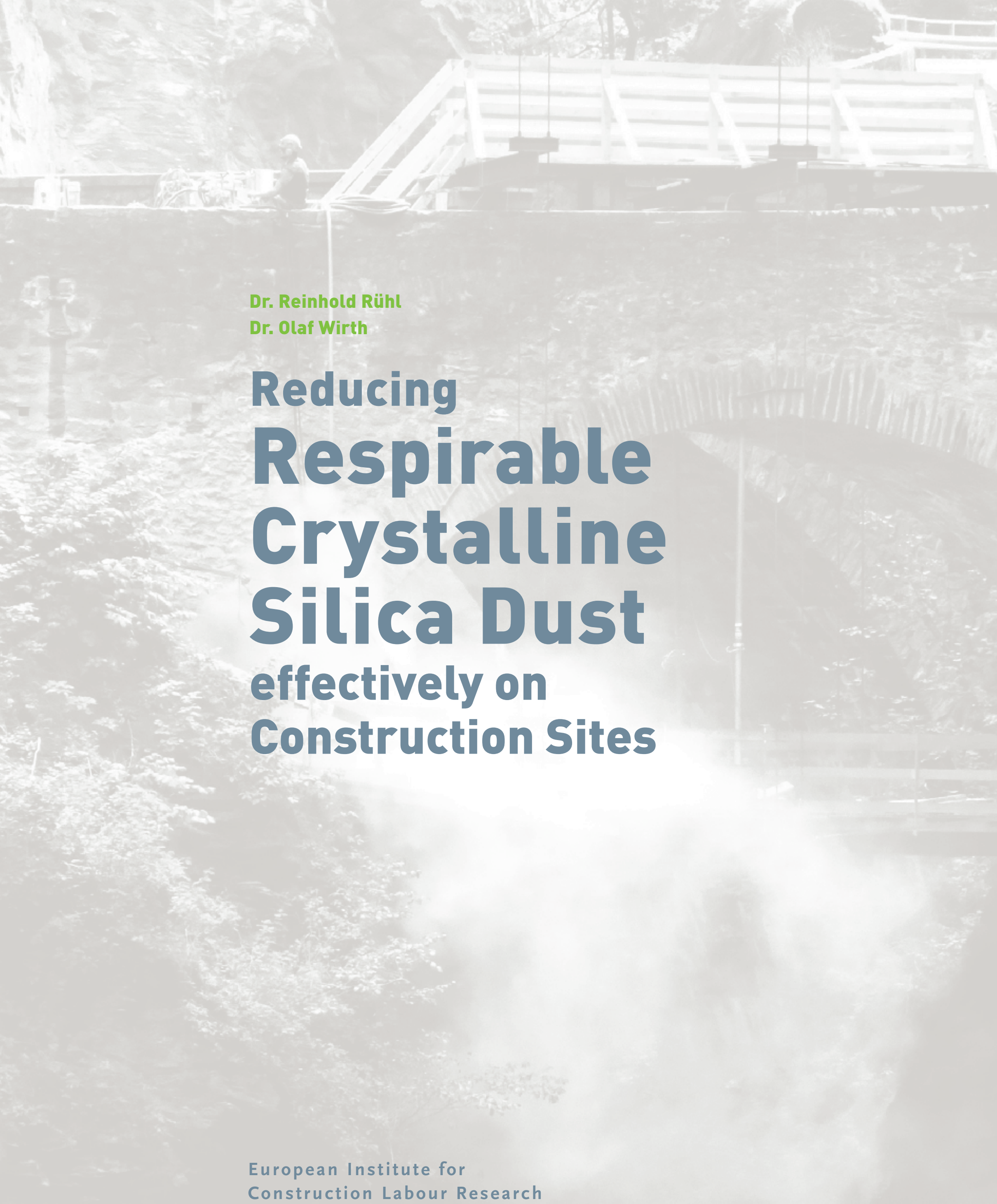

Dr. Reinhold Rühl
Dr. Olaf Wirth

Reducing Respirable Crystalline Silica Dust effectively on Construction Sites

European Institute for
Construction Labour Research

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Reducing Respirable Crystalline Silica Dust effectively on Construction Sites

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REPORT

THIS REPORT is the result of a joint project between the EFBWW and FIEC, the EU sectoral social partners for the construction industry.

THE CONTENT AND PRODUCTION of this guide is the combined and joint work of the project steering group and their external experts actively involved in the project, namely: Jean Marie Branstett, FO / France; Domenico Campogrande, FIEC / Belgium; Christine Deneuvillers, OPPBTP / France; Christian Depue, Constructiv / Belgium; Luis Díaz López, Instituto Nacional de Silicosis / Spain; Christine Le Forestier, FIEC / Belgium; Rolf Gehring, EFBWW / Belgium; Matthieu Lassus, OPPBTP / France; Norbert Kluger, BG BAU / Germany; Marie Thérèse Mbida, FNTP / France; Nadège Larrigaudière, FFB / France; Nikolaus Neiss, AUVA / Austria; Karl C. Nordby, STAMI / Norway; Reinhard Obermaier, ISHCCO/Luxembourg; Willem Van Peer, Constructiv / Belgium; Dr. Reinhold Rühl, Ökopol / Germany; Anja Siegemund, Hauptverband der deutschen Bauindustrie / Germany; Martin Sonnberger, PORR / Austria; Dr. Olaf Wirth, Ökopol / Germany.

PROJECT COORDINATORS
EFBWW European Federation of Building and Woodworkers
FIEC European Construction Industry Federation AISBL

RESEARCH
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FOREWORD

THE EUROPEAN SOCIAL DIALOGUE for the construction industry has a long tradition of paying great attention to the working conditions in the sector. A dedicated working group was already established about two decades ago. Even though positions may differ, e.g. when new occupational exposure limit values or their revision are discussed at European level, the Social Dialogue partners normally find common ground on the issue of prevention at the workplace. Over the years, many joint activities and EU-funded projects have been carried out. Topics addressed by the social dialogue included OSH management systems, the EU-OSHA campaign on safety and health in construction, discussions on EU OSH strategies, nanomaterials in the construction sector, training modules on asbestos or psychosocial risks at work.

We share the conviction that the European legal framework, in particular the concept of the European Framework Directive on Safety and Health at Work, has improved workplace prevention across Europe. However, the complexity of the legal framework, combined with national traditions and institutional differences, needs to be taken into account in order to ensure that this legal framework is applicable in practice. The European institutions should therefore pay attention to and be involved in the legislative implementation adopted by the European Union. Practical experiences, difficulties or success stories should guide European level reflections, discussions and conclusions. For these reasons, the EFBWW and FIEC consider it important to support the implementation of EU law by providing guidance documents on specific topics that can be used by practitioners at company level.

The 2017 revision of Directive 2004/37/EC on carcinogens and mutagens established an EU occupational exposure limit value of 0.1 mg/m^3 for respirable crystalline silica dust (RCS). As it is estimated that 75% of all workers exposed to RCS work in the construction industry, FIEC and the EFBWW established a small working group to discuss the implications of the new limit value for the sector and possible joint actions to support better prevention and successful implementation of the new occupational exposure limit value. The problems are obvious. There is no fixed workplace. The variety of tasks, materials and equipment used is enormous, as different occupational groups have to work together. Working conditions and possible exposure conditions change constantly, as do environmental conditions, especially weather conditions.

As the European regulation needed to be integrated into different prevention practices and underlying concepts in the member states, the European social partners in the construction sector, EFBWW and FIEC, agreed to accompany this process and to support practitioners in the most practical way possible.

Although it will be a long and rocky road to reduce exposure to the current limit value in all construction activities, we can draw on good practices and on enormous experience in organising prevention and implementing risk reduction measures in the workplace. In addition, technical possibilities have improved and many tools used currently in construction work emit less dust. Against this background, EFBWW and FIEC jointly applied for the EU-funded project "Reducing Respirable Crystalline Silica Dust Effectively" to implement the new occupational exposure limit value for silica dust in construction. The project aims to provide information and guidance to practitioners at company level, to national social partners in the construction sector and to other stakeholders such as prevention authorities.

The more specific objectives of the project were:

- To draft this research report with information on the state of the art in RCS prevention, including the most advanced technical and organisational solutions for prevention on construction sites.
- To do a mapping exercise, describing the technical and organisational measures for as many construction activities as possible to reduce the emission or exposure below the limit value. This is an easy-to-understand publication with many photos using the so-called "traffic light system". A green light indicates prevention practices that will meet the limit value, a red light indicates practices that will never meet the limit value, and a grey zone indicates practices that are still unclear and may be closer either to green or red.
- We know that there are still construction activities where the limit value cannot be reached, even if the most advanced technology and best organisational measures are applied. These activities are also mentioned together with info on the research and technological innovation required to reach the limit value.

The report presents procedures and practices that ensure compliance, for most construction activities, with the EU occupational exposure limit value for RCS.

It discusses advanced practices and persisting challenges in the sector, based on collected exposure data, technical articles and practical experience on construction sites from all over the world, focusing on Europe.

The report takes a new approach in that it rarely refers to the wearing of personal respiratory protection, but rather recommends a combination of technical protective measures first.
With this report, we hope both to promote practical prevention on construction sites and to contribute further to the debate on better prevention and accompanying research.

Dr. Reinhold Rühl ÖKOPOL
Christine Le Forestier FIEC
Rolf Gehring EFBWW

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SUMMARY

DUST IS OMNIPRESENT ON CONSTRUCTION SITES; it is part of construction operations. However, construction dust always contains quartz, and can lead to serious diseases such as silicosis, chronic obstructive pulmonary disease (COPD) or lung cancer. In 2017, the EU set a limit value for respirable crystalline silica (RCS), 0.1 mg/m^3, to which EU countries must respond. Currently, EU countries have different limits for quartz dust.

These different limit values, as well as the diversity of conditions on construction sites, mean that is is difficult to make generally valid statements about the exposure of construction workers to dust and the necessary protective measures. This is because work in the construction industry takes place both in confined and large open spaces, there is a wide variety of weather and climatic conditions, the activities vary in duration, and construction work is carried out by individuals as well as by teams.

If, however, rather than a job an activity is considered and this activity is accompanied by dust measurements under the many different conditions occurring in practice, one obtains a set of measurement data that quite accurately represents the exposures during this activity.

Thus, all measurement data show that at least one of the limit values for RCS (S), respirable (R) or inhalable (I) dust is exceeded when working on construction sites without protective measures, even if the highest limit values in European countries (I: 10 mg/m^3; R: 6 mg/m^3; S: 0.15 mg/m^3) are taken as a basis. Measures are therefore always necessary.

When protective measures are sufficient for the various activities, these values must be considered in more detail. Many studies show that the limit values can be undercut when using cut-off grinders, grinding machines or demolition hammers with extractors. However, there are always conditions under which this is not possible despite the use of an extraction system. For this reason, almost all studies call for additional respiratory protection. At the same time, however, these studies point out the lack of protective effect of respiratory protection, especially on construction sites.

This report takes a different approach, also with regard to the STOP principle. If possible, technical measures are preferable to personal protective measures. Therefore, the use of air cleaners is called for in addition to the methods used for extraction with handheld tools.

Air cleaners are not very well known on construction sites. However, they can be used to achieve almost dust-free work, especially indoors. Even when working outdoors, for instance on a façade, the use of an air cleaner can make the difference between falling below or exceeding a limit value.

With this in mind, good or bad practices with respect to dust exposure are described for many activities on construction sites. The aim of this project is not to produce even better scientific characterizations of dust exposures on construction sites. Rather, practical recommendations for dust reduction are given, which are based on exposure data as well as on empirical values and pragmatic assessments.

The basis for classifying an activity as good or poor practice is the extensive set of measurement data from the international literature and experience on construction sites. For some activities, for which the international literature describes high dust loads, innovative developments in individual countries can be identified.

Measurement data were not found for all activities, and the measurement data do not always indicate a trend. Where insufficient data or experience was available, this is also presented. Finally, where improvements are necessary is also indicated.

1. INTRODUCTION

Dust in the workplace is often viewed as a painful reality, whether it is the dust in the office, the dust in the quarry, in agriculture or at construction sites. It's annoying, but it's normal, so to speak, it's always been there. But more and more attempts are being made to avoid dust.

Especially when renovating existing buildings, building owners demand "dust-free" work. There are even craftsperson's who advertise that they work with little dust (Fig. 1). It's about the "annoyance" of dust, about avoiding the extensive cleaning otherwise necessary. Because for many, dust is harmless; it is primarily perceived as annoying because, once it has occurred, it is associated with cleaning work.

In addition, high levels of dust are damaging to the image, regardless of the silica content. In times of a lack of skilled workers, this is a not insignificant aspect.

But dust is not only a nuisance, it is dangerous for people. Especially on construction sites many different and very dangerous dusts occur. Almost everyone knows about asbestos dust, and the fine dust issue should be well known from the environmental debate in many countries. And what about the "normal" dust on construction sites?

FIGURE 1: Advertising of a bathroom studio for dust-free work ("*Staubfreies Arbeiten*") with "Air-Clean technology"

Doesn't it contain RCS? Of course, we know about the lung diseases of the miners, but isn't RCS also part of the dust produced during construction?

This report is intended to provide background information and answers to questions on the subject of dust on construction sites from the point of view of occupational health and safety. However, the respective building owners, residents or occupants of the buildings are also affected by the construction work.

The limit values for inhalable dust, respirable dust and RCS applicable in EU countries are shown, and the dust exposure during the various activities on construction sites is described based on a large amount of measurement data from international publications. And it is shown that it is almost always possible to work with little dust.

This report aims to raise awareness of the issue of dust – neither trivializing nor dramatizing. It is usually technically possible and affordable to work with a minimum amount of dust, if not dust-free. Communicating this is the main aim of this report.

1.1 Diseases caused by dust on construction sites

Like asbestos, lead or wood, crystalline silica does not pose a risk when installed. They can only become a problem during processing and removal if they appear in the form of dust. Dust is above all dangerous if it can be inhaled or even gets into the lungs.

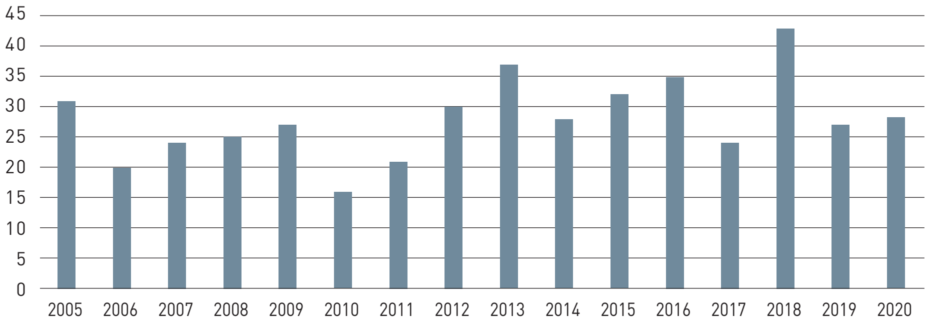
Inhaling RCS can lead to serious health effects such as Chronic Obstructive Pulmonary Disease (COPD), silicosis, and lung cancer. Workers exposed to RCS are also at an increased risk of tuberculosis, kidney disease, cardiovascular diseases, and diseases of the immune system such as scleroderma, rheumatoid arthritis, and systemic lupus erythematosus; although these are quite uncommon (Dement, 2015; SLIC, 2016; Collegium Ramazzini, 2016; Möhner, 2017; Carrieri, 2020). Shtraichman et al. (2015) reported about the outbreak of autoimmune disease in silicosis linked to artificial stone.

The SHEcan project www.occupationalcancer.eu, sponsored by European Commission DG Employment, estimated that in 2010 in the EU in about all branches there would be about 6870 deaths from lung cancer and about 7645 cancer registrations that might be attributable to past exposure to RCS (SHEcan, 2011).

The British HSE reports "many more construction workers were killed by occupational cancer compared to accidents. It is estimated that for every fatal accident in 2012-13, approximately 100 construction workers died from a work-related cancer" (HSE, 2020). And the British 'All Party Parliamentary Group for Respiratory Health' describe under the title "Silica – the next asbestos?", that over 500 construction workers died from silicosis in 2005 (APPG, 2019).

Figure 2 shows the RCS-related deaths in the companies insured by BG BAU in Germany. However, RCS-related deaths amongst electricians, the majority of heating, plumbing and air conditioning companies, and about half of the stonemasons and demolition companies insured with other trade associations are missing.

FIGURE 2: Fatalities caused by RCS as registered by BG BAU in Germany



This is the result of the still too high RCS concentrations on construction sites. RCS-related diseases are still relevant. This is not changed by the fact that the latency period for these diseases is often very long and that the exposures for today's diseases occurred a long time ago. Anyone who looks with open eyes at construction sites knows that the dust situation has changed little over the years. Because no effective treatment exists for silicosis, prevention through exposure control is essential (Meeker, 2009).

Easterbrook and Brough (2009) estimate how many quartz-related deaths could be prevented in Great Britain, depending on the level of the limit value for RCS (Table 1).

Fine dust is a problem even if it does not contain RCS or other 'hazardous substances'. Wiebert et al. (2012) assessed that occupational exposure to particles increases the risk of acute myocardial infarction and other ischemic heart disease. In the justification for the limit value for respirable dust, the Committee for Hazardous Substances in Germany states (AGS, 2014):

"The aim of the AGW for A-dust [limit value for respirable dust] is to avoid chronic, particle-related inflammation processes in the lungs, which is also at the same time coupled with pathological changes, such as Fibroses and the formation of lung tumors observed in animal experiments on rats can be prevented.

Together with environmental medical data, which show the influence of dust particles even in the microgram concentration range on cardiovascular and lung-related morbidity and mortality, the information obtained in occupational medical studies suggests that even very low levels of dust can cause non-negligible effects."

TABLE 1: Estimation of RCS-related deaths over 60 years in Great Britain that could have been prevented depending on the limit value (Easterbrook and Brough, 2009)

POTENTIAL EXPOSURE LIMIT	DEATHS PREVENTED
0.30 mg/m^3	36
0.10 mg/m^3	185
0.05 mg/m^3	300
0.01 mg/m^3	455

2.1 Size of dust particles

Many companies, including employees, still lack an awareness of the dust problem. In addition to the habituation effect – dust has always been part of work – a major cause of this is the underestimation of fine dust concentrations.

The visible dust on construction sites is indeed perceived as a nuisance (not as a danger). But since it can no longer be seen after a while, it is quickly forgotten. The particularly small dust particles that can get into the lungs or alveoli cannot be seen, however, and they also stay in the air for a long time.

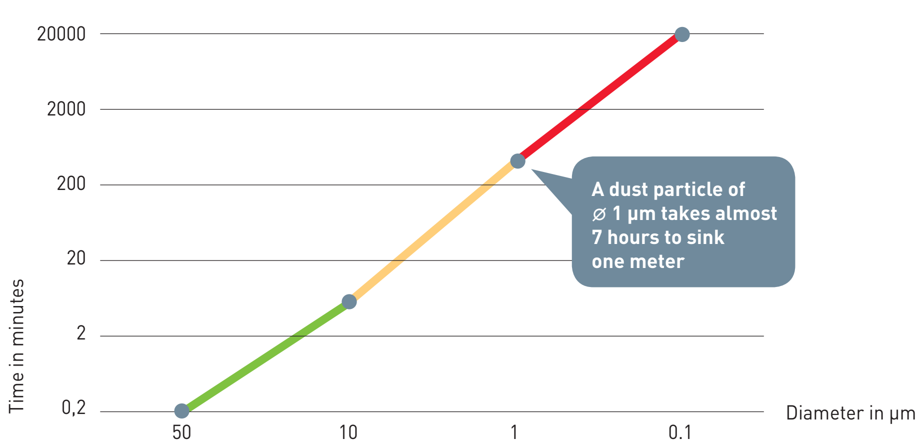
Only in high concentrations is inhalable dust visible to those affected, settling much faster than respirable dust which is accessible to the alveoli. It takes almost seven hours for a dust particle the size of 1 μm to sink one meter (Fig. 3).

The respirable dust can be inhaled for a correspondingly long time and endanger people. Only when this dust is in direct sunlight does it become visible. Everyone knows how small dust particles can be seen in the places where the sun's rays shine into a room. Of course, these particles are everywhere in the room, not just where they can be seen in sunlight. It is difficult to evaluate whether the dangerous fine dust has "cleared". It is still present for a long time after it is no longer seen or suspected in the air.

The finest dust particles (0.1 – 1 μm; 1 μm corresponds to a thousandth of a millimeter, 0.001 mm) can travel particularly deep into the lungs, where they then stick together the alveoli and are stored for months and years. In principle, the lungs can absorb smaller dust concentrations. If you inhale large amounts of dust over long periods of time, the natural cleaning process of the lungs breaks down. Figure 4 shows how the size of the dust particles determines how deeply dust is inhaled.

Even with "short-term" work, much fine dust is whirled up (e.g., when sweeping with a broom or blowing off dust), which then stays in the air for hours before it is removed from the air by ventilation or by sinking.

FIGURE 3: How fast do dust particles sink?



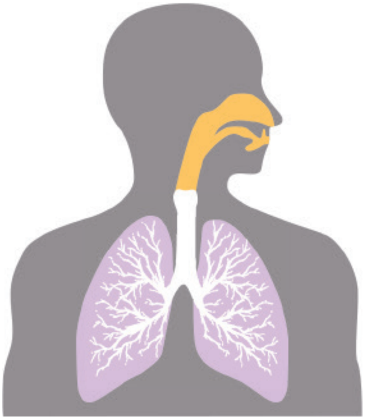


FIGURE 4: The smaller, the deeper the dust particles enter the body

1.3 Content of crystalline silica in construction materials

Before going into the content of crystalline silica in construction materials, a few explanations. There are different crystalline silica forms, here above all quartz and cristobalite. Both forms can occur in construction materials. Cristobalite is mainly found in refractory construction; it is formed during recrystallization of ceramic fibres (Rühl, 1987).

There is also non-crystalline SiO_2 (amorphous silica, e.g. diatomaceous earth), which does not play a role in the construction industry. The literature often refers to “silica dust” or “silica content”. This is actually not correct, because these terms also include amorphous SiO_2. However, since crystalline SiO_2 almost exclusively occurs in the construction industry, this is acceptable.

When construction materials are processed, dust is produced that can be inhaled. The inhalable quartz dust or cristobalite dust is called respirable crystalline silica (RCS). Since quartz dust is almost always present on construction sites, quartz dust is also correct.

It goes without saying that the exposure of employees to RCS and thus the risk of illness is particularly high when processing materials with a high content of crystalline silica. Regardless of the silica content, however, the total dust exposure must be reduced. The dust concentration must fall below the limit values, regardless of whether the processed material processed contains a lot or little crystalline silica.

In the international literature there are many tables of construction materials and the corresponding content of crystalline silica (for example see Table 2). The particular hazard posed by certain materials due to their high content of crystalline silica is also reported (e.g., Artificial Stone, Perez-Alonso et al., 2017; Carrieri et al., 2020; Cooper et al., 2015). Barber et al. (2018), however, could not find any silicosis case in the UK that was attributable to artificial stone. However, it is not very helpful to see the new asbestos

TABLE 2: Amounts of crystalline silica in construction materials (HSE, 2020a)

SANDSTONE, GRITSTONE, QUARTZITE	more than 70%
CONCRETE, MORTAR	25% to 70%
SHALE	40% to 60%
CHINA STONE	up to 50%
SLATE	up to 40%
BRICK	up to 30%
GRANITE	up to 30%
IRONSTONE	up to 15%
BASALT, DOLERITE	up to 5%

here ("Artificial stone dust: the new asbestos". Lawyers, 2018) and thus indirectly to present pollution from other silica as less problematic. Regardless of the content of crystalline silica in the material processed, dust protection measures are always required.

