, erects, maintains and repairs various types of structures and fittings. May perform tasks of assembler, wooden caulking operator, joiner, shipwright, building prop as well as reinforced concrete formwork operator.
F1.03.05 - Steel fixer	Prepares and inserts iron reinforcement for concrete structures or pre-stressed concrete constructions.
F1.04 - Asphalters, asphalt roofers and road pavers	
F1.04.01 - Roofer	Installs and repairs roofs on all types of buildings. Covers roof frameworks with slate and prefabricated tiles, lays waterproof shields and sealing coats and fixes metallic or synthetic materials to a building frame. In the job title the tasks of installing sealing coats, building asphalting and gutter installation are included.
F1.04.02 - Asphalt plant operator	Conducts and oversees asphalt plant operations.
F1.04.03 - Asphalt milling / paving machine operator	Smooths surface of old asphalt pavements by operating asphalt milling/planing machine. Spreads, rolls and tamps asphaltic or bituminous material over road subgrade by hand-held road asphalter or asphalt paving machine. The job title includes the task of boiler and pipe insulation.
F1.04.04 - Concrete road paver	Pours concrete to serve as a road surface. Lays concrete slabs in order to finish a road or to pave driveways, walkways, patios and other surfaces.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F1.05 - Systems, pipes, glass, doors and windows installers	
F1.05.01 - Insulation and soundproofing systems installer	Insulates buildings. The job title includes the tasks of insulator for civil and industrial buildings, decoibentator, insulation and soundproofing systems installer.
F1.05.02 - Glazier	Installs glass, crystals and mirrors in buildings. Cuts, finishes and installs flat glass and mirrors.
F1.05.03 - Civil buildings plumber	Assembles, installs, repairs and maintains pipe systems, drain gutters, ducts and related fittings and fixtures for water, gas, drainage, sewerage, heating and cooling and ventilation systems and for hydraulic and pneumatic equipment. The job title includes the tasks of plumber, tinsmith, drain technician, gas fitter, pipe fitter and thermo-hydraulic systems operator.
F1.05.04 - Heating systems installer	Assembles, installs, repairs and maintains heating systems. The job title includes the tasks of civil refrigeration operator, heating equipment assembler and repair worker, conditioning and heating systems installer as well as radiator installer.
F1.05.05 - Electrician (Civil construction)	Plans layout, installs and repairs wiring, electrical fixtures, apparatus and control equipment for building interiors and exteriors. Prepares sketches showing location of wiring and equipment. Cuts, bends, threads, assembles and installs electrical conduits. Installs control and distribution apparatus. Connects power cables to equipment. Installs security alarms in civil constructions, shop lightening and shop light signs.
F1.05.06 - Door and window installer	Installs doors and windows. Fits together components of fabricated metal or other material products to assemble or repair shutters and blinds, wooden and iron windows and doors.
F1.05.07 - Sewage system maintainer	Runs and controls sewage systems. Purges sewer and empties cesspools.
F1.06 - Aggregates and mining industry skilled workers; rock scaling	
F1.06.01 - Shot-firer	Determines positions and force of explosions required and charges and sets off explosives to dislodge rock from quarry workface (only if associated with construction sites, otherwise classified in B *Mining and quarrying*). Also called blaster. The job title includes the shot-firer assistant.
F1.06.02 - Crusher	Operates crushing plant to reduce rock debris/gravel to suitable size for aggregates or sand gravel (only if associated with construction sites, otherwise classified in B2 *Quarrying of sand and gravel*).
F1.06.03 - Screening plant operator	Tends screening plant for aggregates (only if associated with construction sites, otherwise classified in B2 *Quarrying of sand and gravel*).
F1.06.04 - Rock climber	Performs rock scaling, steel wire mesh application, rockfall and snow barriers installation; building maintenance without scaffolding or elevator; rock drilling on rocky slopes with handheld drilling equipment, inserting riveting, tie rods and anchors, applying mountaineering techniques with ropes, stairs and other equipment.
F1.07 - Machine operators	
F1.07.01 - Forklift operator	Drives forklift in construction sites. May run conveyor belts for building materials.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F1.07.02 - Truck driver	Drives truck, dumper or other vehicles to transport and dump excavated rock and material.
F1.07.03 - Power-shovel / loader operator	Operates power-driven machinery (power-shovel, excavator, loader, bulldozer, grader) at the construction site to excavate and move soil, debris and other materials into a dump truck or dumper and to perform finishing duties.
F1.07.04 - Road roller operator	Drives road roller / roller-compactor to compact earth fills, subgrades, flexible bases and bituminous surfaces (construction of streets, runways, etc.).
F1.07.05 - Crane / lifting systems operator	Operates stationary or mobile crane (cab- or ground controlled) and other hoisting equipment in construction sites to lift, move and position loads such as machinery, equipment, products and solid or bulk materials, workers and passengers. The job title also includes crane hooker and harness operator, building demolition machine operator, dockside / helicopter / locomotive / monorail / bridge / self-propelled crane operators, tie-breaker and hoist and winch operator.
F1.07.06 - Pipelayer	Drives pipelayer and dozer sideboom to lay pipes and dig trenches to accommodate the placement of sanitary sewer pipes, stormwater sewer drainpipes, etc.
F1.07.07 - Dredge operator	Operates power-driven dredge in construction (e.g. cleaning of canal from sediments). The job title includes both the chief operator and the assistants.
F1.07.08 - Rock drill operator	Operates the jackhammer, foundation equipment, loader and well drilling machinery. The job title includes drainer, piling machine operator, driller and pump operators.
F1.08 - Manual labourers, unskilled workers	
F1.08.01 - Unskilled worker for civil building	Performs variety of routine, non-machine tasks, such as erecting, repairing, maintaining and wrecking buildings and any construction. Loads, unloads, lifts, carries and holds building materials, tools and supplies. Cleans tools, equipment, materials and work areas. Mixes, pours and spreads concrete, asphalt, gravel and other materials. Many of these jobs are not full time. The job title includes the tasks of hand limer, wheelbarrow handler, digger (hand), construction assistant, construction harness, nailer, cemetery operator, construction pickaxe worker, lime holder, nail striker, burier, shredder, construction digger, civil building terrace maker and burial chamber.
F1.08.02 - Unskilled worker for roads and dams	Performs variety of routine, non-machine tasks, such as shoveller and digger, paver, road warden, road labourer, road maintenance worker, road ballast operator, blocks road paver, spreader of breccia and road conglomerates, excavator in public works and terrace worker in public works.
F1.09 - Warehouse	
F1.09.01 - Warehouse operator	Handles duties pertaining to the storing, selecting organising and distributing of materials, tools and equipment to be sent to the warehouse or storage yard.
F1.10 - Cleaning	
F1.10.01 - Cleaner	Cleans buildings and equipment. Performs disinfection and treatments for pests. Clears ash and soot from chimneys.

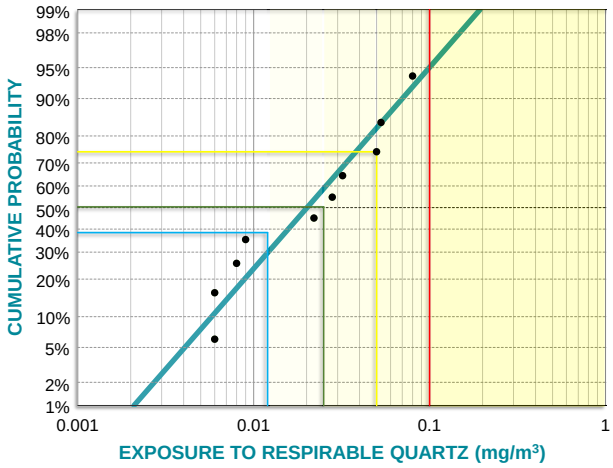
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
F01.01.01 - Construction site manager	1	0.001*	-	-	-	-	-
F01.01.04 - Construction foreman	3	0.030	2.260	-	-	-	-
F01.02.03 - Concrete placer	-	-	-	-	-	-	-
F01.02.04 - Demolition worker	2	0.008	-	-	-	-	-
F01.02.08 - Floor layer and finisher	1	0.073	-	-	-	-	-
F01.02.11 - Plasterer	1	0.001*	-	-	-	-	-
F01.03.04 - Carpenter	-	-	-	-	-	-	-
F01.04.02 - Asphalt plant operator	1	0.037	-	-	-	-	-
F01.04.04 - Concrete road paver	10	0.020	2.632	>93.9%	74.4%	50.3%	38.4%
F01.06.03 - Screening plant operator	2	0.023	-	-	-	-	-
F01.07.02 - Truck driver	10	0.006	2.620		>93.9%	93.2%	74.4%
F01.07.03 - Power-shovel / loader operator	43	0.010	2.744	97.7%	93.5%	83.4%	54.6%
F01.07.06 - Pipelayer	1	0.007	-	-	-	-	-
F01.07.08 - Rock drill operator	2	0.271	-	-	-	-	-
F01.08.01 - Unskilled worker for civil building	7	0.009	1.792			>91.4%	60.1%
F01.08.02 - Unskilled worker for roads and dams	22	0.010	1.818		>97.2%	89.9%	76.0%

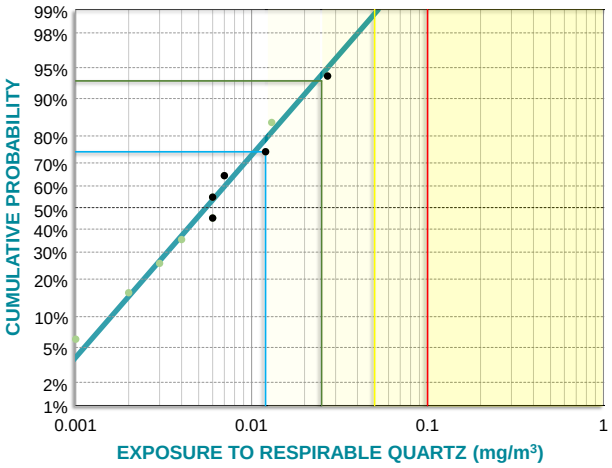
* more than half of the measurements are <LOQ

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

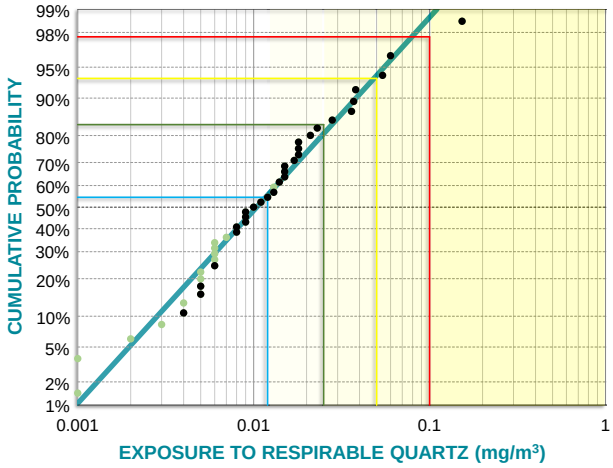
F01.04.04 - Concrete road paver



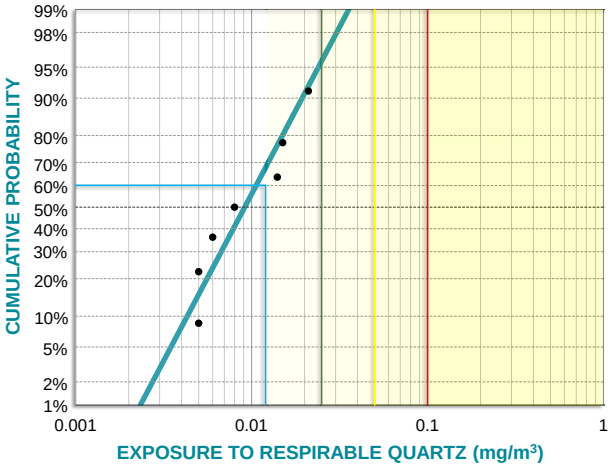
F01.07.02 - Truck driver



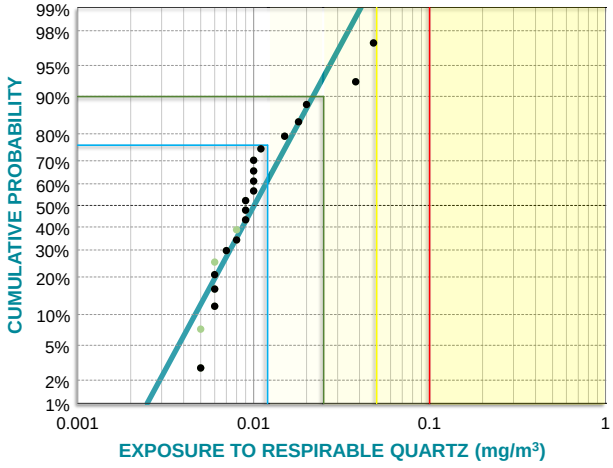
F01.07.03 - Power-shovel / loader operator



