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Hierarchical Arrangement of Nanoquartz for Toxicological Examinations

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Abstract

Quartz dust exposure in the workplace is linked to fatal diseases. A wide range of micrometric to nanometric particles characterize mechanically fractured quartz dust. Due to the strong electrostatic adhesion forces that prevent the nanofraction from being isolated, little is known about how this nanometric fraction affects quartz's overall toxicity. Additionally, fractured silica dust has unique surface characteristics, such as nearly free silanols (NFS), which give quartz a membranolytic activity. Bottom-up methods can be used to make nanoquartz, but the surface chemistry of these crystals is very different from that of fracturing-produced nanoparticles. We present a top-down milling method for producing nanometric quartz with the same toxic surface properties as fractured quartz. By combining the dry and wet stages of ball milling, dispersing the material with water and varying the milling times and rotational speeds, the process was made more efficient. It was possible to obtain nanoquartz with a strong propensity to aggregate into sub micrometric sizes. Surfactants or simulated body fluids had no effect on the deagglomeration. A bimodal crystallite domain size and partial lattice amorphization were observed. Coherence with previous toxicological data was indicated by a moderate membranolytic activity that was correlated with the number of NFS. It was possible to obtain a membranolytic nanoquartz for use in toxicological studies.

Key words: Deagglomeration • Nanoquartz • Nanofraction

Introduction

The portion of silica dust with an aerodynamic diameter of less than 4 m is known as respirable crystalline silica (RCS). Numerous diseases, including silicosis, lung cancer and autoimmune disorders, have been linked to occupational exposure to RCS. Currently, occupational exposure to RCS dusts is the leading cause of occupational lung cancer worldwide. Both crystalline and amorphous forms of silica are extensively utilized in industrial processes and productions due to its ubiquitous nature. Quartz is the most common type of RCS, but cristobalite or a combination of the two polymorphs are used less frequently. The International Agency for Research on Cancer (IARC) has determined that quartz has the potential to cause cancer in humans. However, the toxic effects of various quartz sources frequently vary. The structural and surface changes brought about by the production and processing of quartz sands have been linked to this variability.

Quartz-containing stones and composites undergo mechanical processes like milling sand blasting, cutting and polishing that break up and disorganize the crystals' uppermost atomic surface layers. As a result, the quartz lattice loses its long-range order. In a dynamic process of surface reconstruction, this generates silanols upon reaction with molecular water, possibly spaced by siloxane bridges and this new layer is subjected to chemical and structural rearranging. In rodents, fractured quartz has been shown to be more effective than non-fractured quartz with unaltered surfaces at causing cell membrane damage and lung inflammatory reactions. The nearly free silanols (NFS) are a subset of surface silanols that are produced when quartz fractures. NFS were discovered on milling-generated fractured and disordered surfaces with a unique intersilanol distance of 4 to 6, which is greater than that of the strongly interacting silanols on surfaces that are ordered. They are not isolated silanols at this distance because they are further apart by more than 6 and can be clearly distinguished through vibrational analysis of the O-H stretching mode. NFS is able to specifically interact with the phospholipids that make up the cellular membranes thanks to the peculiar nature of this silanol family. This mechanism proved to be responsible for the activation of the inflammatory response that quartz induced.

Description

The acute inflammation and cytotoxic effects that have been observed for quartz and fumed amorphous Nano silica may be linked to the presence of NFS on both crystalline and amorphous silica. Although the toxicological properties of micrometric quartz dust have been extensively studied over the past few decades, very little is known about the particular physicochemical properties of the nanometre fraction and its potential role in RCS's overall toxicity. According to the most recent recommendation of the European Commission (EC) on the definition of a nanomaterial, i.e., >50% of the particles are 100 nm on a per number basis, the nanometre fraction might outnumber the micrometric particles, de facto creating a nanomaterial, even though the relative mass of the nanometre fraction is frequently negligible in comparison to the dust as a whole [1,2]. It is beyond the realm of possibilities to expect to bar that nanoparticles may show a higher substance and toxicological movement than micrometric particles and mass material. In fact, the specific surface area, curvature and number of surface active sites increase when particle size decreases.

Nanoparticles may exhibit higher toxic effects and a different mechanism of action (MoA) than larger particles due to an increase in particle surface reactivity, which may have an impact on their interactions with the external environment, including biomolecules. Concerns were recently expressed by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) regarding the possibility of crystalline nanosilica playing a role in the toxic activity of fractured quartz dust. Due to the difficulty in obtaining quartz dust of the nanometric size and the fact that the amount and crystalline

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nature of a nanometric fraction may vary, investigations into its properties and toxicity were few and inconclusive.

A recent review of silica's pulmonary toxicity demonstrated the general lack of solid research on the health effects of nanoquartz. In particular, only one study on nanoscale and fine quartz particles in rats was uncovered by the authors. The hypothesis that nanometric and micrometric particles of the same compound are always more dangerous. However, the study used synthetic quartz that was prepared using a bottom-up method [3].

The surface properties of this nanoquartz are likely to be different from those of the nanometric fraction of fracturing quartz dust because it was produced through hydrothermal crystal growth. Mischler and his colleagues used a different strategy to separate the finest fraction of a commercial quartz flour using a multi-cyclone sampling array. Their method, on the other hand, relied on the availability of a lot of quartz dust, which created doubts about the purity, crystallinity and presence of accessory mineral phases, which are always present in natural samples. The toxicity of crystalline silica was the subject of a few additional studies, but none of them provided specific details about the production process or the physicochemical bulk and surface characteristics of the nanosilica. Because of this, these pioneering studies cannot be used to draw conclusions about the mechanisms of nanoquartz toxicity [4,5].

Conclusion

Planetary ball milling was the choice we made out of the various options. The grinding time, the frequency of oscillation or rotational speed, the kind of material that is milled and the size, number, density and hardness of the milling balls all have an impact on ball milling energetics and grinding efficiency. Additionally, distinct mill types produce distinct stress forces. A planetary mill operates through friction and particle abrasion, whereas a vibrational mill reduces particle size primarily through impact and particle fracturing. By adding dispersant agents, milling forces and effects can be further manipulated. At the point when a fluid dispersant, e.g., water or a more unpredictable dissolvable, like isopropanol, is added to the processing combination (wet processing), a superior scattering of the particles and a more uniform molecule size conveyance is accomplished, as opposed to dry processing. Indeed, the presence of a dispersing agent prevents aggregate formation and material caking, both of which could impede an efficient and uniform reduction to size. Wet milling also better preserves the pristine material's crystal structure by reducing energy transfer from the milling balls to the particles .

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Conflict of interest

No potential conflict of interest was reported by the authors.

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