In principle, therefore, the content of crystalline silica of construction materials should not be discussed. Work must always be carried out with low dust. Even if working with low-dust techniques must be standard, artificial stones, or working with artificial stone, represent a special challenge. Here the content of crystalline silica is over 90%, the dust that occurs therefore consists almost entirely of crystalline silica. Even if you work briefly without protective measures, there is a high risk of developing silicosis (Horn, 2019). Silica-related diseases usually do not appear until 40 years after initial exposure. Perez-Alonso et al. report in 2014 on 46 workers who worked on artificial stones and who were already ill at 33 years of age (interquartile range: 29 – 37 years) with an exposure of only 12.8 years (mean). They had worked without control measures.

This report therefore does not go into further detail on the silica content in different construction materials. Work must be carried out with little dust, regardless of the content of crystalline silica.

Asbestos is not an issue in this project. Asbestos abatement requires elaborate protective measures beyond those proposed here in this project to protect against quartz dust. However, the dust measures proposed here may protect workers in the event of unforeseen asbestos exposure, although not always adequately.

Nano is also not an issue in this project. However, the dust control measures proposed here effectively restrain nanoparticles. Although nanoparticles are so small that they could actually fly through the filters, they are retained because they move in a zigzag pattern according to Brownian motion and thus remain trapped in the filter.

2. MEASURING DUST ON CONSTRUCTION SITES

In a workplace measurement, a pump draws working air through a filter via a hose. The pump is attached to the worker's belt. The working air is drawn in as close to the worker's face as possible to collect on the filter the pollutants contained in the worker's breathing air (Fig. 5).

The pollutants collected on the filter are then qualitatively and quantitatively determined in a laboratory. The amount of a substance found, together with the amount of air drawn in by the pump during sampling, yields the concentration of the substance in the employee's breathing air. This type of sampling leads to person-specific measurement results.

It is not always possible to have the pumps carried by the employees. Since not all substances can be collected on one filter, several pumps are often necessary, which cannot all be carried by one person; also, some workplaces are so cramped that carrying pumps is very disruptive. Then the pumps are attached to a tripod and the tripod is carried along (person-based measurement).

FIGURE 5: Two pumps on the belt of the employee; the filters are attached above the chest

Finally, stationary measurement is also used, for example in areas where several employees perform the same activity. In this case, the pumps are attached to a tripod in the center of the work area. Often, stationary and person-specific measurements are performed in parallel.

On construction sites, the different measurement methods – stationary, person-specific, person-based – lead to rather small differences, especially in rooms, as the entire room is "dusty" very quickly during dusty work. Outdoors, there could be slightly different results, but this does not affect the aims of this project.

2.1 Measurement method

The sampling system ensures that only the inhalable or the alveolar dust fraction reaches the filter. Dust particles collected on the filters can thus enter the respiratory tract (inhalable dust) or the lungs (respirable dust). Figure 6 shows a new filter and a filter after being 'loaded' with air for 30 minutes while working with a tamper in a trench with diesel soot particles.

In contrast to wood dust, the results of the measurements of inhalable dust, respirable dust and RCS compare very well, even if they were determined with different measuring systems (pump, filter, separation system, ...; Gabriel et al., 2014). Among other things, wood dust has a lower specific weight and is electrostatically chargeable, which leads to sometimes significantly different results with different measurement methods.

2.2 Shift or activity measurements

A measurement over a shift is not representative of an activity on construction sites. A bricklayer performs different types of work, different activities. The proportion of time he or she spends on each during the shift may be different. The same applies to tilers, roofers, etc. Also, with regard to the working environment, temperature, ventilation conditions, influences from other workplaces, etc. hardly any shift is identical to another.

FIGURE 6: Filter of a Diesel exhaust measurement in the trench;
left: new filter, right: filter after 30 min.

Shift measurements can be quite useful, for instance if biomonitoring is carried out at the same time. Biomonitoring, that is the examination of blood, urine, etc. records the exposure in the hours before sampling. Therefore, parallel stratified measurement, such as in case of exposure to carbon monoxide, solvents, styrene, etc., is useful. Biomonitoring is also valuable for certain dusts, and in the case of lead-containing dusts even more informative than exposure measurement.

However, for the dusts considered here, it is more useful to perform measurements on an activity-by-activity basis (Antonsson and Sahlberg, 2019; Flanagan et al., 2003).

"Full-shift samples often include numerous activities, when the target activity was only one of several activities occurring during the sampling period, making interpretation of the results less clear" (Flanagan et al., 2003).

Activity related exposures also facilitate consideration of the effectiveness of low-dust techniques.

3. LIMIT VALUES FOR DUSTS

With the 2017 revision of the Carcinogens and Mutagens Directive 2004/37/EG an Occupational Exposure Limit Value of 0.1 mg/m³ for respirable crystalline silica (RCS) was established. The European Social Partner organizations for the Construction sector consider the practical implementation of this new limit value to be a challenge.

This project is therefore primarily concerned with RCS on construction sites. Data on exposure to RCS are not available for all activities on construction sites, though often data on exposure to respirable dust is to be found, sometimes also to inhalable dust.

In order to be able to make statements on RCS exposure for as many activities on construction sites as possible, data on respirable and inhalable dust, which are often measured in parallel, are therefore taken into account in addition to RCS. Dust on construction sites usually contains a proportion of RCS. A high exposure to respirable or inhalable dust may indicate exposure to RCS.

It is usually the exposure to RCS that requires the use of protective measures. However, there are also activities that require measures in the case of low RCS exposure but high dust exposure. Or there is no information on RCS, but information on respirable dust, which is also harmful in high concentrations. And finally, the image is damaged by dust, whether it contains RCS or not.

The limit value for RCS has been in flux for decades. It has been adjusted again and again, and currently a reduction to 0.05 or 0.025 mg/m³ is being discussed in many countries.

In the countries of the European Union, different limit values apply for RCS in the workplace (between 0.05 and 0.15 mg/m³). Likewise, there are such ranges for the limit values for respirable dust (1.25 – 6 mg/m³). For inhalable dust, the limit value in each of the EU countries is 10 mg/m³, except in Sweden. There, a value of 5 mg/m³ has been in effect since August 2018. Table 3 gives an overview of the limit value situation, also outside the EU countries (a current and detailed list can be found at www.dguv.de/ifa, webcode d6247).

Dust concentrations at construction sites fluctuate during the shift, as do the concentrations of other substances. For this reason, some countries set 'short-term values' in addition to the limit values for an 8-hour shift. These indicate how far exposure may exceed the limit value in the short term. The 8-hour shift value must still be complied with. The short-term values for the dusts considered here are almost always twice the limit value.

The limit values for the three dusts listed in Table 3 differ significantly in some cases. For example, the limit value for RCS in Hungary is three times as high as in Denmark or Germany. For respirable dust, there is even a difference of a factor of 4 between Hungary and Germany.

TABLE 3: Limit values for RCS, respirable and inhalable dust (mg/m^3)

	RCS	RESPIRABLE	INHALABLE
AUSTRIA	0.05	5	10
BELGIUM	0.1	3	10
DENMARK	0.05	5	10
FINLAND	0.05		
FRANCE*	0.1	5	10
GERMANY	0.05	1.25	10
HUNGARY	0.1	6	10
IRELAND	0.1	4	10
LATVIA	0.1		
NETHERLANDS	0.075		
POLAND			10
SPAIN	0.05**	3	10
SWEDEN	0.1	2.5	5
UNITED KINGDOM	0.1		
EUROPEAN UNION	0.1		
SWITZERLAND	0.15	3	10
AUSTRALIA	0.1		
CANADA – QUÉBEC	0.05		
ISRAEL	0.1		
NEW ZEALAND	0.2		
SINGAPORE	0.1		10
SOUTH KOREA	0.05	3	
USA	0.05	5	15

* The limit values for respirable and inhalable dust in France are only applicable in rooms with specific pollutions (so construction sites are rarely concerned by those values). But, when there is RCS in dust, those values are used, for workers on construction sites, through a formula that has to be respected.
** from 2022

There are two main reasons for these differences. Limit values are derived from epidemiological studies (here mainly RCS) or from the results of animal studies (here mainly inhalable and respirable dust).

In these derivations, safety factors are always used in order to take into account, for example, the differences between animals and humans or individual humans, or the framework conditions of the exposures considered in epidemiological studies, which cannot be completely clarified. In addition, socioeconomic considerations are usually made when setting limits, representing a trade-off between economic benefits and risks to human health (Plate 1).

This explains the differences in dust limits across EU countries. This is in no way to criticize these decisions. However, knowing the background of such decision-making makes it easier to arrive at pragmatic results when assessing exposures.

This is because, taking into account the dust exposures presented in the report, it becomes clear that these differences in limit values hardly play a role with regard to the necessary and sufficient protective measures in the construction industry.

Without protective measures, even the highest dust limit values are exceeded, and with sufficient protective measures, the lowest limit values can be complied with.

For those who have to comply with or control the limit values, it is of course a difference whether the RCS limit value is 0.05 mg/m^3 or 0.15 mg/m^3. This is especially true for stationary workplaces where the working and environmental conditions, and thus the exposures do not or hardly change over the shift (mainly assembly line workers, but also many workers in the chemical or electrical industry).

With regard to exposure to dusts on construction sites, however, the different safety factors or socio-economic considerations and the resulting different limit values in the various countries play less of a role. In simple terms, these dust exposures are above all limits when working without protective measures. If work is carried out correctly with the right protective measures, even the lowest limit value can be complied with.

PLATE 1: Limit Value Findings Using the Example of Sweden and Germany

In the Swedish Work Environment Authority's referral with proposals for new regulations on hygienic limit values in 2017, it was proposed that the limit value for quartz should be halved to 0.05 mg/m^3. After extensive comments from several consultative bodies, the decision was made not to lower the limit value for quartz. From an occupational medicine perspective, it is considered justified to lower the limit value and doctors at the occupational and environmental medicine clinics consider that a reduction to ¼ part of the current limit value is medically justified (Antonsson and Sahlberg, 2019).

In Germany, toxicologists had suggested to the Committee on Hazardous Substances that the limit value for quartz dust should be in the range of 0.01 to 0.025 mg/m^3 in order to also protect against lung cancer (AGS, 2015). A limit value of 0.05 mg/m^3 was adopted.

TABLE 4: Exposures during drilling in walls and ceilings
(mg/m³, Range or geometric mean (GM), number of measurements in parentheses)

WITHOUT EXTRACTION	BG BAU	DEURSSEN 2014	SHEPARD 2009
RESPIRABLE DUST	GM 1.34 (18)	0.02 – 10.9 (46)	GM 3.77 (4)
RCS	GM 1.155 (18)	0.0 1 – 1.36 (46)	GM 0.308 (4)

WITH EXTRACTION	GRAHN 2017	ANTONSSON 2019
RESPIRABLE DUST	0.56 1.01 (2)	0.15 0.16 (2)
RCS	0.054 0.071 (2)	0.009 0.01 (2)

This is illustrated by the example of drilling holes in walls and ceilings. If drilling is carried out without extraction, even the highest limit values for respirable dust (6 mg/m³) or RCS (0.15 mg/m³) are exceeded (Table 4). If extraction drills or vacuum cleaner adapter are used, the concentrations are drastically lower. If, as shown in the following chapters, air cleaners are still used, even the lowest limit values for these dusts are undercut.

4. DUST EXPOSURE ON CONSTRUCTION SITES

Almost all construction workers are exposed to dust. For decades, literature has reported on the high dust exposures on construction sites. “The use of hand-held saws and angle grinders without dust suppression or extraction is commonplace. The very familiarity of Stihl saws and angle grinders may mean that no one gives a second thought to the dust they produce or the harm it may do to workers’ future health” (Chisholm, 1999). Hallin points out the possibilities of low-dust systems as early as 1983. In Germany, Schulz stated as early as 1973 “The times when wearing respirators was considered a practical protective measure are definitely over. Personal respiratory protection must nowadays, where at all possible, be made unnecessary by technical dust protection measures.”

And today? The SHEcan report (2011) on respirable crystalline silica estimates that 63.2% of the workers in the construction industry in Europe have been exposed above 0.05 mg/m^3 RCS (47.6% >0.1 mg/m^3, 32.3% >0.2 mg/m^3). The highest percentage of measurements exceeding the exposure limit proposed by ACGIH was in the construction sector (93%; Scarselli et al., 2014).

The conditions in the training centers show how much dust is taken for granted in construction. Cleaning with a broom is often still the rule there. The high dust exposure is also confirmed by measurement data (Table 5, “Training of construction workers in vocational schools”).

The aim of this project is not to characterize dust exposures on construction sites to a greater scientific level. Rather, practical recommendations for dust reduction are given, which are based on exposure data, but also on empirical values and pragmatic assessments. Thus, it may well make sense to combine sets of measurement data of stationary and personal measurements, which would not do justice to a purely scientific approach (Beaudry et al., 2013).

4.1 Exposure determination

The European Chemical Agents Directive 98/24 requires in Article 4, paragraph 5, that the employer determines the level, type and duration of exposure before the start of the activity (Plate 2). This is also required by directive 2004/37/EC for carcinogenic substances.

Determination can mean that the employer carries out measurements at the workplace. This is particularly useful when workplaces are unchanging for days, months or even years, as on an assembly line or in an office. On construction sites, this approach is not very helpful, because the results of a measurement are usually only available after a few days or weeks, when the construction site, and thus the general conditions of the workplaces, have changed again or the site has come to an end (see also Antonsson and Sahlberg, 2019).

Paragraph 4 in Article 6 of the Chemical Agents Directive 98/24 opens the possibility to demonstrate "by other means of evaluation" exposures at the workplace. By other means of evaluation means that employers can rely on measurement data or assessments obtained at workplaces or during activities similar to those of their employees. Of course, employers can take their own measurements at any time if, for instance, they believe that they have different conditions.

The aim of this project is to compile the exposures for as many activities on construction sites as possible in order to document the dust exposure. In accordance with Article 6 (4) of the European Chemical Agents Directive 98/24, the employer can use this to carry out a risk assessment without further investigation and to take the right measures immediately.

The possibility of using recommendations for risk assessment is also used in the USA. OSHA issues fact sheets for many activities. "Employers may either use the control methods listed in Table 4 of the construction standard, or they may measure worker exposure to silica and decide independently which dust controls are most appropriate to limit exposure in their workplaces to the PEL." (OSHA, 2020). Similar lists of activity-based recommendations include the "National labour inspector RCS task sheets" (SLIC, 2016), TNO's "Prevention control measures respirable quartz" www.dustfreeworking.tno.nl/information/prevention-control-measures-res~ or from the British HSE's "Construction dust: Specific tasks" www.hse.gov.uk/construction/healthrisks/hazardous-substances/construction-dust-specific-tasks.htm

4.2 Exposure data in the literature

The basis for the literature research on dust exposures on construction sites were the documents that came from the steering group of the project. In particular, the current reports from France (ANSES, 2019) and Sweden (Antonsson and Sahlberg, 2019) were of great help with their bibliographies.

The focus was on publications from Europe, but many publications from other countries were also included in the research. From all papers, data for inhalable dust, respirable dust and RCS were noted where available. High exposures to respirable dust are usually associated with high exposures to RCS. And low respirable dust exposures usually mean low RCS exposures. But there are exceptions. For example, dust exposure when working with gypsum is often high with low RCS exposures. Therefore, it is useful to look at the data for all three dusts as far as possible.

In Germany, there is a great deal of exposure data, but it has only been published in German (BGIA-Report, 2006; BG ETE, 2009; BG ETEM, 2014; TRGS 559). At the BG BAU, responsible for the construction industry, a less scientific but more pragmatic approach is taken. Measurements are taken on construction sites and many investigations

PLATE 2: Extract from the European Chemical Agents Directive 98/24

ARTICLE 4: Determination and assessment of risk of hazardous chemical agents

1. ... the employer shall first determine whether any hazardous chemical agents are present at the workplace. If so, he shall then assess any risk to the safety and health of workers arising from the presence of those chemical agents, taking into consideration the following:
   - their hazardous properties,
   - information on safety and health that shall be provided by the supplier, (e.g. the relevant safety data sheet in accordance with the provisions of Directive 67/548/EEC or Directive 88/379/EEC),
   - the level, type and duration of exposure,
   - the circumstances of work involving such agents, including their amount,
   - any occupational exposure limit values or biological limit values established on the territory of the Member State in question,
   - the effect of preventive measures taken or to be taken,
   - where available, the conclusions to be drawn from any health surveillance already undertaken.

5. In the case of a new activity involving hazardous chemical agents, work shall only commence after an assessment of the risk of that activity has been made and any preventive measures identified have been implemented.

ARTICLE 6: Specific protection and prevention measures

4. Unless the employer clearly demonstrates by other means of evaluation that, in accordance with paragraph 2, adequate prevention and protection have been achieved, the employer shall carry out on a regular basis, and when any change occurs in the conditions which may affect workers' exposure to chemical agents, such measurements of chemical agents which may present a risk to worker's health at the workplace as are necessary, in particular in relation to the occupational exposure limit values.

are carried out in a test room. In addition, experience on construction sites is incorporated into corresponding recommendations. Furthermore, knowledge is gained through cooperation with manufacturers, who further develop their equipment according to the investigations in the test room.

Therefore, the statistical considerations necessary for international publications are at the background of BG BAU's prevention work. The acceptance of low-dust techniques is important for BG BAU in order to reduce dust exposure on construction sites.

As far as possible, the following data on dust exposure during activities on construction sites were taken from international literature: number and range of measurement data, geometric mean, mean and 95 percentiles.

TABLE 5: Job and branch-related exposures to dust at construction sites as listed in the corresponding literature (mg/m³)

	Radnoff (CA) 2014	INAIL (IT) 2019	Rappaport (US) 2003
	Kirkeskov (DK) 2016	Deurssen (NL) 2014	Network Italiano 2007
JOB / BRANCH	DGUV, Arnone ´20 (DE)	McLean (NZ) 2017	Scancarello (IT) 2020
Painter	S06: 0.008 - 0.12 GM 0.036		R14: 1.16 - 833 m 13.5 S14: 0.26 - 26.2 m 1.28
Bricklayer	S16: 0.017 - 1.0 GM 0.105	R12: 0.04 - 0.59 GM 0.22 S12: 0.01 - 0.04 GM 0.02	R11: 0.16 - 29.0 m 2.13 S11: 0.00 7 -14.2 m 0.32
Carpenter	I38: 0.08 - 8.40 GM 1.26 R25: <0.09 - 1.5 GM 0.27	R21: 0.03 - 4.67 GM 0.22 S21: 0.01 - 0.09 GM 0.02	
Carpenter	S11: 0.013 - 0.041 GM 0.023		
Carpenter and Joiner			S115: GM 0.045 93% >0.025
General labouring		S05: <0.001 - 0.222 GM 0.004	S505: GM 0.045 93% >0.025
Electrician	S05: 0.015 - 0.064		
Training of construction workers in vocational schools	I19: 0.33 - 26.8 GM 4.49 95 22.05 R24: 0.3 - 4.24 GM 4.49 95 3.71 S22: 95 0.237		
Conversion, renovation of buildings			S80: GM 0.026 95 0.259
Road and railway construction			S43: GM 0.036 95 0.247
Specialised construction work			S18: GM 0.028 95 0.584
House builder		R08: GM 0.296 S07: GM 0.009	
Asphalt paving machine		R10: GM 0.325 6.1% > 1.5 S10: GM 0.020 25.6% > 0.05	
Road construction workers		R23: GM 0.145 S22: GM 0.010	

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

The appendices "Activity related exposures" and "Dust exposure on construction sites" show the data considered in the project. It should be noted

- The measurement data sets usually show a wide range. This can only be surprising when measured data from stationary workplaces are taken as a basis. On construction sites, a wide variety of conditions prevail (premises, temperatures, neighboring trades, ventilation, etc.), the diversity of which is reflected in the range of measurement data.
- Older exposure data can also be used, since no "revolution" has taken place with regard to the processing techniques.
- Dust exposure on construction sites is always significantly above the limit values when working without protective measures.
- There are many other papers on dust exposures on construction sites, mostly on activities for which exposure data are already listed in Appendix.

There are also publications with data sets on jobs or even on branches (Table 5). They show that dust exposures on construction sites are very high overall. However, these data sets do not give any indication of particularly problematic or less exposed activities. They are therefore no help in determining protective measures.

4.3 Tunnel work

Tunneling is an essential sector of the construction industry. Tunneling work involves a variety of risks (Carsat Rhône-Alpes, 2013), including dust exposure. The level of dust exposure depends on the construction method, as well as the rock on which the work takes place.

As with many other construction activities, there are numerous publications on dust exposure for tunneling (including Galea et al., 2016).

In conventional tunneling, the work is performed in a sequence that repeats several times in a shift – drilling, blasting, clearing, securing. This work is usually carried out in a 10-hour shift. Therefore, the limit values have to be converted accordingly (e.g. the limit value for RCS for an 8 h shift is 0.1 mg/m^3, for a 10 h shift 0.1 x 8 / 10 mg/m^3 = 0.08 mg/m^3). All these are special features compared to 'normal' construction sites.

Above all, however, the client specifies the framework conditions for occupational safety more than for any other construction site. The tunnel diameter already determines how the work and the occupational safety measures are to be designed. For example, the diameter of the ducts required for ventilation increases with the length of the tunnel, which requires an increase in the tunnel diameter.

In 2021, BG BAU in Germany will carry out extensive evaluations of many hundreds of RCS measurements. The results will be available in 2022 and can therefore not be given in this report. In Austria, a paper on protective measures against carcinogenic hazards from mineral dusts is currently being prepared.

Therefore, this report does not deal with dust exposure during tunnel work.

Already in 2019, the branch solution "Dust minimization in tunnel construction" www.bauindustrie.de/verband/bundesfachabteilungen/news-detail/staubminimierung-im-tunnelbau was developed by the German social partners of the construction industry on the basis of exposures to inhalable and respirable dust. Although the reference to RCS is missing here, the dust protection measures are corresponding.

Track construction work in tunnels is described in the branch solution "Dust minimization in track superstructure" in 2017:
www.bauindustrie.de/verband/bundesfachabteilungen/news-detail/branchenloesung-staubminimierung

5. EVALUATION OF DUST EXPOSURE ON CONSTRUCTION SITES

Dust on construction sites almost always contains silica. Even in drywall work, where plasterboard, wood and metal are usually handled, RCS is found (Grant et al., 2019). It may come from other trades on the site or have been created by drilling holes in concrete or stone. Even if – which is unlikely – a dry construction site really should become free of RCS at one point, the next construction site is certainly not so.

In terms of dust prevention, discussions about RCS loads that may not be present on individual construction sites distract from the goal of working with low dust levels in general. Companies must provide the necessary equipment and workers must use it.

There is no evidence from the exposure data in the international literature that recent data on working without protective measures are lower than older data. There is no question that working without low-dust techniques exceeds the limits for inhalable dust, respirable dust and RCS.

The data also show that when low-dust techniques are used – grinder, handhold breaker, core drill, etc. with on-tool extraction – dust exposure can be drastically reduced, in some cases by more than 90%.

In most cases, such studies are carried out with the aim of demonstrating the effect of the low-dust technique (by how many percent exposure is reduced compared to work without extraction). Again, and again, these publications point out that compliance with the limit values cannot be guaranteed, partly because too few measurements are available, partly because the limit value is exceeded in the individual measurements from a data set. Therefore, the use of respiratory protection is usually referred to as a "backup measure".

The Senior Labor Inspectors' Committee (SLIC, 2016) also calls for respiratory protection in addition to low-dust technology (extracted machines or addition of water). The English HSE points out in a "controlled dust-hunting video" that: "It is important to note that the extraction does not capture all of the silica. RPE is also needed as a backup measure. It protects against this remaining level of unknown and variable silica risk. It also protects against high exposures caused accidentally by the worker or a fault with the extraction." www.hse.gov.uk/construction/healthrisks/hazardous-substances/chasing-concrete-and-raking-mortar.htm

But surely it cannot be a solution to demand respiratory protection despite the use of technical protective measures? This is only because these protective measures may not be used correctly or are insufficient.

Neither the companies nor the workers could be made to understand that they should use technical protective measures and still have to wear respiratory protection. On the one hand, it is possible to combine technical protective measures in order to push the dust exposure below the limit values. On the other hand, it is neither common nor sensible to demand respiratory protection all the time for all possible faulty operations.

