THE EFFECT OF DUCT CLEANING ON PERCEIVED AIR QUALITY IN TWO OFFICE BUILDINGS

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ABSTRACT

The aim of this experiment was to study the effect of air duct cleaning on the indoor air quality. Three buildings in the Helsinki metropolitan area were selected for the study. In two of the test buildings the ducts were cleaned using three different cleaning methods. The third building serves as a control where no cleaning was done. The air handling systems in the test buildings had operated 26 and 30 years without cleaning. The air quality in the buildings was evaluated by using a trained sensory panel, and tested by the occupants in all these buildings by repeating self-administered questionnaires before and after the cleaning. A trained sensory panel was used to evaluate perceived air quality. The effect of cleaning on the amount of dust in duct system was measured with an optical method.

The amount of dust decreased significantly in all the cleaning methods. Significant differences in the cleaning results between the three cleaning methods were observed. The cleaning of supply air ducts had an effect on indoor air quality perceived by the panel. The panel perceived the air quality worse on the decipol scale after the cleaning than before it. On the other hand, the occupants perceived the indoor air quality as more acceptable after duct cleaning than before it. The improvement was statistically significant in the building with a larger number of occupants. The occupants in both buildings also complained less of dusty surfaces after the cleaning than before.

INTRODUCTION

Air handling systems may be contaminated by pollutants originating from the construction process, or from dust and dirt accumulating in the system during its operation. A contaminated supply air system may have an adverse effect on indoor air quality. Recent laboratory measurements have shown that both new and old components of the air handling system are sources of sensory pollution of the air [2]. Dust and other pollutants may accumulate in the duct systems during operation. Dirty air handling systems may turn out a serious health hazard.

The results from the studies dealing with duct cleaning have been contradictory. In some cases no effect on air quality have been seen. Duct cleaning methods have not been compared before. In most of the previous studies the results of the cleaning have not been well recorded. In our study we used the three methods for cleaning and measured the cleaning result. The air quality was evaluated both by occupants and with a trained panel.

SUBJECTS AND METHODS

Methods

Three office buildings in the Helsinki metropolitan area were selected for the study with the cleaning company ISS Finland. In two case buildings the air handling systems (air handling units and ducts) were cleaned using three different cleaning methods. The actual cleaning was done be professional cleaners and supervised by the research group. The methods applied in duct cleaning were: brushing, cleaning with pressurized air, and manual method. The third building serves as control where no cleaning was done, but where the indoor air quality and symptoms of the occupants were recorded at the same time as in the case buildings. The air quality in the buildings was evaluated one week before the cleaning, twice (1-2 weeks and 7-8 weeks) after the cleaning by the occupants of the buildings, and once (1-2 weeks) with a sensory panel. Indoor air quality and other factors of indoor climate were evaluated by occupants in all the three buildings with repeated self-administered questionnaires before and after cleaning. Prevalence of typical sick building symptoms was recorded with the same questionnaire. A trained sensory panel was used to evaluate perceived air quality.

Buildings

The buildings selected for the investigation were small office buildings in Helsinki. The air handling systems in case buildings had been operated 26 and 30 years without cleaning. The air ducts of the buildings were cleaned in January 1998 [4]. Building (A) was the head office of a manufacturing company located in a suburban area of Helsinki. The building was completed 30 years ago. Smoking was not allowed in the building. During the experiment the average room temperature was 21–23 °C, and relatively humidity 36–43%. Three air handling units served the building (office spaces, auditorium, and kitchen). The air handling systems for the offices had medium efficiency filters (EU6), a heating coil, and a centrifugal fan. Return air was not recirculated back to the building but exhausted. Until the end of 1980's a humidifier was used but not any more due to energy conservation policy. A supply fan was replaced in 1994. Outdoor airflow (ventilation rate) was 32 dm^3/s/person. All air handling units and ducts in the building were cleaned.

