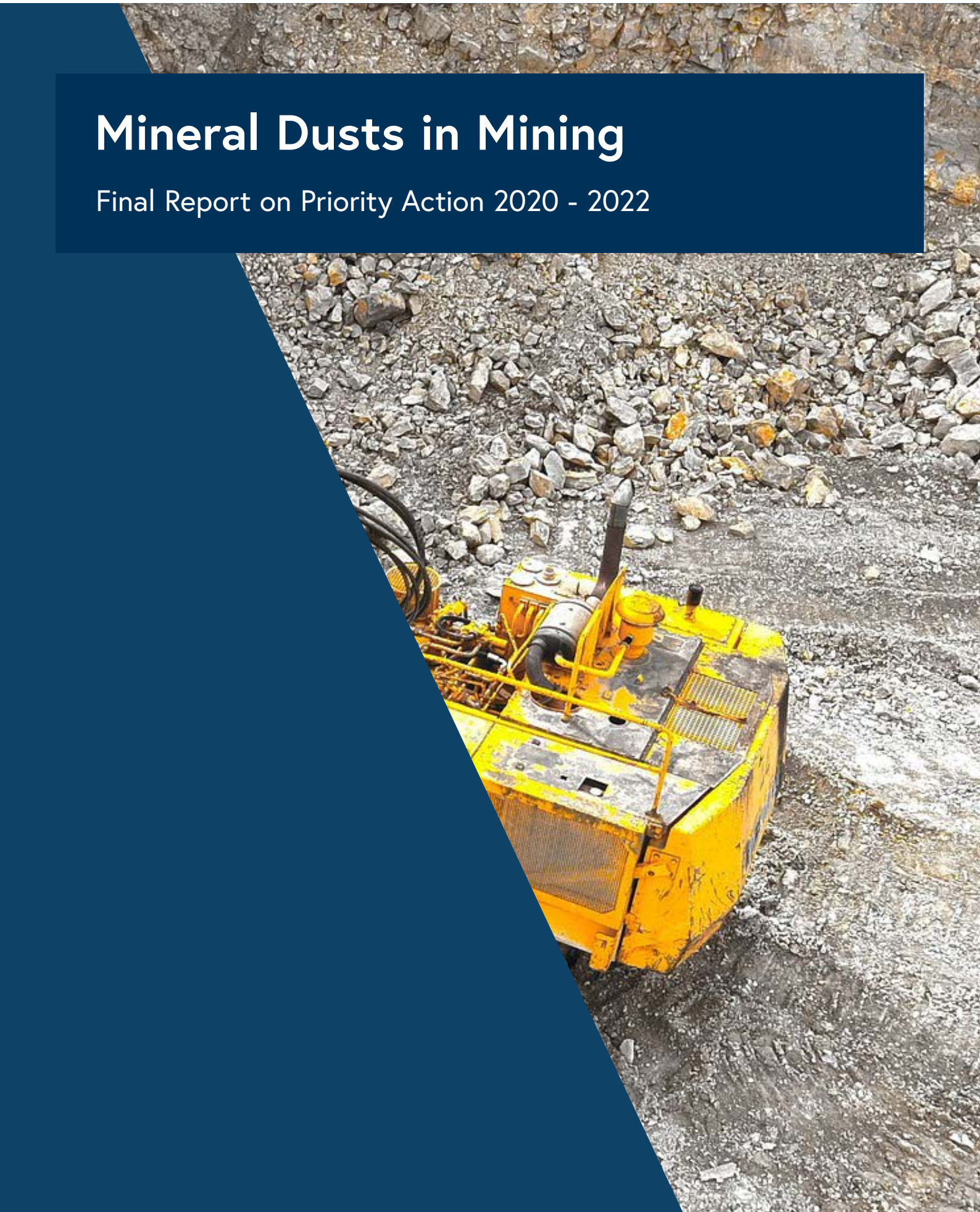
Arbeitsinspektion

Mineral Dusts in Mining

Final Report on Priority Action 2020 - 2022



Publisching Information

Media Owner, Publisher and Editor: Federal Ministry of Labour and Economy (BMAW),
Directorate General II – Labour Law and Central Labour Inspectorate
Author: Mag.rer.nat. Dr. Kolenprat Bernd, BMAW Division II/A/1
Cover Photo: © pixabay.com
Favoritenstraße 7, A-1040 Vienna arbeitsinspektion.gv.at
Vienna, January 2023

Contents

Executive Summary

According to the General Work Accident Insurance Institution (Allgemeine Unfallversicherungsanstalt – AUVA), economic activities in Industrial Section B (Mining and Quarrying) are subject to the highest number of recognised fatal occupational diseases caused by silica dust. In the last two decades, one third of all fatal occupational diseases recognised by AUVA in classes BK-26a to 26c of occupational diseases were attributable to workers in Section B, which is all the more remarkable in view of the low number of employees in this section. Compared with other industrial sections, the rate of fatal occupational diseases caused by silica dust is highest in mining and roughly 40 times higher than in Section F (Construction). Moreover, it was found that four fifths of deaths in Section B were due to mineral dust exposure, whereas fatal accidents at work accounted for only some one fifth of all deaths in mining on average. These figures illustrate an urgent need for action in mining.

