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Dust exposure in workers from grain storage facilities in Costa Rica

María G. Rodríguez-Zamora[a,*], Lourdes Medina-Escobar[a], Glend Mora[a], Jan-Paul Zock[b,c,d], Berna van Wendel de Joode[e], Ana M. Mora[e,f]

[a] Escuela de Ingeniería en Seguridad Laboral e Higiene Ambiental (EISLHA), Instituto Tecnológico de Costa Rica, Cartago, Costa Rica
[b] ISGlobal, Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain
[c] University Pompeu Fabra (UPF), Barcelona, Spain
[d] Biomedical Research Center Network for Epidemiology and Public Health (CIBERESP), Madrid, Spain
[e] Central American Institute for Studies on Toxic Substances (IRET), Universidad Nacional, Heredia, Costa Rica
[f] Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California, Berkeley, CA, United States

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ABSTRACT

Background: About 12 million workers are involved in the production of basic grains in Central America. However, few studies in the region have examined the occupational factors associated with inhalable dust exposure.
Objectives: (i) To assess the exposure to inhalable dust in workers from rice, maize, and wheat storage facilities in Costa Rica; (ii) to examine the occupational factors associated with this exposure; and (iii) to measure concentrations of respirable and thoracic particles in different areas of the storage facilities.
Methods: We measured inhalable (<100 μm) dust concentrations in 176 personal samples collected from 136 workers of eight grain storage facilities in Costa Rica. We also measured respirable (<4 μm) and thoracic (<10 μm) dust particles in several areas of the storage facilities.
Results: Geometric mean (GM) and geometric standard deviation (GSD) inhalable dust concentrations were 2.0 mg/m^3 and 7.8 (range = < 0.2–275.4 mg/m^3). Personal inhalable dust concentrations were associated with job category [GM for category/GM for administrative staff and other workers (95% CI) = 4.4 (2.6, 7.2) for packing; 20.4 (12.3, 34.7) for dehulling; 109.6 (50.1, 234.4) for unloading in flat bed sheds; 24.0 (14.5, 39.8) for unloading in pits; and 31.6 (18.6, 52.5) for drying], and cleaning task [15.8 (95% CI: 10.0, 26.3) in workers who cleaned in addition to their regular tasks]. Higher area concentrations of thoracic dust particles were found in wheat (GM and GSD = 4.3 mg/m^3 and 4.5) and maize (3.0 mg/m^3 and 3.9) storage facilities, and in grain drying (2.3 mg/m^3 and 3.1) and unloading (1.5 mg/m^3 and 4.8) areas.
Conclusions: Operators of grain storage facilities showed elevated inhalable dust concentrations, mostly above international exposure limits. Better engineering and administrative controls are needed.

1. Introduction

Grain dust may contain some inorganic soil particles, plant fragments, rodent droppings, insects, parts of mites, pesticide residues, fungi (e.g., *Aspergillus* and *Penicillium*) (Dacarro et al., 2005; Krysinska-Traczyk et al., 2001), bacteria (Dacarro et al., 2005; Swan and Crook, 1998), and/or secondary metabolites of micro-organisms such as endotoxins (Halstensen et al., 2013; Simpson et al., 1999; Todd and Buchan, 2002), β-(1 → 3)-glucans (Straumfors et al., 2015), and mycotoxins (e.g., aflatoxins and deoxynivalenol) (Desai and Ghosh, 2003; Krysinska-Traczyk et al., 2001; Yoshinari et al., 2014). Occupational exposure to grain dust has been associated with respiratory and allergic problems, such as hypersensitivity pneumonitis (Skórska et al., 1998), asthma (Lachowsky and Lopez, 2001), rhinitis (Ghosh et al., 2014) and eczema (Laraqui et al., 2003). However, it is possible that these health effects could be caused by contaminants present in dust and not by the grain components themselves (Douwes et al., 2003; Skórska et al., 1998; Von Essen, 1997).

Few studies have examined the occupational factors associated with inhalable dust exposure in grain industry workers, and most of them have been conducted in European and North American countries (Halstensen et al., 2013, 2007; Simpson et al., 1999; Smid et al.,

* Corresponding author at: Escuela de Ingeniería en Seguridad Laboral e Higiene Ambiental (EISLHA), Instituto Tecnológico de Costa Rica (ITCR), PO Box 159-7050 Cartago, Costa Rica.
E-mail address: garodriguez@itcr.ac.cr (M.G. Rodríguez-Zamora).

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1992; Straumfors et al., 2015). A study of 131 workers from animal feed manufacturing companies in The Netherlands found higher dust exposure in unloaders compared to other workers such as production managers, transport workers, and packers (Smid et al., 1992). Another study of 73 workers from grain elevators and animal feed mills in Norway showed that the cleaning and process controlling tasks were associated with higher dust exposure levels compared to other tasks including inspection, laboratory work, office work, packing, and truck driving (Straumfors et al., 2015). Moreover, a study of grain handling industries in Great Britain (n = 31 samples) observed that workers who cleaned the silos in docks and operated the flour mills had higher inhalable dust concentrations (Simpson et al., 1999). The lowest concentrations were found in those who worked in maintenance and laboratories' quality control. Finally, a study that compared personal exposure levels to inhalable dust in workers from 85 Norwegian farms (n = 104 samples) found higher dust exposures among those who worked in storage areas compared to those who worked in threshing areas (Halstensen et al., 2007). None of these studies found differences in inhalable dust exposures by grain type (Halstensen et al., 2007), storage technology (Halstensen et al., 2007), or season (Halstensen et al., 2013; Straumfors et al., 2015).