Building (B) was located in the downtown area of the city of Helsinki. The building served as a school until it was renovated in 1972. Smoking was allowed in some rooms of the building (31% of workers were smokers). During the experiment the average room temperature was 21–22 °C, and relatively humidity 40–44%. Six air handling units served the building. Average outdoor air flow rate was 42 dm^3/s/person. The air handling system for the library (AHU2) consisted of a coarse pre-filter, a fine filter, a humidifier, and an axial fan. The other air handling systems (AHU1 and AHU3) that were included in the study did not have humidifiers. The air handling system of the auditorium had a filter (EU3), an axial fan, and rectangular duct work of 20 m.

Buildings (A) and (B) had an air distribution system where the conditioned air was supplied into corridor and exhausted through the registers in the rooms. The conditioned supply air was led from corridor to the offices and other rooms via a register in the wall between the corridor and rooms. Most of the ducts were original, and they did not have residual oil on the duct surfaces from the manufacturing process, most of the ducts were rectangular duct. Only minor

changes had been made into the duct system after the buildings were completed. The running time of the ventilation systems was from 7 am to 6 pm in working days.

The reference building (C) was the head office of a cafetering company in a suburban area of Helsinki.

Study population

Building (A) had 100 occupants of which 60.7% were women. The average age of the workers was 42.9 years. They had worked in the same building on average 10.2 years. 32% of the workers were smokers. All occupants were included in the study. The response rate was low. Only 28, 23, and 19 responded to the first (before cleaning), second and third (after cleaning) questionnaire.

Building (B) had 120 occupants of which 80.3% were women. The average age of the workers was 44.9 years. They had worked in the same building on average 10.5 years. (31% of the workers were smokers). All occupants were included into the study. Response rate to the questionnaire was 49.4%.

The total number of occupants in the reference building (C) was 110 of which 78.9% were women. The average age of the workers was 42.9 years, and they had worked in the same building on average 10.2 years. 63.2% of the workers were smokers. Occupants of the reference and case buildings performed similar type of office work.

Sensory panel

The quality of indoor air, and air in various parts of the air handling system was evaluated with a trained sensory panel, within eleven members [3]. Sensory evaluations were made a week before and two weeks after the duct cleaning in the building (B). The aim was to evaluate the effect of duct cleaning on air quality. Previous studies have shown that a used filter can be a dominant source of sensory pollution in an air handling system [6]. To eliminate effect of dirty filter on air quality the air filters were changed a week before the first measurement and again a day before the second one. The air samples for sensory evaluation were taken from outdoor air, indoor air, and supply air.

Questionnaire study

Indoor air quality perceived by occupants and prevalence of typical sick building symptoms were recorded before and after duct cleaning with self-administered MM-questionnaires [1]. The survey was repeated three times. The first data set was collected 1–2 weeks before air duct cleaning. The following data sets were collected 1–2 and 7–8 weeks after duct cleaning. At the same time a similar questionnaire study was performed in a reference building. The occupants evaluated their working environment and symptoms using scale 1–3. Number one corresponded response or symptom experienced weekly, number two corresponded to response or symptom experienced sometimes, and number three to no response or symptom. Acceptability of the indoor air quality was evaluated with the scale 1–10. Numbers 1–5 indicated clearly acceptable air quality and 6–10 clearly unacceptable air quality. The result of

the questionnaire was analyzed by mathematical statistics program [7]. The statistical significance of the results was tested with t-test.

RESULTS

Dust in air handling system

Ducts were cleaned with three cleaning methods, which are described [4]. The amount of accumulated dust in the duct system was determined with an optical method and visually. The amount of dust on the duct surface had decreased significantly with all cleaning methods. Residual amount of the dust on the bottom surface of rectangular ducts after cleaning was 38–65% from the amount before the cleaning [5].

Sensory panel

During the first measurements, outdoor air temperature was approximately 0 °C, and on the second –16 °C. Indoor air temperature was 21–22 °C and relative humidity 40–44%. The humidity of the air in the air handling system followed the outdoor humidity. The average values of the perceived air quality evaluated by the panel in various locations of the air handling system are presented in Figures 1 and 2 before and after the cleaning. The perceived outdoor air quality was approximately 1.2 decipol in both days when the measurements were performed. Surprisingly, the cleaning deteriorate the perceived air quality in all sampling locations of the system (Figure 1 and 2).