Consequently, respirable quartz-containing dusts (silica dust) were the focus of advice and inspections regarding mineral dusts in surface mining sites in two phases including preliminary and follow-up inspections in 2021 and 2022. Preliminary and follow-up inspections were specifically aimed at monitoring how effective the labour inspectorates' advisory and control activities were. Labour inspectors visited more than 200 workplaces in an advisory capacity to check compliance with the relevant rules, in particular those on agent evaluation and dust concentration measurements.

The results of this labour inspection survey showed that the level of compliance with legal requirements on mineral dusts was already very high during the initial inspection in spring 2021. Follow-up inspections in 2022 by labour inspectors revealed that, within a very short period of time, compliance with certain legal requirements had been improved even further, in some cases by up to 290%.

The results of the labour inspection survey as shown in the 2022 follow-up inspections illustrate that in 84% of the workplaces visited documents were presented on the mineralogical composition of raw materials. They form the basis for an evaluation of agents. In 81% of the workplaces, safety and health documents were presented to labour inspectors providing information on the expected exposure of workers to released mineral dusts (during initial inspections in 2021, 46% of workplaces had such documents). In 87% of cases, the safety and health documents now also included technical and organisational measures to minimise the exposure of workers to released mineral dusts, an almost three-fold increase on the initial inspection round in 2021 where only 30% had such measures in place. Moreover, 50% of workplaces could present protocols of dust concentration measurements (comparison measurements of limit values and/or control

measurements). An analysis of the measurement values recorded by labour inspectors showed that the MAC-TWA for silica dust of 0.05 mg/m^3 was reached around the 80% percentile in the measurement results obtained.

1. Requirement and objective

The annual work plan for labour inspections (BMASGK-460.210/0003-VII/A/5/2019) in 2020 included an Austria-wide advisory and inspection focus on respirable quartz-containing dusts (silica dust) in external worksites, construction sites and mining. Due to the pandemic, the first phase of this priority action was postponed to 2021 (March - July 2021), while the second phase (follow-up) was not carried out until spring 2022 (March - May 2022).

The need for action mainly arose for two reasons:

A great number of occupational disease cases recognised by AUVA was caused by exposure to mineral dusts. In particular asbestos-containing dusts (asbestos dust) and respirable quartz-containing dusts (silica dust) resulted in a soaring number of occupational disease cases recognised by AUVA in certain industries over the past two decades. These figures were also published in the annual activity reports of labour inspection. In Industrial In Industrial Section B (Mining and Quarrying), the problematic situation with regard to silica dust was evident. Details on this issue will be discussed in Chapter 2.

Another reason for carrying out this priority action was the amendment to the Regulation on carcinogenous substances and limit values (Grenzwerteverordnung – GKV, Federal Law Gazette II no. 382/2020), which became necessary in order to transpose Directive (EU) 2017/2398. This amendment classified respirable silica dust as clearly a carcinogen and reduced the eight-hour time weighted average for the maximum allowable workplace concentration (MAC-TWA) for respirable silica dust from 0.15 mg/m^3 to 0.05 mg/m^3 (by two thirds). For details see Chapter 3.

These legal revisions and the great number of occupational disease cases caused by mineral dusts made it necessary to inform and advise employers in mining companies.

This situation led to a priority action being launched with the aim of carrying out advisory inspections. However, it was intended to include not only respirable silica dust in mining but also mineral dusts in general since even non-quartz containing mineral dusts are dangerous agents with biologically inert properties and mineral dusts are released in practically every step during the extraction and processing of mineral raw materials. It should be emphasised that most mineral dusts contain quartz (owing to the

mineralogical and petrological properties of this mineral) and are therefore considered quartz-containing dusts.

Furthermore, the priority action was to focus on surface mining (meaning workplaces and external worksites for surface extraction of mineral raw materials) and its processing plants as they account for the largest share of mining operations. These workplaces and external worksites are subject to the provisions of the Regulation on Surface Mining Work(Tagbauarbeitenverordnung – TAV, Federal Law Gazette II no. 416/2010), which includes a number of special requirements for mineral dusts. The questions asked during the priority action were based on these special requirements of the Ordinance on Surface Mining Work. For theFor the questions asked during the priority action see Chapter 4.

The proposed procedure for this priority action was to carry it out in two phases. The first phase (initial inspection) meant roughly 250 companies were to be visited throughout Austria between March and July 2021 (Decree 2021-0.100.642 of 22 Mar 2021). The second phase was to focus on follow-up inspections of the same workplaces from March to May 2022 (Decree 2021-0.868.726 of 20 Dec 2021). Checking on the same workplaces in two phases was intended to provide before-and-after comparisons to monitor the outcome of the labour inspectors' advisory and inspection activities. For more information on the procedure and contents of the priority action see Chapter 4. The results of the two phases and the evaluation of the protocols on dust concentration measurements kept by the labour inspectorates can be found in Chapters 5 and 6.

2. Cases of occupational diseases caused by mineral dusts in Austria

85% (i.e. more than four fifths) of all cases of fatal occupational diseases recognised by AUVA in the past two decades resulted from exposure to mineral dusts (see distribution in Figure 1), with classes BK-26a to 26c and BK-27a to 27d of occupational diseases being the most relevant for mineral dusts. For the exact designations of these classes of occupational diseases see Table 1. The figures reported by AUVA showed that between 2002 and 2020 (a period of 19 years) a total of 1198 fatalities caused by occupational diseases were attributable to these disease classes. The increase in the number of recognised cases in recent decades is particularly worrying. As illustrated by Figure 2, the number of cases of fatal occupational diseases caused by mineral dusts (red curve) has not only risen sharply in the past two decades but has also exceeded the number of recognised accidents at work in recent years (black curve). This is mainly due to the

increase in recognised fatal occupational diseases resulting from the exposure to dusts containing asbestos minerals (green curve, BK-27a to 27d). The proportion of cases caused by quartz-containing dusts has remained more or less the same (blue curve with about 10 and 20 cases per year, BK-26a to 26c).

