Environmental Research 161 (2018) 284–290

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Isolation and characterization of a respirable particle fraction from residential house-dust

Åsa Gustafsson[a,b,*], Annette M. Krais[a,c], András Gorzsás[b], Thomas Lundh[c], Per Gerde[a,d]

[a] Swetox, Karolinska Institutet, Unit of Toxicology Sciences, Forskargatan 20, SE-151 36 Södertälje, Sweden
[b] Department of Chemistry, Umeå University, Linnaeus väg 6, SE-901 87 Umeå, Sweden
[c] Division of Occupational and Environmental Medicine, Department of Laboratory Medicine, Lund University, SE-221 85 Lund, Sweden
[d] Institute of Environmental Medicine (IMM), Karolinska Institutet, Box 287, SE-17177 Stockholm, Sweden

ARTICLE INFO

Keywords:
Indoor air
House dust
Respirable
Inhalation
Health
Particle characterization

ABSTRACT

Indoor air pollution has caused increasing concern in recent years. As we spend most of our lives indoors, it is crucial to understand the health effects caused by indoor air pollution. Household dust serve as good proxy for accessing indoor air pollution, especially smaller dust particles that can pass into the lungs are of interest. In this study we present an efficient method for the isolation of dust particles in the respirable size range. The respirable fraction was recovered from vacuum cleaner bags, separated by stepwise sieving, followed by characterization for size, morphology, surface area, organic content and elemental composition. The respirable fraction was obtained in a yield of 0.6% with a specific surface area of 2.5 m^2/g and a Mass Median Aerodynamic Diameter of 3.73 ± 0.15 μm. Aluminum and zink were the dominating metals measured in the dust, whereas the major mineral components were found to be silicon dioxide and calcium carbonate. The fraction of organic matter in the dust was measured to be 69 ± 1%. The organic matrix contained bacterial and fungi and a presence of skin fragments. We present here an efficient and fast method for the isolation of dust particles in the respirable size range. That is of considerable value due to the need for large quantities of respirable particle fractions to conduct toxicological studies and risk assessment work.

1. Practical implications

More attention should be paid to exposure to fine dust particles. In order to perform risk assessment following inhalation of dust particles, it is important to select the relevant size range that is representative for inhalation exposure. Selection of size fraction may also affect the accuracy of assessing human exposure to indoor pollutants, such as semi volatile organic compounds that adsorb at surfaces such as the dust and the health impact thereof.

2. Introduction

The U.S. Environmental protection agency (US EPA) and U.S. Centers for disease control (CDC) have evaluated the quality of the indoor environment, ranking indoor air pollution as a high environmental risk (Butte and Heinzow, 2002). Over the last years the prevalence of common diseases such as cancer, diabetes, neurological disorders and infertility have increased. As we spend most of our lives indoors, there could be a correlation with pollutants from indoor air and household dust (Diamanti-Kandarakis et al., 2009; Meeker, 2012). Indoor environments are largely influenced by outdoor sources, but are also dependent on indoor activities such as heating, cooking, cleaning and not at least by the use of numerous consumer products and different types of building materials, including e.g: flame retardants and plasticizers (Butte and Heinzow, 2002; Morawska et al., 2013). The composition of dust particles depends largely on their sources (Abt et al., 2000). Household dust is a heterogeneous material consisting of inorganic metals and minerals, as well as organic contents such as hair, dead skin cells, pollen and a diversity of microorganisms (Betts, 2008; Lewis et al., 1999; Mølhavea et al., 2000; Owen and Ensor, 1992). House dust act as a repository for various compounds with origin from both indoor and outdoor environment (Butte and Heinzow, 2002). Dust is thus an important environmental matrix with respect to human exposure. Therefore a comprehensive characterization of the house dust composition is important to investigate in order to understand impacts from dust exposure on human health (Rager et al., 2016). Humans are constantly exposed to dust particles via multiple routes and the exposure pathway occur via ingestion, skin and by inhalation (Blanchard et al., 2014; Mercier et al., 2011; Weschlera and Nazaroff, 2008). The airways as a route of exposure to the particulate matrix from indoor

* Corresponding author at: Swetox, Karolinska Institutet, Unit of Toxicology Sciences, Forskargatan 20, SE-151 36 Södertälje, Sweden.
E-mail address: asa.gustafsson@swetox.se (&. Gustafsson).

http://dx.doi.org/10.1016/j.envres.2017.10.049
Received 3 September 2017; Received in revised form 27 October 2017; Accepted 28 October 2017
Available online 21 November 2017

environment is poorly explored. Our lungs are in contact with considerable amounts of dust every day, considering a daily inhalation volume of 10 000 L (Tsuda et al., 2013), and an average concentration of particulate matter ($PM_{2.5}$) ranging from 10.6 to 54 μg/m3 of air as measured by personal monitoring (Morawska et al., 2013). Health effects may arise not only from oxidative stress and inflammatory processes (Falcon-Rodriguez et al., 2016), but also due to dust particles acting as carrier vehicles for numerous semi volatile organic chemical compounds (Blanchard et al., 2014; Weschlera and Nazaroff, 2008). Airborne particles may interfere with the airways and will deposit in different regions of the airways, depending on their aerodynamic properties. The parameter most closely linked to airway deposition properties of particles is the aerodynamic diameter, which is the diameter of a unit density sphere, displaying the same deposition behavior as the studied particle. Generally, larger particles, with a diameter between 5 and 10 μm deposit primarily in the extrathoracic airways; particles between 1 and 5 μm diameters mostly deposit in the tracheobronchiol region; whereas particles with diameters below 1 μm commonly deposit in the alveolar region with considerable overlaps (Owen and Ensor, 1992; Oberdörster et al., 2005).