Of course, deficits can occur even when using modern low-dust techniques. In addition, there are situations in which the extraction system, e.g., on stone saws, does not completely capture dust. If a concrete block is cut on a base, dust is only produced on the surface and is captured by the extraction system. If the stone is cut without a base, dust is also produced on the underside, which is not captured by the extraction system.

Exposure can also occur because the water is not sufficiently renewed during wet cutting. On construction sites, it is also observed that there are no filters or no collection bags in the vacuum cleaners and that the dust rejected is then simply poured into a container – again releasing a lot of dust. And of course, with higher content of crystalline silica in the material processed, improper work is more likely to result in a limit value being exceeded than with lower content of crystalline silica in the materials.

Someone who does not work so cleanly in other ways either will probably handle the low-dust techniques correspondingly inadequately.

All these limitations should not prevent the use of low-dust techniques. Just as any construction work can be done carefully or sloppily, a well-trained and motivated construction worker will use low-dust techniques correctly and produce the desired low-dust effect.

Only very rarely is reference made to supplementary technical measures such as air cleaners, which can be used to effectively reduce the dust loads that are still present even if extraction is available. Especially when working indoors, air cleaners are the solution not only to reduce dust exposure by using extraction systems, but also to comply with the limit values and thus dispense with respiratory protection. If an air cleaner is used as a backup measure, respiratory protection is not necessary.

This report shows what can be achieved and draws attention to problems. Implementation must be done on site and depends on the right training, the right equipment, but also on the will of the workers.

The approach may not be scientific, but scientific knowledge is not always consistently transferable to practice. Adaptations are needed, especially in non-stationary workplaces.

Both are necessary – scientific reviews and practical regulations or practical conclusions from these scientific findings.

Occupational safety is only possible if, on the one hand, dust exposure with and without protective measures is scientifically investigated taking into account the construction site situation and, on the other hand, pragmatic recommendations are implemented in practice.

This report attempts a balancing act between both levels. Existing scientifically published or further well-founded measurement data are used to make practical recommendations. It cannot be guaranteed in every single point that the use of low-dust techniques will always fall below the limit values. The goal is to create a dust-free working day, and not just to comply with rules (Limborg et al., 2018).

Many papers give the geometric mean (GM) of their data sets. It should be noted that, in principle, half of the respective measurement data sets are above this value. The GM of a measurement data set is a statistical value, which, however, does not allow any statement to be made for a specific construction site. If a measurement data set is used to assess a corresponding activity on construction sites, the exposure would be estimated too low with the GM in about 50% of the cases.

If one orients oneself to the maximum of the measurement data set, one would be on the safe side. If the maximum is below the limit value, the limit value is complied with for each corresponding activity at each construction site.

However, since there are extreme values in every measurement data set, i.e., very low values as well as very high values, orientation to the maximum value leads to an excessively strict assessment of exposure. In other words, protective measures are taken that are not yet necessary.

Often the 95% percentile is used as a basis. This means that it is not the maximum value that forms the basis for the decision to take protective measures, but a more realistic value. In Germany this approach is also stated in the regulations (TRGS 420, 2019).

6. LOW-DUST TECHNIQUES

The machines, products and techniques shown here can be used to work with low dust, often dust-free. Especially indoors, several techniques should be combined (e.g., sanders with extraction and air cleaner) to be safe.

The low-dust techniques are usually not expensive. A set for a construction crew (e.g., vacuum cleaner, demolition hammer with extraction, and air cleaner; Fig. 7) costs only about 3,000 € (Rühl, 2018).

6.1 Low-dust cleaning with construction vacuum cleaner

The broom is the global standard for cleaning, even on construction sites. However, this creates a lot of dust. "Workers should not clean up with a dry broom or using compressed air" (SLIC, 2016). In Germany, cleaning the work area by sweeping is therefore expressly prohibited (GefStoffV, Annex I, 2.3(6)). OSHA also states in its FactSheet 3630 (2017) "Unless there is a ventilation system that effectively captures the dust cloud, do not use compressed air or blowers to clean surfaces, clothing, or filters because it can increase exposure to silica. Instead, clean with a HEPA-filter equipped vacuum or by wet methods."

FIGURE 7: Low-dust equipment for a construction crew

Dust must be vacuumed up. Removing rubble means pushing the rubble together with a sturdy vacuum cleaner brush, putting the large pieces in a bucket or the wheelbarrow and vacuuming up the rest. The vacuum cleaners used in trade and industry are divided into the categories L, M and H. The vacuum cleaners of the categories L, M and H are used for cleaning. Category L vacuum cleaners are the cheapest and category H vacuum cleaners (known mainly for their use in asbestos removal) are the most expensive.

BG BAU has defined construction vacuum cleaners (*"Bau-Entstauber"*) together with the manufacturers. These vacuum cleaners have special equipment so that they can be used as long as possible in the hard every day work on the construction site both for vacuuming dust and for vacuuming hand machines (chapter 7.3), above all

- Approved as dust extractor, at least for dust class M (EN 60335-2-69, Annex AA);
- Equipment suitable for coarse dirt, smallest internal diameter 28 mm;
- Lines in H 07 RN-F equipment (up to 4 m line also H 05 RN-F);
- washable/wet dirt resistant filters (for wet/dry vacuum cleaners);
- damp dirt-resistant fleece removal bag or plastic disposal bag;
- fully automatic filter cleaning or warning device for increased extraction volumes;
- tested with electric tools with high removal capacity (wall scarifier),
  or identical in construction.

Construction vacuum cleaners (*"Bau-Entstauber"*) that meet these criteria are included in a list: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

When choosing a construction vacuum cleaner, the vacuum cleaner should be weighed against the largest possible volume, so as not to have to empty it all the time, and the volume that is really needed. If the dust container is large, it will also be very heavy when full. If the construction vacuum cleaner is only needed for vacuuming boreholes, a device with a small volume is also sufficient.

It is essential to follow the manufacturer's instructions. Above all, it is important to remove the dust collection bag regularly. „Emptying the extraction unit regularly. Use the correct disposable waste bags. Seal and place in the right waste container. Do not empty these bags to recycle them" (HSE, 2013).

Unfortunately, these dust collection bags are not uniform and very expensive. Although there are only five manufacturers of vacuum cleaners (the many different suppliers of these devices often only modify the color), these have equipped their vacuum cleaners with different disposal bags. These disposal bags are expensive, so construction companies often forgo this purchase. The vacuumed dust is then simply tipped out of the vacuum cleaner into a container. Of course, this leads to enormous dust clouds that counteract or negate the low-dust work.

The aim here should be to design a standardized disposal bag that can then be offered very cheaply, as a kind of giveaway.

6.2 Wet work

The oldest low-dust technique is certainly dust binding with water. The water can be fed automatically to the machines, but often water is also fed manually (Figure 8). There is also the possibility of running the tool through water, e.g., when sawing stones. Here it is important to ensure that the water is changed regularly, otherwise mud is produced which splashes, dries and thus becomes a source of dust. Finally, for larger demolition jobs, spray guns are used to bind the dust.

There are stone saws with water trays that are recessed on one side and have a drainage nozzle at the lowest point, which makes it easier to clean the tray: www.lissmac.com

But "The use of water is not a feasible dust control method for many interior work situations or in the cold" (Flanagan, 2007). And "limitations prevent widespread implementation: a nearby water source is needed for operation, the Worker may become wet and uncomfortable, and freezing temperatures prohibit year-round use" (Middaugh, 2012). Wet work does reduce dust, but not always sufficiently. For example, Beamer et al. (2005) show that low-mist nozzles reduce respirable dust by about 63 %, medium-mist nozzles by about 67 %, high-mist nozzles by about 79 % and free-flowing water by about 93 %.

FIGURE 8: Dust binding by water

FIGURE 9: The mud under the stone saw dries and leads to dust

With this damp or wet work, care must always be taken to remove the resulting mud. Otherwise, after drying, the mud is a new source of dust that can be stirred up (Fig. 9).

During demolition work, spraying water reduces dust formation. Water mist cannons can be used here, and water sprayers on the excavator arm are also useful (Fig. 8).

Wetting of roadways on construction sites to bind dust is dealt with in chapter 6.11.

6.3 Handheld machines with extraction device

In almost all branches of construction, handheld machines are used to work on plaster, bricks, masonry blocks, concrete or sand-lime bricks. Employees are sometimes exposed to very high levels of dust during this work with wall grooving or plaster milling machines, cut-off or orbital sanders, demolition hammers.

Extraction devices for these handheld machines have been available for a long time. Combined with a vacuum cleaner, they at least reduce dust emissions. The effectiveness of these protective measures is being tested in the Netherlands www.dustfreeworking.tno.nl/tools?tools=100038& and in Germany. For years, tests have also been carried out on machines with dust extractors in accordance with DIN EN 50632-1 “Powered electric tools – Dust measurement methods – Part 1: General requirements”; German version 2015. When using these handheld machines with vacuum cleaners, low-dust work is guaranteed. At www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques lists of positively tested machines are maintained.

Many craftsmen are still unaccustomed to working with extraction handheld machines. Without exception, however, they have a positive attitude after using them for the first time (“I didn’t think it was possible to work without dust”).

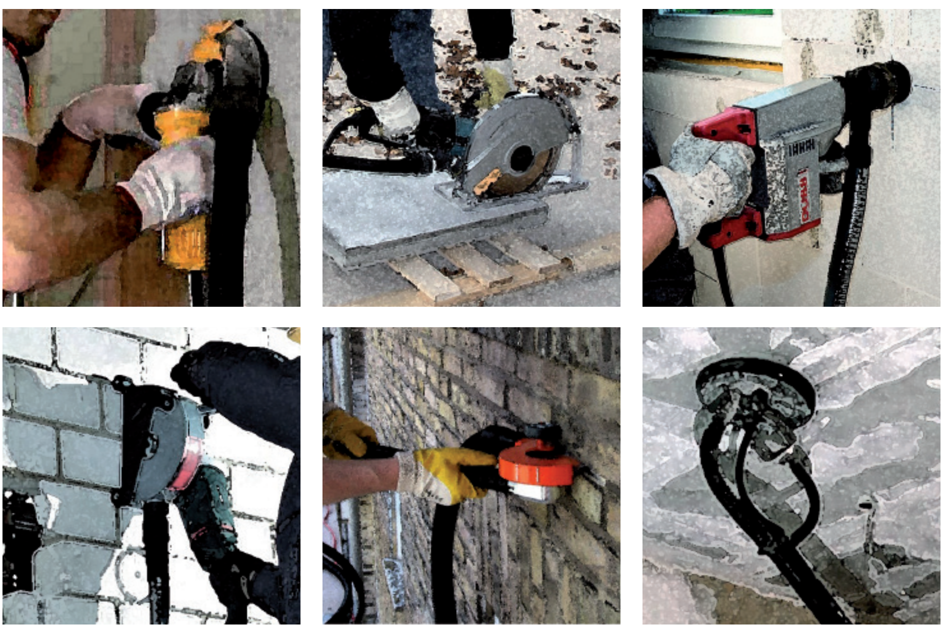


FIGURE 10: Examples of handheld tools with extraction

Almost all manufacturers of handheld machines also offer vacuum cleaners. This could give the impression that these machines can only be operated with dust extractors from the same supplier. However, low-dust work can also be done with vacuum cleaners from other manufacturers. „Manufacturers/ suppliers do provide complete systems, but some parts (especially extraction units) can be used with other tool makes and models" (HSE, 2013).

It is not possible here to go into the many handheld machines with extraction units. Many of these systems can be used in many different activities in many professions. For example, grinders with extraction units are used in concrete restoration, by floor layers or in dry construction, each in special designs.

Special machines/adaptations are also necessary for stonemasonry. Stonemasonry work is not the main focus of this project. However, since they are also carried out on construction sites and the resulting dusts can affect other trades, they are briefly discussed here.

Stonemasonry work is carried out both stationary in the company and on construction sites. This involves not only the renovation of historic buildings, especially churches, but also the installation of kitchen tops, windowsills, stairs, etc. Not all handheld machines used on construction sites are suitable for stonemasonry work. This is because stonemasons have to keep an eye on their workpiece while cutting, polishing, grinding. The usual bonnets with extractors, e.g. on angle grinders, cannot be used here.

There are new developments that enable dust-free working without impairing the view of the workpiece. Merkle and Gunreben (2020) describe a sanding system with extraction in which no extraction bonnet is used, but the dust is extracted very effectively through holes in the sanding disc www.joest-abrasives.de. In measurements, the dust concentrations were below the detection limit.

English-language literature repeatedly reports extremely high dust levels during tuckpoint grinding, the removal of joints between clinkers, even when working with extraction (among other Deurssen et al., 2014; Beaudry et al., 2013; Cooper, M. et al., 2015; Easterbrook and Brough, 2009; Croteau et al., 2002).

A measurement taken by BG BAU in July 2017 during such work with the *Piranha Cutter* from Rokamat showed very low dust levels (Figure 11). Unfortunately, a measurement was not possible on another construction site. However, it was clear that there was little or no dust exposure.

FIGURE 11: Dust-free tuckpointing

6.4 Drill holes with low dust

Drilling holes releases a lot of dust, which is not much different for a do-it-yourselfer who wants to hang up a picture, a lamp or a shelf than for a craftsperson. In the trade, the diameter of the dowels and thus the drill is sometimes larger and the drill more professional. But the process is the same. Very fine dust is always produced, which pollutes the room for hours.

Therefore, it is often common for one partner to drill the hole and the other partner to hold the vacuum cleaner hose under the hole (Fig. 12). This is not necessary, there are appropriate techniques for drilling holes alone with nearly no dust (extraction drill, vacuum cleaner adapter).

VACUUM CLEANER ADAPTER

Vacuum cleaner adapters (Fig. 13) have been on the market for a long time. The drilling dust is extracted at the drill hole. A vacuum is created in the vacuum cleaner adapter, the adapter 'sticks' to the wall and even to the ceiling. One person can drill the holes and there is still no dust, which would spread around the room for hours, especially when drilling in the ceiling.

However, a not inconsiderable amount of dust remains in the drill hole. This dust shortens the usable drill hole depth because it is pushed backwards when the anchor is inserted. It thus reduces the load-bearing capacity of the anchor. Therefore, the approvals (European Technical Approvals / Assessments – ETA – or DIBt approvals) of anchors require dust to be blown out of the drill hole. Here, solutions are required that make blowing out the drill hole unnecessary – the extraction drill.

EXTRACTION DRILLS

Conventional drills have a drill helix to convey the drill dust out of the hole. Extraction drills, in contrast, have a largely smooth cylindrical shank and openings at the tip (Fig. 14), through which the dust is extracted into the vacuum cleaner connected to it via a

FIGURE 12: Left – This is how it is known – the vacuum cleaner nozzle is held under or next to the drill hole; middle – with vacuum cleaner adapter; right – with extraction drill

FIGURE 13: A selection of vacuum cleaner adapters from various manufacturers

coupling attached to the rear part of the drill. The dust from drill holes is thus removed at the point of origin. It is not necessary to blow out the borehole (Rühl et al., 2014).

The extraction of the drilling dust directly in the area of the carbide cutting head means that the extraction drills are in no way inferior to conventional drills with a helix in terms of drilling speed, service life and behavior in the event of reinforcement hits in concrete. The tips of these drills are cooled by the air drawn in, so that the drills run less hot. Extraction drills are virtually a symbol for low-dust work. Extraction drills tested by BG BAU can be found at: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

Extraction drills are one of the technical dust protection measures that do not require the additional use of an air cleaner.

FIGURE 14: Tips of extraction drills and extraction drill with extraction socket

6.5 Air cleaner

Handheld tools with an extraction device are not available for every use on construction sites, and the dust cannot always be completely captured by the extraction system on the machine.

Here, the air cleaner ensures that dust is removed quickly and does not pollute the workers' breathing air. Air cleaners can be used both to capture dust at the point of origin and to clean dust-laden room air; in either case, dusting of the surroundings is prevented. Air cleaners can reduce background levels of dust and quartz (Antonsson and Sahlberg, 2019).

This is done by bringing either the air cleaner itself or a large hose close to the source of the dust. Ideally, the cleaned air is discharged outside. Then a certain negative pressure ensures that no dust enters other areas. It is also possible to return the cleaned air to the work area.

This largely prevents the contamination of neighboring areas. In the work area, the air cleaner serves as a backup measure in case extraction at the handheld tool is not sufficient and to compensate for operating errors.

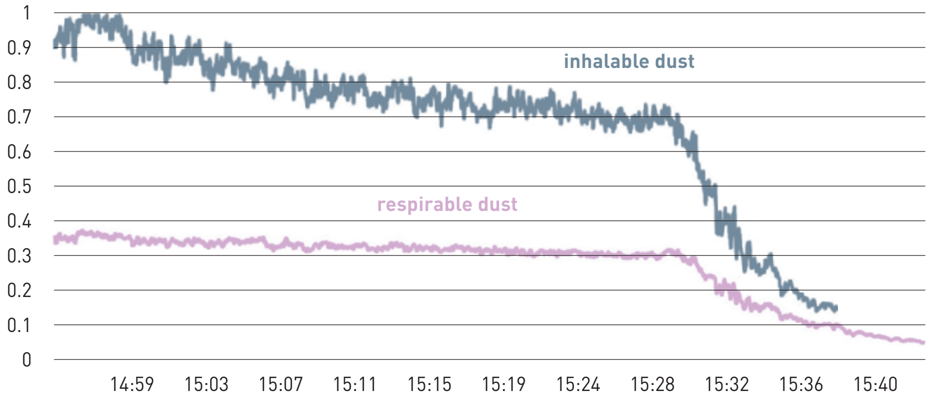
With the additional use of air cleaners, the limit values can be expected to be undercut in most cases. Every column on a construction site should not only have handheld extraction tools, but also an air cleaner. Only the combined use of control measures can reduce exposure to acceptable levels (Tjoe, 2003).

In the Netherlands, dust exposures were measured on almost 400 handheld tools. Only with a combination of machine extraction and air cleaner were the exposures sufficiently low to fall below the limit value for quartz dust (in the Netherlands 0.075 mg/m^3) over an 8 h shift: www.dustfreeworking.tno.nl/tools?term=demolition%20hammer&

Before the Covid 19 pandemic, air cleaners seem to have been little known in many European countries, at least not their use on construction sites. A key recommendation of this project is to use air cleaners as a backup measure instead of respiratory protection. Air cleaners additionally protect others in the room from high exposures (Antonsson and Sahlberg, 2019).

FIGURE 15: Air cleaner on construction site

FIGURE 16: Effect of an air cleaner: dust pollution drops rapidly when the air cleaner is switched on (15:30)



The BG BAU recommends a number of air cleaner models, which all fulfil a set of requirements www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques including the following (Pagels, 2019):

- A minimum of a two-stage filter system, where the main filter must either consist of filters that are equivalent to dust class M or have been tested as dust class H (EN 60335-2-69). The air cleaner is labelled as either air cleaner with M-filter or with H-filter.
- For each air cleaner on the recommended list a maximum room size is given (given as m^2 floor area).
- The device should be designed so that during a filter exchange, dust from the used filter cannot be released to workplace air.
- The mobile air cleaner should be equipped with a display that gives off an alarm if the air flow rate drops below the minimum requirement.
- The mobile air cleaner should be equipped with either an extraction hose or an exhaust hose.

6.6 Pre-separator for a lot of dust

Large quantities of dust are generated during many constructions works. If work is carried out with extractors on chisel hammers, grinding machines or saws, a lot of dust is generated. To prevent this dust from overloading the construction vacuum cleaners or their filters in a very short time, pre-separators can be used.

FIGURE 17: Pre-separator (centre) and vacuum cleaner (right) when using a floor sanding machine

Pre-separators have been mentioned in the literature for many years: “Perhaps cyclones and other pre-separators, with a modest pressure loss, can be used to keep debris off the filters” (Collingwood, 2007). “Future LEV systems used for tuckpointing tasks should include automated mechanisms to periodically clean buildup from filters and should also be equipped with effective prefilters. For example, one promising solution is the use of inertial separators (e.g., cyclones) to collect the larger dust particles before they reach the filters and bag. Such designs may allow the vacuum to maintain flow rate and decrease the need for filter and bag maintenance and replacement” (Meeker, 2009).

Pre-separators are connected between extraction machines and vacuum cleaner. They work with centrifugal separation in a cyclone, the vacuum cleaner acts as a “drive”. Its extraction power determines the centrifugal force that presses the dust against the wall of the cyclone. Gravity causes the dust to move downwards, and the relatively clean air is extracted from the center of the cyclone into the vacuum cleaner. Filters are not needed.

Pre-separators are useful for all activities where a lot of dust is generated in the work process. They can be easily cleaned even with oily or sticky dusts and are relatively inexpensive. It is usually possible to use sturdy commercially available bin liners. Suitable pre-separators are listed at: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

6.7 Dust barriers

To prevent dust from spreading to adjacent areas, it makes sense to install a spatial partition. It is often sufficient to close the doorway with a foil or slats. Such dust protection walls can be useful, for example, during renovation work such as bathroom renovation, work on drywall, separation during pollutant clean-up.

The dust protection walls prevent the spread of dust into non-polluted areas where other work is being carried out or which are occupied during the work. In the partitioned area, the dust load must be reduced in any case. Since the room volume is reduced by partitioning, the effect of air cleaners is increased. It is optimal to create a negative air pressure in the work area with an air cleaner (Pagels, 2019).

6.8 Low-dust mixing

Dust is generated when mixing dusty construction materials such as cement, mortar, gypsum, plasters, fillers, from bags. Dust is created when the bags are opened and when the powdery material is poured into the mixer. Finally, the bags are usually shaken out to get the last remnants into the mixer and compressed to reduce the volume for disposal. Especially the shaking out and squeezing leads to dust loads.

This dust generation can be minimized or completely prevented in various ways:

- Use silos or mini-silos (chapter 6.9);
- Use low-dust construction materials;
- Vacuuming during mixing.

The use of low-dust construction materials significantly reduces dust formation. The first of these products on the market had oils added that were very effective at binding dust. However, there were problems for occupants of rooms built with these low-dust products. This is because the oils evaporate very slowly and pollute the rooms for a long time. Such low-dust products can be used outdoors without any problems.

In the meantime, there are other product systems such as dust-reducing granulates of tile adhesives and levelling compounds without added oil. The dust load when mixing these granulates is significantly reduced. This greatly reduces the health hazards to processors and other parties involved: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

An extraction system for the mixer (concrete, screed, mortar mixer) reduces the dust load when opening and pouring out the construction material bags and during mixing. When mixing in a bucket, extraction devices (*Dustmonkey*, Seitz, 2020, www.dustmonkey.at; *Dust reducer*, www.wakol.com; *Dustex,* www.collomix.com) or bag opening aids (*Ripper,* www.uzin.de) can reduce dust exposure.

However, there remains a risk of dust exposure when shaking out and compacting the bags, unless this is done very carefully. Or low-dust techniques such as disposal containers with extraction are used here as well.

FIGURE 18: Extraction devices for buckets

However, there are also bagged products, especially cement, in dissolvable bags: https://www.lemoniteur.fr/article/lafarge-lance-le-sac-de-ciment-delitable.1184834 These bags are placed unopened in the mixer and then dissolve. This does not produce any dust. Mortar pellets www.youtube.com/watch?v=8qUOxu8zJN0 or mortar pads www.moertelpad.de instead of ready-mixed dry mortar also lead to low-dust work (Mansel, 2015).

6.9 Silos, One-Way-Container

Silos have long been used when large quantities of dusty construction materials are used. From these large silos, the mortar, for example, is often fed directly into a mixer, mixed with water, and pumped to the processing site. In principle, dust cannot be released here.

If smaller quantities of mortar, plaster and similar materials are required and the installation of a large silo is uneconomical, bagged goods are usually used.

This may still make sense for a few bags, for example up to one pallet of bags. But when a truckload or more of bagged product is used on a construction site, it is a problem in terms of dust and ergonomics. A lot of dust is created during transport by damaged bags, when the contents are poured out, when the product is mixed and often underestimated, during the subsequent compaction and disposal of the bags. This is where one-way containers (One-Way-Container, mini-silos) come in handy.