F01.08.01 - Unskilled worker for civil building



F01.08.02 - Unskilled worker for roads and dams



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
F01.01.01 - Construction site manager	1	0.194	-	-	-	-
F01.01.04 - Construction foreman	4	0.270	3.452	-	-	-
F01.02.03 - Concrete placer	1	0.107	-	-	-	-
F01.02.04 - Demolition worker	2	0.864	-	-	-	-
F01.02.08 - Floor layer and finisher	1	2.156	-	-	-	-
F01.02.11 - Plasterer	1	0.414	-	-	-	-
F01.03.04 - Carpenter	2	0.137	-	-	-	-
F01.04.02 - Asphalt plant operator	1	0.663	-	-	-	-
F01.04.04 - Concrete road paver	10	0.325	1.541		>93.9%	40.6%
F01.06.03 - Screening plant operator	2	0.311	-	-	-	-
F01.07.02 - Truck driver	10	0.188	1.805		>93.9%	78.1%
F01.07.03 - Power-shovel / loader operator	50	0.181	2.401	98.7%	97.7%	74.6%
F01.07.06 - Pipelayer	1	0.063	-	-	-	-
F01.07.08 - Rock drill operator	2	1.248	-	-	-	-
F01.08.01 - Unskilled worker for civil building	8	0.296	1.503		>92.4%	48.5%
F01.08.02 - Unskilled worker for roads and dams	23	0.145	1.769		>97.3%	91.2%

Working processes

Tunnels are excavated for many reasons, such as for transportation (railway, subway or vehicular road traffic), for conducting water (e.g. for hydropower generation), for sewage disposal, for mining ores, etc. In this classification, the definition *conventional excavation* is intended to include all the tunnelling techniques that involve the use of excavators (equipped with demolition hammer, bucket or other tools) and the drill and blast methods. The excavation process typically follows the operating cycle described below.

1. **Concrete spraying for stabilisation of the excavation face** – to ensure temporary stability and support to the rock mass when the excavated face is not sufficiently stable, the face is sprayed by a mixture of cement, aggregate, additives and water. Wet sprayed concrete is applied by using a high-pressure concrete pump hydraulically operated, fed by a concrete truck mixer. Other stabilisation techniques require face drilling for jet grouting, for installation of fibreglass pipes or bars or the use of steel bolts.
2. **Excavation of the face** – excavation in soft ground, such as sand and gravel, are often carried out by excavators equipped with a bucket, or it can be equipped with a ripper tooth in the case of clay. Hydraulic breakers (hammers) are used especially for excavation of rock masses and for scaling loose rock from the face at the end of the excavation step. The drill and blast technique, which involves the use of explosives, is suitable to break all types of rocks, in particular hard rocks and includes the following phases:

   - Drilling blast holes by using hydraulic or pneumatic drilling machines (*jumbo*) equipped with rods with cutting tools into which is impressed a rotary-percussive movement.

   - Loading the blast holes with explosives (gelatine cartridges, blasting gelatine or explosive emulsions).

   - Detonating the blast; work will resume after a waiting phase to remove blast fumes by ventilation.
3. **Scaling and mucking out** – the material dislodged from the excavation face is removed by a power shovel, loaded on dump trucks and taken to an outside landfill. At the same time, the face is secured by scaling the loose piece of rocks.
4. **Steel arch positioning as primary support** – a steel arch and a wire-mesh are mounted at the excavation face to support the surrounding rock, preventing deformation and ensuring structural stability. A telehandler equipped with an aerial platform is used to lift the steel arch and fix it to the rock vault and walls.

In a backward position with respect to the excavation face, the following activities are carried out.

1. **Building of invert and side walls** – at the sides of the tunnel, trenches are dug for placing formwork and casting concrete. The iron-reinforced concrete invert at the bottom of the tunnel creates a load-bearing ring providing continuity with the walls of the tunnel.
2. **Waterproofing installation** – PVC or geotextile sheet waterproofing membrane is applied directly on the sprayed concrete to protect the tunnel against damage from the entry of water.
3. **Construction of final lining** – the long-term tunnel support for permanent stability is constructed by casting reinforced concrete on the walls and vault of the tunnel. The concrete is cast in formwork supported by a bearing frame and mounted on a trolley that moves along the tunnel.

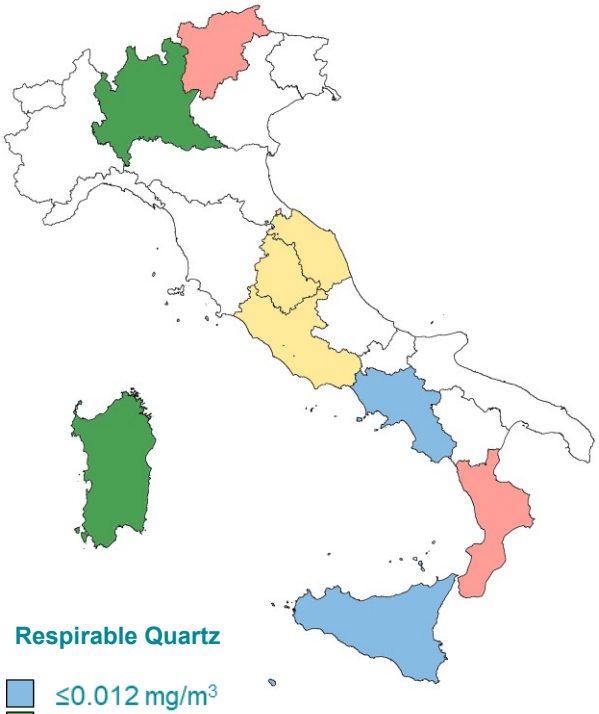
Tunnel construction includes operations that take place in the construction site outside of the tunnel.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	542	0.971	2.386	539	0.042	3.250	6.7
STATIC	25	0.878	4.557	25	0.039	4.026	6.4

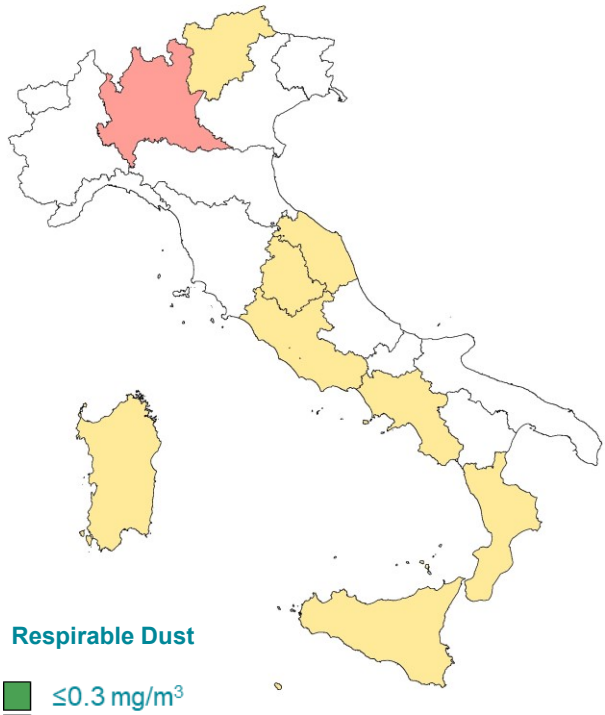
TUNNEL CONSTRUCTION, CONVENTIONAL EXCAVATION: Construction of tunnels using mechanical diggers or conventional drilling and blasting method in rock – Drilling and boring

Geometric mean of personal exposure, by region



Respirable Quartz

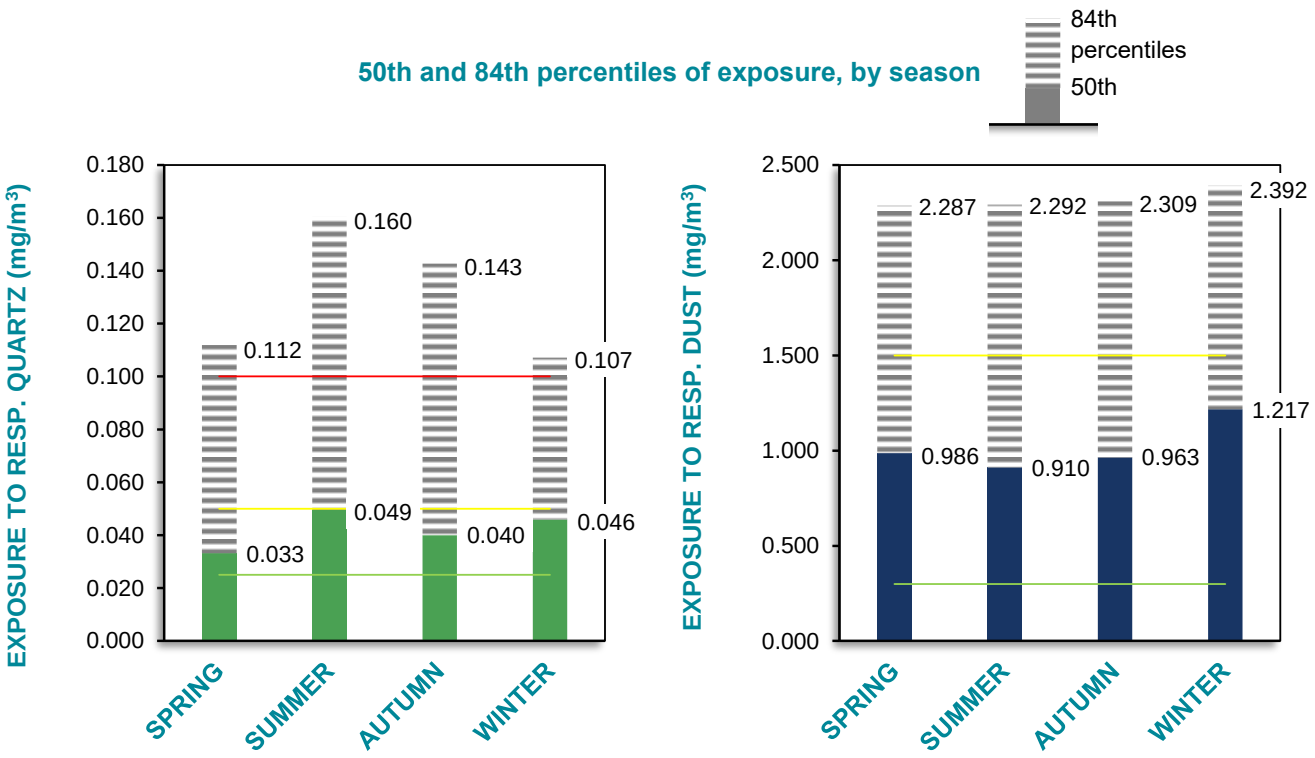
- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample



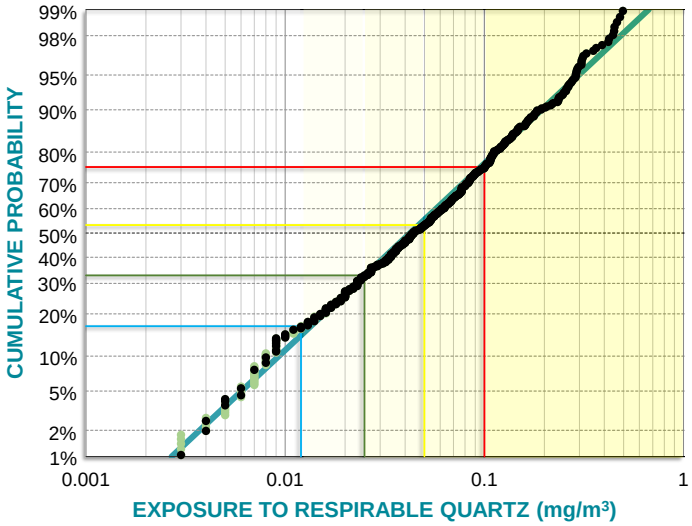
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

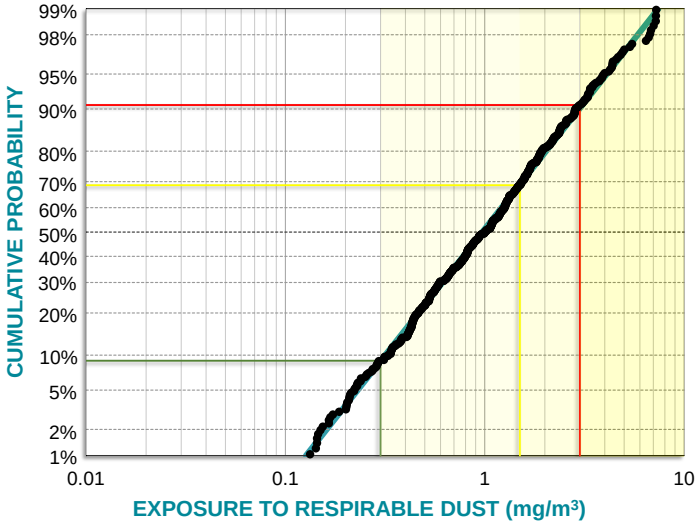


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



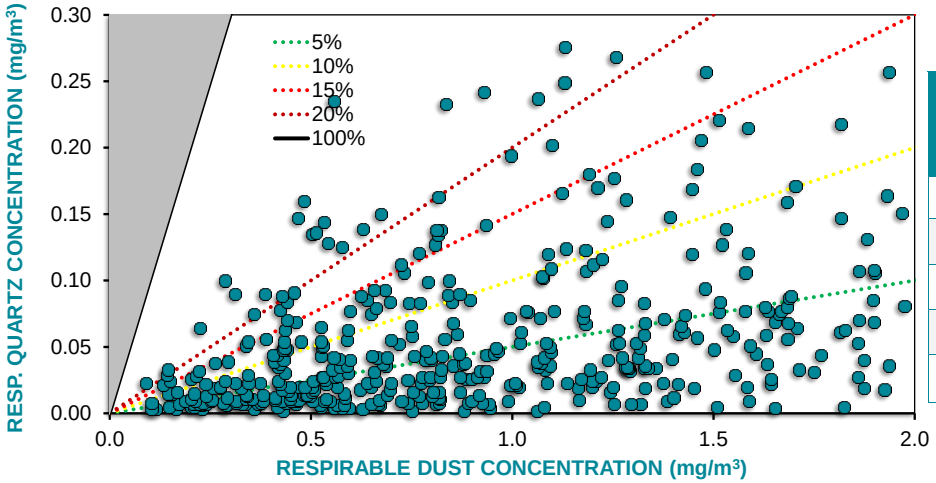
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	75.4%
≤0.05	53.3%
≤0.025	32.9%
≤0.012	16.6%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	90.7%
≤1.5	68.7%
≤0.3	9.0%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	57%
>5% to 10%	22%
>10% to 15%	11%
>15% to 20%	4%
>20%	6%

TUNNEL CONSTRUCTION, CONVENTIONAL EXCAVATION: Construction of tunnels using mechanical diggers or conventional drilling and blasting method in rock – Drilling and boring

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F2.01 - Management and office work	
F2.01.01 - Construction site manager	Carries out the management and/or operational functions involving responsibility, coordination and control of the tunnel construction activities. The role and duties require professional skills to carry out the research and planning activities too. The job may be performed by the general foreman or site supervisor.
F2.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to visit the construction site, in or outside the tunnel.
F2.02 - Activities inside the tunnel	
F2.02.01 - Tunnel crew foreman	Is in charge and directs the working crew for excavation at the tunnel heading or in a backward position (such as the construction of sided walls, digging of invert trench, etc.). Takes part actively in the works that he supervises, carrying out some tasks. Also called shift boss.
F2.02.02 - Truck driver for mucking	Drives truck or dumper to transport the excavated material (muck) out of the tunnel.
F2.02.03 - Power-shovel operator	Operates power-driven machinery (power-shovel, excavator) equipped with a demolition hammer or movable shovel, to excavate the tunnel heading and securing it by scaling from the face the loose pieces of rock. Carries out the dig for the invert arch construction.
F2.02.04 - Loader operator	Operates power-driven loader (mucker) to load the excavated broken rock onto the dump truck (or dumper) or to move it onto conveyor belt for mucking.
F2.02.05 - Shotcrete pump operator	Drives concrete mixer truck into the tunnel. Operates the lance (pump) for spraying wet concrete and additives mixture that is conveyed through a high-pressure hose/nozzle onto the surface of tunnel face for consolidation. The lance is fed by the truck concrete mixer. The job title includes the shotcrete operator helper.
F2.02.06 - Rock drill Jumbo operator	Operates jumbo drilling rig equipped with up to four booms, used for blast hole drilling in tunnelling. Performs drilling and consolidation grouting, micro-piles, anchoring tie-backs, forepolings, fibreglass reinforcement elements, rock bolts and exploratory holes. The job title includes the driller assistant.
F2.02.07 - Shot-firer	Determines the position and the force of explosions required and charges and sets off explosives to dislodge rock from tunnel face. Also called a blaster. The job title includes the shot-firer assistant.
F2.02.08 - Tunnel labourer	Assists the other operators in the crew, performing various kinds of work.
F2.02.09 - Rib positioning operator	After each advance in face excavation, operates a telehandler equipped with hydraulic clamp to lift an arc-shaped steel rib designed to support the tunnel. Operating on an aerial platform lifted by the same telehandler, carries out the fixing of the rib and a layer of welded wire mesh on the rock face.
F2.02.10 - Carpenter	Prepares and carries out the concrete casting of tunnel invert (using machine to vibrate concrete), side walls and crown. Carries out waterproofing and final tunnel linings. These activities take place in a backward position in respect to the tunnel heading.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F2.02.11 - Concrete mixer truck operator	Drives and operates concrete mixer truck for concrete casting in tunnel construction. When the operator also performs shotcrete spraying to the tunnel face, the job title is included in F2.02.05 *Shotcrete pump operator*.
F2.02.12 - Waterproofing membrane installer	Provides waterproofing of tunnel walls and vault by applying thermoplastic membranes such as PVC, thermoplastic polyolefin or polyethylene. A rail mounted slip form is used to pour concrete, casting the final tunnel lining.
F2.02.13 - Boring machine operator for tunnel widening	Operates and controls multifunction boring machinery for widening motorway tunnels in the presence of traffic. A single machine carries out all the construction cycle: rock cutting/excavation, mucking removal from the excavation face through extraction pipe or conveyor belt, erection of concrete segments. The job title includes all the operators engaged in the machinery.
F2.02.14 - Crusher (plant inside the tunnel)	Operates crushing plant to reduce rock debris to suitable size for aggregates or sand gravel. The plant is located inside the tunnel. The job title includes all the plant workers (power shovel/loader operators, truck drivers, etc.).
F2.02.15 - Concrete mixing plant operator (in the tunnel)	Conducts and controls the batching and mixing concrete plant located inside the tunnel. The job title includes all plant operators (working at the control board inside a container room, on the plant or in vehicles).
F2.02.16 - Weigher in the concrete mixing plant (in the tunnel)	Carries out the weighing of concrete mixer trucks after loading in the concrete mixing plant. Generally operates from a closed room (cabin).
F2.03 - Activities in the surface construction site	
F2.03.01 - Tunnel construction surveyor	Performs topographical surveys, assisting the tunnel construction with navigating in the right direction and to ensure the tunnel conforms to the design. Carries out measurements when the area is safe to enter between blasting and excavation of material.
F2.03.02 - Construction foreman (at the surface construction site)	Is in charge and directs the construction crew outside the tunnel and is responsible for organising construction works on site. Generally, the role is assumed by an experienced construction worker.
F2.03.03 - Loader operator (at the surface construction site)	Operates power-driven loader (bulldozer) to load excavated rock and debris onto dump truck (or dumper) or to feed a rock crushing plant hopper at the surface construction site.
F2.03.04 - Truck driver (at the surface construction site)	Drives truck, dumper or other vehicle to transport material at the surface construction site.
F2.03.05 - Power-shovel operator (at the surface construction site)	Operates power-driven excavating machine (power-shovel, excavator) to carry out excavation work at the surface construction site.
F2.03.06 - Bridge-crane operator (at the surface construction site)	Operates the bridge-crane or other cranes in the construction site outside the tunnel.
F2.03.07 - Concrete mixing plant operator (at the surface construction site)	Conducts and controls the batching and mixing concrete plant in the construction site outside the tunnel.
F2.03.08 - Steel fixer (at the surface construction site)	Prepares iron reinforcement frameworks for concrete structures or pre-stressed concrete constructions, working at the surface construction site.

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Contarp 2016 classification

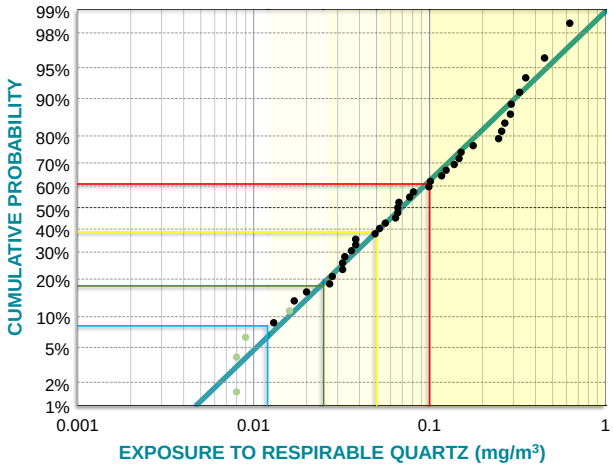
WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F2.04 - Warehouse	
F2.04.01 - Warehouse operator	Handles duties pertaining to the storing, selection, organisation and distribution of materials, tools and equipment to be sent to the warehouse or storage yard.
F2.05 - Mechanical and electrical maintenance	
F2.05.01 - Maintenance mechanic / electrician	Maintains, repairs and assembles machines and/or electrical and auxiliary parts of electronic equipment both in the mechanical workshop and inside the tunnel. The job title includes both foreman / maintenance manager and other workers.

