

中文摘要

陶瓷工廠含高濃度之氣懸二氧化矽粉塵，廠內作業勞工若長期暴露於此環境，將有高風險導致肺部慢性發炎及纖維化，甚至可能罹患肺癌。此外，廠內二氧化矽粉塵濃度會隨製程而異，因此於各製程工作區之暴露風險亦會隨之改變。本研究目的為評估陶瓷工廠各工作區，勞工之氣懸二氧化矽粉塵長期暴露風險，並推估廠內二氧化矽粉塵濃度閾值，以提供勞工長期工作 45 年期間之肺部健康警訊。本研究以現地環境監測數據為基礎，針對廠內氣懸粉塵之二氧化矽含量及粒徑分佈做定量分析，並利用以生理為基礎之肺泡沉積區塊模式，推估勞工長期暴露之肺部二氧化矽粉塵沉積量。本研究以希爾模式 (Hill model) 描述二氧化矽粉塵對人體肺部發炎反應及纖維化之效應，且以韋伯閾值模式 (Weibull threshold model) 推算環境粉塵濃度閾值。本研究藉由機率風險模式評估勞工長期暴露二氧化矽之健康風險及檢視逐年肺部健康惡化程度。本研究顯示，氣懸粉塵質量中位粒徑以家用瓷製造廠燒窯區 $5.64\ \mu\text{m}$ 為最小。結果指出氣懸粉塵之二氧化矽含量與二氧化矽粉塵濃度，以陶磚製造廠噴霧造粒區 33.04% 及 $1246.32 \pm 516.98\ \mu\text{g m}^{-3}$ 為最高；家用瓷製造廠中則以施釉區 2.18% 及 $2.64 \pm 2.84\ \mu\text{g m}^{-3}$ 為最高。在風險為 0.5 之條件下，顯示家用瓷製造廠施釉區勞工長期工作 45 年，其肺部發炎反應及纖維化程度皆為輕度健康惡化，而在陶磚製造廠噴霧造粒區，則是漸從輕度轉為重度健康惡化。本研究所推求之環境粉塵濃度閾值為 $361.16\ \mu\text{g m}^{-3}$ ，可作為廠內環境粉塵濃度之監控參考值。本研究發現勞工長期於陶磚製造廠噴霧造粒區工作之二氧化矽暴露風險為最高，建議業主可每日監控廠內環境粉塵濃度，將濃度降低至閾值之下。本研究亦呼籲年資達 15 年以上之勞工應開始定期做肺部之健康檢查，以預防罹患二氧化矽粉塵暴露之相關疾病。

關鍵字：陶瓷工廠；二氧化矽；氣懸粉塵；肺；暴露；發炎反應；纖維化；機率風險評估

Abstract

Ceramics manufacturing contains high concentration of airborne silica dust. If workers are exposed to such environments over a long period of time, they will have high risk for suffering from chronic inflammation, fibrosis, and lung cancer. In addition, silica dust concentrations vary with different manufacturing processes, resulting in working area-varied exposure risks. The purpose of this study was to assess long-term exposure risks of airborne silica dust in each working area at ceramics manufacturing. A concentration threshold for silica dust was estimated to provide a lung health warning for workers during the prolonged employment of 45 years. Based on *in situ* environmental monitoring data, this study quantified the silica content in the airborne dust samples and characterized particle size distributions in working areas. A physiologically based alveolar deposition models was used to estimate silica lung burden for long-term exposed workers. This study used Hill model to describe the silica dust effects on human lung inflammation and fibrosis. A Weibull threshold model was used to estimate a concentration threshold for environmental dust. This study used the probabilistic risk model to assess the health risk for workers who are exposed to silica over a long period of time for examining the degree of lung health deterioration annually. This study showed that the smallest mass median diameter was found in burning area at commodity ceramic factory of 5.64 μm . Results indicated that granulation area at tile ceramic factory had the highest silica content of 33.04% and silica dust concentration of $1246.32 \pm 516.98 \mu\text{g m}^{-3}$, whereas the highest silica content and silica dust concentration in commodity ceramic factory was found in glazing area of 2.18% and $2.64 \pm 2.84 \mu\text{g m}^{-3}$. Risk assessment results revealed that at risk of 0.5 for glazing workers at commodity ceramic factory during the prolonged employment of 45 years, the degrees of lung inflammation and

fibrosis were mild health deterioration, whereas for those who work in granulation area at tile ceramic factory changed gradually from mild to severe. The estimated threshold value for environmental dust concentration was $361.16 \mu\text{g m}^{-3}$ that could be used as the monitoring reference value for environmental dust concentration in ceramics manufacturing. This study found that workers in granulation area at tile ceramic factory for a long period appeared the highest silica exposure risk, suggesting that the proprietors may monitor the environmental dust levels on a daily basis for reducing concentrations below the threshold. This study also suggests that workers with more than 15-yr seniority should initiate a periodic lung health examination program to prevent silica dust exposure-related diseases.

Keywords: Ceramics manufacturing; Silica; Airborne dust; Lung; Exposure; Inflammation; Fibrosis; Probabilistic risk assessment