A one-way container contains about as much mortar, filler, ... as a pallet of bagged material. The construction company has to push a dosing shaft into the One-Way-Container, which transports the material out (Figure 19). The material can then be mixed with water and pumped to the point of use.

One-way containers normally weigh less than one ton and can also be transported from one construction site to another with trailers for cars/small vans.

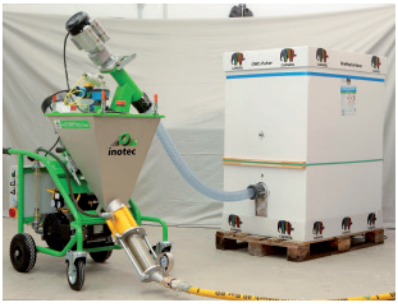


FIGURE 19: One-Way container on the pump truck or with mortar pump

6.10 Scattering quartz sand

Quartz sand is sprinkled into the not yet cured resin floors or in freshly laid mastic asphalt (*Gussasphalt*). The scattering relates to a high RCS load. If the quartz sand is not spread by hand, but with a spreader wagon, the dust load is significantly lower. With low-dust quartz bedding materials scattering is possible nearly without dust (*Dorsicoat* www.dorfner.com/en). This should be used for resin floors.

The scattering of low-dust quartz bedding materials in mastic asphalt is technically not possible. Washed sand from which the fine particles have been removed could be used. Or silica-free bedding, e.g. from recycled glass.

6.11 Dust on construction site roads

Unpaved roads are often found on construction sites. The driving movements on such construction roads often lead to dust swirls that are visible from afar, especially in the summertime. This leads to complaints from neighboring residents or motorists who are "diverted" past the sources of dust on motorway construction sites. Of course, the workers employed on the construction sites are also affected by the dust swirls.

In most cases, humidification of roadways is standard practice on large construction sites and is more or less specifically required by the contracting authority. Especially in the hot summer months – the main period of construction activity – dust turbulence can nevertheless be observed. Particularly during days of drought, not only does the surface being driven on dry out, but also the layers underneath. Applied water therefore quickly seeps into the subsoil and dries quickly on the surface. Depending on the intensity of the sun and the soil conditions, the interval required between wetting processes can vary greatly.

There are dust binding agents that are suitable for binding dust on roadways longer and more effectively, than is the case with water. For example, magnesium chloride can be used, which binds moisture due to its hygroscopic properties and prevents the release of dust particles. Magnesium chloride is also used in winter road maintenance, where it is used in varying proportions when spreading liquid brine. Another dust binding agent, also already tested in winter road maintenance, is the biodegradable calcium magnesium acetate (Gunreben, 2013).

6.12 Liquid soil

Liquid soil (for example www.fi-fb.de/english, www.ral-gg-fluessigboden.de, www.infociments.fr/voiries-urbaines/t62-materiaux-de-remblayage) is a flowable backfill material or a temporarily flowable backfill construction material. Excavated soil material intended for backfilling is made flowable in order to use it for the installation of buried construction components. For this purpose, a mixture of excavated material and additives (plasticizer, accelerator, stabilizers), as well as water and, if necessary, special lime, is produced and backfilled.

This process makes it possible to produce any type of excavated soil, industrially produced and natural aggregates, as well as other mineral materials temporarily flowable, to re-install them in a self-compacting manner and thereby to restore soil-like to ground-level conditions in the soil-mechanical and soil-physical sense.

No dust is produced in the process. In addition, there is no need for workers to be in the trench during backfilling and exhaust fumes from compaction work are avoided (Brinck and Ziegler, 2015).

FIGURE 20: Liquid soil is filled into a trench

7. PROTECTIVE MEASURES

The STOP principle must also be observed when protecting against dust on construction sites in accordance with the hierarchy of protective measures.

1. As far as possible, substitutions must be made, less hazardous materials must be used, or the process must be replaced by less hazardous processes.
2. If this is not possible, technical solutions must be used.
3. If technical solutions are also not possible, organizational measures must be taken.
4. Only if all these measures are not possible or not sufficient, personal protective measures may be used.

It may well be necessary to take several measures in parallel. The chances of lowering exposures to acceptable levels will be better when combining more than one measure to control exposure (Tjoe, 2003).

SUBSTITUTION is usually not possible on construction sites, especially for renovations or refurbishments, because the materials to be processed are specified. However, when using mortar, plaster, tile adhesives, etc., low-dust products can be used as alternatives to the usual materials.

TECHNICAL SOLUTIONS exist with the low-dust techniques for almost all activities on construction sites (see Chapter 6).

IN ORGANIZATIONAL TERMS, the number of people affected on a construction site can be reduced. Dust protection walls can be used to separate dusty areas so that the dust does not spread throughout the room or the building. Air cleaners can be used to create negative pressure in the separated areas, which prevents the spread of dust.

PERSONAL PROTECTIVE EQUIPMENT (PPE) such as respiratory protection may only be required in exceptional cases. PPE shall be used when the risks cannot be avoided or sufficiently limited by technical means of collective protection or by measures, methods, or procedures of work organization (EU-PPE Directive, 1989; Article 3 General rule). Some work, such as blasting or demolition of refractory cladding, can only be carried out with respiratory protection. But then, “Air-line blasting helmets should be worn for abrasive grit blasting” (SLIC, 2016). For the majority of activities on construction sites, there are low-dust techniques that make respiratory protection unnecessary.

The government's occupational health and safety regulators also state "The use of PPE is the last line of defense in the hierarchy of control. The use of PPE can be burdensome to workers and should be kept to a minimum; therefore, the organization of the work is critical. Powered hoods/helmets and full-face respirators may also be worn" (SLIC, 2016).

In practice, habit also plays a role in the choice of protective measures. For example, in almost all countries it is customary to wear a "blaster helmet" with respiratory protection when performing blasting work. In demolition work, which usually involves higher dust loads, or in tuckpoint grinding, this tends not to be a matter of course.

7.1 Technical measures

It is important to reduce exposure in all activities, even if one measure is not sufficient to bring the concentration below the limit value. The less dust generated by one activity, the less the subsequent work, the other trades and the residents are affected or exposed. For example, cutting stone or concrete without protective measures will make the entire construction site dusty. If cutting is done wet or with extractors, the dustiness of the construction site is at least reduced. Use of controls may allow dust-producing activities to be scheduled in the same area where other trades are working – a strong incentive for an industry in which production schedule maintenance is very important (Flanagan, 2003).

In order to work with little or no dust at all, construction sites must be kept clean. Construction debris must always be removed with low dust levels, otherwise it becomes a new source of dust. The main reasons for dust exposure among carpenters were especially use of handheld high-speed tools, grinding, lack of local exhaust ventilation, lack of cleaning during a work task, lack of cleaning before the next occupation began work and dust exposure from other occupations working at the same time (Kirkeskov, 2016).

Handheld machines such as wall cutters, plasterers, cut-off machines and demolition hammers must always be operated with an extraction device and a vacuum cleaner. It is of course possible to combine devices from different manufacturers. In rooms, an additional air cleaner must always be used.

Technical dust protection measures on construction sites were described as early as 1973 by Schulz ("Personal respiratory protection must nowadays, wherever possible, be made unnecessary by technical dust protection measures") or by Hallin (1983). From the 1990s onwards, the reduction of dust exposure through wet work or extraction on handheld machines is described in many articles. Often, despite the use of these low-dust techniques, not all values of a measurement data set are below the limit values.

In most cases, additional respiratory protection is then called as a backup measure. "However, even with the reductions seen in this study, exposures would exceed applicable exposure limits in some cases if this work were carried out for a full shift. This means that appropriate respiratory protection must be used in the context of a comprehensive respiratory protection program" (Meeker, 2009).

SLIC (2016) also calls for respiratory protection as an additional measure: Often respiratory protective equipment is an essential part of silica dust control, in addition to engineering controls. Water suppression and Local Exhaust Ventilation (LEV) systems are not fully reliable and even when functioning effectively they do not eliminate all silica dust. The residual dust concentrations will be variable and unpredictable, so additional personal control will be necessary in many situations [i.e., Respirable Protective Equipment, RPE].

This demand for respiratory protection is omnipresent, although it is known that the protective effect of respiratory protection on construction sites is rather doubtful. Above all, however, there are other technical measures that must be selected, possibly also in combination, according to the STOP principle, before respiratory protection may be used. Therefore, respiratory protection cannot be a backup measure. Because respiratory protection is not safe, too often it is not used properly. “Another important reason for promoting engineering controls is that respirators do not protect nearby workers” (Flanagan, 2003).

Technical measures are possible as an “additional control”, as a backup measure – air cleaners remove dust that is not captured by the vacuum cleaners on the machines and prevent dust from accumulating in the environment. Even air cleaners are probably not always used perfectly. But already according to the STOP principle, air cleaners are preferable to respiratory protection.

Occupational safety and health are only effective if it is accepted by the companies and the workers. The aim must be to use technical protective measures – in this case, extraction machines and air cleaners. Neither companies nor workers can be made to understand that low-dust techniques must be used, and that, despite this, respiratory protection must be worn. Handheld tools with an extraction device and air cleaners used in parallel always lead to low-dust work, mostly to almost dust-free work.

This project report takes a practical approach. It refers to exposure data and experience, always with a view to implementation and acceptance. Where possible, respiratory protection is not required as a safeguard, but air cleaners are used in addition to machines with an extraction device.

The statements made in this project on protective measures apply to work carried out by experienced construction workers under normal site conditions. If special conditions exist – first-time use of low-dust techniques, extremely confined spaces, work in the environment without low-dust systems, there may be deviations from the project statements on the assessment of workplaces. Cooper and Susi (2015) also report that “the operator had limited experience with the dust control system”.

7.2 Respiratory protection

FFP masks ("paper masks") are available on almost every construction site, usually somewhere in the construction trailer, in the toolbox, in stock in the contractor's stores. When "paper masks" are worn, it is often clear that they are just a pretext. The nose clip is not tight, the mask is completely crumpled, and there is hardly any "tight fit" – these are just the most serious mistakes. The current trend towards wearing a beard leads even more often to inadequate protection by respiratory protection. „Protection was inadequate with use of respiratory protection nearly half the time, and higher levels of respiratory protection involve respirators that are more expensive and require greater maintenance (powered air-purifying or supplied air), which bolsters the argument for greater use of engineering controls" (Flanagan, 2003). These are not small things, but deficits that lead to carcinogenic substances being inhaled.

If it is really not possible to reduce the dust exposure of workers below the limit values with technical measures, including combinations of technical measures, half or quarter masks with at least P2 filters must be used. These masks must then also be worn correctly (Use the correct respiratory protection correctly; www.andningsskydd.nu). Since the masks make breathing difficult, in many countries workers must be examined to determine whether they are physically fit to wear them. Finally, wearer breaks must be taken into account. If such work is required over the entire shift, additional personnel are necessary.

Wearing respiratory protection means, among other things:

- select and buy the right types and filters of respiratory protection,
- check whether the employees are physically able to wear respiratory protection,
- provide sufficient respiratory protection,
- carry out instructions on how to wear respiratory protection correctly,
- consider wearing time limitations (i.e. possibly using replacement columns), and
- check that the respiratory protection is worn correctly.

The 'Senior Labour Inspectors' Committee' (SLIC, 2016) points out that disposable masks [filtering facepiece (FFP) respirators] are mostly 'single shift' products and so should not be used for more than a single day.

Wearing respiratory protection must not be a permanent measure. "The workers who are permitted to work in the affected area shall be provided with appropriate protective clothing, personal protective equipment, specialized safety equipment and plant which they must use as long as the situation persists; that situation shall not be permanent" (Chemical Agents Directive EC 98/24, Article 7, 3.).

The EU PPE Directive (1989) stipulates in Article 4 "General provisions" that:

1. Personal protective equipment must comply with the relevant Community provisions on design and manufacture with respect to safety and health.

   All personal protective equipment must:

(a) be appropriate for the risks involved, without itself leading to any increased risk;
(b) correspond to existing conditions at the workplace;
(c) take account of ergonomic requirements and the worker's state of health;
(d) fit the wearer correctly after any necessary adjustment.

6. Personal protective equipment shall be provided free of charge by the employer, who shall ensure its good working order and satisfactory hygienic condition by means of the necessary maintenance, repair, and replacements.

The regulations on respiratory protection are not uniform in the European countries. Table 6 presents an overview of the different regulations in different countries. However, the daily changing of disposable masks is always necessary, if only because the manufacturers specify this.

This means about 400 masks per year for each two-man crew. FCC Construcción (2020) gives the cost of the masks as follows: Disposable respirator 0.06 – 0.12 €/piece; Self-filtering particulate respirator with valve and FFP3 protection 3.60 – 4.10 €/piece. In addition to these costs for the masks, there are further expenses due to examining workers, replacing teams during breaks. In some countries, protective suits are also required (Overall < 10 €/piece; Disposable overall 4.26 €/pack; FCC Construcción, 2020).

TABLE 6: Respiratory protection regulations for exposure to respirable crystalline silica

	P2 OR P3	WEARING BREAKS	PHYSICAL FITNESS TEST
DENMARK	at least P2	Filtering respirators may be worn for up to three hours per day	Employees must have access to a health examination before starting work
FRANCE*	P 3	?	yes
GERMANY	P2, >30 x 0.05 mg/m³ P3	Without exhalation valve after 75 min for 30 min, with exhalation valve after 120 min for 30 min	yes
LUXEMBOURG	P3	no	A respiratory function test (at regular intervals)
PORTUGAL	P2 or P3	Not mandatory in legal requirements	Not mandatory in legal requirements
SPAIN	P3	Maximum recommended continuous use time: 120 min	Mandatory once a year in mining sector
SWEDEN	P3 is usually sufficient	General advice: Usage more than 2 hours require supply air	yes
UNITED KINGDOM	P3	Breaks do not have to be observed because of mask wearing – just normal breaks	The physical examination is to ensure that the mask makes a tight seal with the face, not an examination of the lungs

*mandatory in France when handling asbestos

In spite of these expenses / costs, protection by respiratory masks is at least questionable.

- FFP2 dust mask quickly becomes clogged (Chisholm, 1999);
- In the current study carpenters did not use respiratory protection and the demolition workers used respiratory protection in less than 1/3 of the dusty work processes. (Kirkeskov, 2016);
- Peter Crosland, Civil Engineering Director of the National CECA "I have never encountered fully effective protection where tight fitting facepieces have been selected" (APPG, 2019);
- Respirators must fit snugly, and therefore preclude the growing of facial hair. For silicosis prevention in high exposure jobs, respirators are insufficient. It must be noted that a respirator limits dust exposure for just one person while co-workers and nearby residents continue to be exposed. Although Dust Masks looks attractive in terms of cost, the total efficacy is extremely limited (Lahiri, 2005);
- Do not allow facial hair for employees using respirators. Facial hair can interfere with the sealing surface of respirators (Grant, 2019);
- Where there is exposure to RCS, the RPE selected should be of a type which gives protection at least equivalent to that of an FFP3 respirator. However, the actual device selected will depend upon the nature of the task, the environment, and the wearer (In some cases a higher degree of protection may be required). In some member states a fit test is required for a tight-fitting mask, to check it matches the wearer's face and seals adequately. The fit test may be qualitative (based on the wearer's subjective assessment by sensing a test agent), or quantitative (measured using specialized equipment). Workers must be clean-shaven to get an effective seal to the face with a tight-fitting mask. Long hair or other facial features can interfere with the seal (SLIC, 2016).

7.3 Environmental protection/neighborhood protection

It is not possible to go into detail here about the impact of construction sites on the environment or on people living or working in the neighborhood. However, it is obvious that construction site dust pollutes both the environment, especially if it is asbestos dust or dust containing lead, and the people in the neighborhood.

Added to this pollution is the image of construction work. It is unfortunately common today for construction work to be associated with dust. Even in advertising, construction activities or construction machinery are promoted with pictures depicting a dusty way of working. Or construction workers are shown wearing dust masks.

This can be prevented by working in a low-dust manner. All in all, it can be said that low-dust work not only protects the workers on the construction site, but also does not pollute the environment and the neighborhood and promotes a better image of the construction industry.

8. MAPPING OF ACTIVITIES ON CONSTRUCTION SITES

The aim of the project is to describe how low-dust work can be carried out for activities on construction sites. For this purpose, exposure data were collected and evaluated, and findings from construction sites were taken into account.

Recommendations for low-dust work must cover the usual framework conditions on construction sites. Companies and workers cannot be required to determine what the quartz content is in the processed materials, how large the work area is, what the ventilation conditions are, and so on, before starting each activity. Of course, there are extreme situations that may not be covered by the recommendations. Here, solutions have to be found in practice.

Recommendations are needed that cover 90%, maybe 95% of all cases. Only if the guidelines are clearly formulated can acceptance be expected, not only among companies and workers. It is important that forepersons, works councils or supervisory authorities can quickly see whether the work is being carried out according to the specifications.

The Mapping lists recommendations for low-dust work on construction sites in the form of a traffic light system. Red means poor practice, i.e. the dust limits have been exceeded. Green (good practice) indicates that low-dust, often even dust-free work is being carried out. Grey describes working methods that are neither green nor red, often because sufficient data are lacking.

Numerous institutions (including OSHA, 2009; SLIC, 2016; BG BAU, 2018; OSHA 2020) specify protective measures for activities on construction sites. However, respiratory protection is almost always required in addition to technical protective measures. Although the insufficient protective effect of respiratory protection on construction sites is usually pointed out at the same time. Moreover, the effectiveness of respiratory protection is much more difficult to verify than the functionality of technical protective measures.

Therefore, respiratory protection is not suggested here as a "backup measure", but the use of air cleaners. In principle, this corresponds to the SLIC paper (2016), except that we recommend air cleaners instead of respiratory protection, following the STOP principle. Experience shows that air cleaners – if used correctly – significantly reduce dust exposure, especially when working indoors.

On this basis, the Mapping makes pragmatic suggestions for low-dust work on construction sites. Of course, technical protective measures such as air cleaners can also be used incorrectly, so that exposure is subsequently too high. But this must be clarified in practice. Construction work is also not always carried out perfectly and can lead to construction errors.

The Mapping gives pragmatic, easy-to-understand recommendations. There are already forepersons, works councils and representatives of supervisory bodies who intervene on construction sites if work is not carried out at low dust levels. These people will also ensure that dust is not created unnecessarily in the future. For all others, the Mapping represents a tool with which they can proceed on construction sites without much background knowledge.

The Mapping is structured according to construction occupations. For each occupation, the corresponding activities are listed.

The recommendations on vacuum cleaners, air cleaners, extraction systems on hand-held tools refer to the lists recommended by BG BAU:

www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

9. INNOVATIONS AND PROBLEM AREAS

9.1 Innovations

A topic like "Reducing Respirable Crystalline Silica Dust Effectively" thrives on innovation. All manufacturers of handheld tools, vacuum and air cleaners and other low-dust techniques are constantly developing their products. However, there are also low-dust techniques that are already used in some countries but are unknown in others.

The aim of this project was to get low-dust techniques onto construction sites throughout Europe. Therefore, space was also given to techniques that are only known in some countries or regions. These innovative approaches are summarized here once again.

- Dissolvable bags from Lafarge (Chapter 6.8)
- *Dorsicoat* from Dorfner (Chapter 6.10)
- *Dustex* from Collomix (Chapter 6.8)
- *Dustmonkey* from Brandner Parkettprofi (Chapter 6.8)
- *Dust reducer* from Wakol (Chapter 6.8)
- *Hytile tilecutter* from Hytile (Appendix 12.1, Cutting and Sawing)
- *Maxit mörtelpad* from Maxit (Chapter 6.8)
- *P1 System* from Joest (Chapter 6.3)
- *Piranha Cutter* from Rokamat (Chapter 6.3; Appendix 12.1, Tuckpoint grinding)
- *Ripper* from Uzin (Chapter 6.8)

TNO and BG BAU test low-dust techniques. Their websites contain lists of recommended handheld tools with extraction device, vacuum and air cleaners and other low-dust techniques: www.dustfreeworking.tno.nl/tools?tools=100038& and www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

9.2 Problem areas

Activites were identified for which little or no exposure data could be found and the exposure could not be derived by analogy. Furthermore, there is always exposure data for activities that do not match the experience on construction sites. Finally, low-dust techniques are not known for all activities.

- There is still no satisfactory solution for the low-dust cutting of roof tiles. Roof tiles can be cut by perforation and subsequent breaking. But if a visible edge is to be created, a smooth cut is necessary, e.g. as a valley cut. Here, cutting has to be done on the roof. There are first developments with extracted cut-off grinders. However, the exposures are still too high (Appendix 12.1, Cutting and sawing).
- When dismantling scaffolding, the rubble lying on the planks is shaken off. The BG BAU exposure data show very low dust exposures here (all below "Limit of determination"). Anyone who has seen how every plank is first pushed open during scaffolding removal in order to shake off the remains of plaster, stones, etc. on top of it knows that these data do not represent reality. Measurements are needed here. Even if this is less a health problem than an image problem, a solution to this dust problem is not known (Appendix 12.1, Scaffolding).
- When using sacks, considerable dust loads occur both when emptying the sacks and when subsequently shaking them out and, above all, when compressing the sacks to obtain the smallest possible volume for disposal. One possibility to work quasi dust-free are dissolvable bags. In France, these bags are offered by two cement plants. It is to be hoped that other manufacturers will follow this example and, above all, that it will be adopted in practice. When storing these bags, even more care must be taken than with normal cement bags, to ensure that they are not affected by rain or humidity.
- The data on work with air cleaners on construction sites must be increased. All responsible institutions are called upon to carry out appropriate measurements in practice and to publish the results.
- Wall sawing is often done with very large saw blades. Wet work is often possible. When working wet, mud is produced that turns back into dust when it dries and pollutes the environment. Extraction systems for this are not known (Appendix 12.1, Cutting and sawing).
- The dust collection bags in vacuum cleaners are unfortunately not uniform and, above all, very expensive. True, there are only five manufacturers of vacuum cleaners (the many different suppliers of these devices often only modify the colour). The five manufacturers have equipped their vacuum cleaners with different disposal bags. These disposal bags are expensive, so construction companies often forgo this purchase. The vacuumed dust is then simply tipped out of the vacuum cleaner into a container. Of course, this leads to enormous dust clouds that counteract or relativize the low-dust work (Chapter 6.1).

  The aim here should be to design a standardized disposal bag that can then be offered very cheaply, as a kind of giveaway.
- Scraping/Rubbing/Smoothing plaster can involve a dust load. However, little data are available on this (Appendix12.1, Plastering).

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12. APPENDIX

12.1 Activity related exposures

This assessment of dust exposures during activities on construction sites is the basis for the classification of activities on construction sites into good and poor practice – The "Mapping". The activities are each described in words and pictures. Then the exposure data are presented in the following way.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)	Alazard (FR) 2021
Small milling machines on asphalt pavements, operator	I16: <0.25-3.14 GM 0.65 95 2.70 R19: <0.14-1.90 GM 0.29 95 1.53 S16: 0.003-0.37 GM 0.024 95 0.20	R04: <0.04 - <0.60 S04: <0.001 - 0.03

S: silica R: respirable I: inhalable GM: geometric mean 95: 95 percentile

The references (for example 'Alazard (FR)') see the bibliography. Depending on the data given there, the exposures (mg/m^3) for inhalable dust (I), respirable dust (R) and RCS (S) are listed:

1. number of measurements
2. range of measured values, in case of few measurements the single values
3. geometric mean (GM)
4. mean value (m); sometimes median
5. 95 percentiles (95)

In some cases, further statistical data are given (28% >1.5 means that 28% of the data set are above 1.5 mg/m^3).

The subsequent assessment of dust exposures primarily considers these exposure data. However, experience is also considered for a recommendation for good practice. In the assessment of the exposures, the following limit values are essentially referred to

- inhalable dust 10 mg/m^3 (limit value in most EU countries),
- respirable dust 3 mg/m^3 (limit value in most EU countries),
- silica dust 0.1 mg/m^3 (limit value by the EU).

