THE EFFECTS OF CLEANING ON CONCENTRATIONS OF SURFACE DUST AND AIRBORNE PARTICLES

E Pesonen-Leinonen*

Dept. of Agricultural Engineering and Household Technology, University of Helsinki, Finland

ABSTRACT
Dust decreases the aesthetic properties of surfaces and can cause adverse health effects. The purpose of this study was to determine dust build-up on surfaces during one week in buildings, and the influence of cleaning on airborne dust concentrations. Surface dust sampling was performed by the foil sampling method and the fluctuation of the number of airborne particles was measured using an optical particle counter. Occupant satisfaction with cleaning was investigated using a questionnaire. In each building the dust build-up on surfaces was lowest on the furniture surfaces. The greatest variation in surface dust concentration between the buildings was on the floors, with the lowest concentrations on well-polished floors. Cleaning activities increased the number of airborne particles with size > 1 µm. The surface dust concentration before and after cleaning, and occupant satisfaction with cleaning, provide practical information for developing cleaning programmes to fulfil the demand for cleanliness in buildings.

INDEX TERMS
Dust, Office, Cleaning, Indoor environment, Quality

INTRODUCTION

The indoor environment is cleaned to maintain an acceptable level of perceived cleanliness and to prevent adverse effects caused by dust and other soil on surfaces. Surface dust, which can be a source of airborne dust indoors, contains chemically and biologically active components such as microbes, endotoxins, allergens and irritants (Gyntelberg *et al*., 1994; Mølhave *et al*., 2000). Dust on surfaces has been found to have adverse health effects. Increased amounts of settled dust and the areas of surfaces are found to correlate with the prevalence of symptoms (Skov *et al*. 1990). The concentration of gram-negative bacteria and macromolecular components in floor dust was correlated with the prevalence of sick building syndrome symptoms among office workers (Gyntelberg *et al*. 1994). Further, significant effects on the eyes after exposure to particles resuspended from floor dust (Hauschildt *et al*. 1996) and more nasal obstruction among employees in schools with more settled dust (Wålinder *et al*. 1999) has been reported.

The influence of cleaning on surface and airborne dust concentrations has been demonstrated in some studies. Studied factors have been cleaning frequency and intensity. It was found that a decrease in cleaning frequency increased airborne particle concentrations in residence environments (Raunemaa *et al*., 1989), a low frequency of floor cleaning increased facial complaints in video screen workers (Sundell *et a*l.,1994) and a lower frequency of cleaning caused more nasal symptoms in school environments (Wålinder *et al*., 1999; Smedje and Norback, 2001). Furthermore, it has been reported that a rigorous deep cleaning could reduce airborne particle mass, total volatile organic compounds and culturable bacteria and fungi

* Contact author email: eija.pesonen-leinonen@helsinki.fi

(Franke *et al*. 1997), and that intensive cleaning compared to superficial cleaning could reduce airborne dust levels and complaints related to mucosal symptoms in offices (Skulberg *et al*. 1999). Previous investigations have shown that the cleaning frequency affects surface dust concentration and the amount of resuspended dust, but these studies do not consider the question of an appropriate cleaning interval.

The aim of this study was to determine how much dust is accumulated on surfaces during a week in normal office environments, how the cleaning activities affect indoor dust concentration, and what is occupant opinion of the current cleaning programme. The study is a part of the project "Cleaning and indoor environment quality".

METHODS

Six buildings were selected to represent typical, multi-floor office buildings near the centre of a city. The buildings had mechanical ventilation systems, no reported indoor air quality problems or complaints, and weekly cleaning in rooms. The cleaning was performed during the study as normally: horizontal easily accessible surfaces and floors were cleaned once a week, expect for the floors of one building which were cleaned twice a week. Cleaning methods were commonly moist, because dust was the dominant contaminant on surfaces.

Surface dust sampling was performed by the adhesive foil sampling method (Schneider *et al*., 1994, 1996). The dust contamination in the foil was quantified by measuring with a laser light extinction meter, a BM-Dustdetector (BM Environmental Engineering vof). The sampling was performed on two furniture surfaces and a floor surface before and after cleaning. The samples were taken on one day of the week during two weeks. Approximately 2300 samples were taken from the surfaces of office rooms. On average 40 rooms per building were selected by a systematic sampling method.