With regard to Industrial Section B (Mining and Quarrying), AUVA figures show an alarming picture: almost one third (30.6%) of all cases of fatal occupational diseases recognised in all industrial sections in classes BK-26a to 26c of occupational diseases (caused by quartz-containing mineral dusts) were attributable to this Section (see Figure 3).

Given the low headcount in the mining industry, this result can only be explained by a very high percentage of workers being also exposed to silica dust or having been exposed to it in the past.

If one calculates the ratio of cases of fatal occupational diseases caused by silica dust (which can be regarded as a certain measure of the degree of risk), the resulting ratio is approx. 6 deaths per 10 000 employees per year for Industrial Section B. This compares with a ratio of approx. 0.14 deaths per 10 000 employees per year in Section F (Construction) and approx. 0.05 deaths per 10 000 employees per year in Section C (Manufacturing), down by a factor of 43 and 138, respectively, compared with mining.

Another indication that mining apparently has a major (silica) dust problem is illustrated by the fact that four fifths of deaths in mining were due to exposure to mineral dusts (96% attributable to BK-26a to 26c and only 4% to BK-27a to 27d), whereas fatal accidents at work accounted on average for only one fifth (21%) of all deaths in mining according to AUVA.

The figures underscore that surface and underground mining have serious problems with mineral dusts, in particular quartz-containing dusts.

In view of these dramatic figures, the priority action was primarily aimed at counteracting the above trend by advisory inspections.

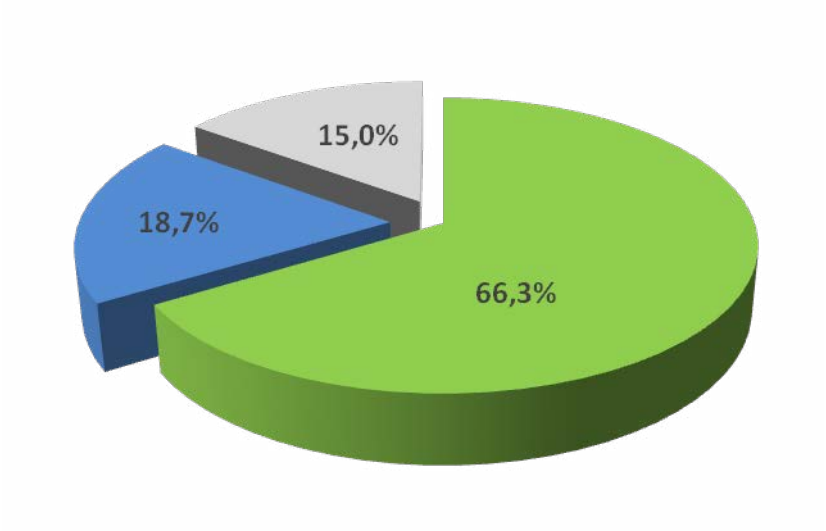
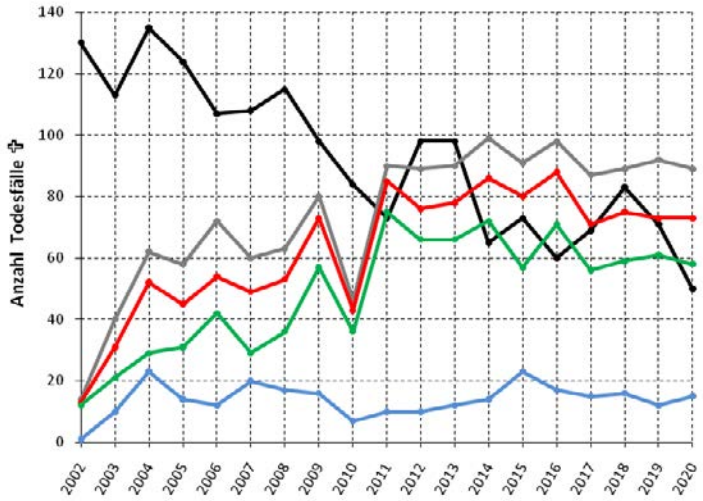


Figure 1: Distribution of fatal occupational diseases recognised by AUVA between 2002 and 2020. 66.3% of the cases (green portion of the pie chart) were attributable to occupational disease classes BK-27a to 27d (asbestos-containing dusts) and 18.7% of the cases (blue portion of the pie) were attributable to occupational disease classes BK-26a to 26c (quartz-containing dusts) resulting in a total of 85% of fatal occupational diseases caused by exposure to mineral dusts. The remaining 15% are distributed among all other classes of occupational diseases.