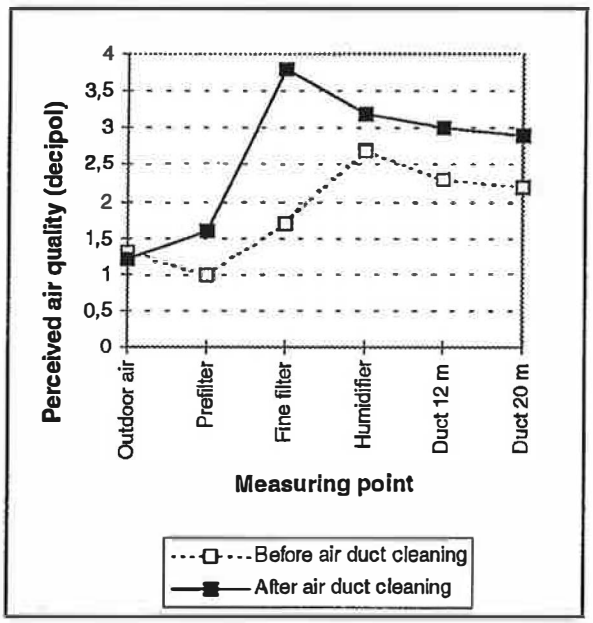

Figure 1. Perceived air quality after by each component in the air handling system AHU2 in the building (B) before and after cleaning of the air handling system (cleaned by compressed air washing)

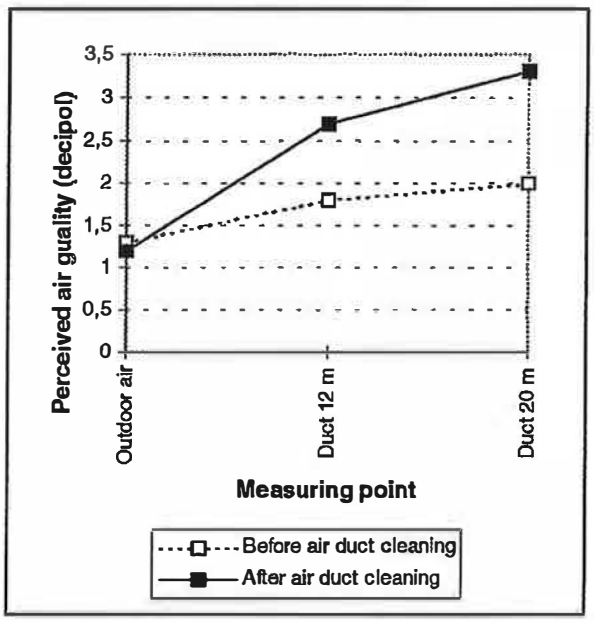

Figure 2. Perceived air quality in the duct AHU3 in the building (B) before and after cleaning of the air handling system (cleaned by hand wiping)

It is interesting how the greatest change in perceived air was measured when the air was led through the filters even though they were just replaced, and how the air quality improved in

the duct system. Perceived air quality in a duct that was cleaned by hand wiping (AHU2) increased from 0.7 to 2.1 decipol although no detergents were used. Similar results were also achieved in the air handling systems AHU1.

Questionnaire study

The results before, and 7–8 weeks after the duct cleaning are presented in Table 1. The results show no differences in most indoor air parameters except in acceptability of indoor air quality in both case buildings. A statistically significant number of occupants perceived the indoor air quality better after the duct cleaning in the building (B). The acceptability of the air quality in the reference building decreased a little during the same period but not significantly. The occupants of case buildings complained also less of dusty surfaces after the cleaning than before, but the difference was not statistically significant. No changes were seen in the prevalence of sick building symptoms before and after duct cleaning in case or reference buildings.