To fully understand the potential health effects of inhalational exposure to household dust, it is crucial to achieve a more complete characterization of the respirable dust fraction. The objective of this study was to develop a method for fractionating dust in the respirable size range and to perform a physical and chemical characterization of the respirable size fraction of house dust.

In this study we present a fast method in which the isolation of dust particles in the respirable size range is achieved with high yield. Such a method is crucial when evaluating the possible health hazards of the respirable sized particles in house dust and it may be a valuable tool for improving risk assessments of indoor environments in the future.

3. Material and methods

3.1. Collection of house dust

The house dust was acquired through active sampling of the home environments by the normal use of vacuum cleaning, exercised by household residents. There were no prescribed instructions to the vacuum cleaner users of the residences who volunteered. Vacuum cleaner bags were collected from households in the cities of Stockholm and Södertälje in Sweden during the autumn of 2015. The vacuum cleaner bags where stored in black plastic bags in the dark at the temperature of 21 °C and a relative humidity of 20–30% until the sieving process started. In total thirty-two vacuum cleaner bags yielded a total mass of 5925 g household dust.

3.2. Sieving of house dust

In order to separate the respirable size fraction, the house dust was processed in two steps. A schematic description is presented in Fig. 1. In step 1, the vacuum cleaner bag was cut up with a scissor and the dust was removed with an industrial vacuum cleaner (Dustcontrol 2500, Norsborg, Sweden) at a flow of approximately 30 l per s. Consecutively, the house dust was drawn through a staple of six wood boxes, each containing a stainless steel mesh at the bottom. The stainless mesh (plane weave) -dimensions were: 2000 μm, 1000 μm, 390 μm (AISI 316, Stockholms Plåt och Gummiperforering SPG AB, Västerhaninge, Sweden) followed by meshes of 190 μm, 75 μm and 25 μm, all plain weave (SS 2343, Silduksfabriken in Jönköping AB, Tenhult, Sweden). In order to obtain a better yield the house dust was gently brushed back and forth on each mesh using a fine hair paintbrush to de-agglomerate the dust. Following the last mesh, via a plastic funnel, the dust entered an ash cyclone (Virvelvind, Pellvac AB, Strömsnäsbruk, Sweden) connected with a polypropylene tube with a 45 mm diameter (Krauta, Sweden). After the cyclone the dust continued into a HEPA filter container (Clas Ohlson, Sweden) in which the fine size fraction was collected in a filter bag (Swirl M50, Melitta Nordic AB, Helsingborg, Sweden). The cyclone and filter container were connected with a polypropylene tube of 45 mm diameter (Krauta, Sweden). Each house dust fraction was transferred to pre weighed glass bottles and stored in the dark. The dust collected in the vacuum cleaner bag was removed by extraction using a vacuum pump (Becker, Germany) on to a nylon membrane filter (0.45 μm, NY4514225, Sterlitech, WA, USA) placed in an aluminum filter holder. From that filter the dust was gently removed with a brush and collected in a glass vial.

A schematic description is presented in Fig. 1. Step 2. A small amount of house dust from step 1 was dispersed on a twilled weave mesh 25 μm (Silduksfabriken in Jönköping AB, Tenhult, Sweden) and drawn on to a subsequent 6 μm nylon mesh (Nitex 03 6/5, Sefar AG, Heiden, Switzerland) using an industrial vacuum cleaner described in step one. In order to obtain a larger yield the house dust was gently brushed back and forth for further de-agglomeration. Dust collected on the nylon mesh was removed by extraction with a vacuum pump (Becker, Germany) on to a nylon membrane filter (0.25 μm, NY4514225, Sterlitech, WA, USA) placed in an aluminum filter holder. From the final filter the dust was gently removed by brushing into a glass vial. Before the physical and compositional characterization of the dust it was homogenized by rotation of the glass vial overnight. For all analyses only one replicate was used, except for determination of dry matter- and ignition residue where three replicates were used.

3.3. Physical characterization of the house dust

3.3.1. Size distribution of the house dust

The size distribution of the house dust was determined using a cascade impactor (Marple Andersen, EnVirREC AB, Sweden). The house dust was aerosolized with the PreciseInhale system (Inhalation Sciences Sweden AB, Stockholm, Sweden) and the aerodynamic size distribution of the dust was determined with the cascade impactor at a flow rate of 2 l/min as previously described (Selg et al., 2010, 2013). The mass of dust deposited on the nine stages in the impactor was used to calculate the mass median aerodynamic diameter (MMAD) and the geometric standard deviation (GSD).

3.4. Scanning electron microscopy (SEM)

The house dust particle size, morphology and tendency to agglomerate was characterized by field emission scanning electron microscopy (SEM; Carl Zeiss Merlin) using a backscatter electron detector at accelerating voltage of _ kV and probe current of _ pA (the values can be seen on the data bar of the taken images).

3.5. Surface area

The specific surface area of the house dust was determined with the Brunauer-Emmett-Teller (BET) method by employing a Micrometrics ASAP2020 volumetric adsorption analyzer. The sample was treated under vacuum conditions at a temperature of 60 °C for 10 h. Nitrogen adsorption-desorption isotherms were recorded at liquid-nitrogen temperature (77 K) for the dust sample. The specific surface areas of the adsorbent dusts were then calculated, according to the BET method, from the recorded data in the range of $P/P0 = 0.05–0.15$.

3.6. Composition of the house dust

3.6.1. Determination of dry matter- and ignition residue

Three replicates of house dust samples were analyzed for dry matter residue and organic matter content by ignition residue, conducted according to standardized procedures in SS 028113 (SIS, Swedish Standards Institute, 1981).