In the appendix "Dust exposures on construction sites", all exposure data collected within the scope of the project are listed together.

BASICS OF ASSESSMENT

It should be noted that half of the respective measurement data sets are above the geometric mean (GM). If the GM were used to assess a corresponding activity on construction sites, the exposure would be assessed too low in about 50 % of the cases.

If one orients oneself to the maximum of the measurement data set, one is on the safe side. However, since there are extreme values in every measurement data pool, both very low and very high values, orientation to the maximum value leads to too strict an assessment of exposure. Protective measures would be taken that are not yet necessary.

The recommendations for the ‘Mapping’ are not only based on these statistical values, but also on the framework conditions of the measurements, experiences on construction sites and with regard to practicability in practice.

No distinction is made between the different materials being processed when assessing exposure. Whether the limit value for silica dust is more or less exceeded, protective measures must always be taken. Even if the material processed contains very little quartz and the exposure to silica dust is below the limit value, the limit value for respirable dust is certainly exceeded during work without control measures and measures are therefore required. Furthermore, a differentiated consideration of the materials processed would mean that at least qualitative material analyses would have to be carried out and documented on every construction site before work begins.

Similar activities are grouped together. For example, the cutting of stones, bricks, tiles, etc. is described under “Cutting and sawing”. Because very similar or even the same handheld tools are often used here. Also, solutions from cutting one material can possibly be transferred to cutting other materials. After all, not enough data are available for cutting all materials. Therefore, data from cutting stones can also allow conclusions to be drawn about exposure when cutting tiles. Or the experience of cutting paving stones can help to describe the exposures when cutting kerbstones.

TABLE OF ACTIVITIES

Asphalt milling

Milling asphalt pavements removes the uppermost layers of the road pavement, e.g. in order to repair defective areas or produce trenches for supply lines. The resultant RAP (reclaimed asphalt pavement) is essentially coarse-grained and can be reused completely.

Large milling machines run on crawlers and the RAP is removed by conveyor systems running in the direction of travel. Small milling machines run on wheels, have a maximum milling width of 1 m and the RAP is removed in the direction opposite to the milling direction. During the milling process, the cutting tools mounted on a drum are cooled with water to prevent them overheating. In relation to the amount of RAP, small milling machines require roughly ten times more water than the large milling machines.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)	Hammond (US) 2017	Alazard (FR) 2021
Small milling machines on asphalt pavements, operator	I16: <0.25-3.14 GM 0.65 95 2.70 R19: <0.14-1.90 GM 0.29 95 1.53 S16: 0.003-0.37 GM 0.024 95 0.20		R04: <0.04 - <0.60 S04: <0.001 - 0.03
Big milling machines on asphalt pavements with extraction, operator	I07: 0.17-1.52 GM 0.34 R11: <0.08-1.38 GM 0.21 95 0.98 S08: <0.003-0.045 GM 0.009	S10: <LOD - 0.011 GM 0.0042 S11: <LOD - 0.013 GM 0.0062	I06: 0.38 - 1.22 R06: <0.09 - 0.66 S06: 0.006 - 0.035
Big milling machines on asphalt pavements with extraction, ground man		S10: <LOD - 0.024 GM 0.0090 S11: <LOD - 0.010 GM 0.0061	
Big milling machines on asphalt pavements without extraction, operator	I08: 0.47-8.21 GM 2.37 95 8.21 R77: 0.11-47.10 GM 4.47 95 26.24 S77: 0.002-7.90 GM 0.210 95 4.44		I03: 0.39 - 3.87 R03: 0.09 - 1.23 S03: 0.01 - 0.08
Scraping of asphalt			I02: 0.42, 0.8 R06: <0.06 - 0.08 S06: 0.003 - 0.01

S: silica R: respirable I: inhalable GM: geometric mean 95: 95 percentile

When assessing the exposure during work with small milling machines, it must be remembered that the net milling time is less than two hours per day. The rest of the shift is devoted to work on the milling machines with low dust levels, as well as loading and driving.

Overall, when milling asphalt with small milling machines, compliance with the limit values can be expected for each layer. Large milling machines must be equipped with extraction systems.

Blasting

In sandblasting, surfaces are treated with an abrasive. Compressed air is used to generate a powerful jet of air that blasts the abrasive at high speed onto the surface to be treated. Although quartz sand is no longer permitted as an abrasive in most countries, silica dust is released from surfaces.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)	INAIL (IT) 2019	Flanagan (US) 2006 Easterbrook (GB) 2009
Abrasive blasting			R65: GM 3.74 S64: GM 0.24
Blasting, dry	R90: GM 2.43 95 63.8 S90: GM 0.122 95 2.819	R04: m 1.06 S04: m 0.092	R02: 18.66, 75.04 S02: 0.16, 1.22
Blasting, wet	R38: GM 0.87 95 4.97 S38: GM 0.40 95 0.332		

S: silica R: respirable GM: geometric mean m: mean 95: 95 percentile

Sandblasting produces high concentrations of fine dust. Workers must generally be protected by full protective suits, if only because of the risk of injury from the parts flaking off the surfaces being treated. This also includes a helmet with forced ventilation.

Bricklaying

Mainly pointing mortar between bricks; several times per day, involving preparing mortar or cutting bricks.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)		
Brick laying, outdoors, without stone cutting	R11: 0.11 - 0.77 S10: 0.004 - 0.123	GM 0.28 GM 0.0095	95 0.7 95 0.071
Brick laying, indoors, without stone cutting	R19: <0.29 - 4.43 S17: <0.009 - 0.12	GM 1.08 GM 0.023	95 2.49 95 0.102

S: silica R: respirable
GM: geometric mean
95: 95 percentile

There is always a dust load due to dried mortar. If the bricks are not broken but cut, e.g. with an angle grinder, the dust load is considerably higher (see “Cutting and sawing”).

When using bagged cement, at least the limit values for inhalable and respirable dust are exceeded (see “Mixing”). Extraction at the mixer is only of limited help, as the shaking out and especially the squeezing of the bags is not covered by the extraction system.

If the cement is delivered in a silo (large silo or One-Way container), the concrete, screed or tile adhesive can be mixed without creating dust.

With thorough cleaning of the construction site after each shift, as well as the breaking of the bricks, the dust load is low. If bricks have to be cut, this should be done with a wet saw or dry with extraction, indoors additionally with air cleaner.

Chimney sweeping

When cleaning chimneys and combustion plants, dust pollution occurs in addition to the problematic polycyclic aromatic hydrocarbons. Silica dust is not an issue here.

EXPOSURE DATA

Wanck
I06: 6.18 - 16.75 R06: 0.73 - 3.56

I: inhalable R: respirable

PAHs dominate inhalation and dermal exposure during chimney sweeping work (Alhamdow, 2017; MSB, 2017). Some measurements also indicate possible exposure to inhalable and respirable dust, depending on the type of fuel.

For larger combustion plants, a vacuum cleaner is recommended for cleaning, otherwise respiratory protection should be worn.

Cleaning

Both during the final cleaning after completion of a construction site and during daily cleaning, construction dust, usually also construction debris (see section "Removing construction rubble") is removed.

EXPOSURE DATA

ACTIVITY	SUVA (CH) / BG ETE (DE) 2009 / BG BAU (DE)	Alazard (FR) 2021 / Chisholm (GB) 1999 / Flanagan (US) 2003	Beaudry (CA) 2013 / Flanagan (US) 2006 / Nij (NL) 2003
Construction site cleaner	R33: GM 1.18 95 8.38 S33: GM 0.039 95 0.408	R11: GM 0.55 5% >3 S11: GM 0.03 50% >0.05	R12: 0.14-2.5 GM 0.58 S12: 0.0016-0.097 GM 0.017
Construction site cleaner		R03: <0.13 - 0.87 S03: <0.003 - 0.016	R62: GM 0.66 S61: GM 0.05
Cleaning with the sweeper	R19: GM 0.54 95 2.043 S19: GM 0.013 95 0.039		
Cleaning	R04: 0.39 - 0.69 S04: 0.33 - 0.57		S30: 0.00 - 0.69 GM 0.03
Sweeping	I06: 2.40 - 25.11 m 8.16 R06: <NG - 2.6 m 0.89	R04: 0.8 - 5.0 m 2.5 S04: 0.07 - 0.69 m 0.41	

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

Cleaning should always be done with a vacuum cleaner www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques, never dry sweep with a broom. Ideally, the debris is pushed together with a robust hoover brush, the coarser parts are put into a bucket or wheelbarrow with a shovel and the fine residues are vacuumed up.

Sweepers often generate a lot of dust. Especially if the side sweeping brushes are not caught by the extraction.

The additional use of an air cleaner is ideal: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

Compacting

When compacting by hand, vibratory plates, rollers or vibratory rammers are used to obtain a load-bearing subsoil for buildings.

EXPOSURE DATA

BG BAU (DE)	Alazard (FR) 2021
I09: 0.24 - 12.17 GM 1.71 95 10.4	
R23: 0.11 - 3.65 GM 0.45 95 2.72	R04: 0.14 - 10.3
S22: 0.004 - 0.66 GM 0.02 95 0.45	S04: <0.009 - 0.23

S: silica R: respirable I: inhalable GM: geometric mean
95: 95 percentile

The dust exposure depends on the soil moisture. For technical reasons alone, a certain soil moisture is required to achieve the necessary compaction. If this soil moisture is present, dust exposure can be assumed to be below the limit values.

If large construction machines are used for compacting, windows and doors of the cabins must be closed (see "Driving of construction machines and vehicles").

Another solution for compaction in the trench is liquid soil. Here there is no need for compaction because liquid soil is temporarily flowable and self-compacting. This also prevents the workers in the trench from being exposed to exhaust fumes.

Core drilling

In core drilling, the drill 'saws' a core out of the wall, ceiling, ... This creates holes with a larger diameter. A special case is box countersinking, for installation work for plug sockets and junction boxes.

EXPOSURE DATA

	BG ETE (DE) 2009		Flanagan (US) 2001
ACTIVITY	SUVA (CH)		
Box countersinking without extraction	I06: 6.84 - 88.00 R06: 1.42 - 7.98	m 35.55 m 3.36	
Box countersinking with extraction	I08: 1.93 - 19.03 R08: 0.18 - 1.9	m 5.03 m 1.06	
Core drilling, concrete, wet	R02: 0.08, 0.18 S02: 0.02, 0.05		S02: 0.02, 0.02

S: silica R: respirable I: inhalable m: mean

Basically, the exposures are similar to drilling. Core drilling should be done wet or with extraction equipment. Indoors the additional use of an air cleaner is ideal: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

There are no data known for core drilling with diameters over 15 cm.

EXPOSURE DATA CUTTING AND SAWING

ACTIVITY / JOB			
	iQ-power-tools (US) 2018	SUVA (CH)	CooperJ (US) 2015
	Garcia (US) 2006	Hall (US) 2013	McLean (NZ) 2017
	Chisholm (GB) 1999	Beaudry (CA) 2013	Constructiv '20; van Peer '21 (BE)
	Meeker (US) 2009	Middaugh (US) 2012	ARBOUW '12 (NL)
	BG BAU (DE)	Echt (US) 2007	Valiante (US) 2004
Cutting paving stones, dry	I05: 20.49-87.71 R10: 3.38-20.87 GM 7.04 95 19.21 S09: 0.03-5.74 GM 1.48 95 5.48	R17: GM 16.4	S03: 0.032, 0.703, 2.955 S01:4.0
Cutting paving stones, wet	R5: <0.25 - 1.75 m 0.78 S5: <0.009 - 0.58 m 0.164	R14: GM 3.60 wet R12: GM 4.40 with LEV	S01: 0.118 S01: 0.12
Cutting paving stones with extraction			
Cutting stones, dry	S05: 1.0 - 4.0 m 2.83 block S05: 0.45 - 1.6 m 0.94 brick	R05: 21-115 GM 43.2 S05: 5.7-38 GM 12.7	R01: 69.60 S01: 44.37
Cutting stones, wet	S05: 0.09 - 0.61 m 0.26 block S05: <0.05 - 0.14 m 0.09 brick	R05: 2.9-11 GM 5.73 S05: 1.0-2.2 GM 1.62	R04: 1.81-5.97 m 3.81 S04: 0.920-3.405 m 2.161
Cutting stones with extraction	S05: <0.05 - 0.17 m 0.11 block S05: <0.05 - 0.15 m 0.08 brick	R05: 1.9-3.6 GM 2.58 S05: 0.79-1.1 GM 0.95	S01: 0.08
Cutting stones, wet and with extraction			R04: 0.20-1.20 m 0.60 S04: nd-0.669 m 0.253
Cutting cement roof tiles		R38: 0.2 - 3.6 GM 0.94 S38: 0.04 - 0.44 GM 0.14	
Cutting roof tiles, dry, without extraction	R42: GM 2.215 95 13.26 S42: GM 0.442 95 2.832	S10: 0.29 - 0.45 GM 0.35	R12: 11.7 - 65 GM 26.7 95 58.8 S12: 2.09 - 12 GM 4.83 95 10.8
Cutting roof tiles, dry, with extraction	R06: 6.04 - 17.40		R30: 4.54 - 42 GM 18.2 95 38.8 S30: 0.81 - 8.6 GM 3.44 95 7.63
Cutting roof tiles, wet			R12: 2.96 - 11 GM 5.47 95 9.55 S12: 0.16 - 1.2 GM 0.41 95 0.16
Cutting roof tiles, tablesaw, with extraction			R24: 3.91 - 61 GM 13.9 95 34.5 S24: 0.02 - 11 GM 1.35 95 6.85
Cutting tiles, dry			
Cutting tiles, wet			
Blowing dust from roof tiles	R06: 2.16 - 5.39		
Cutting Linea board (fibre cement)			S04: 0.002-0.486 GM 0.017
Cutting concrete, dry			S01: 0.311 S01: 1.54
Cutting concrete / bricks with extraction	R05: 0.044 - 0.30 S05: <0.008 - 0.034		
Sawing concrete	R39: GM 2.13 95 13.21 S39: GM 0.041 95 0.244		S06: 0.15 - 0.50 m 0.348
Cutting concrete / brick			

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

Thorpe (GB) 1999
Flanagan (US) '03/'06
Alazard (FR) 2021
Croteau (US) 2002
R06: GM 89.85 S06: GM 22.52
R06: GM 4.31 S06: GM 0.95
R06: 8.0 - 58.0 S06: <0.5 - 4.8
R04: 0.6, 1.3, 1.9, 6.4 S04: <0.3, <0.3, <0.4, <0.6
R02: 0.2, 0.7 S02: <0.35, <0.5
R03: 2.26, 5.8, 17.8 S03: 0.09, 0.31, 1.40
R01: 0.58 S01: 0.035
R03: <0.24, <0.25, <0.37 S03: <0.009, 0.006, 0.006
R04: 4.27 - 7.00 S04: 0.32 - 0.85
R01: <0.73 S01: 0.087
R185: GM 0.72 S164: GM 0.08

Cutting and sawing

Cutting, like sawing, separates building materials with various machines. Exposure data on these activities are not always separated ("A gas powered cutting saw is used" (Hall, 2013); "The block and brick cutting tools tested were two stationary saws" (Meeker, 2009)). For example, when paving stones are cut, this can be done with an angle grinder (cutting), but also with a stone saw (sawing).

Regardless of which machine is used for cutting, dust exposures are very high when working dry without extraction.

If cutting or sawing is done wet, the exposures are significantly lower, although not always below the limit values. However, when working wet, mud is produced that turns back into dust when it dries and pollutes the environment. If possible, the water must be either permanently renewed or at least replaced once a day. The mud in the environment must be removed daily.

EXPOSURE DATA

ACTIVITY / JOB			
	iQ-power-tools (US) 2018	SUVA (CH)	CooperJ (US) 2015
	Garcia (US) 2006	Hall (US) 2013	McLean (NZ) 2017
	Chisholm (GB) 1999	Beaudry (CA) 2013	Constructiv '20; van Peer '21 (BE)
	Meeker (US) 2009	Middaugh (US) 2012	ARBOUW '12 (NL)
ACTIVITY / JOB	BG BAU (DE)	Echt (US) 2007	Valiante (US) 2004
Cutting concrete or asphalt		S40: 0.00 - 0.14 GM 0.02	
Sawing concrete, dry, inside and outside	R04: 7.3 - 84 m 41.2 S04: <0.14 - 3.8 m 1.49		
Sawing concrete, wet	R04: 0.55 - 4.1 m 1.54 S04: 0.08 - 1.3 m 0.40	R02: 0.15, 0.24 S02: 0.02, 0.02	S01: 0.027
Table saw, concrete			S01: 11.823 without extraction S01: 2.366 with extraction S01: <0.036 wet
Alligator saw, aerated concrete			S01: 0.015
Sawing asphalt			S08: nd - 0.07 m 0.041

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

The available data show no great difference between 'cutting' and 'sawing'. The material being processed also has hardly any influence on the dust load.

However, paving stones, bricks, roof tiles and tiles can also be broken. In this case, mainly larger fragments are produced, and the exposure to fine dust is considerably lower.

WALL SAWING

Wall sawing is often done with very large saw blades. Extraction systems for this are unknown. Wet work is often possible. When working wet, mud is produced that turns back into dust when it dries and pollutes the environment. The mud must be removed regularly.

TILES

Dry cutting of tiles creates a lot of dust. Cut-off machines with extractors can be used for cutting of tiles.

Tiles can also be cut wet. When working wet, mud is produced that turns back into dust when it dries and pollutes the environment. If possible, the water must be either permanently renewed or at least replaced once a day. The mud in the environment must be removed regularly.

Tiles can also be broken. This produces only a small amount of fine dust. The workplace must be cleaned daily.

Thorpe (GB) 1999
Flanagan (US) '03/'06
Alazard (FR) 2021
Croteau (US) 2002
R15: GM 0.76 14%>3 S15: GM 0.07 77%>0.05
R08: <014 - 0.63 S08: 0.003 - 0.21
R07: <0.34 - 0.24 S07: <0.09 - 0.03

The use of an air cleaner is recommended for all cutting and crushing techniques: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

ROOF TILES

Roof tiles are usually cut on the roof. Dry cutting of roof tiles creates a lot of dust, wet cutting of roof tiles on the roof is not a good alternative. This is because the resulting red sludge pollutes the facade and cleaning is very difficult. Cut-off machines with extractors can be used for cutting on individual roof tiles.

Often a straight cut must be made across several tiles, e.g. in roof valleys the 'valley cut'. Cut-off cutters with extractors for valley cutting are available, but development work is still needed here.

Flat roof tiles can be cut and then broken. Roofing tiles can be "perforated" and then broken www.hytile.eu. This produces only a small amount of fine dust, Sheehy et al. (2006) found respirable dust below detection limit. However, the tile pieces obtained in this way can only be used in places on the roof where the broken edges cannot be seen. Otherwise, the building owner would complain about this.

Demolishing

Demolition work includes the removal of parts of buildings or entire buildings. This can be done with large construction machines, especially excavators, or with hand-operated machines, especially jackhammers or electric chisels. But even today, it is often necessary to work with hammers and chisels.
For removing mortar, plaster, tiles see “Knocking off mortar, plaster, tiles”.

EXPOSURE DATA

		McLean (NZ) 2017	Kirkeskov (DK) 2016
	Szadkowska (PL) 2006	Deurssen (Nl) 2014	Valiante (US) 2004
	Constructiv (BE) 2020	Antonsson (SE) 2019	Chisholm (GB) 1999
	Lumens (NL) 2001	Flanagan (US) 2003	Network Italiano 2007
ACTIVITY	BG BAU (DE)	Echt (US) 2004	Tjoe (NL) 2003
Demolisher	R82: 0.5 - 298.8 GM 2.1 S82: n.d. - 35.9 GM 1.1	R45: 0.09-33.76 GM 1.17 S45: 0.01-0.91 GM 0.12	R21: 0.20-9.4 GM 1.4 S21: 0.038-1.3 GM 0.14 67% >0.075
Demolishing, chimney and refractory construction	R47: GM 4.69 95 19.5 S47: GM 0.372 95 4.176		
Demolishing, manually, inside	I03: GM 66.0 R03: GM 16.2	S02: 0.001, 0.037	R14: <0.05-3.5 GM 0.60 95 3.42 S14: 0.014-0.114 GM 0.042 95 0.109
Demolishing, manually, inside			I08: 31.0 - 460 GM 138 R02: 3.3, 3.5 S02: 0.67, 0.71
Demolishing, manually, outside	I15: GM 2.7 R15: GM 0.5		
Demolishing, mechanical (with extraction), inside			I04: 0.92 - 61.0 GM 4.42 R04: 0.05 - 3.3 GM 0.43 S04: 0.02 - 0.45 GM 0.09
Demolishing with jackhammer, inside		R14: GM 0.96 21%>3 S14: GM 0.10 88%>0.05	R12: 1.08 - 8.9 GM 2.25 95 6.65 S12: <0.02 - 1.56 GM 0.27 95 1.15
Demolishing, jackhammer, outside, dry	S01: 0.317	R04: 0.38-2.77 m 1.37 S04: 0.05-0.43 m 0.2	S25: 0.09 - 0.63 m 0.276
Demolishing, demolition hammer, outside, wet		R04: 0.26-0.83 m 0.61 S04: 0.04-0.29 m 0.13	
Demolishing, chiseling, manual	R85: 0.085 - 19.3 GM 1.92 95 9.28 S81: 0.081 - 7.0 GM 0.18 95 1.88		
Demolishing with Robot Brokk 40		R03: 0.15 0.32 0.46 S03: 0.003 0.05 0.06	

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

All authors indicate high to very high exposures to respirable dust and silica dust during demolishing. Only the two measurements by McLean are out of the ordinary with very low exposures. McLean does not give any information on the general conditions during the measurements. The data from Antonsson when working with a demolition robot indicate a solution to the dust problem for workers during demolition.

When buildings are demolished, sprinkling or spraying with water can prevent too much dust from getting into the environment.

When excavators or other large construction machines are used in demolition work, the cab windows and doors must be kept closed. See chapter "Driving of construction machines" for exposure data. Water spraying devices for machine arms are useful.

If workers are required outside of the construction machinery, respiratory protection must be worn.

If handheld tools like electric chisel or hammer drill are used, extraction is important. Indoors the additional use of air cleaners is necessary. Air cleaners must also be used for manual chiseling. A low-dust or dust-free alternative can be the use of demolition robots. But the operator must work in a cabin.

Drilling

Drilling holes in walls, ceilings, etc. is one of the most common jobs on construction sites and is carried out by many professions. It involves drilling into a wide variety of materials, bricks, sand-lime bricks, concrete, etc.

Core drilling creates holes with larger diameter, see "Core drilling".

EXPOSURE DATA

	SUVA (CH)		
	BG ETE (DE) 2009	Alazard (FR) 2021	Grahn (SE) 2017
	Valiante (US) 2004	Antonsson (SE) 2019	Beaudry (CA) 2013
	CooperM (US) 2012	McLean (NZ) 2017	Sheperd (US) 2009
ACTIVITY	BG BAU (DE)	Deurssen (NL) 2014	Flanagan (US) 2006
Drilling	R18: GM 1.34 95 7.00 S18: GM 0.155 95 2.153		S172: 0.0 - 94 GM 0.04 Masonry S12 :0.01 - 0.13 GM 0.02 Stone
Drilling	I07: 2.94 - 10.11 m 6.09 R07: 1.12 - 2.73 m 1.75	S04: <0.001-0.762 GM 0.007	
Drilling in concrete	S02: 0.05 0.16	R46: 0.02-10.86 GM 0.86 S46: 0.01- 1.36 GM 0.20	I04: GM 47.2 R04: GM 3.77 S01: 0.308
Drilling in concrete	S05: 0.42-0.84 m 0.68	R03: 0.25 5.01 18.5 S03: <0.02 0.02 0.90	R95: GM 1.82 S97: GM 0.20
Drilling in concrete, wet	R02: <0.04 0.21 S02: <0.01 0.02		R02: 0.56 1.01 S02: 0.054 0.071
Drilling in concrete with extraction	S05: <0.02 - 0.05 m 0.04	R02: 0.1 0.16 S02: 0.009 0.01	I14: GM 2.1 - 6.19 R14: GM 0.24 - 0.37 S04: 0.006 - 0.28 GM 0.015
Drilling in concrete with extraction		R01: <0.4 S01: <0.01	

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

Some of these data were obtained when drilling in concrete, some when drilling in concrete or stone, others without differentiating in terms of the material worked with. The result is always that there is a high dust load when drilling without protective measures. And dust remains in the drill hole.

