# RCS MAPPING AS A DIAGNOSTIC AND CONTROL TOOL

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## ABSTRACT

The European Union has included "work involving exposure to respirable crystalline silica (RCS) dust generated in a work process" as a carcinogen in Directive (EU) 2017/2398 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work.

This Directive provides a minimum level of protection for all EU workers of 0.1 mg/m$^3$ of respirable CS dust. In Spain, Royal Decree 1154/2020 established a limit value for respirable CS dust of 0.05 mg/m$^3$, with a transition period for implementation up to 31 December 2021, during which time the limit value stands at 0.1 mg/m$^3$.

When assessing RCS exposure at work, it is important to bear in mind that smaller CS particles can penetrate the respiratory system by inhalation. Particle penetration capacity varies with size, and particles that are fine enough to remain suspended in the air for a long time and penetrate as far as the pulmonary alveoli, the last receptacles where oxygen and carbon dioxide are exchanged with the blood, are collectively known as the respirable fraction.

In the ceramics and related industries, the main sections that produce dust emissions and contribute to higher RCS levels in the plant's indoor ambient air are raw material preparation and tile forming.

In order to guarantee a safe and risk-free work environment for workers, adequate control and mitigation of the presence of RCS in industrial plants is required, and to that end, it is considered of interest to evaluate the specific contributions to particulate matter (respirable fraction) emissions made by different potential sources of RCS emissions along the production process.

This paper explains the experimental method applied and the results obtained of a study of contribution levels from sources in industrial plants under real-world industrial conditions.

The experimental method established to evaluate particulate matter emissions is based on the use of continuous sampling equipment (optical spectrometers), which enable concentration values of the respirable fraction to be obtained at short intervals of time (every minute). Simultaneously, an exhaustive record of incidents and operations taking place near each identified emission source are registered. Gravimetric pumps are used to take samples for subsequent RCS assessment.

The results obtained provide time-based series of respirable fraction concentration, which identify the type of emission, the presence of concentration peaks, and the source. Thereafter, concentration maps were produced that allowed the emission sources associated with the production process that most significantly contribute to RCS concentration levels to be identified. All this information made it easier to select appropriate technical control measures and to prioritise actions, as part of a comprehensive improvement plan to mitigate the impact of the presence of RCS at the workplace.

## 1. INTRODUCTION

The European Union has included "work involving exposure to respirable crystalline silica (RCS) dust generated in a work process" as a carcinogen in Directive (EU) 2017/2398 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work.

The Directive calls for a minimum level of protection for all EU workers of 0.1 mg/m$^3$ of respirable CS dust. In Spain, Royal Decree 1154/2020 established a limit value for respirable CS dust of 0.05 mg/m$^3$, with a transition period for implementation up to 31 December 2021, during which time the limit value stands at 0.1 mg/m$^3$.

In view of recent legislation concerning RCS, the mining firm "S.A. Minera Catalano-Aragonesa" decided to undertake a detailed study of the different sections of its production process to identify the main emission sources of particulate matter, specifically the respirable fraction, that contribute significantly to occupational exposure to RCS.

When assessing occupational exposure to RCS, it is important to bear in mind that smaller CS particles can penetrate our respiratory system by inhalation. Particle penetration capacity varies with size, and the 'respirable fraction' is what has the greatest impact on human health, because it is formed by particles that are fine enough to remain suspended in the air for a long time and penetrate as far as the pulmonary alveoli.

Detailed knowledge of the specific contribution made by each stage in the production process will enable specific mitigation measures to be established and prioritised in order to minimize the concentration of particles and thus of RCS.

The work proposed here was divided into a series of steps: firstly, a selection of potential emission sources was made, and then sampling was carried out to continuously record the respirable fraction of particle concentration.

After that, where emission sources had been identified as significant, experimental measuring was performed to determine RCS concentration in the particles emitted from those sources. This sampling made it possible to quantify how much the most significant emission sources contribute to RCS levels in ambient air and to identify the most problematic operations taking place close to the emission source. For each emission source and/or activity thus identified, a series of specific corrective measures have been proposed to mitigate the impact of RCS in the workplace.