A large number of workers handle basic grains in Latin American countries (Baumeister, 2010; Cruz Delgado et al., 2012; Wong and Sánchez, 2011). For instance, only in Central America, there are about 12 million people involved in the production of these grains (Baumeister, 2010). Costa Rica has one of the lowest basic grain production rates across the region (Baumeister, 2010). Nevertheless, in this country, the agricultural sector is the second largest employment sector (SEPSA, 2015) and the production of basic grains represents approximately 8% of all agricultural activities (INEC, 2015). Costa Rica also depends heavily on grain imports, especially for rice, yellow maize, and wheat (SEPSA, 2015); these imported products are transported to the same facilities where the grains harvested in the national territory are stored. To date, few studies in Latin American countries have examined inhalable dust exposure in workers from grain storage facilities (Ardusso et al., 2000; Corzo and Naveda, 1998; González Vara et al., 1992; Ochoa and Jacas, 1999; Rojas Viteri and García Prieto, 2015), but none has been conducted in Costa Rica.

The objectives of this study were: (i) to assess the exposure to inhalable dust in workers from rice, maize, and wheat storage facilities in Costa Rica; (ii) to examine the occupational factors associated with this exposure; and (iii) to measure concentrations of respirable and thoracic particles in different areas of the storage facilities.

2. Materials and methods

2.1. Study population

We identified 22 grain storage facilities in Costa Rica (13 of rice, seven of maize, and two of wheat), using information from institutions involved in grain import, regulation, and marketing [i.e., Ministry of Agriculture and Livestock, Costa Rican Chamber of Industry, Production National Board, National Rice Corporation (CONARROZ), and the National Insurance Institute]. We then invited these facilities to participate in this study and eight (36%) (four rice, three maize, and one wheat) accepted. Once permission from the storage facilities was obtained, workers were invited to participate in the study. Eligible participants were male (given that all operators were men), ≥18 years old, and working the day shift when the storage facilities were visited by the study staff. A total of 138 workers were invited to participate and 136 (99%) accepted.

All study activities and instruments were approved by the Ethical Committee of the Universidad Nacional and written informed consent was obtained from all participants.

2.2. Interviews

We administered a structured questionnaire to all study participants to collect information on socio-demographic and occupational characteristics, such as age, education, work history, time in the company, current job category [i.e., operators (unloading in pits, unloading in flat bed sheds, drying, dehulling, and packing) or administrative staff and others (purchasing agents, laboratory technicians, warehouse workers, forklift drivers, plant managers, mechanics, security officers, and weighers)], time in current job category, work shift, and cleaning task (defined as cleaning the storage facility during at least half of the workday).

2.3. Personal inhalable dust concentrations

2.3.1. Sample collection

Inhalable dust (particles with an aerodynamic mass median diameter <100 μm) samples were collected using the method "*MDHS 14/4: General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols*" (HSE, 2014). We used sampling heads from the Institute of Occupational Medicine (IOM) with polyvinyl chloride filters (SKC Inc, 25 mm of diameter, 5.0 μm of pore size), cellulose support pads, and personal sampling pumps (Zefon, model ESCORT ELF) calibrated at a flow rate of 2.0 L/min.

We measured inhalable dust concentrations in 176 samples collected from 136 workers. Thirty-four workers were sampled twice and three were sampled three times (median = 253 days between measurements, range = 2–364). All workers were sampled during ≥70% of their workdays (median = 7.4 h of sampling, range = 5.6–10.1). Workers who did cleaning work were sampled during days in which they cleaned and completed their typical job tasks (i.e., those associated with their job category). All samples were collected between October and November 2014 and between May and December 2015.

2.3.2. Sample analysis

Dust samples were analyzed by gravimetry in the Laboratorio de Higiene Analítica at the Instituto Tecnológico de Costa Rica (ITCR). Samples and field blanks were weighed in duplicate, before and after sampling, to ensure that the average relative deviation was <3%. Mass data were divided by the samples' air volume and used to estimate the time-weighted average inhalable dust concentrations. The mass limit of detection (LOD) was 0.2 mg, and was defined as the average mass of the field blanks (n = 19) plus three times the standard deviation (SD). Therefore, the concentration LOD was between 0.2–0.3 mg/m^3 (calculated from the 0.2 mg per filter LOD and the sample volume range of 0.67–1.21 m^3). The robust regression on order statistics (ROS) was used to impute the concentrations <LOD (19%) (Helsel, 2011).

2.4. Area sampling per particle size

Area dust concentrations were measured with a dust monitor (TSI, Dust Trak II-Model 8532) with impactors of 1.0, 2.5, 4.0, and 10.0 μm. Forty-four measurements were collected for each particle size fraction (each measurement took 20 min with an aerosol flow of 2 L/min). Measurements were performed during the same days that personal inhalable dust samples were collected and in the same areas where the operators were working (i.e., packing, unloading, drying, and dehulling areas). Dust monitors were placed in front of the main dust emission sources, at workers' respiratory-zone height, and as close to the workers as possible. Administrative