For certain anchors, the drill holes must be dust-free. Then the drill holes are blown out, which leads to considerable dust pollution.

If extraction drills are used, no dust gets into the breathing air and no dust remains in the borehole. Then even air cleaners are no longer necessary.

If extraction drills are not possible, a vacuum cleaner adapter should be used. In this case, the additional use of air cleaners makes sense. But dust remains in the drill hole.

If drill holes must be blown out, dust removal systems should be used. This allows the dust to be blown out of the borehole and extracted at the same time. This way blowing out boreholes can be done dust-free.

Driving of construction machines and vehicles

Construction machines and vehicles such as excavators, trucks, bulldozer, tippers, etc. today have ventilation, often air conditioning.

EXPOSURE DATA

ACTIVITY	BG BAU (DE) Radnoff (CA) 2014	Alazard (FR) 2021 McLean (NZ) 2017 INAIL (IT) 2019
Construction machinery, Cabins open	R39: 0.18 - 7.73 GM 0.99 95 4.22 S37: 0.002 - 0.784 GM 0.055 95 0.445	S05: 0.001 - 0.143 GM 0.009
Construction machinery, Cabins closed	R71: 0.04 - 3.53 GM 0.30 95 1.04 S64: 0.002 - 0.081 GM 0.007 95 0.037	R04: <0.017 - <0.17 S04: <0.004 - 0.01
Excavator driver		R50: GM 0.181 2.8% > 1.5 S43: GM 0.010 6.5% > 0.05
Truck driver, dump truck driver	S16: 0.004 - 0.11 GM 0.013	R10: GM 0.188 6.1% > 1.5 S10: GM 0.006 6.1% > 0.05

S: silica R: respirable GM: geometric mean 95: 95 percentile

In McLean, Radnoff and INAIL it is not recognizable whether the data come from closed or open cabins. At Alazard, the worked soil was damp, on the construction site the overall dust level was low. The BG BAU data are based on an evaluation where ‘closed’ means that all windows and doors are closed.

These data show that the usual filters in the ventilation/air conditioning systems of construction machinery and vehicles retain construction dust.

To prevent dust from construction site roads from polluting the surrounding area, these mostly unpaved roads are kept wet. However, the dust-binding effect of water is often quickly exhausted, especially at higher temperatures and with heavy construction site traffic. Here, there are environmentally compatible additives that significantly prolong the dust-binding effect.

Formworking

The formwork is the mould into which fresh concrete is placed for the production of concrete components.

After concreting, the formwork is removed and, if necessary, cleaned.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)			
Cleaning formwork, inside/outside	R 26 S 26	GM 0.34 GM 0.007		95 1.15 95 0.034
Strip the formwork from concrete components	R 40 S 40	GM 0.19 GM 0.005	90 1.02 90 0.04	95 2.13 95 0.2

S: silica R: respirable
GM: geometric mean
90: 90 percentile 95: 95 percentile

Hardly any dust is produced when stripping the formwork. This is also confirmed by the measurement data.

Dust pollution is also low when cleaning the formwork. In the data set of BG BAU, there are only two outliers (out of 40 values) that lead to the 95% values being above the limit values.

Grinding

Grinding (sanding, polishing) involves working on different surfaces, concrete, screed, plasterboard, mortar.

Concrete chipping refers to using a hammer drill to cut off uneven concrete walls after removing the molding. Concrete grinding is the use of a grinder to level a concrete surface after removing the molding (Park, 2019).

EXPOSURE DATA

	BG BAU (DE)		SUVA (CH)
	Park (KR) 2019	McLean (NZ) 2017	Flanagan (US) 2001, ´03, ´06
	Szadkowska (PL) 2006	Beaudry (CD) 2013	Grant (US) 2019
	Akbar (US) 2002/´07	Alazard (FR) 2021	Croteau (US) 2002
ACTIVITY	Constructiv ´20 (BE)	Antonsson (SE) 2019	Grahn (SE) 2017
Concrete grinding	R58: 4.26 - 367.5 GM 50.0 S58: 0.1 - 17.62 GM 2.06	R10: GM 5.5 S10: 0.012 - 3.207 GM 0.657	R23: GM 6.17 84% > 3 S23: GM 0.63 100% > 0.05
Concrete grinding	R34: 0.34-81.0 m 24.3 GM 14.3 S34: 0.02-7.10 m 1.5 GM 0.929	R04: 1.95 - 14.7 S04: <0.01 - 0.88	R03: 1.36 1.63 1.78 S03: 1.13 1.35 1.48
Concrete chipping	R36: 0.19 - 62.72 GM 1.78 S36: 0.005 - 3.06 GM 0.12		R05: GM 165.3 S05: GM 29.16
Surface grinding		S244: 0.00 - 2.0 GM 0.09	R114: GM 2.72 S122: GM 0.29
Concrete floor sanding	S01: 1.536		R09: GM 0.63 7% > 3 S09: GM 0.07 80% > 0.05
Polishing concrete	I08: GM 58.0 R08: GM 7.5	R05: GM 4.2 S05: 0.003 - 4.767 GM 0.306	
Concrete wet grinding	R04: 5.27 - 12.8 m 7.77 GM 7.29 S04: 0.33 - 0.93 m 0.52 GM 0.477		
Concrete grinding with extraction	R15: 0.81-12.7 m 5.49 GM 4.10 S15: 0.03-1.00 m 0.38 GM 0.250		R02: 0.23 0.24 S02: 0.01 0.006
Concrete grinding with extraction	I01: 1.03 R01: 0.56 S01: 0.054	R05: 0.17 - 2.79 S05: 0.004 - 0.247	R05: GM 8.0 S05: GM 1.7
Sack and patch concrete			R13: GM 0.40 3% > 3 S13: GM 0.03 40% > 0.05
Concrete grinding with extraction and air cleaner		R04: 0.13, 0.13, 0.3, 0.89 S04: 0.008, 0.014, 0.03, 0.07	
Screed grinding	I05: 2.37 - 67.5 R08: 0.2 - 9.77 S07: 0.006 - 1.4		
Drywall sanding	I26: 1.12-353.43 GM 20.33 95 233.7 R32: 0.41-36.50 GM 3.30 95 29.80 S14: 0.0025-0.400 GM 0.032 95 0.205	R03: 2.09, 2.17, 2.38 S01: <0.0005	R17: 1.7 - 7.3 GM 3.3 95 6.6 S13: 0.006-0.033 GM 0.01 95 0.025
Drywall, Cutting and mounting panels		R04: 0.42 - 0.95 S04: 0.02 - 0.04	

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

The measurement data were obtained while working with different grinding techniques on different surfaces. If high-speed handheld tools (disc grinders, belt grinders, orbital sanders, angle grinders) are used without protective measures, the exposure to respirable dust is very high (GM mostly > 3 mg/m³). The silica dust exposure varies depending on the quartz content of the surface, but the GM is always > 0.05 mg/m³ (except drywall).

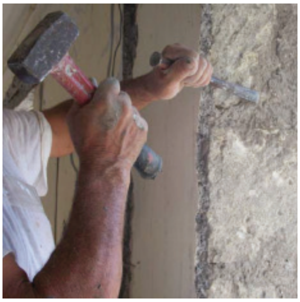
In drywall construction, gypsum boards are essentially processed. Gypsum contains hardly any quartz. However, when holes are drilled for fixing the gypsum boards, dust containing quartz is produced. In addition, when working on materials containing gypsum without protective measures, the limit value for respirable dust is exceeded. For this reason alone, protective measures are necessary.

There are some data during sanding with extraction. Sanding blocks/pads or grinding discs need enough holes to allow the dust to be extracted through them (HSE, 2013). Here the exposure is significantly lower. The measurement data from recent years show that today sufficiently optimized on-tool extraction for grinders are offered to fall below the limit values.

To be on the safe side, an air cleaner should also always be used in rooms: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

When using self-levelling screeds (https://travauxbeton.fr/chape-autonivelante/), usually gypsum screed, there is usually no need for sanding.

Knocking off mortar, plaster, tiles



The removal of mortar, plaster, tiles can be done outside and inside with handheld tools, but also with hammer and chisel.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)		
Knocking off plaster, inside	R13: - 18.4 S13: - 1.1		95 12.5 95 0.788
Knocking off plaster, outside	R13: <0.42 - 4.15 S13: <0.018 - 0.55	GM 1.81 GM 0.065	95 4.03 95 0.426
Knocking off tiles, electric chisel with extraction and air cleaner	I02: 8.82 R02: 1.04 S02: 0.04	sometimes without air cleaner	4.26 0.81 0.16

S: silica R: respirable
I: inhalable GM: geometric mean
95: 95 percentile

If handheld tools like electric chisel or hammer drill are used, extraction is important. Indoors the additional use of air cleaners is necessary.

Air cleaners must also be used for manual chiseling.

Levelling work

Levelling work is mainly carried out with large machines such as excavators and caterpillars. Smaller work, e.g. on shaft openings, is also carried out by hand.

The dust exposure during levelling work depends on the soil moisture. For technical reasons alone a certain soil moisture is required. If this soil moisture is present, dust exposure can be assumed to be below the limit values.

If construction machines are used, windows and doors of the cabins must be closed (see “Driving of construction machines and vehicles”).

Milling slots

For milling slots for the electrical installation and during the installation of heating and water systems, cut-off machines, wall chasers, caulking hammers, etc. are used.

When using a wall chaser, two slots are created and the webs between them must then be broken out.

Even today, slots are still cut by hand with a chisel.

Tuckpoint grinding is a special case of milling, see "Tuckpoint grinding".

EXPOSURE DATA

			Szadkowska (PL) 2006
	Betten (DE) 2005	Lumens (NL) 2001	Network Italiano 2007
ACTIVITY	BG ETEM (DE) 2010	SUVA (CH)	Tjoe (NL) 2003
Milling slots	I31: 1.5-134 m 42.8 95 111.4 R31: 0.02-23.18 m 4.43 95 16.34 S31: 0.01-2.85 m 0.49 95 2.15	R02: 0.69, 2.32 S02: 0.10, 0.32	R32: 10.9 - 183.3 GM 41.3 95 106.8 S15: 1.058-5.198 GM 2.42 95 5.035
Milling slots			I05: GM 11.0 R05: GM 2.9
Recess milling		R53: n.d. - 18.9 GM 3.1 S53: n.d. - 6.9 GM 0.7	R14: 0.33-14.3 GM 1.9 S14: 0.036-4.7 GM 0.42
Milling slots with extraction	I04: 0.92-11.9 m 6.45 R04: <0.55-2.82 m 1.56 S04: <0.016-0.35 m 0.137	R05: 11.08 - 22.91 S05: 1.88 - 3.89	R11: 0.2 - 21.6 GM 3.94 95 17.3 S02: 0.346, 0.672
Milling slots with extraction	I22: 0.21 - 20.7 m 5.23 95 13.4 R22: 0.40 - 3.10 m 1.29 95 2.88		
Break webs between slots, crushing chisel, manual	I09: 0.28 - 20.49 m 5.59 95 15.51 R09: 0.25 - 2.69 m 1.33 95 0.68		
Break webs between slots, jackhammer	I16: 1.79 - 77.76 m 15.93 95 54.5 R16: <NG - 6.85 m 1.61 95 4.26		
Knocking slots by hand			R01: 17.9 S01: 1.388

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

During milling slots, parts of plaster and stones are removed from the wall. High-speed handheld tools produce large quantities of fine dust in this process. The limit values for inhalable, respirable and silica dust are always significantly exceeded.

When working with on-tool extraction, exposure is significantly reduced. When working indoors, the additional use of air cleaners reduces exposure below the limit values in many cases, especially when breaking out the webs: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

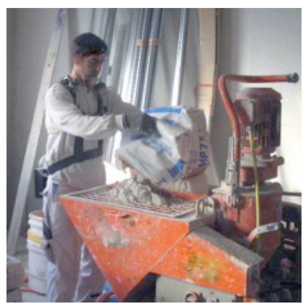
Mixing

When using dusty building materials such as cement, mortar, gypsum, plasters, fillers, floor levelling compounds, bagged material is mostly used.

EXPOSURE DATA

ACTIVITY	Network Italiano 2007 IGF (DE) 2010 BG BAU (DE)	Neiss (AT) 2016 Beaudry (CA) 2013 Flanagan (US) 2003	Alazard (FR) 2021 Flanagan 2006
Mixing mortar/ glue/ concrete	R06: 1.38 - 5.02 m 2.34 S02: 0.02, 0.048	R09: GM 0.91 13% >3 S09: GM 0.02 20% >3	R05: 0.45 - 1.83 S05: <0.009-0.03
Mixing cement	I63: 0.18 - 65.24 GM 5.1 95 46.2 R23: 0.16 - 8.96 GM 1.42 95 8.15	S28: 0.01-0.06 GM 0.01	R32: GM 1.39 S32: GM 0.04
Mixing mortar, vacuumed plastering machine	R14:0.5 - 1.05 GM 0.68 95 1.05		
Mixing screed		I01: 8.0 with I01: 0.2 R01: 3.5 Dustmonkey R01: <0.1	
Mixing low-dust powdery products	I12: 2.50 - 5.20 95 4.96 R12: 0.50 - 1.10 95 0.77		

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

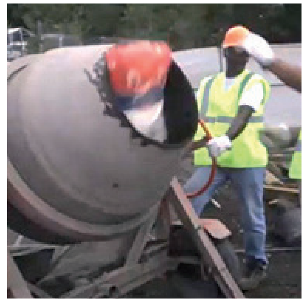


The individual bags are heavy to carry; dust is also generated when they are opened and especially when the powdered material is shaken out into the mixer. Finally, the bags are usually compressed to reduce the volume for disposal. Dust is also released in the process.

When using bagged material, at least the limit values for inhalable and respirable dust are exceeded and depending on the silica content of the building material, also the limit value for silica dust.

However, there are also bagged products, especially cement, in dissolvable bags https://www.lemoniteur.fr/article/lafarge-lance-le-sac-de-ciment-delitable.1184834. These bags are placed unopened in the mixer and then dissolve. This does not produce any dust.

If the material is delivered in a silo (large silo, One-Way container, pump truck), the concrete, screed or floor levelling compounds can be mixed without creating dust.



An extraction system on the mixer (concrete or mortar mixer, screed boy) reduces the dust load when opening and pouring out the building material bags and during mixing. But pressing together the bags remains a dust problem.

If smaller quantities of mortar, tile adhesive, floor levelling compounds or other dusty construction materials are prepared in buckets, low-dust products should be used.

Extraction devices on the bucket (*Dust reducer*, www.wakol.com; *Dustmonkey*, www.dustmonkey.at; *Dustex*, www.collomix.com) or bag opening aids (*Ripper*, www.uzin.de) reduce dust exposure. However, there remains a risk of dust exposure when shaking out and compacting the bags, unless this is done very carefully. Or low-dust techniques such as disposal containers with suction are used here as well.

Paving

Pavers cut and set stones, sweep sand into joints, and compact the pavement.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)	Constructiv 2020 (BE) van Peer 2021 (BE)	Middaugh (US) 2012
Cutting paving stones, dry	I05: 20.49-87.71 R10: 3.38-20.87 GM 7.04 95 19.21 S09: 0.03-5.74 GM 1.48 95 5.48	S03: 0.032, 0.703, 2.955 S01: 4.0	R17: GM 16.4
Cutting paving stones, wet	R5: <0.25 - 1.75 m 0.78 S5: <0.009 - 0.58 m 0.164	S01: 0.118 S01: 0.12	R14: GM 3.60 wet R12: GM 4.40 with LEV
Shake the pavement, without cutting stones	I04: 0.82 - 7.75 m 4.92 R11: <0.31 - 2.46 GM 0.49 95 1.81 S11: <0.009-0.058 GM 0.01 95 0.05		

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

If paving is only laid without cutting stones, there is hardly any dust. Sanding, the spreading of sand into the joints, and compacting, also produces little dust, especially if the sand is kept moist.

When stones are cut dry, a lot of dust is generated (see chapter ‘Cutting’). Here always work with machines with extraction. If the stones are crushed, mainly coarse dust is produced.

If cutting or sawing is done wet, the exposures are significantly lower, although not always below the limit values. However, when working wet, mud is produced that turns back into dust when it dries. If possible, the water must be either permanently renewed or at least replaced once a day. The mud in the environment must be removed regularly.

Plastering

When plastering, mortar is mixed, plaster is applied to the wall by hand or by machine, finally the fresh plaster is smoothed.

For the removal of plaster see "Knocking off mortar, plaster, tiles", for the mixing "Mixing", for spraying of concrete "Spraying/pouring of concrete".

EXPOSURE DATA

ACTIVITY	SUVA (CH) / BG BAU (DE) / Szadkowska (PL) 2006	Park (KR) 2019 / Grahn (SE) 2017 / Alazard (FR) 2021
Plastering	I07: GM 2.1 R07: GM 0.4	R35: 0.002 - 1.07 GM 0.32 S35: nd - 0.027 GM 0.003
Plastering	R15: 0.11 - 2.42 GM 0.6 95 2.16 S06: 0.003 - 0.06 m 0.03	R01: 0.43 S01: 0.021
Spraying of plaster	R06: 0.33 - 2.25 m 1.06 S06: 0.01 - 0.32 m 0.08	
Plastering, smoothing, inside; plastering machine	R17: 0.21 - 6.54 GM 0.92 95 4.19 S15: 0.004-0.039 GM 0.0098 95 0.031	
Plastering, smoothing, outside; plastering machine	R13: 0.17 - 1.88 GM 0.38 95 1.80 S12: <0.009-0.049 GM 0.012 95 0.039	
Plastering, smoothing; inside with extraction		R02: 0.59, 0.62 S02: <0.001, <0.007
Scraping/ Rubbing of plaster		R04: 1.02 - 28.6 S04: <0.012 - 0.035

S: silica R: respirable I: inhalable GM: geometric mean
m: mean 95: 95 percentile

When using bagged goods to produce plaster, dust is generated when opening, shaking out and squeezing the bags.

An extraction system on the mortar mixer reduces dust exposure when opening and shaking out the bags as well as during mixing. However, squeezing the bags remains a source of dust.

If smaller quantities of plaster are prepared in buckets, low-dust products should be used. Extraction devices on the bucket or bag opening aids reduce dust exposure (see chapter "Mixing"). But the squeezing of the bags is not covered by the extraction system.

If the material is delivered in a silo (large silo or One-Way container), the plaster can be mixed without generating dust.

Scraping/Rubbing/Smoothing plaster involves a dust load. However, little data are available on this.

Polishing

When polishing (grinding, sanding), surfaces are treated with disc, belt or orbital sanders, but also by hand. This usually produces very fine dust. Exposure data see chapter “Grinding”.

Refractory / chimney construction

Refractory construction involves the construction of refractory building components, including kilns for bricks and porcelain. Often the demolition of existing kilns is necessary beforehand. Refractory materials are also used, at least in part, in chimney construction.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)		
Refractory and chimney construction, demolishing	R44: 0.25 - 90 S47:	GM 3.75	95 51.2 90 3.01
Refractory and chimney construction, mixing	R10: 0.37 - 24.9 S12:	GM 1.88	95 18.8 90 2.16

S: silica R: respirable
GM: geometric mean
90: 90 percentile 95: 95 percentile

Refractory bricks and mortars contain a lot of quartz. Therefore, when demolishing such structures, dust with a high quartz content is produced. Such work often takes place in very confined spaces.

Removing construction rubble

On construction sites, there is usually not only dusty waste, but also parts of stones, tiles, wood, concrete, etc. Before being vacuumed up, the coarser parts have to be collected. To do this, the rubble should be sprayed to stop the dust from forming. The coarser parts are then put into a wheelbarrow or bucket with the shovel and the remaining debris is removed with a vacuum cleaner.

The building debris can also be pushed together with a coarse hoover nozzle. This way, the fine dust is picked up immediately by the hoover. Then the coarser pieces are put into the wheelbarrow and the remaining fine dust is vacuumed up.

The additional use of an air cleaner is indoors ideal: www.bgbau.de/themen/sicherheit-und-gesundheit/staub/low-dust-techniques

Road construction

Road construction encompasses a wide range of activities. Measurements in Italy listed here were not determined as activity related.

EXPOSURE DATA

	Alazard (FR) 2021	Valiante (US) 2004
ACTIVITY	INAIL (IT) 2019	Beaudry (CA) 2013
Cement road construction	R10: GM 0.325 6.1% > 1.5 S10: GM 0.020 25.6% > 0.05	
Road construction workers	R23: GM 0.145 S22: GM 0.010	
Sawing asphalt	R07: <0.34 - 0.24 S07: <0.09 - 0.03	S08: nd - 0.07 m 0.041
Cutting concrete or asphalt		S40: 0.00 - 0.14 GM 0.02

S: silica R: respirable GM: geometric mean m: mean
nd: not detectable

The exposure data quoted here usually refer to several activities or, in the case of ‘Cutting concrete or asphalt’, to the processing of very different materials. Therefore, no concrete protective measures can be recommended.

In general, however, it is always recommended to work wet when cutting or sawing road surfaces.

For further exposure data see “Asphalt milling” and “Paving”.

Rubble recycling

Construction waste is often sorted, crushed and partly reused on the construction site.

EXPOSURE DATA

ACTIVITY	Alazard (FR) 2021 DGUV 2020, Arnone 2020 (DE)	Easterbrook (GB) 2009
Rubble recycling	R02: 0.48, 9.44 S02: 0.007, 0.30	R01: 0.35 S01: 0.118
Rubble recycling, Crusher, mill	I40: 95 23.4 R46: 95 4.57 S39: 95 0.349	
Rubble recycling	I31: 95 7.25 R33: 95 1.45	
Rubble recycling, Conveying, loading	I40: 95 5.38 R44: 95 1.93 S37: 95 0.0493	
Rubble recycling, Control cabin, test bench	I13: 95 5.69 R13: 95 1.63 S12: 95 0.032	

S: silica R: respirable I: inhalable 95: 95 percentile

The crushing of building components naturally produces a lot of dust, with a high proportion of silica.

Windows and doors of the cabins of machines, vehicles and control rooms must be closed. If work has to be carried out outdoors, respiratory protection must be worn if the dust load cannot be reduced sufficiently by other means e.g. by spraying with water.

Sanding

When sanding (grinding, polishing), surfaces are treated with disc, belt or orbital sanders, but also by hand. This usually produces very fine dust.

Exposure data see chapter “Grinding”.

Sawing

In sawing, as in cutting, construction materials are separated. The exposure data for these activities are not always neatly separated. Therefore, they are summarized and discussed under “Cutting and sawing”.

Scaffolding

In scaffolding, dust occurs when drilling holes for scaffolding anchors and when dismantling scaffolding.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)
Scaffold dismantling	R12: <0.86 - <2.5 S06: <0.83 - <0.125

S: silica R: respirable

No data are available on dust exposure when drilling holes for the scaffolding anchors. However, the dust exposure is rather low here. The use of drilling machines with integrated extraction is recommended.

When dismantling scaffolding, the rubble lying on the planks is shaken off. The exposure data of the BG BAU certainly do not reflect the dust exposure. A solution to this dust problem, which is also damaging to the image, is not known.

Scattering quartz sand

Quartz sand is sprinkled into not yet cured resin floors or in freshly laid mastic asphalt *(Gussasphalt)*.