## 2. METHOD

### 2.1. MAP OF PARTICULATE MATTER CONCENTRATIONS

The method employed to develop concentration maps of particulate matter consisted of continuously recording - for an approximate period of 30 minutes - the concentration of particulate matter.

To implement each series of experiments, GRIMM optical spectrometers were used to determine concentration levels in the selected areas. The equipment's operating principle is based on running a known flow of an air stream through an inlet head to enable measurement, by means of a detector, of the dispersion of a laser beam produced by the different particles (Light-Scattering). These devices measure in real time the concentration of the respirable fraction with a time resolution of one minute.

The emission sources selected in the micronizing section were located inside the plant: Mill 1(M1A, M1B and M1C), Mill 3 (M3A, M3B and M3C), Mill 4 (M4A, MAB and M4C), Mill 5 (M5 and M5C) and cabin operators (COM). Outside the facility, samples were taken in the product loading area (PA) and in the area where belt conveyors feed raw materials into the micronizing section (CTP). Finally, readings were taken at the entrance to the micronizing section, where a weather station was also set up.

In the dry-spraying section, the spots selected for sampling were Spray dryer 1 (AT1A and AT1B), Spray dryer 3 (AT3A and AT3B) and Spray dryer 4 (AT4A and AT4B). In the slip preparation area, two spots - B1 and B2 – were tested. Readings were also taken inside an operators' cabin (COAT3) and in the corridor leading to the loading area (PAC). Outdoors, three places were tested in the street where the spray-dried powder loading stations are located: C1 and C3. Finally, readings were taken at the entrance to the spray-drying section, where a weather station was also set up.

In order to assess the data's reproducibility, two campaigns of experiments were carried out. The measurements taken made it possible to assess emissions, determine concentration series, and produce a map of the respirable fraction of particulate matter concentrations in the plant. Based on the results obtained from the mappings, the most significant sources of particulate matter emission were identified.

### 2.2. ASSESSMENT OF OCCUPATIONAL EXPOSURE TO RCS

The mappings carried out in the tasks above made it possible to identify the main hotspots in the micronizing and spray-drying sections. Once they had been identified, the hotspots of respirable fraction of particles were short-listed. At those points, RCS concentration was determined by performing static and dynamic measurements and continuous recording of the respirable fraction.

Static and dynamic measurements were taken using personal air sampling pumps, which allowed the particles present in the ambient air to be captured on a PVC filter for subsequent testing and estimation of RCS concentration.

The amount of quartz on the filters was quantified by X-ray diffraction testing, which produced a diffractogram from which the types of minerals present were identified. Certified reference materials were used to quantify and validate the measurements: BCR-66, SRM 1878a and SRM 2950-2957.

In all cases, measurements were taken on at least two different workdays with the aim of increasing the sampling's representativeness and to assess the repeatability of the tasks performed by operators. In addition, an exhaustive record was made of incidents and operations performed.

## 3. RESULTS AND DISCUSSION

### 3.1. MAP OF PARTICULATE MATTER CONCENTRATIONS

The results obtained provided time-based series of respirable fraction concentration, which enabled the type of emission, the presence of concentration peaks, and the source of emissions to be identified.

From the series of concentrations obtained, the average value of the concentrations, recorded with a time resolution of one minute, was determined for the different sampling points and the concentration map was elaborated. It is important to note that the method applied does not allow for direct comparison of the average values obtained with the pre-set ELV for the respirable fraction (3mg/m$^{3)}$, because the sampling time applied (20-30 minutes per source) is shorter than is required for compliance with statutory limits and the equipment used (optical spectrometer).

Figure 1 shows the concentration ranges obtained for respirable fraction at the different emission points inside and outside the production plant.