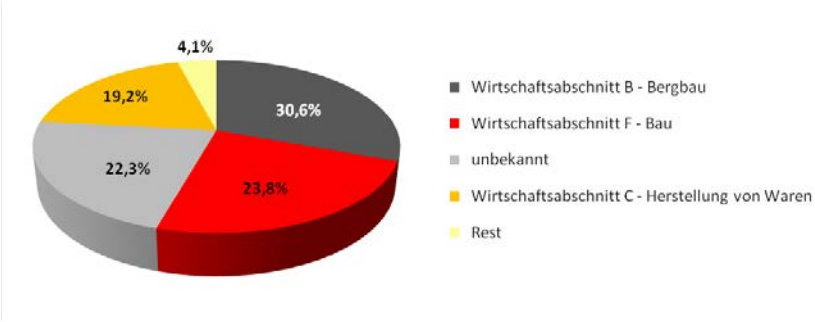
Serial no.	Occupational diseases
(BK-26a)	Dust disease (silicosis or silicatosis) with objectively identifiable reduction in the performance of respiratory and circulatory systems
BK-26b)	Dust disease in combination with actively progressing lung tuberculosis (silico-tuberculosis)
(BK-26c)	Malignant neoplasms of the lung caused by exposure to crystalline silica in silicosis. This class has only been reported since 2012.
(BK-27a)	Asbestos dust disease (asbestosis) with objectively identifiable reduction in the performance of respiratory and circulatory systems
(BK-27b)	Malignant neoplasms of the pleura, the pericardium and the peritoneum caused by asbestos. Until 2012, cases of malignant neoplasms of the lung and larynx caused by asbestos were included in this class. Now they are found in classes BK-27c and BK-27d.
(BK-27c)	Malignant neoplasms of the lung caused by asbestos
(BK-27d)	Malignant neoplasms of the larynx caused by asbestos

Table 1: Classes of occupational diseases according to § 177 of the General Social Insurance Act (Allgemeines Sozialversicherungsgesetz – ASVG) and Annex 1 of the ASVG with relevance to mineral dusts



Anzahl Todesfälle = number of deaths

Figure 2: Development of fatal accidents at work and cases of fatal occupational diseases recognised by AUVA between 2002 and 2020 (data source: AUVA, data published in the labour inspection activity reports from 2002 to 2020); black curve: sum total of all recognised accidents at work, grey curve: sum total of all recognised cases of fatal occupational diseases, red curve: recognised cases of fatal occupational diseases caused by mineral dusts, green curve: recognised cases of fatal occupational diseases caused by asbestos dust (BK-27a to 27d), blue curve: recognised cases of fatal occupational diseases caused by silica dust (BK-26a to 26c).



Wirtschaftsabschnitt B – Bergbau = Section B - Mining

Wirtschaftsabschnitt F – Section F - Construction

Unbekannt = unknown

Wirtschaftsabschnitt C – Herstellung von Wirtschaftsgütern = Section C - Manufacturing

Figure 3: Distribution of recognised cases of fatal occupational diseases caused by silica dust (occupational disease classes BK-26a to 26c), time series 2002 to 2015, data source: AUVA based on Austrian NACE 2-digit-SICs

3. Amendment to GKV and VGÜ

In addition, priority action became necessary through amendments to the Regulation on carcinogenous substances and limit values (Grenzwerteverordnung – GKV 2021) and the Regulation on health surveillance at work (Verordnung über die Gesundheitsüberwachung am Arbeitsplatz – VGÜ 2017).

Directive (EU) 2017/2398 of the European Parliament and of the Council of 12 December 2017 amended and supplemented Directive 2004/37/EC on the protection of workers from the risks related to the exposure to carcinogens or mutagens at work by classifying silica dust (respirable crystalline silica dust) as a carcinogenic agent and setting a limit of 0.1 mg/m^3 for respirable silica dust. This made it necessary to amend the Ordinance on Limit Values.

With the amendment to the Ordinance on Limit Values (Federal Law Gazette II no. 382/2020), silica dust has been classified as clearly a carcinogen (Annex III, Section C, number 13 of GKV) and the eight-hour time weighted average for the maximum allowable concentration (MAC-TWA) for respirable silica dust was reduced by 2/3 from 0.15 mg/m^3 to 0.05 mg/m^3.

The amendment to the VGÜ (Federal Law Gazette II no. 382/2020) set forth that suitability and follow-up tests for exposure to silica dust may be omitted if one of the following four requirements are met:

- The average daily exposure is no more than 5 hours per workweek (≤ 60 minutes per workday) irrespective of the level of concentration,
- A representative measurement shows that no more than half of the MAC-TWA (≤ 0.025 mg/m^3) is reached,
- State-of-the-art assessment can demonstrate that no more than half of the MAC-TWA (≤ 0.025 mg/m^3) is reached,
- Compliance with the MAC value (≤ 0.05 mg/m^3) is proven by a representative measurement or by comparative data, and exposure of workers is kept as low as possible by protective measures.

These legal changes require information and advice to employers.

4. Procedure and contents of the priority action

As already mentioned, plans for the priority action included two phases comprising an initial and a follow-up inspection in the following year.

