Respirable Crystalline Silica

A well-recognised occupational health hazard

- Workers from mining, construction, and engineered stones industries are particularly vulnerable to the exposure to Respirable Crystalline Silica (RCS).
- RCS can lead to an array of conditions, ranging from silicosis to lung cancer.
- Dr Akemi Ichikawa and her colleagues at TestSafe Australia / SafeWork NSW compared two different analytical techniques to measure RCS.
- Accurate and sensitive analyses are essential for ensuring compliance with occupational exposure limits and minimising health risks.

Respirable Crystalline Silica (RCS) are very fine particles that have a diameter of less than 10 micrometres, which is about 10–20 times smaller than the diameter of human hair. RCS can cause silicosis, a condition where fine dust inhalation over prolonged periods of time results in inflammation and scar tissue within the lungs. Patients affected by silicosis feel weak, tired, and out of breath. In the worst cases, they can experience respiratory failure years after being exposed to the fine silica particles. Inhalation can also be linked to lung cancer and other lung diseases which endanger the health of workers in the mining, construction, and kitchen bench-top manufacturing industries. Internationally, there has been a drive to reassess the occupational exposure limits due to increasing occurrence of silicosis among workers. In this context, it is important to optimise analytical techniques so they can achieve the sensitivity required to accurately detect RCS in workplace air. A sample of the fine dust in the air of the worker breathing zone is collected on a membrane filter and sent to the laboratory for RCS determination.

Dr Akemi Ichikawa and her colleagues at TestSafe Australia have compared the different analytical techniques of RCS determination of the direct-on-filter methods using X-ray diffraction (XRD) and Fourier transform infrared (FT-IR) spectroscopy. The study was relevant to real-life scenarios, as it included 253 workplace air samples collected from 34 different sampling sites in Australia from 2014 to 2018. The sampling sites covered major industries including road construction (47%), coal mining (23%) and kitchen benchtop manufacturing (25%), among others.

Monitoring compliance

Fourier transform infrared (FT-IR) spectroscopy and X-ray diffraction (XRD) are the two analytical techniques employed by most laboratories for the analysis of RCS, to monitor compliance with the occupational exposure limits to RCS. Ichikawa's study compares the two commonly used methods, 'direct-on-filter FT-IR' and 'direct-on-filter XRD'.

The researchers explain that 'direct-on-filter' methods require very little preparation other than making sure that the operator presents a filter onto a mount that is placed into the required analytical instrument. Apart from the obvious ease of use considerations, this method offers the advantage of minimising the losses that are typically associated with more complex preparations.

Ichikawa and her colleagues used pure samples of α-quartz – the most common crystal form of crystalline silica – to make a fair comparison between the FT-IR and the XRD techniques. When the pure samples were analysed, the team could hardly find any difference in the results yielded by either technique. Surprisingly, the data from workplace samples showed that the FT-IR results were on average 9% higher than their XRD counterparts. This led the team to speculate that the workplace samples

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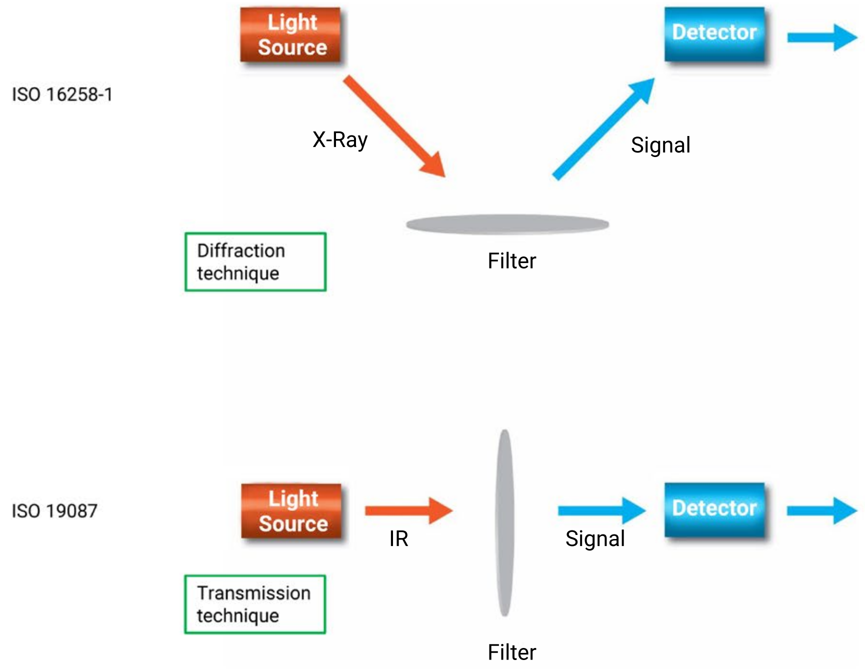
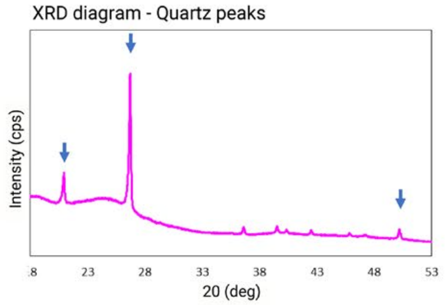
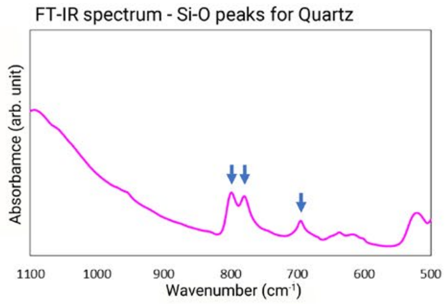
might contain some matrices other than RCS that interfered with the FT-IR spectra, while remaining less likely to interfere in the XRD technique.