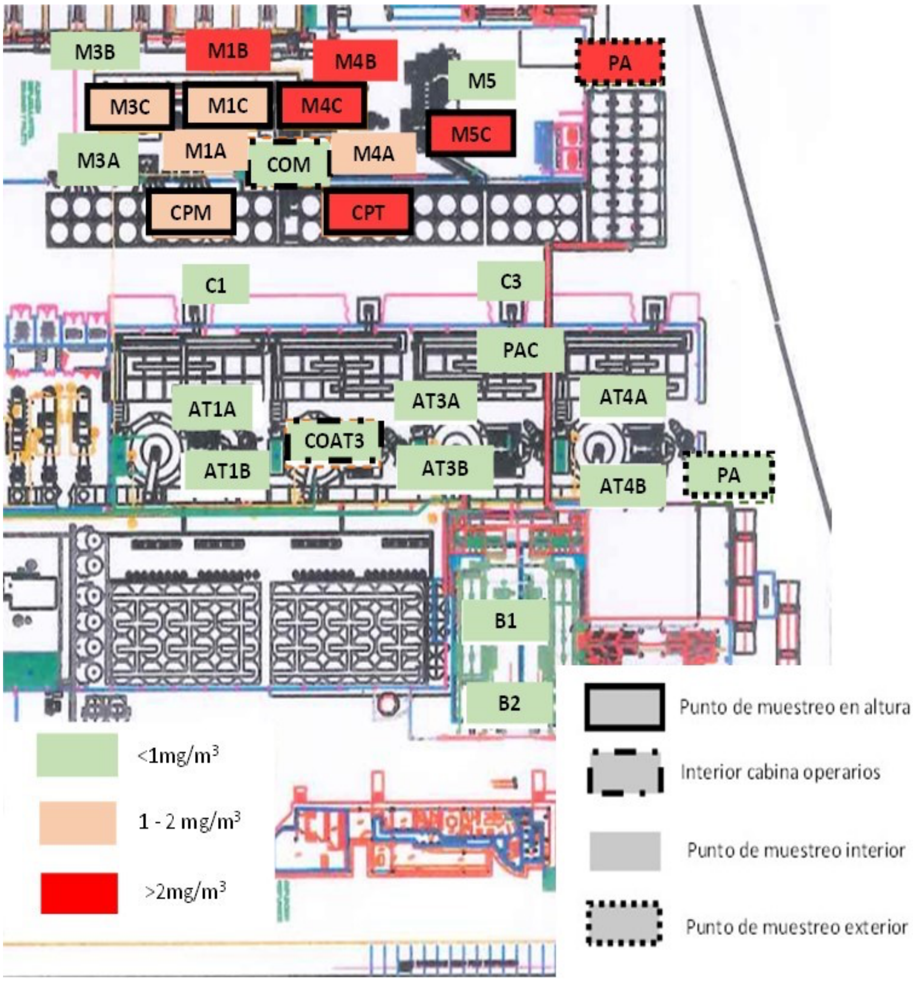

***Figure 1**. Map of average respirable fraction concentration (mg/m$^{3)}$ at the selected emission sources*

The map of respirable fraction concentrations thus obtained allowed us to identify the milling area, and more specifically the area near the conveyor belts, as the main sources of particulate matter emissions inside the plant.

The outdoor emission measurements revealed hopper feeding and truck loading operations to be the sources that most contributed to the average levels measured.

## 3.2. ASSESSMENT OF OCCUPATIONAL EXPOSURE TO RCS

Based on the results of the respirable fraction concentration mappings, the main emission sources were selected. At these points, static and dynamic measurements were taken using sampling pumps and the respirable fraction was continuously recorded with GRIMM meters. Measurement at each of the selected points lasted approximately 8 hours, during which time a detailed record of incidents and operations carried out was taken.

The main results obtained are shown below, where the influence of performing certain operations and the presence of other emission sources close to the source under study were evaluated, as well as the efficiency of implementing best practices.

Figure 2 shows how starting up the M2 emission source affects the concentrations of respirable fraction recorded at the M4 emission point, due to the presence, in the vicinity of the M4, of crossovers between belt conveyors carrying raw materials that feed the M2 mill. In this sense, the simultaneous evaluation of different emission sources made it possible to identify more accurately operations and/or emission sources that lead to a significant increase in the levels measured at the M4 sampling spot.