EXPOSURE DATA

ACTIVITY	BG BAU (DE)	Network Italiano 2007
Sanding, with spreader car		R04: <0.2 - 1.4 m 0.7 S04: 0.017 - 0.079 m 0.040
Scatter quartz sand in resin floors	R11: 1.71 - 4.71 GM 3.15 95 4.7 S11: 0.36 - 1.70 GM 0.715 95 1.55	R08: <0.04 - 5.9 m 1.1 S08: 0.028 - 0.293 m 0.088
Scatter low-dust quartz sand in resin floors	R06: <0.13 - 0.27 GM 0.059 S06: 0.007 - 0.037 GM 0.015	
Scatter quartz sand in mastic asphalt	R24: 0.7 - 38.4 GM 4.57 95 33.34 S24: <0.05 - 0.236 GM 0.071 95 0.206	

S: silica R: respirable GM: geometric mean m: mean 95: 95 percentile

The scattering relates to a high silica dust load. If the quartz sand is not spread by hand, but with a spreader wagon, the dust load is significantly lower.

For resin, low-dust quartz bedding materials can be used: *Dorsicoat*, www.dorfner.com/en

The scattering of low-dust quartz bedding materials in mastic asphalt is technically not possible. Washed sand from which the fine particles have been removed could be used. Or silica-free bedding, e.g. from recycled glass.

Spraying/pouring of concrete

Concrete is mixed on site for smaller quantities; otherwise it is delivered to the site by truck mixer. There it is poured or sprayed.

EXPOSURE DATA

ACTIVITY	Alazard (FR) 2021
Spraying of concrete	I03: 11.4, 18.6, 36.9 R03: 1.93, 4.55, 4.84 S03: <0.028, 0.01, 0.03

S: silica R: respirable I: inhalable

No measurement data are available for pouring concrete. Since it is a liquid material, only a low dust load is to be expected here.

For the spraying of concrete, Alazard reports that at least the limit values for inhalable and respirable dust are exceeded. Other measurement data are necessary but, in the meanwhile, technical solutions to lower emissions while spraying concrete should be investigated. Respiratory protections are necessary, and should be adapted to each construction site, but particularly when spraying concrete in closed places (ex : tunnels, ...).

For mixing concrete see chapter “Mixing”.

Stonemasonry on construction site

Stonemasonry work is carried out both stationary in the company and on construction sites. This involves not only the renovation of historical buildings, especially churches, but also the installation and finishing of kitchen tops, windowsills, staircases, etc.

EXPOSURE DATA

ACTIVITY	BG BAU (DE) Healy (IE) 2014 DGUV 2020, Arnone 2020 (DE)
Grinding natural stone, indoor, without extraction	I09: 6.52 - 51.2 R08: 2.94 - 10.1 S08: 0.25 - 2.2
Grinding with extraction, Marble, Granite, Artificial stone (Joest P1)	I02: <0.5, <0.75 R02: <0.5, <0.75 S02: <0.018, <0.028
Sandstone grinding	R32: GM 7.1 S16: GM 4.2
Sandstone grinding with on-tool extraction	R80: GM 0.5 S40: GM 0.03
Stonemasonry, wet sawing, milling, cutting	I73: 95 3.74 R89: 95 2.22 S89: 95 0.40
Stonemasonry, mechanical grinding	I48: 95 22.5 R49: 95 7.72 S50: 95 0.83
Stonemasonry, manual grinding	I28: 95 26.2 R28: 95 2.098 S28: 95 0.344

S: silica R: respirable
GM: geometric mean
95: 95 percentile

Many of the low-dust techniques used on construction sites are less suitable for stonemasonry work. This is because stonemasons have to keep an eye on their workpiece when cutting, polishing or grinding. The usual bonnets with extractors, e.g. on angle grinders, can therefore not be used. However, there are new developments (Joest P1) that allow dust-free work without impairing the view of the workpiece.

Track construction work

Track construction work includes a variety of activities. Most of these activities are carried out by large track construction machines.

Operators are exposed to high dust levels if they are not in enclosed cabins of the track construction machines.

EXPOSURE DATA

ACTIVITY	Funk (DE) 2020 / Alazard (FR) 2021 / BG BAU (DE)
Ballast installation, dry	I18: 0.27 - 80.8 GM 5.75 95 52.8 R18: 0.005 - 16.1 GM 0.99 95 13.6 S18: 0.004 - 1.8 GM 0.11 95 1.63
Ballast installation, wet	I5: 1.4 - 5.09 GM 3.53 m 3.89 R6: 0.4 - 2.23 GM 0.66 m 0.83 S6: 0.005 - 0.27 GM 0.047 m 0.093
Clearing Chain	I8: 1.51 - 59.6 GM 9.20 m 20.4 R8: 0.22 - 4.59 GM 1.22 m 1.94 S7: 0.037 - 0.3 GM 0.143 m 0.173
Control station, in the cabin	I7: 0.04 - 2.61 GM 0.54 m 1.18 R8: 0.01 - 0.84 GM 0.23 m 0.24 S6: 0.002 - 0.095 GM 0.02 m 0.039
With extraction	I04: 3.05 - 9.69 R05: 0.66, 0.8, 1.33, 2.07, 2.33
Manual removal of a railway track	I09: <2.9 - 0.71 R09: <0.05 - 0.17 S09: <0.002 - 0.148

S:silica R:respirable I:inhalable
GM: geometric mean m: mean
95: 95 percentile

In the branch solution “Dust minimization in track superstructures” (2017) BG BAU describes good and bad practice. Initial measurements (Funk, 2020) show technical attempts to reduce dust exposure during track bed renovation.

Alazard (2021) describes the manual removal of a railway track (ballast, sleepers, rails and fastenings) in order to then lay a new track.

In view of the dust loads usually encountered during this work (see also Alazard’s picture), the low exposures are surprising. However, during the measuring it was mostly damp, sometimes there was heavy rain.

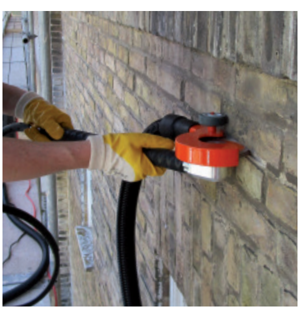
Tuckpoint grinding

Tuckpoint grinding is a special case of milling slots. To prevent water damage, exterior building renovation often requires the removal of deteriorated mortar between bricks or blocks and the subsequent replacement with new mortar.

EXPOSURE DATA

ACTIVITY	CooperM (US) 2015 Deurssen (NL) 2014 Meeker (US) 2009 BG BAU (DE)		Easterbrook (GB) 2009 Beaudry (CD) 2013 Croteau (US) 2002 Tjoe (NL) 2003		Collingwood (US) 2007 Flanagan (US) 2006 Shields (US) 1999 Echt (US) 2007	
Tuckpoint grinding	S05: 3.06 - 7.24 S05: 5.25 - 25.8	m 4.99 m 10.9	R14: S14:	GM 22.17 GM 3.04	R 97: S101:	GM 6.05 GM 0.60
Tuckpoint grinding	R25: 0.36 - 17.04 S25: 0.02 - 0.80	GM 3.42 GM 0.18	R10: 0.55-8.0 S10: 0.089-1.6	GM 2.4 GM 0.35	R37: 0.25 - 349.1 S37: 0.01 - 76.10	GM 12.3 GM 1.14
Tuckpoint grinding	S05: 4.57 - 9.90 S05: 3.46 - 31.4	m 7.23 m 10.9	S97: 0.00 - 24	GM 0.25	R06: 13-105 S06: 3.9-34	GM 48 GM 12
Tuckpoint grinding			R04: 0.16-6.93 S04: 0.03->3.6	m 3.24 m >0.23		
Tuckpoint grinding, wet					R06: <0.01-26 S06: <0.01-7.6	GM 5.81 GM 1.58
Tuckpoint grinding with extraction	S05: 0.19 - 0.50 S05: 0.28 - 0.85	m 0.33 m 0.47	R14: GM 6.11 S14: GM 1.02	low ventilation	R06: <0.02-1.3 S06: <0.01-0.72	GM 0.49 GM 0.41
Tuckpoint grinding with extraction	S07: <0.069 - 0.137 S05: 0.224 - 0.738	m 0.091 m 0.375				
Tuckpoint grinding with extraction	I01: 0.66 S01: <0.009	R01: <0.25	R13: GM 3.01 S13: GM 0.47	high ventilation	R22: 0.31 - 4.50 S22: <0.01-0.86	GM 1.0 GM 0.06

S: silica R: respirable I: inhalable GM: geometric mean m: mean



Tuckpoint grinding without protective measures is associated with very high dust exposure. The first publications of measurements with extraction systems on the grinders (since 1999) show a clear reduction in dust exposure, but the limit values are still considerably exceeded. The data from Croteau et al. (2002) make this particularly clear. Wet work does not lead to safe work either.

The first measurements with Piranha Cutter indicate that the limit values can be undercut with it https://rokamat.com/produkte/fugenfraese/piranha-cutter/. On another construction site it was obvious that no or hardly any dust was produced when using the Piranha Cutter. Unfortunately, it was not possible to take measurements on this site.

Wall chasing

Wall chasers are handheld electric tools which are used in the electrical installation and during the installation of heating and water systems.

For exposure data see chapter "milling slots".

12.2 Dust exposure on construction sites

Here all exposure data collected within the scope of the project are listed together.

The references (for example 'Alazard (FR)') see the bibliography. Depending on the data given there, the exposures (mg/m^3) for inhalable dust (I), respirable dust (R) and RCS (S) are listed:

1. number of measurements
2. range of measured values, in case of few measurements the single values
3. geometric mean (GM)
4. mean value (m); sometimes median
5. 95 percentiles (95)

In some cases, further statistical data are given (28% >1.5 means that 28% of the data set are above 1.5 mg/m^3).

DUST EXPOSURE ON CONSTRUCTION SITES

ACTIVITY / JOB	Park (KR) 2019 Various Kirkeskov (DK) 2016 Scancarello (IT) 2020 DGUV 2020, Arnone 2020 (DE) Betten (DE) 2005 BG ETEM (DE) 2010 BG BAU (DE)	 Antonsson (SE) 2019 Christensson (SE) 2012 SUVA (CH) McLean (NZ) 2017 INAIL (IT) 2019 Meeker (US) 2009 Deurssen '14; ARBOUW '12 (NL)	Garcia (US) 2006 Constructiv '20; van Peer '21 (BE) Network Italiano 2007; Scarcelli 2014 Hall '13; CooperJ '15; Grant '19 (US) CooperM (US) 2012/2015 Rappaport '03; Collingw. '07 (US) Akbar '02/'07; Shields 1999 (US) Tjoe (NL) 2003; Hammond (US) 2017	Croteau (US) 2002 Grahn (SE) 2017 Flanagan (US) 2001/2003 Radnoff (CA) 2014 Thorpe (GB) 1999 Beaudry (CA) 2013 Alazard (FR) 2021 Lumens (NL) 2001	Healy (IRL) 2014 Chisholm (GB) 1999 Flanagan (US) 2006 Szadkowska (PL) 2006 Easterbrook (GB) 2009 Valiante (US) 2004 Middaugh (US) 2012 Echt (US) 2004/2007
Small milling machines on asphalt pavements, operator	I16: <0.25-3.14 GM 0.65 95 2.70 R19: <0.14-1.90 GM 0.29 95 1.53 S16: 0.003-0.37 GM 0.024 95 0.20			R04: <0.04 - <0.60 S04: <0.001 - 0.03	
Big milling machines on asphalt pavements with extraction, operator	I07: 0.17-1.52 GM 0.34 R11: <0.08-1.38 GM 0.21 95 0.98 S08: <0.003-0.045 GM 0.009		S10: <LOD - 0.011 GM 0.0042 S11: <LOD - 0.013 GM 0.0062	I06: 0.38 - 1.22 R06: <0.09 - 0.66 S06: 0.006 - 0.035	
Big milling machines on asphalt pavements with extraction, Ground man			S10: <LOD - 0.024 GM 0.0090 S11: <LOD - 0.010 GM 0.0061		
Big milling machines on asphalt pavements without extraction, operator	I08: 0.47-8.21 GM 2.37 95 8.21 R77: 0.11-47.10 GM 4.47 95 26.24 S77: 0.002-7.90 GM 0.210 95 4.44			I03: 0.39 - 3.87 R03: 0.09 - 1.23 S03: 0.01 - 0.08	
Scraping of asphalt				I02: 0.42, 0.8 R06: <0.06 - 0.08 S06: 0.003 - 0.01	
Abrasive blasting				S22: 0.06 - 11 GM 1.6	R65: GM 3.74 S64: GM 0.24
Blasting, dry	R90: GM 2.43 95 63.8 S90: GM 0.122 95 2.819	R04: m 1.06 S04: m 0.092			R02: 18.66, 75.04 S02: 0.16, 1.22
Blasting, wet	R38: GM 0.87 95 4.97 S38: GM 0.40 95 0.332				
Bricklayer		R12: 0.04-0.59 GM 0.22 S12: 0.01-0.04 GM 0.02	R11: 0.16 - 29.0 m 2.13 S11: 0.007-14.2 m 0.32	S16: 0.017 - 1.0 GM 0.105	I07: GM 3.0 R07: GM 1.3
Brick laying, outdoors, without stone cutting	R11: 0.11-0.77 GM 0.28 95 0.71 S10: 0.004-0.123 GM 0.0095 95 0.071				
Brick laying, indoors, without stone cutting	R19: <0.29-4.43 GM 1.08 95 2.49 S17: <0.009-0.12 GM 0.023 95 0.102				

Construction site cleaner	R33: GM 1.18 95 8.38 S33: GM 0.039 95 0.408		R12: 0.14-2.5 GM 0.58 S12: 0.0016-0.097 GM 0.017	R11: GM 0.55 5%>3 S11: GM 0.03 50%>0.05	R62: GM 0.66 S61: GM 0.05
Construction site cleaner				R03: <0.13 - 0.87 S03: <0.003 - 0.016:	
Cleaning				S30: 0.00 - 0.69 GM 0.03	
Cleaning concrete floor		R04: 0.39 - 0.69 S04: 0.33 - 0.57			
Cleaning with the sweeper	R19: GM 0.54 95 2.043 S19: GM 0.013 95 0.039				
Sweeping	I06: 0.26 - 25.11 m 8.16 A06: <NG - 2.6 m 0.89				R04: 0.8 - 5.0 m 2.5 S04: 0.07 - 0.69 m 0.41
Compacting with hand machines	I09: 0.24 - 12.17 GM 1.71 95 10.4 R23: 0.11 - 3.65 GM 0.45 95 2.72 S22: 0.004 - 0.66 GM 0.02 95 0.45				
Pipeline construction, excavation, compacting				R04: 0.14 - 10.3 S04: <0.009 - 0.23	
Box countersinking without extraction	I06: 6.84 - 88.00 m 35.55 R06: 1.42 - 7.98 m 3.36				
Box countersinking with extraction	I08: 0.20 - 19.03 m 5.03 R08: 0.18 - 1.93 m 1.06				
Core drilling, wet		R02: 0.08, 0.18 S02: 0.02, 0.05		S02: 0.02, 0.02	
Cutting paving stones, dry	I05: 20.49-87.71 R10: 3.38-20.87 GM 7.04 95 19.21 S09: 0.03-5.74 GM 1.48 95 5.48		S03: 0.032, 0.703, 2.955 S01:4.0	R06: GM 89.85 S06: GM 22.52	R17: GM 16.4
Cutting paving stones, wet	R5: <0.25 - 1.75 m 0.78 S5: <0.009 - 0.58 m 0.164		S01: 0.118 S01: 0.12		R14: GM 3.60 wet R12: GM 4.40 with LEV
Cutting paving stones with extraction				R06: GM 4.31 S06: GM 0.95	
Cutting stones, dry		S05: 1.0 - 4.0 m 2.83 block S05: 0.45 - 1.6 m 0.94 brick	R01: 69.60 S01: 44.37	R06: 8.0 - 58.0 S06: <0.5 - 4.8	R05: 21-115 GM 43.2 S05: 5.7-38 GM 12.7
Cutting stones, wet		S05: 0.09 - 0.61 m 0.26 block S05: <0.05 - 0.14 m 0.09 brick	R04: 1.81-5.97 m 3.81 S04: 0.920-3.405 m 2.161	R04: 0.6, 1.3, 1.9, 6.4 S04: <0.3, <0.3, <0.4, <0.6	R05: 2.9-11 GM 5.73 S05: 1.0-2.2 GM 1.62
Cutting stones with extraction		S05: <0.05 - 0.17 m 0.11 block S05: <0.05 - 0.15 m 0.08 brick	S01: 0.08	R02: 0.2, 0.7 S02: <0.35, <0.5	R05: 1.9-3.6 GM 2.58 S05: 0.79-1.1 GM 0.95

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

DUST EXPOSURE ON CONSTRUCTION SITES

ACTIVITY / JOB	Park (KR) 2019 Various Kirkeskov (DK) 2016 Scancarello (IT) 2020 DGUV 2020, Arnone 2020 (DE) Betten (DE) 2005 BG ETEM (DE) 2010 BG BAU (DE)	Antonsson (SE) 2019 Christensson (SE) 2012 SUVA (CH) McLean (NZ) 2017 INAIL (IT) 2019 Meeker (US) 2009 Deurssen '14; ARBOUW '12 (NL)	Garcia (US) 2006 Constructiv '20; van Peer '21 (BE) Network Italiano 2007; Scarcelli 2014 Hall '13; CooperJ '15; Grant '19 (US) CooperM (US) 2012/2015 Rappaport '03; Collingw. '07 (US) Akbar '02/'07; Shields 1999 (US) Tjoe (NL) 2003; Hammond (US) 2017	Croteau (US) 2002 Grahn (SE) 2017 Flanagan (US) 2001/2003 Radnoff (CA) 2014 Thorpe (GB) 1999 Beaudry (CA) 2013 Alazard (FR) 2021 Lumens (NL) 2001	Healy (IRL) 2014 Chisholm (GB) 1999 Flanagan (US) 2006 Szadkowska (PL) 2006 Easterbrook (GB) 2009 Valiante (US) 2004 Middaugh (US) 2012 Echt (US) 2004/2007
Cutting stones, wet and with extraction			R04: 0.20-1.20 m 0.60 S04: nd-0.669 m 0.253		
Cutting cement roof tiles			R38: 0.2 - 3.6 GM 0.94 S38: 0.04 - 0.44 GM 0.14		
Cutting roof tiles, dry, without extraction				R03: 2.26, 5.8, 17.8 S03: 0.09, 0.31, 1.40	
Cutting roof tiles, dry, without extraction	R42: GM 2.215 95 13.26 S42: GM 0.442 95 2.832	R12: 11,7 - 65 GM 26,7 95 58,8 S12: 2,09 - 12 GM 4,83 95 10.8		S10: 0.29 - 0.45 GM 0.35	
Cutting roof tiles, dry, with extraction		R30: 4.54 - 42 GM 18.2 95 38.8 S30: 0.81 - 8.6 GM 3.44 95 7.63	R06: 6.04 - 17.40	R01: 0.58 S01: 0.035	
Cutting roof tiles, wet		R12: 2,96 - 11 GM 5,47 95 9,55 S12: 0,16 - 1,2 GM 0,41 95 0,16		R03: <0.24, <0.25, <0.37 S03: <0.009, 0.006, 0.006	
Cutting roof tiles, table-saw, with extraction		R24: 3.91 - 61 GM 13.9 95 34.5 S24: 0.02 - 11 GM 1.35 95 6.85			
Cutting tiles, dry				R04: 4.27 - 7.00 S04: 0.32 - 0.85	
Cutting tiles, wet				R01: <0.73 S01: 0.087	
Blowing dust from roof tiles			R06: 2.16 - 5.39		
Cutting Linea board (fibre cement)		S04: 0.002 - 0.486 GM 0.017			
Cutting concrete, dry			S01: 0.311 S01: 1.54		
Cutting concrete/bricks with extraction	R05: 0.044 - 0.30 iQ-power-tools S05: <0.008 - 0.034				
Sawing concrete	R39: GM 2.13 95 13.21 S39: GM 0.041 95 0.244				S06: 0.15 - 0.50 m 0.348

Cutting concrete / brick					R185: GM 0.72 S164: GM 0.08
Cutting concrete or asphalt				S40: 0.00 - 0.14 GM 0.02	
Sawing concrete, dry, inside and outside				R15: GM 0.76 14%>3 S15: GM 0.07 77%>0.05	R04: 7.3 - 84 m 41.2 S04: <0.14 - 3.8 m 1.49
Sawing concrete, wet		R02: 0.15, 0.24 S02: 0.02, 0.02	S01: 0.027	R08: <014 - 0.63 S08: 0.003 - 0.21	R04: 0.55 - 4.1 m 1.54 S04: 0.08 - 1.3 m 0.40
Table saw, concrete			S01: 11.823 without extraction S01: 2.366 with extraction S01: <0.036 wet		
Alligator saw, aerated concrete			S01: 0.015		
Sawing asphalt				R07: <0.34 - 0.24 S07: <0.09 - 0.03	S08: nd - 0.07 m 0.041
Demolisher		R45: 0.09-33.76 GM 1.17 S45: 0.01-0.91 GM 0.12	R21: 0.20-9.4 GM 1.4 S21: 0.038-1.3 GM 0.14 67% >0.075	R82: 0.5 - 298.8 GM 2.1 S82: n.d. - 35.9 GM 1.1	
Demolishing, Chimney and Refractory construction	R47: GM 4.69 95 19.5 S47: GM 0.372 95 4.176				
Demolishing, manually, inside	I08: 31.0 - 460 GM 138 R02: 3.3, 3.5 S02: 0.67, 0.71	S02: 0.001, 0.037	R14: <0.05-3.5 GM 0.60 95 3.42 S14: 0.014-0.114 GM 0.042 95 0.109		I03: GM 66.0 R03: GM 16.2
Demolishing, manually, outside					I15: GM 2.7 R15: GM 0.5
Demolishing, mechanical (with extraction), inside	I04: 0.92 - 61.0 GM 4.42 R04: 0.05 - 3.3 GM 0.43 S04: 0.02 - 0.45 GM 0.09				
Demolishing with jackhammer, inside				R14: GM 0.96 21%>3 S14: GM 0.10 88%>0.05	R12:1.08-8.9 GM 2.25 95 6.65 S12:<0.02-1.56 GM 0.27 95 1.15
Demolishing, demolition hammer, outside, dry			S01: 0.317		R04: 0.38-2.77 m 1.37 S04: 0.05-0.43 m 0.2
Demolishing, jackhammer, outside					S25: 0.09 - 0.63 m 0.276
Demolishing, demolition hammer, outside, wet					R04: 0.26-0.83 m 0.61 S04: 0.04-0.29 m 0.13