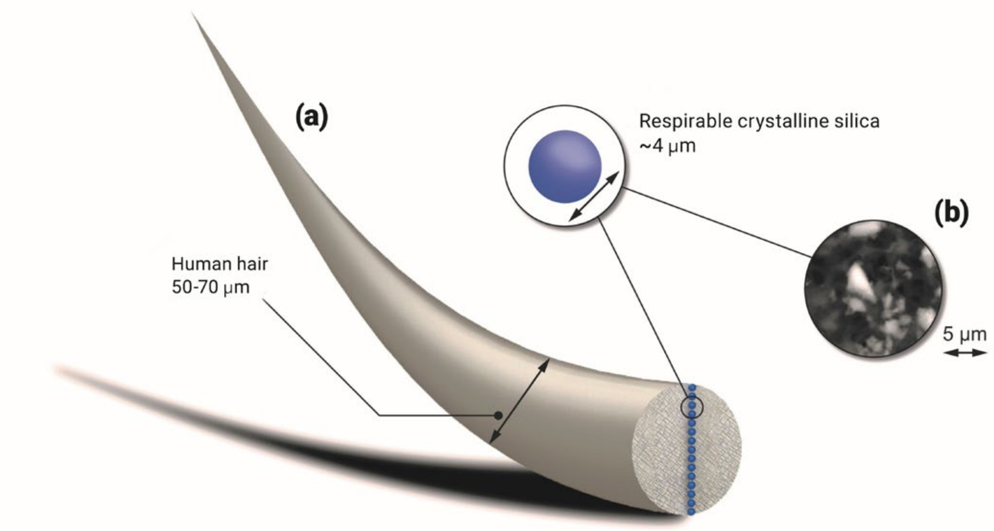
A robust and accurate method of analysis

The researchers showed in their study that interference from other silicates caused a positive bias in the analysis of α-quartz by FT-IR. They showed that silicates such as kaolinite and cristobalite, present as impurities in a synthetic mixture sample, could cause even more than a 20% positive bias in the FT-IR signal when present above 60% kaolinite or 15% cristobalite. The team also demonstrated that,