The first phase (according to Decree 2021-0.100.642 of 22 Mar 2021) included roughly 250 workplaces and external worksites that were subject to the Regulation on Surface Mining Work(Tagbauarbeitenverordnung – TAV, Federal Law Gazette II no. 416/2010) and were to be visited throughout Austria between March and July 2021 for advisory inspections. The number of companies to be inspected per labour inspectorate was determined by the proportion of surface mining operations in the individual districts under labour inspection supervision (see Table 2), while the specific selection of TAV workplaces was at the discretion of the labour inspectorates themselves. Workplaces were thus not selected on the basis of sampling criteria and a list of specified workplaces to be visited (as was the case in other campaigns), meaning that the results of this priority action cannot be used to draw conclusions about possible distributions in the population. To test the effectiveness of the action, follow-up inspections of the same workplaces were to be carried out during the second phase (in accordance with Decree 2021-0.868.726 of 20 Dec 2021) between March and May 2022. This before-and-after comparison was to monitor the outcome of inspections and advisory activities of labour inspection and highlight the improvements thus achieved (in particular with regard to compliance with legal requirements).

As can be seen in Table 2, a total of 286 workplaces was visited in the first phase, i.e. approx. 14% more workplaces than specified. In the second phase, a total of 238 workplaces was inspected, 217 of which had already been visited in the first phase and which could be used for comparing the effectiveness of the action (outcome monitoring).

	Target	Phase I	Phase II	I ∩ II
Vienna South and Surroundings	11	16	8	6
Vienna North and Lower Austria	25	31	25	22
Lower Austria Industrieviertel	16	17	15	12
Lower Austria Most- and Weinviertel	31	54	42	36
Upper Austria East	31	21	31	31
Upper Austria West	17	17	17	17
Salzburg	16	21	18	18
Styria	44	52	38	35
Carinthia	22	17	16	16
Tyrol	19	23	17	13
Vorarlberg	5	5	1	1
Burgenland	13	17	10	10
	250	**291**	**238**	**217**

Table 2: Distribution of TAV workplaces inspected by the individual labour inspectorates, the inspection target and the workplaces actually visited in the first and second phase. I ∩ II refers to the intersection of the workplaces which were visited in both phases and designed to provide before-and-after comparisons (outcome monitoring).

The reason for focussing on surface mines and their processing plants in the priority action resulted from the fact that they account for the largest share of mining operations with the most employees in Industrial Section B. In borehole mining (drilling for oil and gas and drilling for brine solution), workers are not expected to be exposed to mineral dusts, while the number of workers in underground mines is currently very low. In surface mines, the provisions of the Regulation on Surface Mining Work (TAV, Federal Law Gazette II no. 416/2010) are to be applied. These health and safety regulations include special additional provisions on the evaluation of agents under §§ 41 and 43 of the Health and Safety at Work Act (Arbeitnehmerschutzgesetz – ASchG) concerning the exposure of workers to mineral dusts released in surface mines.

These are:

- According to § 8 (1) no 4 TAV, the composition of mineral raw materials and overburden must be taken into account in risk identification and assessment, in particular with regard to the occurrence of quartz and asbestos minerals and the expected exposure of workers to the mineral dusts released in surface mines.
- According to § 8 (2) no 2 TAV, the risks identified and assessed according to § 8 (1) no 4 TAV are to be used as a basis for defining the technical and organisational measures to minimise the exposure of workers to mineral dusts released.
- The results of risk identification and assessment according to § 8 (1) no 4 TAV as well as the related protective measures to minimise the exposure of workers to released mineral dusts as defined in § 8 (2) no 2 TAV are to be included in the safety and health documents according to § 8 (5) no 1 TAV.
- According to § 8 (6) TAV, these contents of the safety and health documents must be readily available for inspection (in written or digital form) by the workers on site in the surface mine or the workplace at any time.

The objective of the priority action was to carry out advisory inspections and, more specifically, to check compliance with the above provisions of the Ordinance on Surface Mining Work. In addition, this action was also designed to check compliance with the general requirements of agents as defined in the 4th section of the Health and Safety at Work Act (in particular §§ 41-43 ASchG) as well as the general requirements of dust concentration measurements to be carried out under the Ordinance on Limit Values (comparison measurements of limit values and control measurements under §§ 28 and 29 GKV 2021).

For the purpose of documenting the activity, the following questions had to be asked and entered in the labour inspection activity database (TDA):

Question 1:
Are safety and health documents available on site in the surface mine or the TAV workplace at the time of inspection?

The requirement for the safety and health documents to be available on site in the surface mine or in the TAV workplace is based on the provisions of § 8 (6) TAV. This questions was to be answered with Yes or No. If safety and health documents were available on site in the surface mine or in the TAV workplace, questions 2 to 4 had to be answered. If not, no further questioning and no further documentation was possible.

Question 2:

Do the presented safety and health documents include information on the composition of the mineral raw materials and the overburden, in particular with regard to the occurrence of quartz or asbestos minerals?

The requirement that the mineralogical composition of the raw materials must be determined and taken into account within the context of risk identification and assessment is based on the provisions of § 8 (1) no 4 TAV. This question was to be answered with Yes or Not Completely or No.

Question 3:

Do the safety and health documents address and record the expected exposure of workers to released mineral dusts?

The need to determine and take into account the expected exposure of workers to released mineral dusts within the context of risk identification and assessment is based on the provisions of § 8 (1) no 4 TAV, the provisions of § 46 ASchG as well as the requirements of limit value comparison measurements and control measurements (as defined in §§ 28 and 29 GKV 2021. This question was to be answered with Yes or Not Completely or No.

Question 4:

Do the presented safety and health documents address and record the technical and organisational measures taken to minimise the exposure of workers to released mineral dusts?