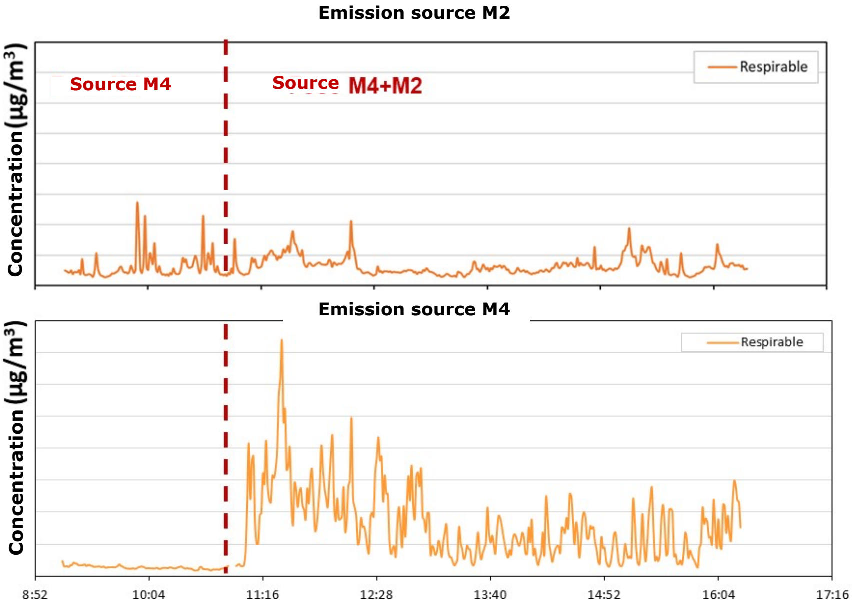

***Figure 2.*** *Influence of M2 emission source on the series of respirable fraction concentrations (mg/m³) recorded at M4 emission source.*

The methodology applied also made it possible to evaluate the contribution of emission sources located outside the plant on the concentrations of respirable fraction recorded inside it (Figure 3).

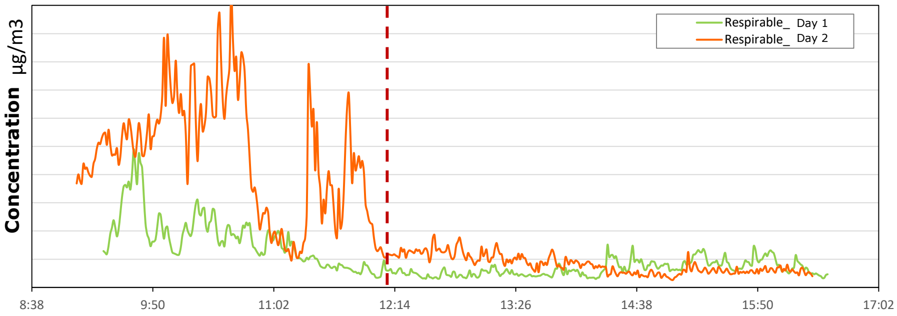

***Figure 3.*** *Series of respirable fraction concentrations (mg/m³) recorded at point M5 over two measuring campaigns: Day 1 with outside door closed and Day 2 with the outside door open.*

Figure 3 shows significant differences in the levels recorded at M5 emission source, mainly during the period from 09h00 to 12h00. When the different sampling campaigns were studied in detail, it was noticed that when measurements were carried out on Day 2, the outside door located near M5 remained open, whereas on Day 1 it was closed. This fact could explain the increase in concentrations recorded up until noon, since in the area where the plant is located, during the summer, atmospheric dynamics are determined by local and regional winds – mainly sea and land breezes – that include a change in the direction of the prevailing wind at noon. Consequently, the prevailing wind until noon facilitated particle entry, caused by the continuous truck loading and transfer, from outdoors into the plant.

Finally, Figure 4 shows the efficiency achieved in the concentrations of inhalable and respirable fractions after maintenance operations and a series of improvements were implemented at the plant.