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

DUST EXPOSURE ON CONSTRUCTION SITES

ACTIVITY / JOB					
	Park (KR) 2019		Garcia (US) 2006	Croteau (US) 2002	Healy (IRL) 2014
	Various	Antonsson (SE) 2019	Constructiv '20; van Peer '21 (BE)	Grahn (SE) 2017	Chisholm (GB) 1999
	Kirkeskov (DK) 2016	Christensson (SE) 2012	Network Italiano 2007; Scarcelli 2014	Flanagan (US) 2001/2003	Flanagan (US) 2006
	Scancarello (IT) 2020	SUVA (CH)	Hall '13; CooperJ '15; Grant '19 (US)	Radnoff (CA) 2014	Szadkowska (PL) 2006
	DGUV 2020, Arnone 2020 (DE)	McLean (NZ) 2017	CooperM (US) 2012/2015	Thorpe (GB) 1999	Easterbrook (GB) 2009
	Betten (DE) 2005	INAIL (IT) 2019	Rappaport '03; Collingw. '07 (US)	Beaudry (CA) 2013	Valiante (US) 2004
	BG ETEM (DE) 2010	Meeker (US) 2009	Akbar '02/'07; Shields 1999 (US)	Alazard (FR) 2021	Middaugh (US) 2012
ACTIVITY / JOB	BG BAU (DE)	Deurssen '14; ARBOUW '12 (NL)	Tjoe (NL) 2003; Hammond (US) 2017	Lumens (NL) 2001	Echt (US) 2004/2007
Demolishing, chiseling, manual	R85: 0.085 - 19.3 GM 1.92 95 9.28 S81: 0.081 - 7.0 GM 0.18 95 1.88				
Demolishing with Robot Brokk 40		R03: 0.15 0.32 0.46 S03: 0.003 0.05 0.06			
Drilling	R18: GM 1.34 95 7.00 S18: GM 0.155 95 2.153				
Drilling	I07: 2.94 - 10.11 m 6.09 R07: 1.12 - 2.73 m 1.75	S04: <0.001-0.762 GM 0.007		Masonry S172: 0.0-94 GM 0.04 Stone S12:0.01 - 0.13 GM 0.02	
Drilling in concrete	I04: GM 47.2 R04: GM 3.77 S01: 0.308 Sheperd 2009	R46: 0.02-10.86 GM 0.86 S46: 0.01- 1.36 GM 0.20	S05: 0.42-0.84 m 0.68		R95: GM 1.82 S97: GM 0.20
Drilling in concrete				R03: 0.25, 5.01, 18.5 S03: <0.02, 0.02, 0.90	S02: 0.05, 0.16
Drilling in concrete, wet		R02: <0.04, 0.21 S02: <0.01, 0.02		R02: 0.56, 1.01 S02: 0.054, 0.071	
Drilling in concrete with extraction	I14: GM 2.1 - 6.19 R14: GM 0.21 - 0.37 S04: 0.006 - 0.28 GM 0.015 Sheperd'09	R02: 0.15, 0.16 S02: 0.009, 0.01	S05: <0.02 - 0.05 m 0.04		
Drilling in concrete with extraction				R01: <0.4 S01: <0.01	
Construction machinery, Cabins open	R39: 0.18 - 7.73 GM 0.99 95 4.22 S37: 0.002 - 0.784 GM 0.055 95 0.445	S05: 0.001 - 0.143 GM 0.009			
Construction machinery, Cabins closed	R71: 0.04 - 3.53 GM 0.30 95 1.04 S64: 0.002 - 0.081 GM 0.007 95 0.037			R04: <0.017 - <0.17 S04 <0.004 - 0.01	
Excavator driver		R50: GM 0.181 2.8% > 1.5 S43: GM 0.010 6.5% > 0.05			
Truck, dump truck driver		R10: GM 0.188 6.1% > 1.5 S10: GM 0.006 6.1% > 0.05		S16: 0.004 - 0.11 GM 0.013	

Concrete grinding	R58: 4.26 - 367.5 GM 50.0 S58: 0.1 - 17.62 GM 2.06	R10: GM 5.5 S10: 0.012 - 3.207 GM 0.657	R34: 0.34-81.0 m 24.3 GM 14.3 S34: 0.02-7.10 m 1.5 GM 0.929	R23: GM 6.17 84% >3 S23: GM 0.63 100% >0.05	
Concrete grinding		R03: 1.36, 1.63, 1.78 S03: 1.13, 1.35, 1.48		R04: 1.95 - 14.7 S04: <0.01 - 0.88	
Concrete chipping	R36: 0.19 - 62.72 GM 1.78 S36: 0.005 - 3.06 GM 0.12			R05: GM 165.3 S05: GM 29.16	
Surface grinding				S244: 0.00 - 2.0 GM 0.09	R114: GM 2.72 S122: GM 0.29
Concrete floor sanding			S01: 1.536	R09: GM 0.63 7%>3 S09: GM 0.07 80%>0.05	
Polishing concrete		R05: GM 4.2 S05: 0.003 - 4.767 GM 0.306			I08: GM 58.0 R08: GM 7.5
Concrete wet grinding			R04: 5.27 - 12.8 m 7.77 GM 7.29 S04: 0.33 - 0.93 m 0.52 GM 0.477		
Concrete grinding with extraction	I01: 1.03 R01: 0.56 S01: 0.054		R15: 0.81-12.7 m 5.49 GM 4.10 S15: 0.03-1.00 m 0.38 GM 0.250	R02: 0.23, 0.24 S02: 0.01, 0.006	
Concrete grinding with extraction				R05: 0.17 - 2.79 S05: 0.004 - 0.247	
Concrete grinding with extraction				R05: GM 8.0 S05: GM 1.7	
Sack and patch concrete				R13: GM 0.40 3%>3 S13: GM 0.03 40%>0.05	
Concrete grinding with extraction and air cleaner		R04: 0.13, 0.13, 0.3, 0.89 S04: 0.008, 0.014, 0.03, 0.07			
Screed grinding	I05: 2.37 - 67.5 R08: 0.2 - 9.77 S07: 0.006 - 1.4				
Drywall, sanding	I26: 1.12-353.43 GM 20.33 95 233.7 R32: 0.41-36.50 GM 3.30 95 29.80 S14: 0.0025-0.400 GM 0.032 95 0.205	R03: 2.09, 2.17, 2.38 S01: <0.0005	R17: 1.7 - 7.3 GM 3.3 95 6.6 S13: 0.006-0.033 GM 0.01 95 0.025		
Drywall, Cutting and mounting panels		R04: 0.42 - 0.95 S04: 0.02 - 0.04			

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

DUST EXPOSURE ON CONSTRUCTION SITES

ACTIVITY / JOB					
	Park (KR) 2019 Various Kirkeskov (DK) 2016 Scancarello (IT) 2020 DGUV 2020, Arnone 2020 (DE) Betten (DE) 2005 BG ETEM (DE) 2010 BG BAU (DE)	 Antonsson (SE) 2019 Christensson (SE) 2012 SUVA (CH) McLean (NZ) 2017 INAIL (IT) 2019 Meeker (US) 2009 Deurssen '14; ARBOUW '12 (NL)	Garcia (US) 2006 Constructiv '20; van Peer '21 (BE) Network Italiano 2007; Scarcelli 2014 Hall '13; CooperJ '15; Grant '19 (US) CooperM (US) 2012/2015 Rappaport '03; Collingw. '07 (US) Akbar '02/'07; Shields 1999 (US) Tjoe (NL) 2003; Hammond (US) 2017	Croteau (US) 2002 Grahn (SE) 2017 Flanagan (US) 2001/2003 Radnoff (CA) 2014 Thorpe (GB) 1999 Beaudry (CA) 2013 Alazard (FR) 2021 Lumens (NL) 2001	Healy (IRL) 2014 Chisholm (GB) 1999 Flanagan (US) 2006 Szadkowska (PL) 2006 Easterbrook (GB) 2009 Valiante (US) 2004 Middaugh (US) 2012 Echt (US) 2004/2007
Knocking off tiles, electric chisel with extraction and air cleaner	I02: 8.82 sometimes 4.26 R02: 1.0 without 0.81 S02: 0.04 air cleaner 0.16				
Knocking off plaster, inside	R13: -18.4 95 12.5 S13: -1.1 95 0.788				
Knocking off plaster, outside	R13: <0.42-4.15 GM 1.81 95 4.03 S13: <0.018-0.55 GM 0.065 95 0.426				
Milling slots	I31: 1.5-134 m 42.8 95 111.4 R31: 0.02-23.18 m 4.43 95 16.34 S31: 0.01-2.85 m 0.49 95 2.15	R02: 0.69, 2.32 S02: 0.10, 0.32	R32: 10.9 - 183.3 GM 41.3 95 106.8 S15: 1.058-5.198 GM 2.423 95 5.035		I05: GM 11.0 R05: GM 2.9
Recess milling			R14: 0.33-14.3 GM 1.9 S14: 0.036-4.7 GM 0.42	R53: n.d. - 18.9 GM 3.1 S53: n.d. - 6.9 GM 0.7	
Milling slots with extraction	I04: 0.92-11.9 m 6.45 R04: <0.55-2.82 m 1.56 S04: <0.016-0.35 m 0.137	R05: 11.08 - 22.91 S05: 1.88 - 3.89	R11: 0.2 - 21.6 GM 3.94 95 17.3 S02: 0.346, 0.672		
Milling slots with extraction	I22: 0.21 - 20.7 m 5.23 95 13.4 R22: 0.40 - 3.10 m 1.29 95 2.88 S18: 0.02 - 0.93 m 0.33 95 0.91				
Knocking slots by hand			R01: 17.9 S01: 1.388		
Break webs between slots, crushing chisel, manual	I09: 0.28 - 20.49 m 5.59 95 15.51 R09: 0.25 - 2.69 m 1.33 95 0.68				
Break webs between slots, Jackhammer	I16: 1.79 - 77.76 m 15.93 95 54.5 R16: <NG - 6.85 m 1.61 95 4.26				
Mixing mortar/glue/concrete			R08: <0.18 - 5.02 m 1.78 S02: 0.02, 0.048	R09: GM 0.91 13% >3 S09: GM 0.02 20% >3	R32: GM 1.39 S32: GM 0.04
Mixing mortar/glue/concrete				R05: 0.45 - 1.83 S05: <0.009 - 0.03 R07:	I07: GM 2.1 GM 0.8

Mixing cement	I63: 0.18 - 65.24 GM 5.1 95 46.2 R23: 0.16 - 8.96 GM 1.42 95 8.15			S28: 0.01 - 0.06 GM 0.01	
Mixing mortar, vacuumed plastering machine, IGF2010	R14: 0.5 - 1.05 GM 0.68 95 1.05				
Mixing screed, Neiss 2016	I01: 8.0 with I01: 0.2 R01: 3.5 Dustmonkey R01: <0.1				
Mixing low-dust powdery products	I12: 2.50 - 5.20 95 4.96 R12: 0.50 - 1.10 95 0.77				
Paving; set stones, shake the pavement, without cutting stones	I04: 0.82 - 7.75 m 4.92 R11: <0.31 - 2.46 GM 0.49 95 1.81 S11: <0.009-0.058 GM 0.014 95 0.0495				
Plastering	R35: 0.002 - 1.07 GM 0.32 S35: nd - 0.027 GM 0.003	R15: 0.11 - 2.42 GM 0.6 95 2.16 S06: 0.003 - 0.06 m 0.03		R01: 0.43 S01: 0.021	I07: GM 2.1 R07: GM 0.4
Spraying of plaster		R06: 0.33 - 2.25 m 1.06 S06: 0.01 - 0.32 m 0.08			
Plastering, smoothing, indoors with plastering machine	R17: 0.21-6.54 GM 0.92 95 4.19 S15: 0.004-0.039 GM 0.0098 95 0.031				
Plastering, smoothing, outside with plastering machine	R13: 0.17-1.88 GM 0.38 95 1.80 S12: <0.009-0.049 GM 0.012 95 0.039				
Plastering, smoothing; inside with extraction				R02: 0.59, 0.62 S02: <0.001, <0.007	
Scraping of facade plaster				R04: 1.02 - 28.6 S04: <0.012 - 0.035	
Refractory and chimney construction, demolishing	R44: 0.25 - 90 GM 3.75 95 51.2 S47: 90% 3.01				
Refractory and chimney construction, mixing	R10: 0.37 - 24.9 GM 1.88 95 18.8 S12: 90% 2.16				
Cement road construction		R10: GM 0.325 6.1% > 1.5 S10: GM 0.020 25.6% > 0.05			
Road construction workers		R23: GM 0.145 S22: GM 0.010			

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DUST EXPOSURE ON CONSTRUCTION SITES

ACTIVITY / JOB	Park (KR) 2019 Various Kirkeskov (DK) 2016 Scancarello (IT) 2020 DGUV 2020, Arnone 2020 (DE) Betten (DE) 2005 BG ETEM (DE) 2010 BG BAU (DE)	Antonsson (SE) 2019 Christensson (SE) 2012 SUVA (CH) McLean (NZ) 2017 INAIL (IT) 2019 Meeker (US) 2009 Deurssen '14; ARBOUW '12 (NL)	Garcia (US) 2006 Constructiv '20; van Peer '21 (BE) Network Italiano 2007; Scarcelli 2014 Hall '13; CooperJ '15; Grant '19 (US) CooperM (US) 2012/2015 Rappaport '03; Collingw. '07 (US) Akbar '02/'07; Shields 1999 (US) Tjoe (NL) 2003; Hammond (US) 2017	Croteau (US) 2002 Grahn (SE) 2017 Flanagan (US) 2001/2003 Radnoff (CA) 2014 Thorpe (GB) 1999 Beaudry (CA) 2013 Alazard (FR) 2021 Lumens (NL) 2001	Healy (IRL) 2014 Chisholm (GB) 1999 Flanagan (US) 2006 Szadkowska (PL) 2006 Easterbrook (GB) 2009 Valiante (US) 2004 Middaugh (US) 2012 Echt (US) 2004/2007
Rubble recycling				R02: 0.48, 9.44 S02: 0.007, 0.30	R01: 0.35 S01: 0.118
Rubble recycling, Crusher, mill	I39: 0.56 - 84.6 GM 2.53 95 25.9 R44: 0.16 - 5.95 GM 0.48 95 2.36 S39: 95 0.35				
Rubble recycling, mixing, screening, sorting	I31: 0.31 - 10.9 GM 1.84 95 7.25 R33: 0.14 - 4.89 GM 0.35 95 1.45				
Rubble recycling, Conveying, loading	I40: 0.33 - 11.3 GM 0.65 95 5.38 R44: 0.13 - 3.25 GM 0.23 95 1.93 S37: 95 0.049				
Rubble recycling, Control cabin, test bench	I13: 0.24 - 7.51 GM 1.13 95 5.69 R13: 0.12 - 1.77 GM 0.32 95 1.63 S12: 95 0.032				
Scaffold dismantling	R12: <0.86 - <2.5 S06: <0.83 - <0.125				
Scatter quartz sand in mastic asphalt	R24: 0.7-38.4 GM 4.57 95 33,34 S24: <0.051-0.236 GM 0.071 95 0.206				
Sanding, with spreader car			R04: <0.2 - 1.4 m 0.7 S04: 0.017 - 0.079 m 0.040		
Scatter quartz sand in resin floors	R11: 1.71 - 4.71 GM 3.15 95 4.7 S11: 0.36 - 1.70 GM 0.715 95 1.55		R08: <0.04 - 5.9 m 1.1 S08: 0.028 - 0.293 m 0.088		
Scatter low-dust quartz sand in resin floors	R06: <0.13 - 0.27 GM 0.059 S06: 0.007 - 0.037 GM 0.015				
Spraying of concrete				I03:11.4, 18.6, 36.9 R03:1.93, 4.55, 4.84 S03: <0.028, 0.01, 0.03	

Grinding natural stone, indoor, without extraction	I09: 6.52 - 51.2 R08: 2.94 - 10.1 S08: 0.25 - 2.2				
Grinding with extraction, Marble, Granite, Artificial stone (Joest P1)	I02: <0.5, <0.75 R02: <0.5, <0.75 S02: <0.018, <0.028				
Sandstone grinding					R32: GM 7.1 S16: GM 4.2
Sandstone grinding with on-tool exctraction					R80: GM 0.5 S40: GM 0.03
Stonemasonry, wet sawing, milling, cutting	I73: 95 3.74 R89: 95 2.22 S89: 95 0.40				
Cutting stones, wet and dry, masonry construction	R27: GM 0.655 95 2.345 S27: GM 0.0251 95 0.184				
Stonemasonry, mechanical grinding	I48: 95 22.5 R49: 95 7.72 S50: 95 0.83				
Stonemasonry, manual grinding	I28: 95 26.2 R28: 95 2.098 S28: 95 0.344				
Cutting stones dry, masonry construction	R31: 0.37-174 GM 3.35 95 69.95				
Cutting stones wet, masonry construction	R16: <0.21-7.88 GM 1.11 95 4.22				
Track bed cleaning Ballast installation, dry	I18: 0.27 - 80.8 GM 5.75 95 52,8 R18: 0.005 - 16.1 GM 0.99 95 13,6 S18: 0.004 - 1.8 GM 0.11 95 1.63				
Track bed cleaning ballast installation, wet	I5: 1.4 - 5.09 GM 3.53 m 3.89 R6: 0.4 - 2.23 GM 0.66 m 0.83 S6: 0.005 - 0.27 GM 0.047 m 0.093				
Track bed cleaning Clearing Chain	I8: 1.51 - 59.6 GM 9.20 m 20.4 R8: 0.22 - 4.59 GM 1.22 m 1.94 S7: 0.037 - 0.3 GM 0.143 m 0.173				

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DUST EXPOSURE ON CONSTRUCTION SITES

ACTIVITY / JOB					
	Park (KR) 2019		Garcia (US) 2006	Croteau (US) 2002	Healy (IRL) 2014
	Various	Antonsson (SE) 2019	Constructiv '20; van Peer '21 (BE)	Grahn (SE) 2017	Chisholm (GB) 1999
	Kirkeskov (DK) 2016	Christensson (SE) 2012	Network Italiano 2007; Scarcelli 2014	Flanagan (US) 2001/2003	Flanagan (US) 2006
	Scancarello (IT) 2020	SUVA (CH)	Hall '13; CooperJ '15; Grant '19 (US)	Radnoff (CA) 2014	Szadkowska (PL) 2006
	DGUV 2020, Arnone 2020 (DE)	McLean (NZ) 2017	CooperM (US) 2012/2015	Thorpe (GB) 1999	Easterbrook (GB) 2009
	Betten (DE) 2005	INAIL (IT) 2019	Rappaport '03; Collingw. '07 (US)	Beaudry (CA) 2013	Valiante (US) 2004
	BG ETEM (DE) 2010	Meeker (US) 2009	Akbar '02/'07; Shields 1999 (US)	Alazard (FR) 2021	Middaugh (US) 2012
ACTIVITY / JOB	BG BAU (DE)	Deurssen '14; ARBOUW '12 (NL)	Tjoe (NL) 2003; Hammond (US) 2017	Lumens (NL) 2001	Echt (US) 2004/2007
Track bed cleaning Control station, in the cabin	I7: 0.04 - 2.61 GM 0.54 m 1.18 R8: 0.01 - 0.84 GM 0.23 m 0.24 S6: 0.002 - 0.095 GM 0.02 m 0.039				
Track bed cleaning with extraction (Funk, 2020)	I04: 3.05 - 9.69 R05: 0.66, 0.8, 1.33, 2.07, 2.33				
Manual removal of a railway track				I09: <2.9 - 0.71 R09: <0.05 - 0.17 S09: <0.002 - 0.148	
Tuckpoint grinding		S05: 3.06 - 7.24 m 4.99 S05: 5.25 - 25.8 m 10.9	R37: 0.25 - 349.1 GM 12.3 S37: 0.01 - 76.10 GM 1.14	R12: GM 2.25 46%>3 S12: GM 0.22 100%>0.05	R 97: GM 6.05 S101: GM 0.60
Tuckpoint grinding		R25: 0.36 - 17.04 GM 3.42 S25: 0.02 - 0.80 GM 0.18	R10: 0.55-8.0 GM 2.4 S10: 0.089-1.6 GM 0.35	S97: 0.00 - 24 GM 0.25	R04: 0.16-6.93 m 3.24 S04: 0.03->3.6 m >0.23
Tuckpoint grinding			S05: 4.57 - 9.90 m 7.23 S05: 3.46 - 31.4 m 10.9	R14: GM 22.17 S14: GM 3.04	R06: 13-105 GM 48 S06: 3.9-34 GM 12
Tuckpoint grinding, wet					R06: <0.01-26 GM 5.81 S06: <0.01-7.6 GM 1.58
Tuckpoint grinding with extraction	I01: 0.66 R01: <0.25 S01: <0.009	S05: 0.19 - 0.50 m 0.33 S05: 0.28 - 0.85 m 0.47	R22: 0.31 - 4.50 GM 1.0 S22: <0.01-0.86: GM 0.06	R14: GM 6.11 low S14: GM 1.02 ventilation	R06: <0.02-1.3 GM 0.49 S06: <0.01-0.72 GM 0.41
Tuckpoint grinding with extraction			S07: <0.069 - 0.137 m 0.091 S05: 0.224 - 0.738 m 0.375	R13: GM 3.01 high S13: GM 0.47 ventilation	
Inner wall construction	R115: 0.30 - 21.16 GM 1.18 95 12.3		R05: 0.55-4.00 GM 1.5 S05: 0.016-0.084 GM 0.036	R36: 0.2 - 10.6 GM 2.1 S36: n.d. - 0.2 GM 0.04	
Drywall, laying, spackling	R28: 0.30 - 3.29 GM 0.79 95 2.89 S25: 0.004 - 0.26 GM 0.019 95 0.15				
Process plasterboard		I01: 5.3 R01: 0.5			

Cleaning formwork, inside/outside	R26: GM 0.34 95 1.15 S26: GM 0.007 95 0.034				
Strip the formwork from concrete components	R40: GM 0.19 95 2.13 S40: GM 0.005 95 0.2				
Chimney sweeping Wank 2021	I06: 6.18 - 16.75 R06: 0.73 - 3.56				
Background exposures on construction sites		I17: 0.10 - 2.9 m 1.2 R13: 0.03 - 1.5 m 0.39			
Electrician				S05: 0.015 - 0.064	
Electrical installation, with extraction	R12: 95 2.67 S14: 0.02 - 2.0				
Carpenter	I38: 0.08 - 8.40 GM 1.26 R25: <0.09 - 1.5 GM 0.27	R21: 0.03-4.67 GM 0.22 S21: 0.01-0.09 GM 0.02		S11: 0.013 - 0.041 GM 0.023	
Carpenter and Joiner			S115: GM 0.045 93% >0.025		
Construction, conversion, renovation of buildings	S80: GM 0.026 95 0.259				
General labouring		S05: <0.001-0.222 GM 0.004	S505: GM 0.045 93% >0.025		
House builder		R08: GM 0.296 S07: GM 0.009			
Painter			R14: 1.16 - 833 m 13.5 S14: 0.26 - 26.2 m 1.28	S06: 0.008 - 0.12 GM 0.036	
Training of construction workers in vocational schools	I19: 0.33 - 26.8 GM 4.49 95 22.05 R24: 0.3 - 4.24 GM 0.844 95 3.706 S22: 95 0.237				
Road and railway construction	S43: GM 0.036 95 0.247				
Specialised construction work	S18: GM 0.028 95 0.584				

S: silica R: respirable I: inhalable GM: geometric mean m: mean 95: 95 percentile

PICTURE SOURCE REFERENCE

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Bässler (p. 79)
BG ETEM (pp. 77, 91)
Bibermax (p. 81)
Bosch (p. 85)
Branstett (p. 81)
Caparol (p. 45, Fig. 19b; p. 93)
Collomix (p. 44, Fig. 18c)
CooperM (p. 104)
Dorfner (p. 100)
Dustmonkey (p. 44 Fig. 18a; p. 93)
FCC Construction (p. 36, Fig. 8b, 8c; p. 83)
Gehring (pp. 80, 83)
Hilti (pp. 79, 85)
Hytile (p. 81)
Italiano Silice (p. 90)
Joest (p. 102)
Kluger (pp. 92, 93)
Lafarge (p. 93)
Milwaukee (p. 99)
Nahlbach (p. 105)
OPPBTP (pp. 96, 98, 101, 103)
Preuß (pp. 72, 76)
Rokamat (p. 104)
Roll (p. 43)
Schmidt (p. 97)
Starmix (pp.77, 89)
Stetefeld (p. 94)
Uzin (p. 44, Fig. 18b; p. 45, Fig. 19a; p. 93)
Wiermann (p. 74)
Wirth (p. 38)

Reducing Respirable Crystalline Silica Dust effectively on Construction Sites

Dust, which is omnipresent on construction sites, can be harmful to the health of construction workers. Therefore, dust prevention is a priority for occupational health and safety in the construction industry.

This EU funded research report was elaborated in the framework of a European social partner project entitled "Reducing Respirable Crystalline Silica Dust Effectively", which aims to implement best practices in the prevention of exposure to quartz dust.

The report presents procedures and practices that ensure compliance, for most construction activities, with the EU occupational exposure limit value for RCS.

It discusses advanced practices and persisting challenges in the sector, based on collected exposure data, technical articles and practical experience on construction sites from all over the world, focusing on Europe.

European Federation
of Building
and Woodworkers