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Harmful effects of airborne dust diffused from ceramic tiles during home decoration

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ABSTRACT

Exposure to airborne dust from ceramic tiles usually occurs during home decoration and may cause various diseases, such as chronic bronchitis, asthma and pneumoconiosis. The hazardous effects of dust particles are associated with their particle characteristics (i.e., size distributions, shape factors and elemental composition). This study proposed a method for evaluating the harmful effects of airborne dust on decorators. Scanning electron microscopy (SEM) and image processing technology were used to characterize the morphology of the particles and to measure the size and size distribution of dust particles generated from cutting and grinding of ceramic tiles. In addition, the 3D natural morphology of the dust was featured by atomic force microscopy (AFM) simply. The major chemical composition of the particles was characterized qualitatively through SEM in conjunction with energy dispersive X-ray spectroscopy (EDX). X-ray fluorescence (XRF) was used to quantitatively determine the major elements and toxic trace elements quantitatively which were not detected by EDX. Experimental results showed that 99% of the particles were <2.5 μm in 2D equivalent diameter, polygonal in 2D projection shape and flaky in natural morphology. Most particles were composed of silica and aluminosilicate. The particles also contained some toxic trace elements, such as Cr, Pb and As, exceeded the allowed standard. The proposed method can effectively characterize the features of dust, and this study can be used as basis for implementing protection guidelines for decorators.

1. Introduction

Decoration is necessary for improving the living standard of people; however, home decoration is recognized as a source of indoor environmental pollution. A considerable number of reports suggest that exposure to the decoration materials, such as formaldehyde, phthalate esters and other organic compounds, may be associated with many diseases [1–5]. However, limited literatures concentrated on evaluation of the levels of harmful effects of occupational exposure to airborne dust diffused from ceramic tiles during home decoration. In terms of particle pollution, the scientific interest is moving from particle mass concentrations to particle size distributions, which better determines the levels of particle pollution [6]. During home decoration, exposure to dust generated from cutting, grinding or drilling ceramic tiles is one of the most important occupational hazards to decorators. The ceramic tiles are made from clays, whose ingredients contain a lot of silica and aluminosilicate minerals. The International Agency for Research on Cancer of the World Health Organization changed the designation of silica and aluminosilicate from class 2 to class 1 carcinogen [7]. Repeated exposure to silica and aluminosilicate dust is associated with increased risk to various diseases, such as chronic bronchitis, asthma, pneumoconiosis and even cancer [8–10].

Harmful dust consists of particles that are inhalable, thoracic and respirable according to the Aerodynamic Equivalent Diameter (AED). AED is the diameter of a unit density sphere that has identical settling velocity. According to this definition, the respirable fraction of less than 2.5 μm AED, namely, particulate matter (PM) 2.5, can penetrate through the terminal bronchioles to the gas-exchange region [11]. Recent studies have shown a positive correlation between high concentrations of PM concentrations and deterioration in human health [12–14]. The raw minerals used for manufacturing ceramic tiles are complex inorganic compounds, such as kaolinite, silica, talc and vermiculite [15]. Moreover, ceramic tiles require small amounts of additives, such as barium compounds to control scumming, bentonite to increase plasticity, grog or perlite to provide texture and metal oxides to impart color [16]. These additives may interfere with one or more of the mechanisms that usually clear the respiratory tract or act as conductors to toxic substance absorption [17]. In addition, particles can serve as