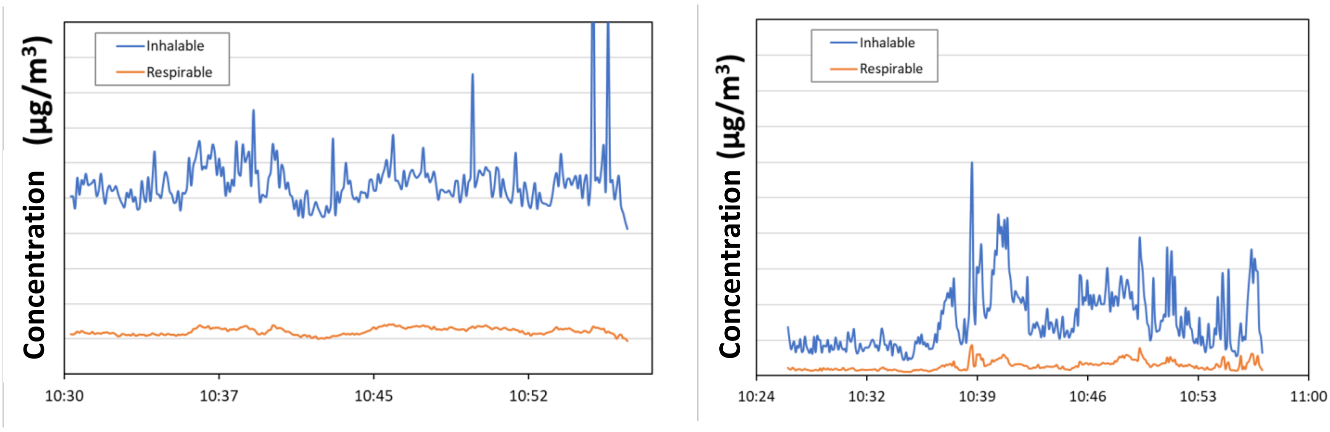

***Figure 4.*** *Series of inhalable and respirable fraction concentrations (mg/m$^{3)}$ recorded before (left graph) and after (right graph) implementing improvement actions.*

The concentrations recorded show that the series of improvements made in the plant afford high overall efficiency, with a significant decrease in the levels of inhalable and respirable fraction being noted compared to the values taken before specific technical measures were carried out.

Specifically, at all the sampling points included in the evaluation, a significant decrease in the concentration of inhalable and respirable fraction was recorded, with reduction efficiencies ranging between 70 and 90% for both fractions.

In regard to RCS testing, the influence on RCS exposure levels of possible incidents that increase emissions of the respirable fraction of particulate matter at the plant was studied, and it was seen that RCS concentrations stay at lower levels when the plant operates under optimal conditions and thus meets the set RCS exposure limit values (0.1 mg/m$^3$ until 31/12/2021 and 0.05 mg/m$^3$ as from 01/01/2022).

## 5. CONCLUSIONS

The methodology applied as a means of diagnosis and control in the management of RCS has allowed identification of the type and source of emission and the presence of concentration peaks. Drawing up concentration maps under real-world operating conditions makes the facility's situation in terms of air quality inside the plant easier to view and, together with the rest of the information, has enabled corrective measures that mitigate the impact associated with the possible presence of RCS to be proposed and prioritised.

The concentration map evaluated both indoor emission sources - at heights and at operator level - and outdoor emission sources and pin-pointed the sources that most contribute to the levels of respirable fraction recorded during the experimental samplings. Inside the plant, the milling section was identified as the main source of particulate matter emission, while the assessment of outdoor emission sources showed that a significant contribution to the readings came from hopper feed and truck loading operations.

Based on the results of the respirable fraction concentration maps, the main emission sources were evaluated in detail and samplings were performed throughout the working day. The main conclusions reached were:

- The simultaneous evaluation of different emission sources has made it possible to identify, with greater accuracy, the influence of certain operations and/or contribution from other emission sources to the significant increases in the concentrations recorded at the source under study.

- Leaving the outside door to the plant open led to an increase in concentrations of respirable fraction recorded inside the plant. The increase in levels was mainly noted up until 12h midday, when the prevailing wind direction facilitated entry into the plant of particles caused by continuous truck loading and transfer operations outside.

- The fine-tuning and implementation of a series of improvement measures in the plant has led to a significant decrease in levels, yielding reduction efficiencies in the range of 70-90% for respirable and inhalable fractions of particulate matter.

Occupational exposure to RCS was evaluated at the most significant emission sources and showed that possible operating incidents that lead to increased emissions of the respirable fraction of particulate matter in the plant have a direct impact on the levels of exposure to RCS. When the plant is working under optimal operating conditions, it is possible to meet the required RCS exposure limit values.

On the whole, it was observed that frequent cleaning, good maintenance and the implementation of improvement actions in a production plant are essential to ensuring optimal levels of the respirable fraction of particulate matter both inside the production plant and outside, and thus to complying with the legislation concerning RCS.

## REFERENCES

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