Table 1. The effect of cleaning on the working environment in the office buildings rated on a 1 to 3 scale (see text for details)

Working environment	**Building A**		**Building B**		**Reference building**	
	Before cleaning (mean) n=28	After cleaning (mean) n=19	Before cleaning (mean) n=66	After cleaning (mean) n=50	Before (mean) n=21	After (mean) n=11
Acceptability of air quality (scale 1–10)	4.07	3.78	4.10	**3.18*)**	2.26	2.44
High room temp.	1.75	1.89	2.43	2.34	2.50	2.33
Varying room temp.	2.11	2.11	1.90	2.16	2.18	2.13
Low room temp.	2.29	2.37	1.74	2.26	2.28	2.11
Draught	2.04	2.47	1.58	2.16	2.42	2.44
Stuffy air	1.96	1.89	1.84	1.86	2.39	2.11
Dry air	2.08	1.89	1.80	1.94	2.17	1.56
Unpleasant odor	2.43	2.26	2.30	2.24	2.44	2.56
Static electricity	2.46	2.47	2.54	2.44	2.63	2.33
ETS	2.89	2.89	2.41	2.48	2.74	2.89
Noise	2.04	1.84	2.26	2.18	2.32	2.44
Light	2.25	2.63	2.58	2.48	2.63	2.56
Dusty indoor air	1.86	1.89	1.57	1.76	2.05	1.67
Dusty surfaces	1.79	2.11	1.51	1.60	1.74	1.56

*) Significant ($p < 0.0001$)

DISCUSSION

The results of the study showed a clear improvement of air quality due to cleaning of the air handling systems. The difference was significant in building (B) with higher number of respondents to the questionnaire. The result is contradictory to the results from of the trained sensory panel, which perceived the air quality less well after cleaning. This may be due to different time intervals between the cleaning and the measurement. The panel evaluated the air quality two weeks after the cleaning, and the questionnaire was made 7–8 weeks after the

cleaning. The cleaning may have changed the interior surface of ducts so that it emitted immediately after the cleaning more odorous substances than before the cleaning, and the strength of the new source declined rapidly. Another possible explanation for the contradictory results may be in the fact that the cleaning of ducts was done during the working days, and the occupants of the building saw the work, which may have influenced on their response. However, the results of the questionnaire 1–2 weeks after the cleaning did not show an effect on perceived air quality by occupants.

An interesting observation was how the new filters deteriorated the air quality, and how the perceived quality of supply air actually improved in uncleaned and cleaned duct system. It was surprising that the cleaning of duct by hand wiping also deteriorated supply air quality perceived by the panel. An explanation to this may be that wiping exposed fresh surface of residual dust in the duct, which had higher emission rate than the original surface. The changes in air humidity of the supply due to change in outdoor air temperature may have had an effect on the results, too. The response rates in the study were low and the number of respondents decreased after each questionnaire, which may have biased the results.

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REFERENCES

1. Andersson, K, Fagerlund, I, Stridh, G, Larsson, B. 1993. The MM-Questionnaires: A tool when solving indoor climate problems. Örebro Medicial Center Hospital. Sweden. 16 s.

2. Björkroth, M, Seppänen, O, Torkki, A. 1997. Components of the Air Handling Unit and Air Quality. In: Woods, JE, Grimsrud, DT, Boschi, N. *Proceedings of Healthy Buildings '97.* Healthy Buildings/IAQ '97, Washington DC, USA. Vol. 1, pp. 599–603.

3. Clausen, G, Fernandes, E. 1997. European Data Base on Indoor Air Pollution Sources in Buildings. The European Commission: Joule II project (contract JOU2-CT93-0343).

4. Holopainen, R, Palonen, J, Seppänen, O. 1999a. Cleaning Technology of the Air Handling System. *The 8th International Conference on Indoor Air Quality & Climate – Indoor Air '99.* Laboratory of Heating, Ventilating and Air Conditioning. Helsinki University of Technology.

5. Holopainen, R, Palonen, J, Seppänen, O. 1999b. Measuring Methods for Determining The Level of Dust in The Air Duct. *The 8th International Conference on Indoor Air Quality & Climate – Indoor Air '99.* Laboratory of Heating, Ventilating and Air Conditioning. Helsinki University of Technology.

6. Pejtersen, J. 1994. Forureningskilder i ventilationsanlæg. Laboratoriet for Varme- og Klimateknik. Danmarks Tekniske Højskole. Marts. 130 s. + app. (In Danish).

7. SAS Institute Inc. 1988. SAS/STAT™ User´s Guide. Release 6.03 Edition. Cary. NC: SAS Institute Inc. 1028 pp.