Exposure to respirable quartz, by job title

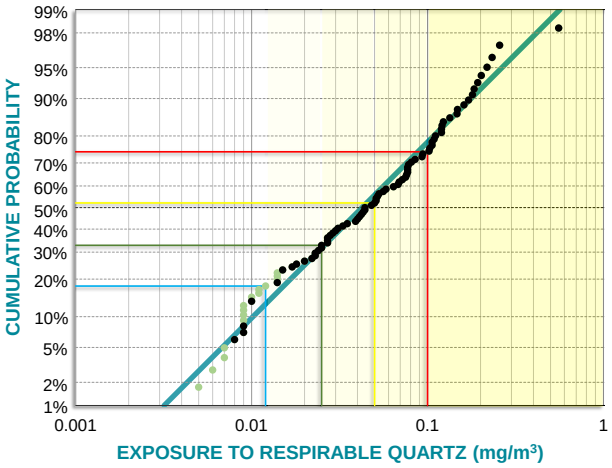
Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
F02.02.01 - Tunnel crew foreman	41	0.069	3.158	60.9%	38.7%	17.8%	8.2%
F02.02.02 - Truck driver for mucking	93	0.042	3.026	74.4%	52.1%	32.8%	17.8%
F02.02.03 - Power-shovel operator	81	0.041	3.417	71.9%	57.4%	36.9%	17.4%
F02.02.04 - Loader operator	60	0.032	2.691	89.0%	61.9%	41.7%	22.6%
F02.02.05 - Shotcrete pump operator	52	0.025	3.456	91.1%	65.0%	42.7%	27.4%
F02.02.06 - Rock drill Jumbo operator	47	0.054	3.727	65.9%	47.0%	24.6%	11.9%
F02.02.07 - Shot-firer	6	0.043	2.346	>90.0%	32.2%	19.1%	12.8%
F02.02.08 - Tunnel labourer	43	0.053	4.964	53.6%	38.2%	34.5%	24.1%
F02.02.09 - Rib positioning operator	24	0.048	2.163	83.8%	49.8%	20.9%	4.6%
F02.02.10 - Carpenter	73	0.040	2.693	79.5%	59.6%	36.3%	13.1%
F02.02.11 - Concrete mixer truck operator	1	0.096	-	-	-	-	-
F02.02.12 - Waterproofing membrane installer	5	0.051	1.712	-	-	-	-
F02.02.13 - Boring machine operator for tunnel widening	5	0.035	1.161	-	-	-	-
F02.02.14 - Crusher (plant inside the tunnel)	3	0.076	2.949	-	-	-	-
F02.02.15 - Concrete mixing plant operator (in the tunnel)	3	0.186	2.619	-	-	-	-
F02.02.16 - Weigher in the concrete mixing plant (in the tunnel)	1	0.038	-	-	-	-	-
F02.03.03 - Loader operator (at the surface construction site)	1	0.020	-	-	-	-	-

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

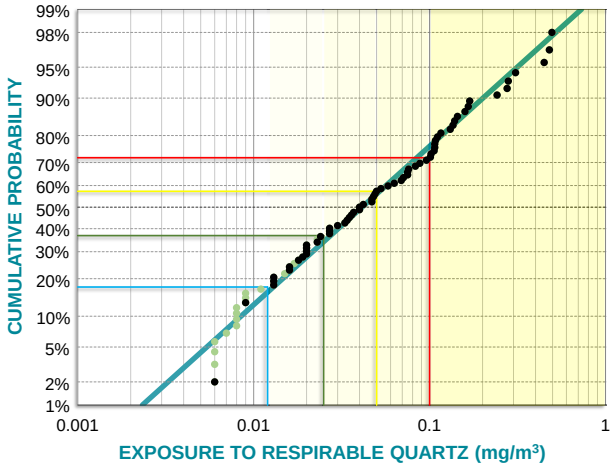
F02.02.01 - Tunnel crew foreman



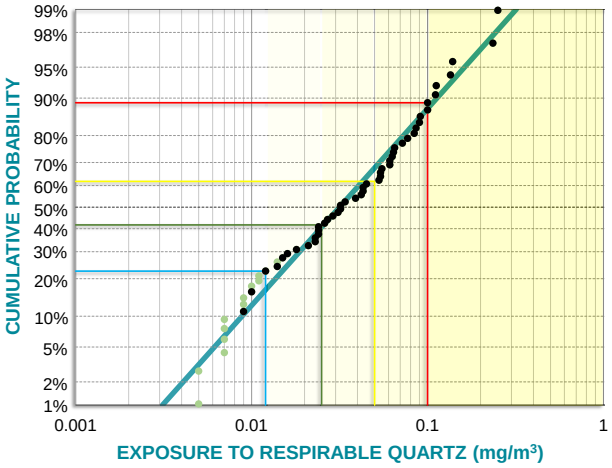
F02.02.02 - Truck driver for mucking



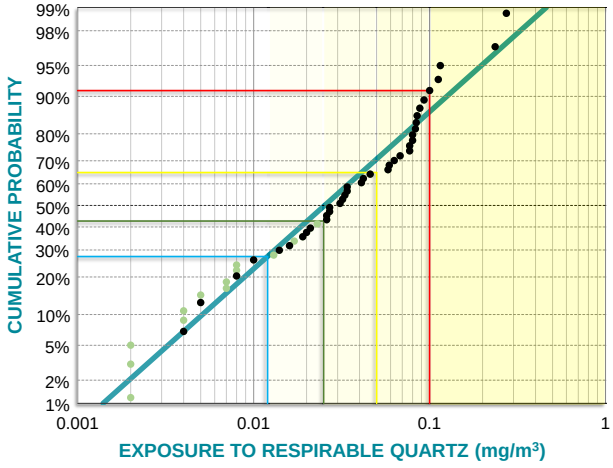
F02.02.03 - Power-shovel operator



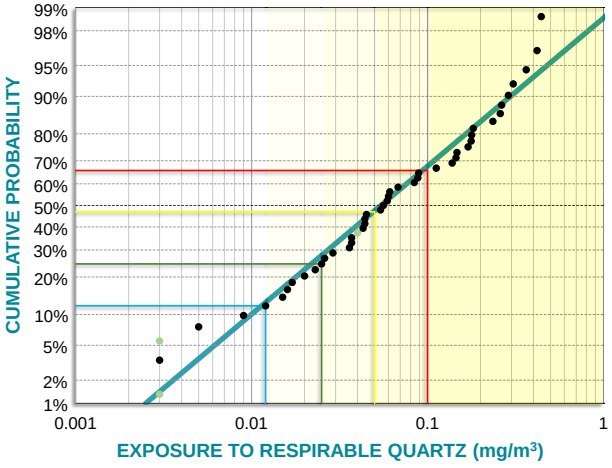
F02.02.04 - Loader operator



F02.02.05 - Shotcrete pump operator



F02.02.06 - Rock drill Jumbo operator



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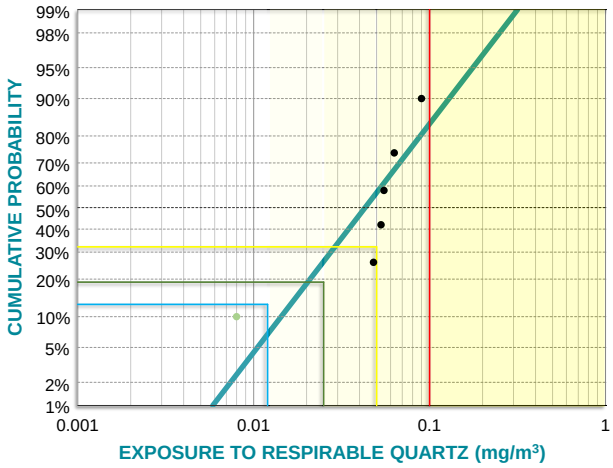
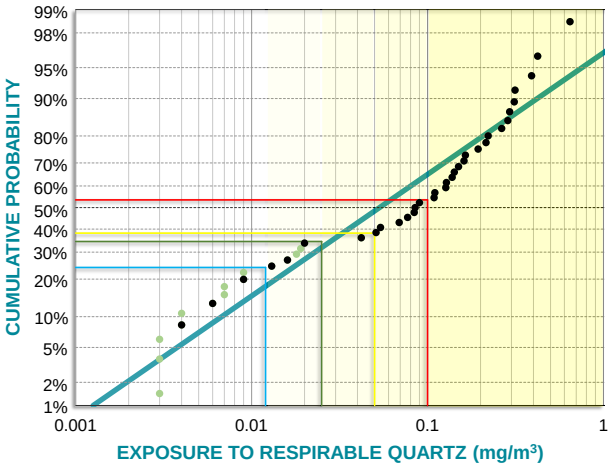
Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

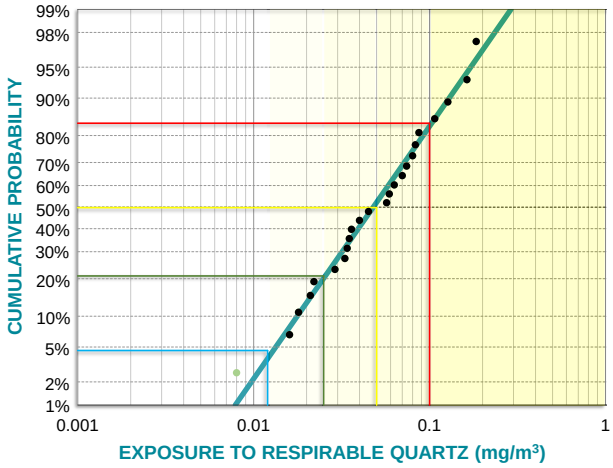
F02.02.07 - Shot-firer



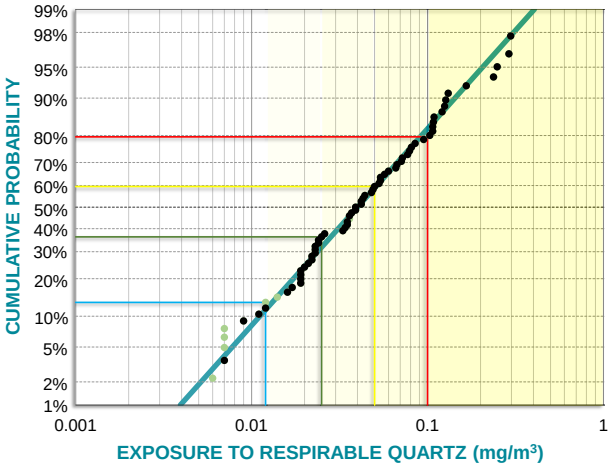
F02.02.08 - Tunnel labourer



F02.02.09 - Rib positioning operator



F02.02.10 - Carpenter



Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m^3	≤1.5 mg/m^3	≤0.3 mg/m^3
F02.02.01 - Tunnel crew foreman	40	1.528	2.433	74.6%	46.9%	7.3%
F02.02.02 - Truck driver for mucking	94	0.879	2.066	94.7%	78.3%	6.1%
F02.02.03 - Power-shovel operator	80	0.991	2.334	89.8%	66.8%	6.8%
F02.02.04 - Loader operator	62	0.604	2.409	98.9%	83.9%	22.4%
F02.02.05 - Shotcrete pump operator	52	1.222	2.201	89.4%	62.1%	2.0%
F02.02.06 - Rock drill Jumbo operator	47	0.878	2.948	88.9%	69.8%	13.3%
F02.02.07 - Shot-firer	6	0.472	1.561		>90.0%	<10.0%
F02.02.08 - Tunnel labourer	43	1.129	2.713	83.1%	54.5%	13.5%
F02.02.09 - Rib positioning operator	26	1.155	1.869	93.3%	65.8%	4.1%
F02.02.10 - Carpenter	73	1.031	2.209	90.1%	67.2%	5.5%
F02.02.11 - Concrete mixer truck operator	1	1.271	-	-	-	-
F02.02.12 - Waterproofing membrane installer	5	1.525	2.646	-	-	-
F02.02.13 - Boring machine operator for tunnel widening	5	1.088	1.258	-	-	-
F02.02.14 - Crusher (plant inside the tunnel)	3	0.405	1.597	-	-	-
F02.02.15 - Concrete mixing plant operator (in the tunnel)	3	1.442	1.672	-	-	-
F02.02.16 - Weigher in the concrete mixing plant (in the tunnel)	1	0.262	-	-	-	-
F02.03.03 - Loader operator (at the surface construction site)	1	1.251	-	-	-	-

Working processes

Tunnel excavation and lining can be carried out in a completely mechanised way by a full section Tunnel Boring Machine (TBM), which excavates tunnels with circular cross-sections. A TBM may have a diameter of several meters, the entire machine can be more than 100 m long and weigh several hundred tons. The following gives an overview of the essential characteristics of a double shield TBM for hard rock, described in its four components.