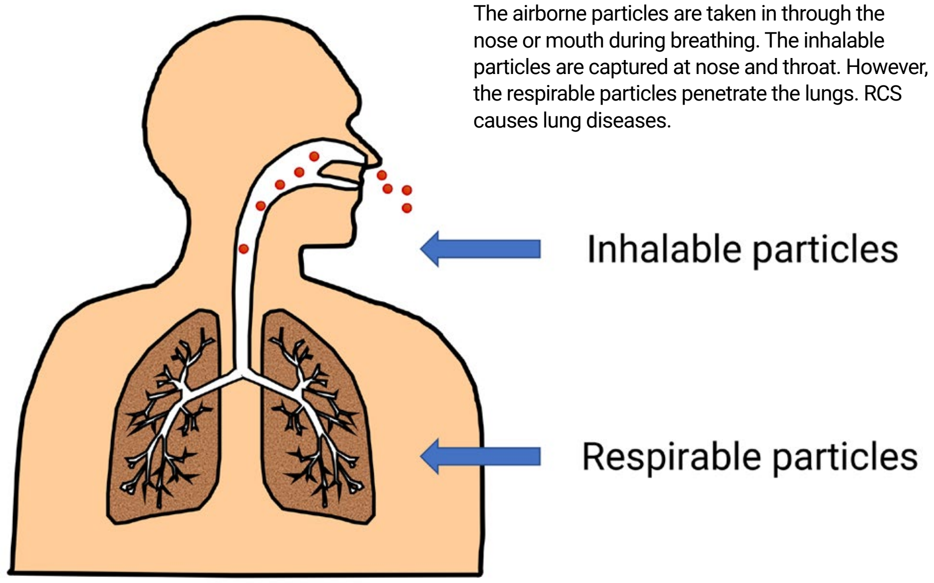








(a) Comparison of human hair and respirable crystalline silica (RCS), which is smaller particles than 10µm.
(b) Scanning electron microscope (SEM) image of respirable crystalline silica. The picture was taken by TestSafe Australia.



The airborne particles are taken in through the nose or mouth during breathing. The inhalable particles are captured at nose and throat. However, the respirable particles penetrate the lungs. RCS causes lung diseases.

The XRD method could handle up to twice the sample loading and was able to achieve lower limits of detection.

while almost a third of the results obtained by FT-IR were affected by the presence of silicates, the same did not happen with the XRD analyses, concluding that the XRD method is more robust and reliable when testing workplace silica dust in air samples for α-quartz.

Ichikawa and her colleagues explain that when the influence of interferences is kept to a minimum, as is easily the case when using XRD, the sample loading on the filter can be increased, meaning that high loading samples can be tested in a single analytical run. Furthermore, the signal from the XRD spectrometer is strong enough to detect lower quantities of α-quartz per mass of sample analysed. The scientists determined that the XRD method could handle up to twice the sample loading and was able to achieve a lower limit of detection of two micrograms of α-quartz per single air filter.

Concluding remarks

Compliance with occupational exposure limits to RCS is important to safeguard the health and safety of workers in a broad range of industries. International occupational exposure limits for crystalline silica are being reduced as new evidence emerges of the risks to health occurring at lower exposure levels. This study shows that the use of the XRD technique to determine RCS gives a more accurate and sensitive analysis with less interferences. This allows policy makers worldwide to make better decisions to help protect the health and safety of workers.

Personal response

What attracted you to your research field?

I am interested in material science and analytical chemistry, especially nanomaterials and lower detection range of analysis, which are challenging but attractive research fields to encounter new findings.

Are there any findings from the real workplace samples you analysed?

Our study showed that cristobalite, which is another crystal form in crystalline silica, was detected in the samples from engineered stone in kitchen bench-top manufactures. Many engineered stones comprise α-quartz as well as cristobalite.

Historically, only α-quartz has been monitored for RCS in Australia. The awareness to cristobalite has increased since we shared our results at the AIOH2018 conference – the main conference for occupational hygienists and professionals in Australia.

What are the next exciting projects in your research?

Our laboratory measures many hazardous chemicals in workplace air and biological samples to determine exposures to workers. These chemicals include dusts, asbestos, smoke, paints, solvents, and hospital drugs. However, we also have research programmes focusing on new and improved analytical methods, including lowering detection limits in the measurement of RCS.

Are there other implications that stem from the results of your current project, besides occupational health and safety?

We showed how to improve the analysis of RCS and revealed interferences in FT-IR analysis. This type of approach can be used in any other areas to improve the accuracy and detection limits of the analysis.

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Bio

Akemi Ichikawa is a senior analytical chemist at TestSafe Australia / SafeWork NSW. She is an expert in workplace health and safety, as well as chemical analysis including X-ray diffraction, electron microscopy, chromatography, material science, and nanotechnology. Ichikawa has been working in the workplace health industry since 2017. Before that, she was a research scientist in the electronics industry. To date, she has published over 30 peer-reviewed papers and 200 patents.

Further reading

Ichikawa, A, et al, (2022) Comparison of the Analysis of Respirable Crystalline Silica in Workplace Air by Direct-on-Filter Methods using X-ray Diffraction and Fourier Transform Infrared Spectroscopy, *Annals of Work Exposures and Health*, 66(5), 632–643.

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