The requirement that technical and organisational measures to minimise the exposure of workers to released mineral dusts must be defined as part of risk identification and assessment is based on the provisions of § 8 (2) no 2 TAV and the requirements defined in § 43 ASchG. This question was to be answered with Yes or No.

The above questions were made available to labour inspectors in questionnaires accompanied by appropriately detailed explanations.

To enable a before-and-after comparison, the same surface mines (as already described) were to be visited in the second phase with the same questions being asked as in the first phase.

Since the surveys conducted by labour inspection in the first phase (see Chapter 5) revealed that compliance with the relevant legal provisions was quite high, the second phase was intended to include the aspect of exposure levels at certain workplaces and to record them in the activity statistics of the TDA database using the presented dust concentration measurements.

This was to show if and to what extent the dust concentration measurements required by law (comparison measurements of limit values and control measurements according to §§ 28 and 29 GKV 2021) were actually carried out, and then subsequently to enable labour inspectors to assess whether the technical and organisational measures to minimise the workers' exposure to released mineral dusts were sufficient. Another important aspect was to create a data pool of dust concentration measurements for surface mining based on the documentation of the surface mines' measurement protocols in the TDA, which would allow conclusions on possible exposure levels for certain workplaces (e.g. cabin workplaces in self-propelled work equipment).

A documentation of the mineralogical composition was to be included in the TDA so as to identify correlations between the results of dust concentration measurements and the proportion of quartz in the rock (in % by vol, % by mass or % by weight).

In addition, the following supplementary data were to be collected in the second phase:

If the 2nd question on mineralogical composition was answered with Yes or Not Completely, the **mineralogical composition was to be documented and recorded in the TDA**.

If the 3rd question on the identification of exposure was answered with Yes or Not Completely, the available dust concentration measurements (measurement protocols and limit value comparison and/or control measurements) were to be documented and recorded in the TDA. A fifth question was introduced to facilitate the read-out of any existing and recorded measurement protocols:

Question 5:
Are measurement protocols available for limit value comparison and/or control measurements regarding the concentration of mineral dusts in the air breathed by workers?

This question was to be answered with Available or Not Available.

5. Ergebnisse der Phase I (März bis Juni 2021)

In the first phase of the priority action, a total of 286 workplaces subject to TAV were visited.

For an evaluation of the inputs by labour inspectorates refer to the results matrix of Table 3, which shows the following:

Question 1 (Yes/No)	Question 2 (Yes/Not Completely/No)	Question 3 (Yes/Not Completely/No)	Question 4 (Yes/No)	in absolute figures (n = 286)	%	
No	-	-	-	56	19.6	20%
Yes	-	-	-	230	80.4	80%
Yes	Yes	-	-	114	39.9	62%
Yes	Not Completely	-	-	63	22.0	
Yes	No	-	-	53	18.5	
Yes	Yes	Yes	-	69	24.1	46%
Yes	Yes	Not Completely	-	14	4.9	
Yes	Yes	No	-	27	9.4	
Yes	Not Completely	Yes	-	8	2.8	
Yes	Not Completely	Not Completely	-	41	14.3	
Yes	Not Completely	No	-	14	4.9	
Yes	No	Yes	-	7	2.4	
Yes	No	Not Completely	-	2	0.7	
Yes	No	No	-	44	15.4	
Yes	Yes	Yes	Yes	61	21.3	30%
Yes	Yes	Yes	No	8	2.8	
Yes	Yes	Not Completely	Yes	4	1.4	
Yes	Yes	Not Completely	No	9	3.1	
Yes	Yes	No	Yes	3	1.0	
Yes	Yes	No	No	24	8.4	
Yes	Not Completely	Yes	Yes	6	2.1	
Yes	Not Completely	Yes	No	1	0.3	
Yes	Not Completely	Not Completely	Yes	6	2.1	
Yes	Not Completely	Not Completely	No	29	10.1	
Yes	Not Completely	No	Yes	0	0.0	
Yes	Not Completely	No	No	14	4.9	
Yes	No	Yes	Yes	3	1.0	
Yes	No	Yes	No	4	1.4	
Yes	No	Not Completely	Yes	0	0.0	
Yes	No	Not Completely	No	2	0.7	
Yes	No	No	Yes	3	1.0	
Yes	No	No	No	40	14.0	14%

Table 3: Evaluation (results matrix) TAV workplaces visited in the first phase (n = 286 workplaces, date of enquiry: 15 Dec 2021)

According to the surveys of the labour inspectorates, 80% (four fifths) of the workplaces had safety and health documents available on site, meaning that the other questions (2 to 4) could be asked and dealt with.

In 62% of the workplaces, the mineralogical composition of the raw materials and the overburden was at least partially known, meaning that labour inspectors entered Yes or Not Completely in response to Question 2. This suggests that about two thirds of the companies know about the mineralogical composition of the raw materials and have information enabling them to evaluate agents in respect of the proportion (% by vol, % by mass or % by weight) of the individual mineral phases (in particular those of quartz) in the rock.

46% of the presented safety and health documents provided information on the expected exposure of workers to released mineral dusts so that Question 3 could be answered with Yes or Not Completely.

This means that almost half of all workplaces were able to present safety and health documents to labour inspectors showing the exposure to mineral dusts, i.e. an evaluation of agents and the identification and assessment of exposure to mineral dusts. Only 14% of the workplaces presented safety and health documents that did not include any information on mineral dusts.

In 30% of the safety and health documents presented, technical and organisational measures to minimise the exposure of workers to released mineral dusts were recorded.