1. **Front shield and gripper shield** – a double shield TBM is made of two parts: the front and the gripper shields. The front shield contains a rotating cutterhead and the motors. Fixed on the rotating bearing of the cutterhead are the cutting discs, which roll in concentric circles crushing and breaking the rock when the cutterhead is pressed against the tunnel face. The gripper shield contains the grippers which brace against the tunnel, so that the reaction forces can be transferred to the cutterhead, allowing the excavation of the rock face. The two shields are telescopically connected so that the front shield can advance independently from the gripper shield. Hydraulic thrust cylinders push the section forward a given amount (e.g. 1.5 m) at the end of which the support system is recalled by recovering the advance of the jacks.
2. **Mucking system** – the crushed material produced by the cutters is collected by buckets installed at the cutterhead and falls on a screw conveyor. From the screw conveyor, the excavated muck is transferred on a conveyor belt, fixed on the tunnel vault and transported out of the tunnel.
3. **Back-up section** – connected to the gripper shield, consists of metal carpentry modules that contain the TBM operator's driver's cab, hydraulic control units, pumps, transformers, lubrication, ventilation, lighting, telephone, toilet and emergency services. The backup also includes tools to erect the tunnel support (lining) and to remove the excavated muck. As the shields advance, the backup section also advances until the machine has regrouped and operations resume from the beginning of the sequence. Since the machine is able to mount the lining ring at the same time as the cutterhead advance, an almost continuous excavation cycle is obtained.
4. **Rolling stock** – the backup section is crossed in the middle by a service train railway, leaving a space on both sides for personnel transit. The train consists of wagons used to transport all the necessary material (tunnel lining segments, mortar and aggregates) as well as personnel to the TBM.

The advance of a double shield TBM, described below, is cyclical, although excavation, assembly of the lining segments and transport of the excavated material (muck) take place at the same time.

1. **Thrust** of the pistons on the last ring of prefabricated lining segments, already positioned.
2. **Advance** of the cutterhead for a length equal to the width of the lining segments.
3. **Retraction** of the thrust pistons.
4. **Positioning** of a ring of lining segments.

Tunnel construction with a TBM also includes operations that take place in the surface construction site, outside the tunnel.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	48	0.809	2.402	48	0.108	2.569	16.1
STATIC	-	-	-	-	-	-	-

TUNNEL CONSTRUCTION, MECHANICAL EXCAVATION: Construction of tunnels using hard rock tunnel boring machines or tunnelling shields

Geometric mean of personal exposure, by region

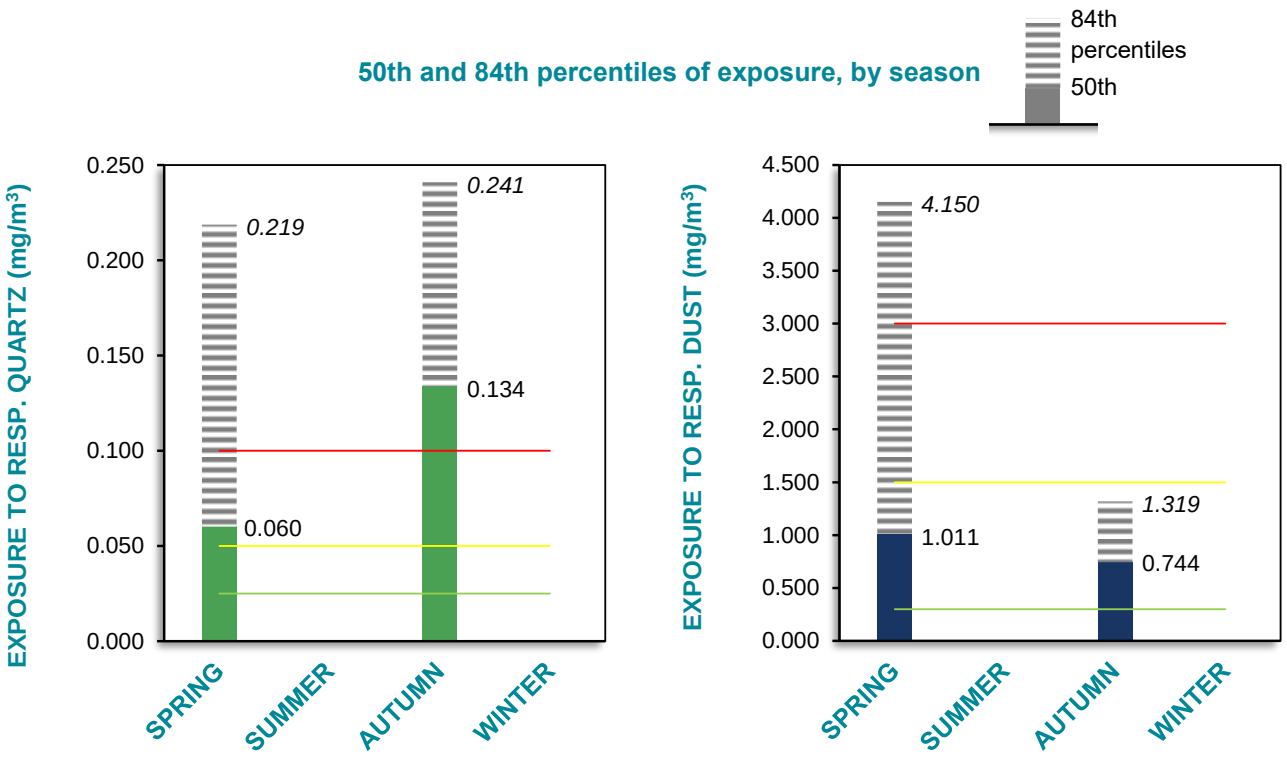
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

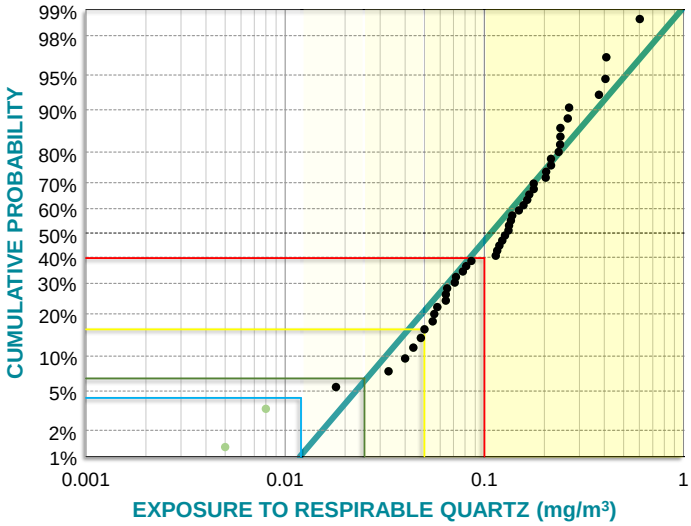
Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season

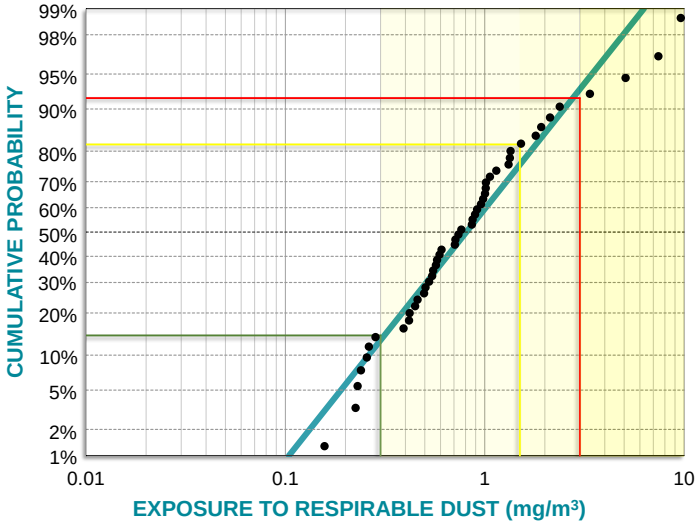


Lognormal probability distribution of personal exposure to respirable quartz (data from all the job titles)



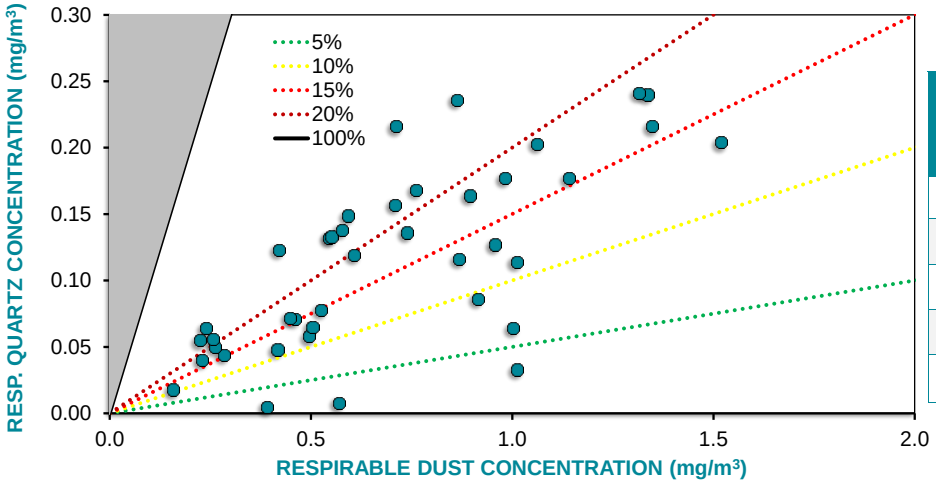
Exposure to respirable quartz (mg/m^3)	Compliance probability
≤0.1	39.7%
≤0.05	15.8%
≤0.025	6.5%
≤0.012	4.3%

Lognormal probability distribution of personal exposure to respirable dust (data from all the job titles)



Exposure to respirable dust (mg/m^3)	Compliance probability
≤3	91.8%
≤1.5	81.9%
≤0.3	14.1%

Quartz content in the respirable dust — personal samples



Quartz content	Percentage of samples in the range
≤5%	10%
>5% to 10%	10%
>10% to 15%	19%
>15% to 20%	33%
>20%	27%