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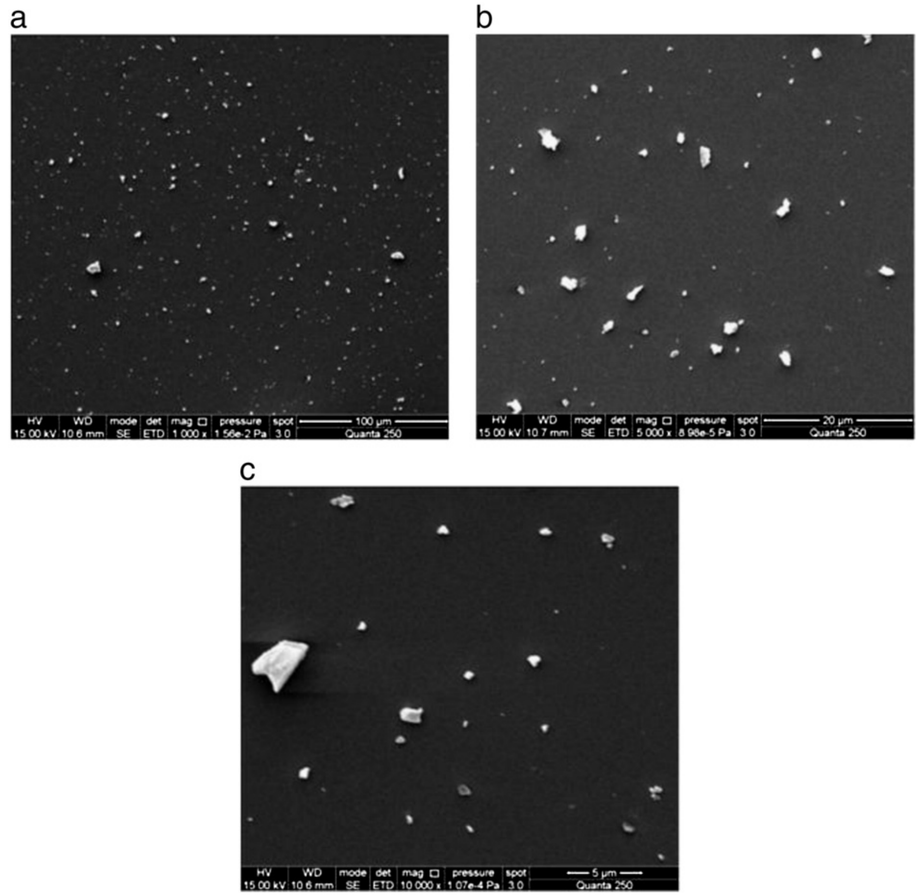

Fig. 1. Pictures of different magnifications.

carriers of heavy metals. Therefore, fine PM contains more heavy toxic metals than coarse particles [18].

The particle size and size distribution of dust can be assessed with several methods, including basic mechanical sieving and advanced laser diffraction methods. Sieve analysis is not an accurate method of classifying particulate materials by length [19]. Some indirect advanced methods involving scattered or diffracted light or laser assume dust particles to be spherical, which is not always the predominant case with natural particulate materials. Machine vision is another approach used to measure the size of particles. A digital camera is a relatively inexpensive device for capturing particle images; however, this device is only applicable to millimeter-sized or larger particles [20–22]. Scanning electron microscopy (SEM) is a suitable method for detecting micron-sized or smaller particles. Atmospheric particles from industrial area [23], wood dust from furniture [24] and biomass particles [25] can be observed through SEM. Furthermore, image processing technology [26–28] can be used to evaluate the size and size distribution of particles from images with accurate results. Note that previous researches focused on the 2D projection shape of particles. Atomic force microscopy (AFM) is an effective tool to characterize 3D microstructure and surface morphology [29,30].

Moreover, SEM coupled with energy dispersive X-ray spectroscopy (EDX) plays an important role in determination of the chemical composition of particles qualitatively [31–33]. For EDX-undetectable toxic trace elements, X-ray fluorescence (XRF) can be applied to determine the geological composition quantitatively [34,35].

In home decoration, dust particles are generated by mechanical breakdown processes, such as cutting, grinding and drilling of ceramic tiles. Air movement caused by the high-speed rotation of grinding wheel and cooling fan of hand-held cutting machines disperses dust. Characterization of the particles is necessary to evaluate the risks associated with occupational exposure to dust. Based on the advanced devices introduced above, in this study, SEM and AFM were used to determine the 2D projection and 3D particle shape of dust particles. Meanwhile, our image processing program was used to extract the information of the 2D size, size distribution and shape of the particles from images. The chemical composition of the particles was analyzed by SEM coupled with EDX. Trace elements of the particles were determined quantitatively with XRF. In this investigation, airborne dust defused from ceramic tiles during home decoration were collected, and were characterized with several advanced devices to describe the particle size and its distribution, morphology and composition. Experimental results and discussion are also presented.

2. Experimental methods

2.1. Sample collection and preparation

Samples were collected in a common house being decorated where decorators were laying ceramic tiles without any protection. Dust originates from mechanical breakdown processes, such as cutting, grinding and drilling ceramic tiles, and is dispersed by air movement. This harmful working environment is common during the decoration of ordinary Chinese houses. A dust collector for PM10 (model HuaRui CCZ20) was placed at a height of approximately 5 ft in work areas where decorators breathe. Air passing through the filter cassettes was driven by battery-powered personal air sampling pumps at a flow rate of 2.5 L/min to simulate human respiration. The ceramic dust was collected by a filter