In 21% of all workplaces subject to TAV (i.e. one fifth), all 4 questions of the first phase of the priority action were answered in the affirmative (Yes) and documented as such in the TDA.

Overall, the findings obtained by labour inspectors in the first phase of the priority action – given that this was an initial survey – show that compliance with the legal requirements (§§ 41 to 43 ASchG, §§ 28 and 29 GKV 2021 and § 8 TAV) was quite high.

6. Results of Phase II (March to May 2022)

In the second phase of the priority action, a total of 238 workplaces was inspected, 217 of which had already been visited in the first phase and which could be used for comparing the effectiveness of the action (outcome monitoring).

For an evaluation of the findings obtained refer to the results matrix of Tables 4 and 5. Table 4 shows the evaluation of all 238 TAV workplaces visited in Phase II, whereas Table 5 illustrates the evaluation of those 217 TAV workplaces that were visited in both phases.

The results matrix of Table 5, which can be used for the before-and-after comparison, shows the following:

The availability of safety and health documents on site had improved in the workplaces. Compared with an 80% availability in the first phase, the second phase showed that 96% of TAV workplaces had safety and health documents available on site, so that in virtually all the workplaces visited Questions 2 to 4 could be addressed and, consequently, the mineralogical composition and measurement protocols on dust concentration measurements queried.

In 84% of the workplaces, the mineralogical composition of the raw materials and the overburden was at least partially known, meaning that labour inspectors entered Yes or Not Completely in response to Question 2, i.e. yet another increase on the first phase by 62%. This signifies that roughly four fifths of the companies now know the proportions of the individual mineral phases (in particular quartz) in the composition of the rocks present.

81% (four fifths) of the presented safety and health documents provided information on the expected exposure of workers to released mineral dusts so that Question 3 was answered with Yes or Not Completely by the visiting labour inspectors.

This is a definite increase by a remarkable 177% on 46% in the first phase.

The number of workplaces where measurement protocols on dust concentration measurements could be presented and documented in the TDA totalled 50% of the workplaces visited.

In 87% of the workplaces, safety and health documents were presented which included technical and organisational measures to minimise the exposure of workers to released mineral dusts. This compares with only 30% in Phase I, i.e. an enormous improvement by 290%.

Moreover, the results show that in Phase II only 0.5% of the workplaces (versus 14% in Phase I) presented safety and health documents that did not include information on mineral dusts.

Overall, after completion of Phase II, major improvements could be identified in all aspects of compliance with legal requirements. A particularly positive finding was that half of all workplaces were able to present protocols on dust concentration measurements to labour inspectors.

If one regards the measurement values documented in the priority action as a kind of sample which roughly reflects the exposure in surface mining operations, the following can be seen:

The histogram in Figure 4 shows the distribution of 93 measurement values on respirable silica dust as documented in the priority action. The red line marks the limit value of 0.05 mg/m^3. Eleven measurements showed dust concentrations above this limit value.

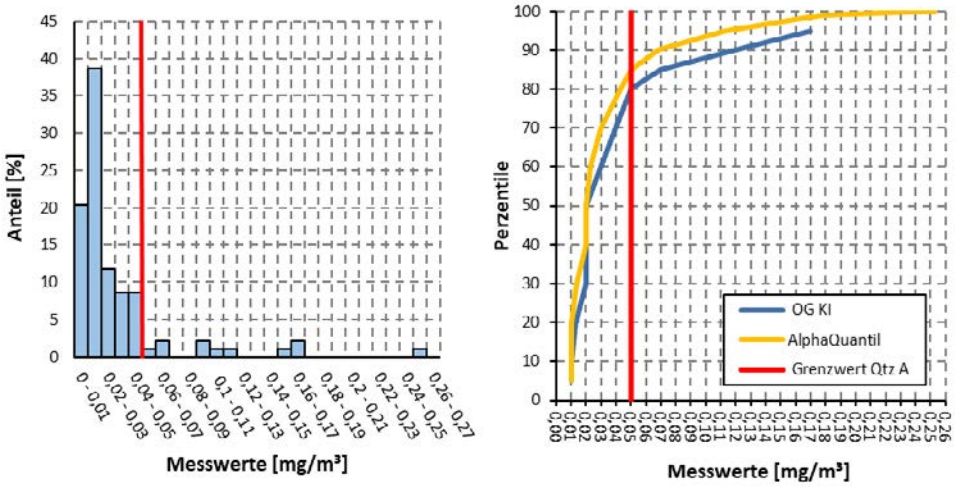
If the upper limits of confidence intervals for percentiles are determined by distribution-independent methods (according to RINNE, H., 2008: Taschenbuch der Statistik, 4th ed., p. 471) with an error probability of α = 0,05, it becomes apparent that the limit value for respirable silica dust is exceeded approximately at the 80% percentile (see blue curve in Figure 4 and Table 6). The 95% percentile would correspond to a value of 0.17 mg/m^3 and even exceed the previous MAC-TWA for respirable silica dust (0.15 mg/m^3). The quantile function offered by Microsoft Excel provides a similar result. According to this approach, the limit value for respirable silica dust would be exceeded at the 83% percentile (see yellow curve of Figure 4 and Table 6). The 95% percentile would correspond to a value of 0.11 mg/m^3.