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F3.01 - Management and office work	
F3.01.01 - Construction site manager	Carries out management and/or operational functions involving responsibility, coordination and control of the tunnel construction activities. The role and duties require professional skills to carry out research and planning activities too. The job may be performed by the general foreman or site supervisor.
F3.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to visit the construction site, in or outside the tunnel.
F3.02 - Activities inside the tunnel	
F3.02.01 - TBM crew foreman	Is in charge and directs the Tunnel Boring Machine (TBM) crew for excavation at the tunnel heading. Takes part actively in the works that he supervises, carrying out some tasks. Also called shift boss.
F3.02.02 - Tunnel locomotive driver	Drives the underground train for transporting personnel and construction materials from the surface to the Tunnel Boring Machine (tunnel heading).
F3.02.03 - TBM machine operator	Operates the Tunnel Boring Machine (TBM), driving and regulating the shield and monitoring the TBM systems from the panel controls in the cabin, located in the TBM back-up system.
F3.02.04 - Segment erector operator	Operates the segment erector integrated inside the Tunnel Boring Machine to install the tunnel ring using console. Each ring is typically made of six segments. The erector is equipped with a mechanical arm that uses a gripper system with vacuum plates.
F3.02.05 - Segment fitter	Unloads the concrete segments from the underground train and moves them towards the erector by using a transfer crane. Assists the erector to place and fix the segments into position to build the tunnel ring.
F3.02.06 - Concrete pump operator	Operates concrete pump and monitors mortar injection. After the laying of tunnel ring, fills the gap with grout between the excavated surface and concrete segments. Carries out systematic maintenance of pumping circuits.
F3.02.07 - Conveyor belt mucking operator	Controls the loading of excavated material on the conveyor belt which transfers it out of the tunnel (mucking). Cleans the conveyor belt and carries out its maintenance. If a convoy of wagons is used for the transfer of excavated material, their filling is controlled.
F3.02.08 - Tunnel finishing operator	Carries out tunnel finishing operations.
F3.02.09 - Tunnel labourer	Assists the other operators in the crew, performing various kinds of work (extension of the walkways, advancement of the railway, fixing of technological lines, cleaning of the head boring machine tunnel, etc.).
F3.02.10 - Maintenance electrician	Carries out maintenance tasks on the electric components of the equipment and deals with the extension of technological lines in the tunnel.
F3.02.11 - Maintenance mechanic	Maintains, repairs and assembles machines both in mechanical workshop and inside the tunnel. Carries out monitoring and mechanical maintenance of vehicles and conveyor belts. The job title includes both foreman / maintenance manager and other workers.

Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F3.03 - Activities in the surface construction site	
F3.03.01 - Construction foreman (at the surface construction site)	Is in charge and directs the construction crew outside the tunnel and is responsible for organising construction works on site. Generally, the role is assumed by an experienced construction worker.
F3.03.02 - Loader operator (at the surface construction site)	Operates power-driven loader (bulldozer) to load excavated rock and debris onto the dump truck (or dumper) or to feed a crushing plant hopper at the surface construction site.
F3.03.03 - Truck driver (at the surface construction site)	Drives truck, dumper or other vehicle to transport material, working at the surface construction site.
F3.03.04 - Power-shovel operator (at the surface construction site)	Operates a power-driven excavating machine (power-shovel, excavator) to carry out excavation work at the surface construction site.
F3.03.05 - Bridge-crane operator (outside the tunnel)	Operates the bridge-crane or other cranes in the construction site outside of the tunnel.
F3.03.06 - Concrete mixing plant operator (at the surface construction site)	Conducts and controls the batching and mixing of the concrete plant in the construction site outside the tunnel.
F3.04 - Warehouse	
F3.04.01 - Warehouse operator	Handles duties pertaining to the storing, selecting, organising and distributing of materials, tools and equipment to be sent to the warehouse or storage yard.

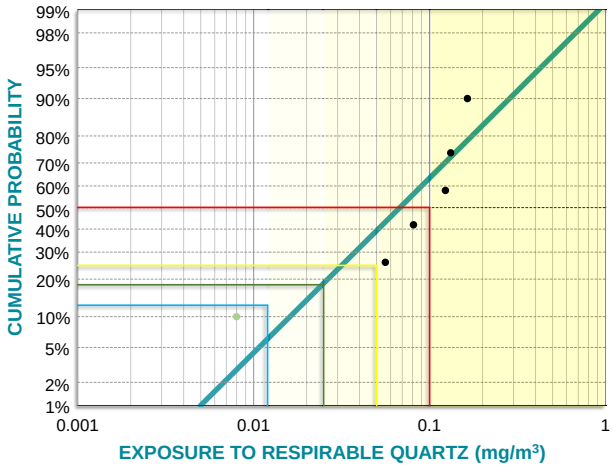
TUNNEL CONSTRUCTION, MECHANICAL EXCAVATION: Construction of tunnels using hard rock tunnel boring machines or tunnelling shields

Exposure to respirable quartz, by job title

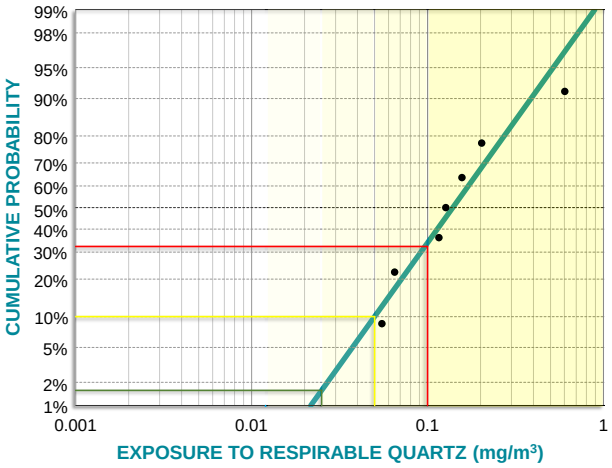
Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m^3	≤0.05 mg/m^3	≤0.025 mg/m^3	≤0.012 mg/m^3
F03.02.01 - TBM crew foreman	2	0.104	-	-	-	-	-
F03.02.02 - Tunnel locomotive driver	6	0.068	3.049	50.1%	24.8%	18.2%	12.5%
F03.02.03 - TBM machine operator	7	0.139	2.214	32.4%	<8.6%	-	-
F03.02.04 - Segment erector operator	7	0.153	1.560	16.8%	<8.6%	-	-
F03.02.05 - Segment fitter	2	0.111	-	-	-	-	-
F03.02.06 - Concrete pump operator	7	0.079	1.791	67.2%	22.4%	<8.6%	
F03.02.08 - Tunnel finishing operator	1	0.262	-	-	-	-	-
F03.02.09 - Tunnel labourer	8	0.175	2.232	24.6%	10.8%	<7.6%	
F03.02.10 - Maintenance electrician	1	0.133	-	-	-	-	-
F03.02.11 - Maintenance mechanic	1	0.048	-	-	-	-	-
F03.03.02 - Loader operator (at the surface construction site)	3	0.079	3.801	-	-	-	-
F03.03.03 - Truck driver (at the surface construction site)	3	0.047	7.652	-	-	-	-

Exposure profile to respirable quartz, by job title, according to a lognormal probability distribution

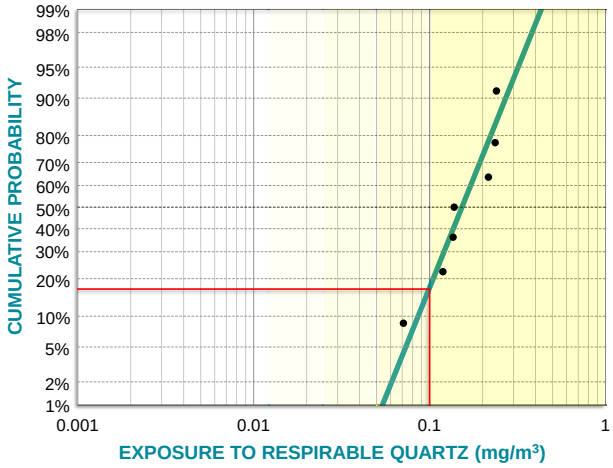
F03.02.02 - Tunnel locomotive driver



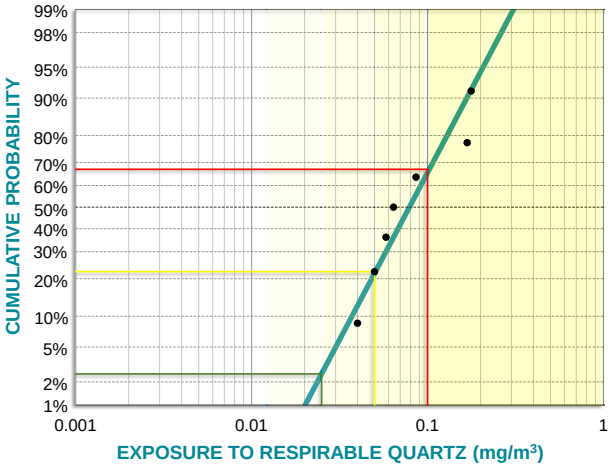
F03.02.03 - TBM machine operator



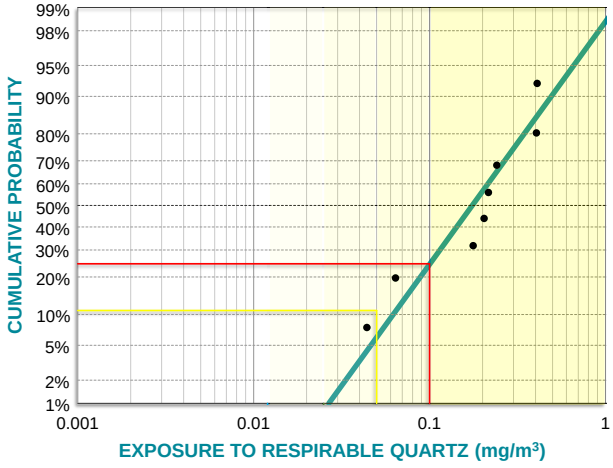
F03.02.04 - Segment erector operator



F03.02.06 - Concrete pump operator



F03.02.09 - Tunnel labourer



TUNNEL CONSTRUCTION, MECHANICAL EXCAVATION: Construction of tunnels using hard rock tunnel boring machines or tunnelling shields

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability ≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
F03.02.01 - TBM crew foreman	2	0.515	-	-	-	-
F03.02.02 - Tunnel locomotive driver	6	0.643	2.139	>90.0%	83.7%	14.1%
F03.02.03 - TBM machine operator	7	0.912	2.899	86.0%	80.7%	12.5%
F03.02.04 - Segment erector operator	7	0.785	1.515		>91.4%	<8.6%
F03.02.05 - Segment fitter	2	1.394	-	-	-	-
F03.02.06 - Concrete pump operator	7	0.586	1.919		>91.4%	25.1%
F03.02.08 - Tunnel finishing operator	1	5.081	-	-	-	-
F03.02.09 - Tunnel labourer	8	1.129	3.275	83.8%	55.7%	20.4%
F03.02.10 - Maintenance electrician	1	0.551	-	-	-	-
F03.02.11 - Maintenance mechanic	1	0.417	-	-	-	-
F03.03.02 - Loader operator (at the surface construction site)	3	0.593	3.186	-	-	-
F03.03.03 - Truck driver (at the surface construction site)	3	0.885	3.212	-	-	-

Working processes

Sandblasting for cleaning the surfaces of buildings floors or walls and industrial structures, is intended to remove scale, paint and rust. This activity also includes the sandblasting of bricks, radiators, wooden beams, doors and shutters, rock surfaces, metal frames, etc. In the case of single and small pieces, the operation can be carried out in tanks or closed cabins. A sandblasting machine projects a high-speed jet of abrasive material on the surface with a grain size suitable for the surface. Siliceous sand, which can have a quartz content even greater than 80%, is often used, or other materials such as sodium bicarbonate, corundum, silicon carbide, metal grit, or dry ice (which is used in cryogenic cleaning). Airpower is supplied by a compressor. Sandblasting treatment can be applied dry, obtaining maximum effectiveness but generating large quantities of dust: in this case, it is necessary to operate in a sandblasting booth whenever possible. When working outdoors the operator must wear protective clothing and a powered respirator helmet which protects the head, face, eyes, ears and respiratory system against dust, with a blower unit which sends filtered air through a breathing tube to the inside of the helmet. The jet of abrasive material can also be accompanied by a water jet (hydro blasting): in this case, the operator's exposure to airborne dust is lower, but so is the effectiveness of the treatment and the water jet smears the surface with mud that then has to be removed. The water jet can also be applied with a humidification device which uses a dry sandblaster as a base, where water is combined outside the abrasive mix with air, after it comes out of the nozzle (but the results are even less effective). A dry blasting operation is described below.