The influence of cleaning activities on the concentration of airborne particles was investigated using an optical particle counter (OPC, CI-500; Climet Instruments Co.). OPC counted particles in 6 size channels (greater than 0.3, 0.5, 1, 5, 10 and 25 μm) in a 2.83 L min^{-1} sample flow. Particle number was monitored in two buildings: in one building during the cleaning (20 min before and 30 min after cleaning) and in another building throughout the working day. Particle number was measured at the centre of the room at a height of 1.1 m.

The satisfaction with cleaning was examined using questionnaires, which were sent to occupants before the dust particle measurements. The occupants were asked to evaluate the quality of cleaning and to rate their satisfaction on a 5-point scale ranging from 'highly satisfied' to 'not satisfied'.

RESULTS

As shown in Figure 1, in each building the dust build-up on surfaces was the lowest on furniture surfaces compared to the floor surfaces. The dust amount varied most between the floors of buildings. The lowest dust amount was found on the well-polished floor coverings. Cleaning removed dust and dirt by about 21 – 42 % depending on the surface and the amount removed appeared to depend on surface quality.

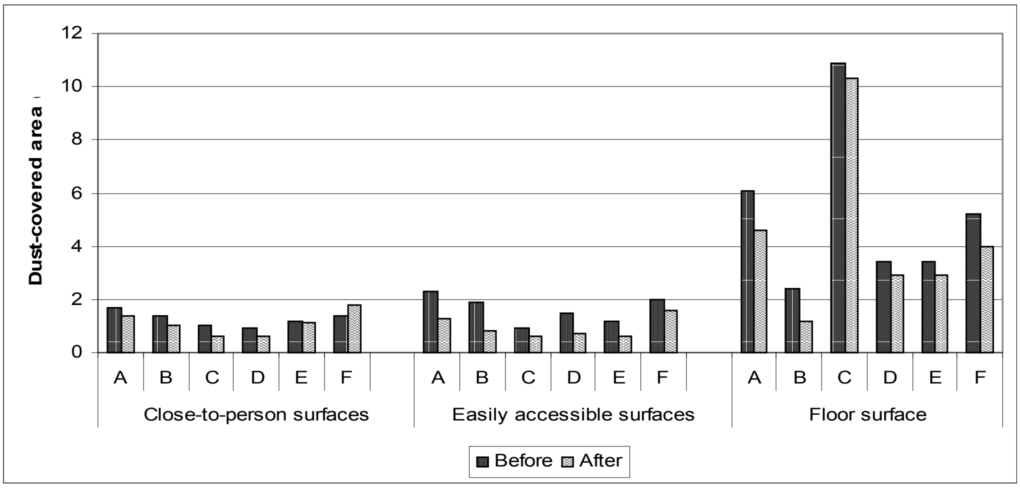

Figure 1. Settled dust on different surfaces before cleaning (after a 1-week dust build-up) and after cleaning in the buildings A, B, C, D, E, and F. The amounts of settled dust are expressed as the area of dust as a percentage of total surface area.

As shown in Figure 2, the cleaning activity increased the number of airborne particles with size > 1 µm (the uppermost line) for a short time. This change in particle concentrations was demonstrated in almost all the study rooms. Activities were found to increase the airborne particle concentrations even more than cleaning during a working day.

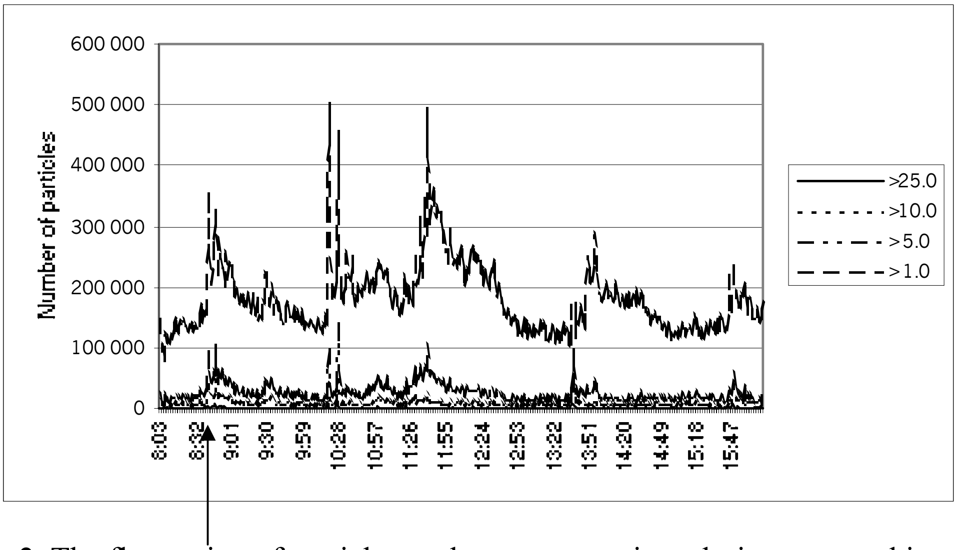

Figure 2. The fluctuation of particle number concentrations during one working day and the influence of cleaning on airborne particle number concentrations. The room was cleaned between 8:40 and 8:44 (arrow).