Question 1 (Yes/No)	Question 2 (Yes/Not Completely/No)	Question 3 (Yes/Not Completely/No)	Question 4 (Yes/No)	Question 5 (Available/Not Available)	in absolute figures (n = 286)	%	
No	-	-	-		11	4.6	5%
Yes	-	-	-		227	95.4	95%
Yes	Yes	-	-		174	73.1	83%
Yes	Not Completely	-	-		24	10.1	
Yes	No	-	-		29	12.2	
Yes	Yes	-	-	Available	100	0.42	50%
Yes	Not Completely	-	-	Available	5	0.02	
Yes	No	-	-	Available	13	0.05	
Yes	Yes	Yes	-		146	61.3	80%
Yes	Yes	Not Completely	-		26	10.9	
Yes	Yes	No	-		2	0.8	
Yes	Not Completely	Yes	-		9	3.8	
Yes	Not Completely	Not Completely	-		9	3.8	
Yes	Not Completely	No	-		5	2.1	
Yes	No	Yes	-		22	9.2	
Yes	No	Not Completely	-		3	1.3	
Yes	No	No	-		4	1.7	
Yes	Yes	Yes	Yes		146	61.3	86%
Yes	Yes	Yes	No		0	0.0	
Yes	Yes	Not Completely	Yes		18	7.6	
Yes	Yes	Not Completely	No		8	3.4	
Yes	Yes	No	Yes		0	0.0	
Yes	Yes	No	No		2	0.8	
Yes	Not Completely	Yes	Yes		9	3.8	
Yes	Not Completely	Yes	No		9	3.8	
Yes	Not Completely	Not Completely	Yes		3	1.3	
Yes	Not Completely	Not Completely	No		6	2.5	
Yes	Not Completely	No	Yes		3	1.3	
Yes	Not Completely	No	No		2	0.8	
Yes	No	Yes	Yes		22	9.2	
Yes	No	Yes	No		0	0.0	
Yes	No	Not Completely	Yes		2	0.8	
Yes	No	Not Completely	No		1	0.4	
Yes	No	No	Yes		1	0.4	
Yes	No	No	No		3	1.3	1%

Table 4: Evaluation (results matrix) TAV workplaces visited in Phase II (n = 238 workplaces, date of enquiry: 20 June 2022)

Question 1 (Yes/No)	Question 2 (Yes/Not Completely/No)	Question 3 (Yes/Not Completely/No)	Question 4 (Yes/No)	Question 5 (Available/Not Available)	in absolute figures (n = 286)	%	
No	-	-	-		8	3.7	4%
Yes	-	-	-		209	96.3	96%
Yes	Yes	-	-		160	73.7	84%
Yes	Not Completely	-	-		23	10.6	
Yes	No	-	-		26	12.0	
Yes	Yes	-	-	Available	92	42.4	50%
Yes	Not Completely	-	-	Available	5	2.3	
Yes	No	-	-	Available	11	5.1	
Yes	Yes	Yes	-		132	60.8	81%
Yes	Yes	Not Completely	-		26	12.0	
Yes	Yes	No	-		2	0.9	
Yes	Not Completely	Yes	-		8	3.7	
Yes	Not Completely	Not Completely	-		9	4.1	
Yes	Not Completely	No	-		5	2.3	
Yes	No	Yes	-		21	9.7	
Yes	No	Not Completely	-		3	1.4	
Yes	No	No	-		2	0.9	
Yes	Yes	Yes	Yes		132	60.8	87%
Yes	Yes	Yes	No		0	0.0	
Yes	Yes	Not Completely	Yes		18	8.3	
Yes	Yes	Not Completely	No		8	3.7	
Yes	Yes	No	Yes		0	0.0	
Yes	Yes	No	No		2	0.9	
Yes	Not Completely	Yes	Yes		8	3.7	
Yes	Not Completely	Yes	No		8	3.7	
Yes	Not Completely	Not Completely	Yes		3	1.4	
Yes	Not Completely	Not Completely	No		6	2.8	
Yes	Not Completely	No	Yes		3	1.4	
Yes	Not Completely	No	No		2	0.9	
Yes	No	Yes	Yes		21	9.7	
Yes	No	Yes	No		0	0.0	
Yes	No	Not Completely	Yes		2	0.9	
Yes	No	Not Completely	No		1	0.5	
Yes	No	No	Yes		1	0.5	
Yes	No	No	No		1	0.5	0,5%

Table 5: Evaluation (results matrix) of those TAV workplaces visited in both phases (I ∩ II with n = 217 workplaces, date of enquiry 20 June 2022)



Messwerte = measurement values

Anteil = percentage

Perzentile = percentile

OG KI = upper limit CI

AlphaQuantil = α quantile

Grenzwert Qtz A = limit value qtz A

Figure 4: Distribution of 93 measurement values on respirable silica dust as documented in the priority action (histogram of left chart) as well as distribution of percentile values (right chart)

Perzentile	OG KI	α-Quantil
5	0,01	0,010
10	0,01	0,010
20	0,01	0,010
30	0,02	0,014
40	0,02	0,020
50	0,02	0,020
60	0,03	0,023
70	0,04	0,030
80	0,05	0,043
85	0,07	0,050
90	0,12	0,068
95	0,17	0,112
100	-	0,253

Perzentile = percentile

OG KI = upper limit CI

α-Quantil = α quantile

Table 6: List of percentile values determined by distribution-independent methods and Excel quantile function