1. **Preparation of the mixture** – the sand contained inside the tank of the sandblasting machine is mixed with the air coming from the compressor, in specified proportions.
2. **Sandblasting** – a hose with a spray nozzle is connected to the sandblasting machine, then the operator manually directs the jet of air and sand mixture to the surface to be cleaned. At the end of each step the operator stops the outflow of the jet from the sandblasting machine, by switching the automatic jet control system off, or by a pneumatic control system. Before resuming the work or starting a new one, an interruption is required. Indoor sandblasting steps cannot last longer than 10-30 minutes, due to the dust cloud; work is then suspended until the dust is settled and good visibility restored. Therefore, personal airborne dust sampling is usually very short-lived; static sampling is often carried out in place of personal sampling, due to the difficulty of attaching the personal sampler to the operator clothing.

Geometric mean and geometric standard deviation values of exposure measurements

	RESPIRABLE DUST			RESPIRABLE QUARTZ			
TYPE OF SAMPLING	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Analysed samples (No.)	Geometric Mean (mg/m^3)	Geometric St. Dev.	Average quartz content (%)
PERSONAL	4	1.060	11.916	4	0.092	8.823	9.0
STATIC	-	-	-	-	-	-	-

SAND BLASTING FOR BUILDING EXTERIORS: Sand blasting for building exteriors and for cleaning of pavements

Geometric mean of personal exposure, by region

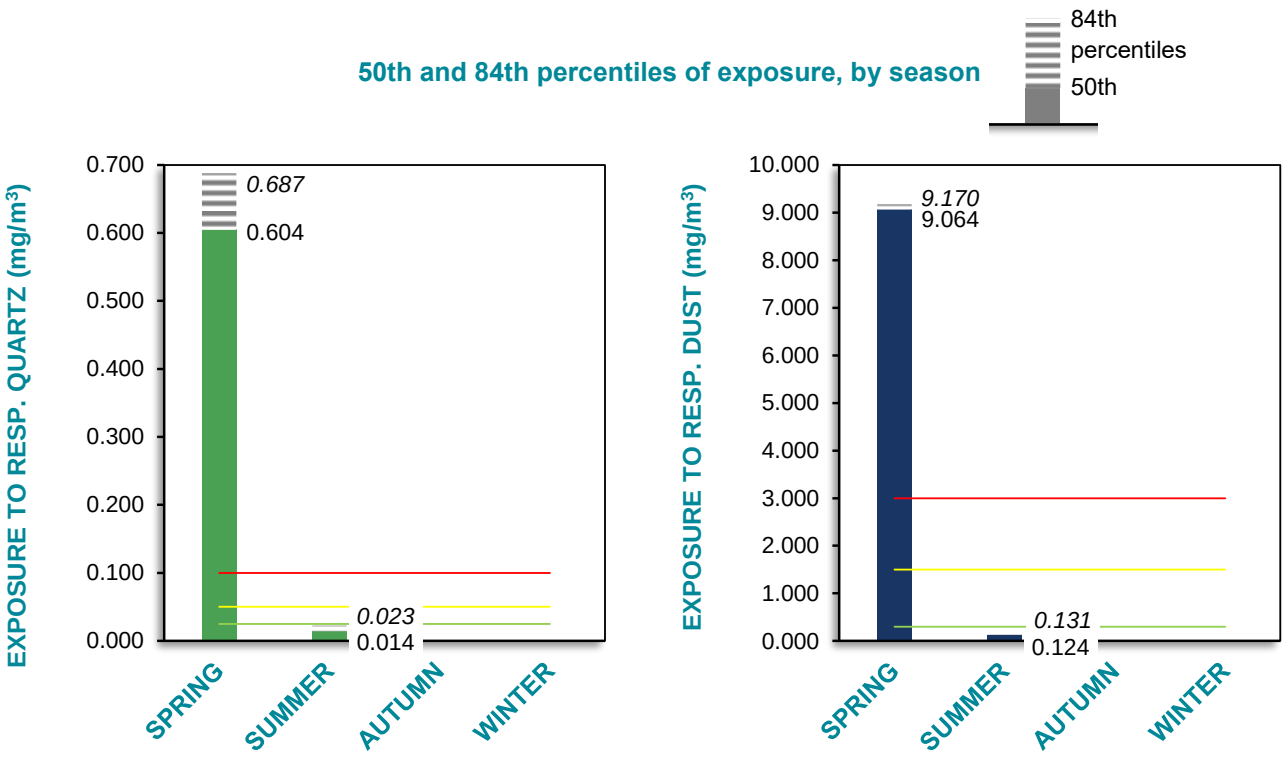
Respirable Quartz

- ≤0.012 mg/m³
- from >0.012 to 0.025 mg/m³
- from >0.025 to 0.05 mg/m³
- from >0.05 to 0.1 mg/m³
- >0.1 mg/m³
- No sample

Respirable Dust

- ≤0.3 mg/m³
- from >0.3 to 1.5 mg/m³
- from >1.5 to 3 mg/m³
- >3 mg/m³
- No sample

50th and 84th percentiles of exposure, by season



Contarp 2016 classification

WORK PHASE-DEPARTMENT / JOB TITLE	Job definition
F4.01 - Management and office work	
F4.01.01 - Construction site manager	Carries out management and/or operational functions involving responsibility, coordination and control of construction site activities. The role and duties require professional skills to carry out research and planning activities too. The job may be performed by the general foreman or site supervisor.
F4.01.02 - Office worker	Performs clerical or technical tasks in the office. Duties may include a variety of roles and responsibilities. Occasionally, may be required to work in the construction site.
F4.02 - Sandblasting	
F4.02.01 - Dry sandblasting operator	Cleans exterior surfaces of stone, brick and metal structures by means of a jet of silica sand mixed with air. Uses a lance connected to a sand storage tank. Wears a suit of protective clothing and an air respirator.
F4.02.02 - Hydro-sandblasting operator	Cleans exterior surfaces of stone, brick and metal structures by means of a jet of silica sand mixed with air and water. Uses a hose connected to a sand storage tank. Wears PPE consisting of a suit of protective clothing and an air respirator.
F4.02.03 - Non-silica sandblasting operator	Cleans exterior surfaces of stone, brick and metal structures by means of a jet of a material other than silica sand mixed with a fluid. Uses a hose connected to a material storage tank. Wears PPE consisting of a suit of protective clothing and an air respirator.
F4.02.04 - Sandblasting assistant	Cooperates with the sandblasting operator in the cleaning of exterior surfaces of stone, brick and metal structures. Starts and shutters the air compression system.
F4.03 - Warehouse	
F4.03.01 - Warehouse operator	Handles duties pertaining to the storing, selecting, organising and distributing of materials, tools and equipment to be sent to the warehouse or storage yard.
F4.04 - Various workspaces	
F4.04.01 - Polyvalent worker	Performs a wide and diverse range of duties that generally involve repeated procedures or handiwork. Assists other workers in various work assignments as needed or fills in for absent workers. Also called multipurpose worker. May also include forms of on-the-job training or apprenticeship.

SAND BLASTING FOR BUILDING EXTERIORS: Sand blasting for building exteriors and for cleaning of pavements

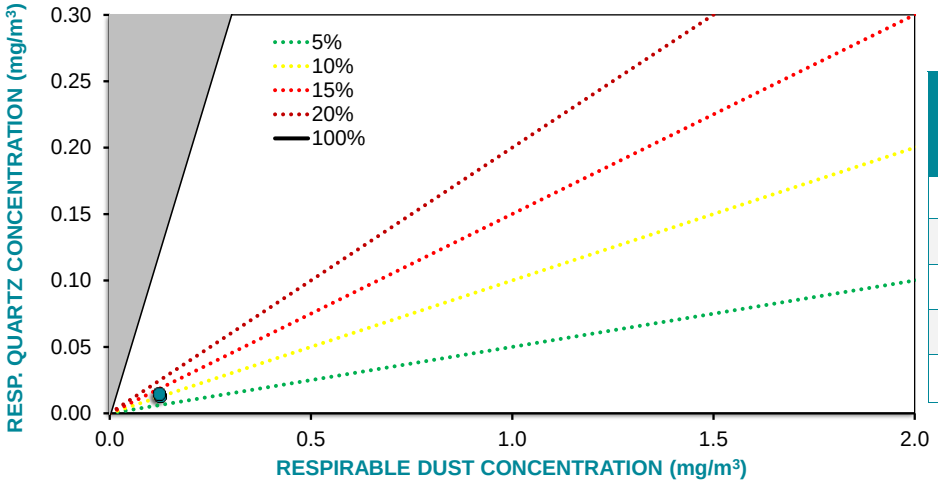
Exposure to respirable quartz, by job title

Job titles	Respirable Quartz						
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability			
				≤0.1 mg/m³	≤0.05 mg/m³	≤0.025 mg/m³	≤0.012 mg/m³
F4.02.01 - Dry sandblasting operator	2	0.014	-	-	-	-	-
F4.02.02 - Hydro-sandblasting operator	2	0.604	-	-	-	-	-

Exposure to respirable dust, by job title

Job titles	Respirable Dust					
	No. of samples	Geom. Mean mg/m³	Geom. St. Dev.	Exposure compliance probability		
				≤3.0 mg/m³	≤1.5 mg/m³	≤0.3 mg/m³
F4.02.01 - Dry sandblasting operator	2	0.124	-	-	-	-
F4.02.02 - Hydro-sandblasting operator	2	9.064	-	-	-	-