Figure 3 presents occupant satisfaction with cleaning in the buildings A, B, C, D, E, and F. The satisfaction is expressed as the sum of 'highly satisfied' and 'satisfied' occupants as a percentage of the total number of respondants. The response rate was on average 50%.

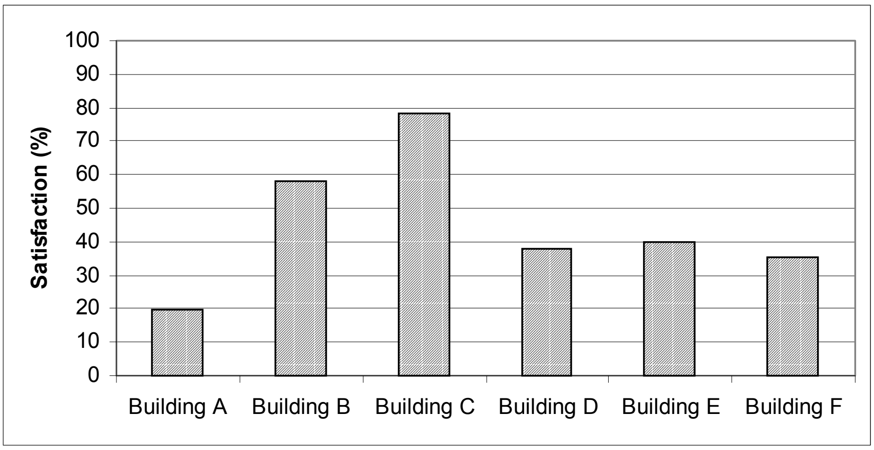

Figure 3. Occupant satisfaction with cleaning in the buildings A, B, C, D, E, and F expressed as the combined percentage of highly satisfied and satisfied occupants.

DISCUSSION

The results indicate that the amount of accumulated dust on surfaces is related to the type and quality of surface, and that cleaning influences the number of airborne dust particles.

Each building had its own surface dust concentration profile. The amount of settled dust on the furniture surfaces was at a rather similar level in the different buildings. The lowest dust level after cleaning was achieved on the easily accessible surfaces, which is congruent with the results of one study concerning the impact of improved cleaning methods (Kildesø *et al.*, 1998). An interesting exception was building F, in which the dust concentration on close-to-person surfaces was higher after cleaning than before cleaning. An explanation for this might be that the desks were filled with files, and therefore the area for cleaning was small. Occupant activities might reposition dust from desks onto files and vice versa.

The data of airborne particle fluctuation provides qualitative information. Cleaning appears not to be the only activity causing an increase of airborne particle (< 1 μm) concentration. The results agree with the findings of Thatcher and Layton (1995) who reported that the size of resuspended particles is 1-25 μm. Luoma and Batterman (2001) reported that 24-55 % of the variation in the concentration of 1- 25 μm particles is explained by occupant activities. Thus, the effect of cleaning activities on concentrations of airborne dust merits additional study.

Comparing surface dust concentrations on floors, the lowest amount of dust was on the well-polished floors in building B. Surprisingly, the cleaning was rather inefficient on floors. Further research is needed to investigate the efficiency of cleaning methods in relation to the properties of surfaces in indoor environments.

The occupants most satisfied with cleaning were those in building C, although in this building the amount of dust on floors was at the highest level. The amount of surface dust on the furniture appears to be an important factor when occupants evaluate their satisfaction with cleaning. The low response rate in this study might decrease the reliability of the satisfaction estimates. Further studies could investigate the perception of surface dust in relation to the amount of dust on surfaces.

CONCLUSION AND IMPLICATIONS

The cleaning activities affected both surface dust concentration and airborne dust concentration. Every building had its own profile for surface dust and for satisfaction with cleaning. The results provided practical information for cleaning contractors to develop cleaning programmes fulfilling the demand for cleanliness of the indoor environment, and to develop cleaning methods to remove dust efficiently from surfaces. Further research is needed to investigate the efficiency of cleaning methods, and the relations between dust particle concentrations, satisfaction with cleaning, health effects and productivity.

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