Quartz content in the respirable dust — personal samples



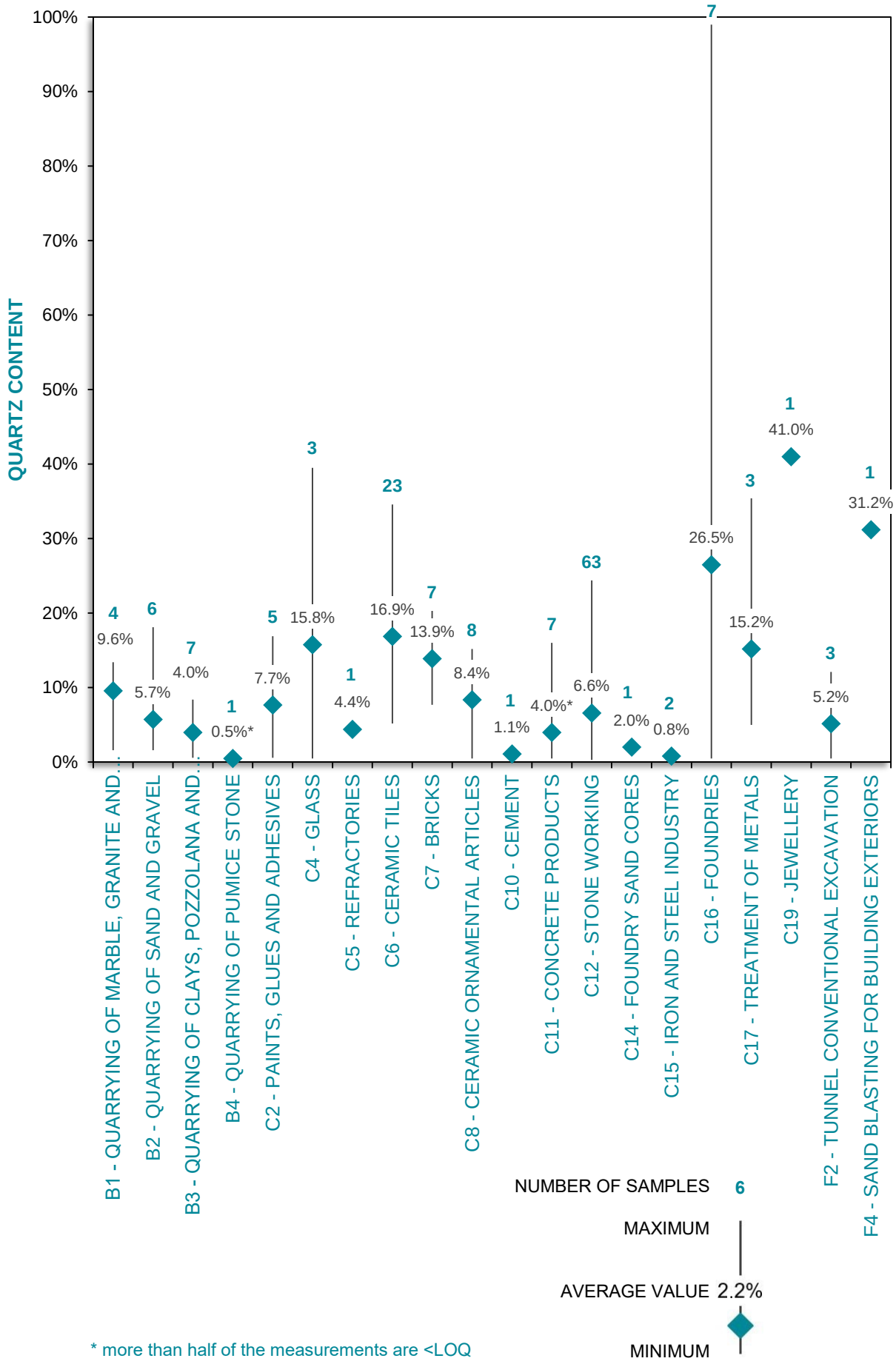
Quartz content	Percentage of samples in the range
≤5%	0%
>5% to 10%	50%
>10% to 15%	50%
>15% to 20%	0%
>20%	0%

PART 4.

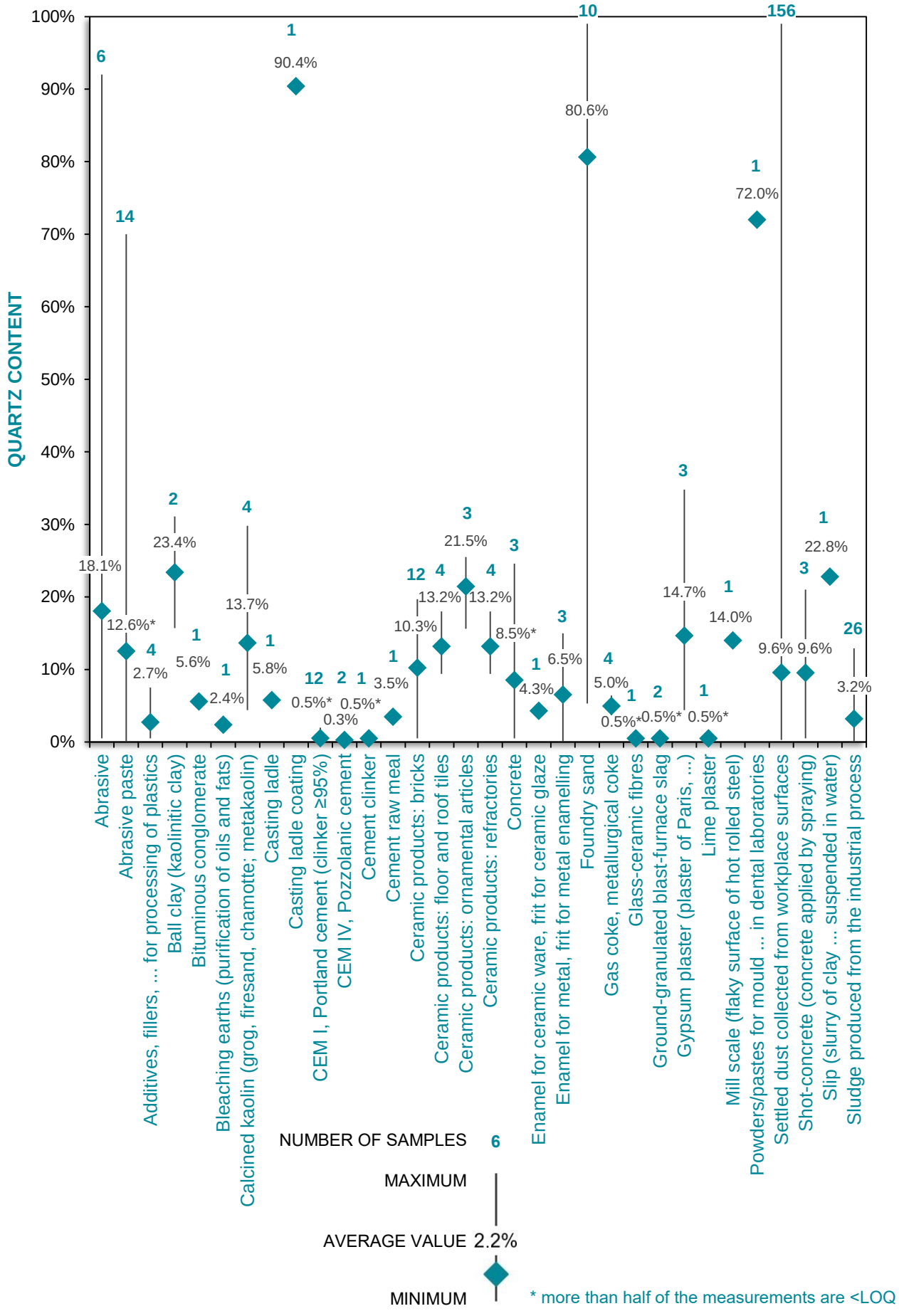
QUARTZ CONTENT

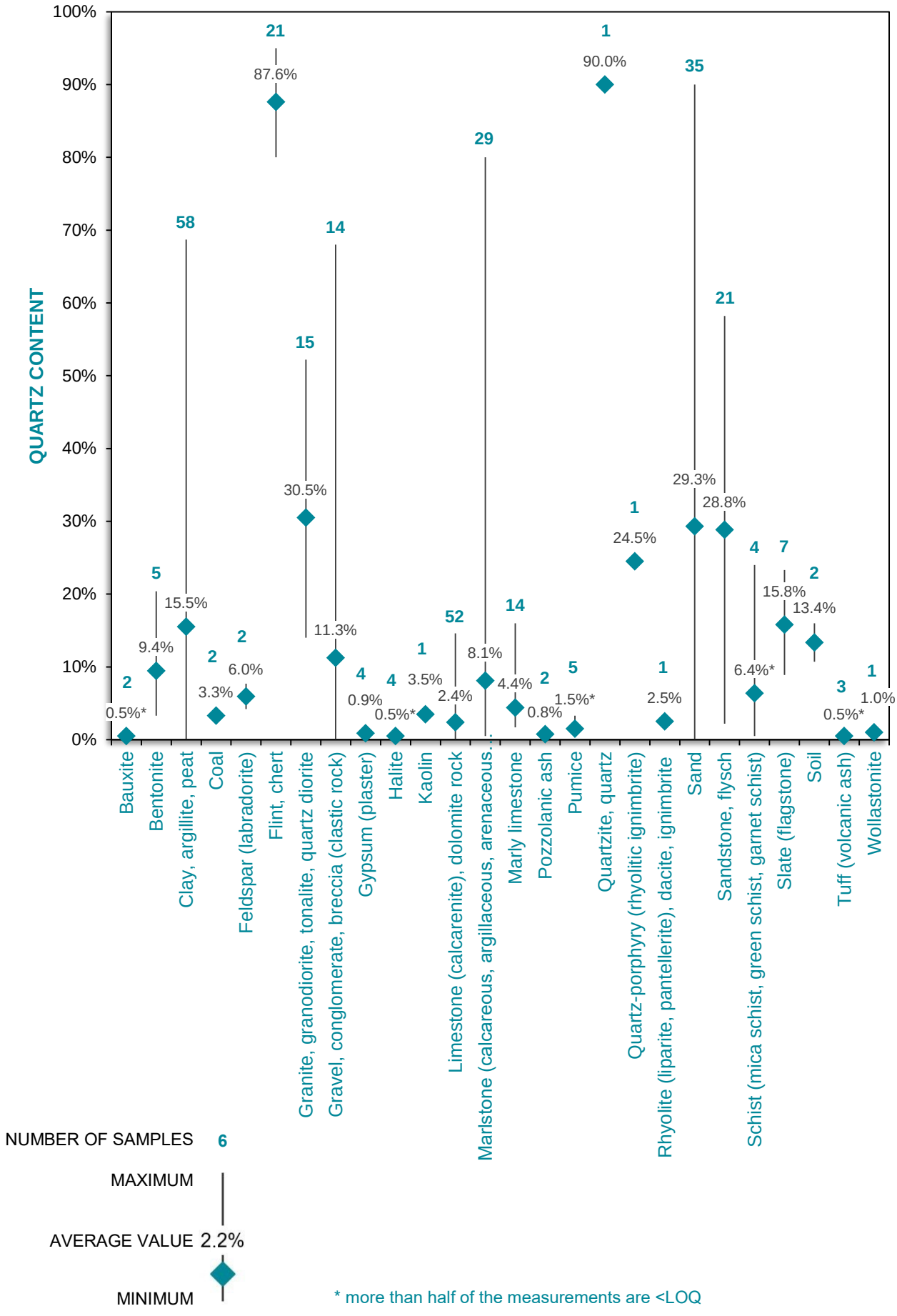
IN BULK MATERIALS

4.1 Quartz content in settled dust, by production activity



* more than half of the measurements are <LOQ


QUARTZ CONTENT
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Abrasive
Abrasive paste
Additives, fillers, ... for processing of plastics
Ball clay (kaolinitic clay)
Bituminous conglomerate
Bleaching earths (purification of oils and fats)
Calcined kaolin (grog, firesand, chamotte; metakaolin)
Casting ladle
Casting ladle coating
CEM I, Portland cement (clinker ≥95%)
CEM IV, Pozzolanic cement
Cement clinker
Cement raw meal
Ceramic products: bricks
Ceramic products: floor and roof tiles
Ceramic products: ornamental articles
Ceramic products: refractories
Concrete
Enamel for ceramic ware, frit for ceramic glaze
Enamel for metal, frit for metal enamelling
Foundry sand
Gas coke, metallurgical coke
Glass-ceramic fibres
Ground-granulated blast-furnace slag
Gypsum plaster (plaster of Paris, ...)
Lime plaster
Mill scale (flaky surface of hot rolled steel)
Powders/pastes for mould ... in dental laboratories
Settled dust collected from workplace surfaces
Shot-concrete (concrete applied by spraying)
Slip (slurry of clay ... suspended in water)
Sludge produced from the industrial process
NUMBER OF SAMPLES
MAXIMUM
AVERAGE VALUE
MINIMUM
* more than half of the measurements are <LOQ



* more than half of the measurements are <LOQ

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