Cleanliness of ventilation systems - a REHVA guidebook

Pertti Pasanen[1], Rauno Holopainen[2], Birgit Müller[3], Jorma Railio[4], Harri Ripatti[5], Olle Berglund[6] and Kimmo Haapalainen[7]

[1]University of Kuopio, Finland
[2]Occupational Health Institute, Finland
[3]Techical University of Berlin, Germany
[4]Finnish Association of Mechanical Building Services Industries, Finland
[5]Climaconsult Ltd, Finland
[6]Wintclean Air, Sweden
[7]Lifa Air Ltd, Finland

Corresponding email: Pertti.Pasanen@uku.fi

SUMMARY

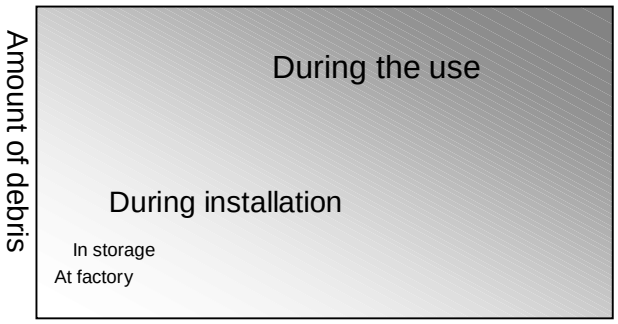
The published REHVA guidebook provides comprehensive up-to-date information about design features, criteria for cleanliness, inspection and cleaning instructions of ventilation systems. The guidebook is aimed at practitioners, designers and those who are setting criteria for cleanliness of ventilation systems. The design practice includes guides to construct a clean ventilation system and which cleanliness can be maintained during whole lifetime of the building. This provides to take account the cleanliness in building construction and installation processes as well as demands for proper maintenance actions including the functional checks and cleaning. A pathway for verification of the cleanliness and measuring methods are presented. Training practices for inspection and maintenance personnel in different countries are also introduced. The content of the guidebook is a consensus of the state of art information reviewed and discussed with the European specialists representing practice and science.

INTRODUCTION

Dust and other contaminants accumulate on the surfaces of the ventilation system during construction and operation and it is revealed that the ventilation systems itself may be potential sources of pollutants in buildings. Dusty surfaces may increase energy consumption, decrease air flow rate and cause malfunction problems to ventilation system. Additionally, contamination in the supply air duct may cause negative health impacts to occupants. Thus, the ventilation system has to be inspected regularly and cleaned whenever the inspection has revealed that the amount of accumulated dust has exceeded the acceptable limit. Ventilation systems, which convey very dusty and/or fire hazardous contaminants must be cleaned frequently.

During the last few years there has been increasing awareness of the importance of cleanliness in air ducts. Dust accumulation in newly installed air ducts was found to be high when attention had not been paid to the cleanliness of the ducts during construction. Dust and other impurities in new ducts originate particularly from installation work and when the particle concentration is high at the building site. After the construction process, pollutants accumulate on duct surfaces during the operation of the ventilation system. During operation,

the main causes of dust accumulation in the supply air duct are polluted out-door air and inadequate maintenance of the filters (Figure 1). Highly efficient filtration protects supply air ducts during operation of the system and thus can increase the length of the intervals between cleaning.



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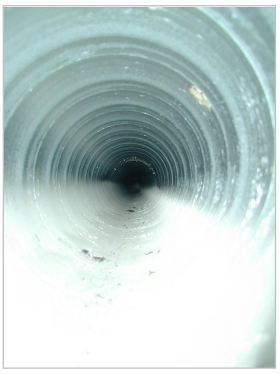


(b)

Figure 1. (a) Principle of dust accumulation on ventilation system after the components are manufactured. (b) Typical dust accumulation on round air duct.

The guidebook gathers the scientific and practical information in a way that it is easy to utilize during the many phases of the work towards cleaner ventilation systems. These guidelines will give guidance to practitioners on how to take the cleanliness aspects properly into account in design, construction, commissioning and operation.

CRITERIA FOR CLEANLINESS

In some countries official guidelines are given for cleanliness criteria for ventilation systems. However, most of these guidelines focus on fire safety and seek to minimise the amount of flammable material in ducts, especially in exhaust-air ducts. In only a few countries cleanliness criteria are specified for hygienic reasons. Different are given for new and existing systems. E.g. European standard gives hygiene requirements and recommendations for air-handling units (AHU), different components and sections of AHUs [1].

The guideline for **new systems** focuses on design and installations instructions and the demands for cleanliness of components. It aims that the new ventilation system is clean after installation and building construction as well as the system can be kept clean during the whole lifetime of the building. Limit values for dust accumulation in newly installed air ducts and systems are presented in Table 1. The production and installation of components for new ventilation systems is very important. Manufacture of sheet metal components includes critical phases because lubrication is needed between a tool and the metal sheet. Oil residues may serve as nutrients for micro-organisms which produce odour. During operation a surface with oil residues tends to accumulate dust faster, and the resulting dust layer is sticky and difficult to remove. In a system it is important to use only equipment and components which do not emit harmful substances, fibres or odours.

The following three major contaminants from all components which may reduce IAQ should be kept to minimum:

- residues of lubricants
- dust accumulated during manufacture and installation, or debris from construction
- micro organisms, particularly when toxic species are present and conditions during installation and storage are favourable for their survival and growth.

Table 1. Limit values for dust accumulation in newly installed air ducts and air-handling systems.

Country	Application	Category	Prior to clean ducts	Evaluating method	Reference
Finland	Supply	P1 [a] P2 [a]	1 g/m^2 2.5 g/m^2	Visual [d] or Vacuum test [e]	[2]
Germany	General	High [b] Middle [b] Basic [b]	Visually unclean Visually unclean Heavy dirt	Visual [f] Visual [f] Visual [f]	[3]
Norway	Supply	Class A [c] Class B [c]	3% 5%	Optical [g] Optical [g]	[4]
Sweden	Supply	–	1 g/m²	Not mentioned [h]	[5]
USA	General	–	Visually unclean	Visual [i]	[6]

Categories:
[a] cleanliness categories, [b] cleanliness levels, [c] cleanliness class levels
Evaluating methods:
[d] Visual inspection with a reference scale as the primary method [7]
[e] Vacuum test (FiSIAQ -test 2) [8]
[f] Requirements for specific categories (A and B) and training to inspectors before they are authorised to inspection work [9]
[g] Optical method with gelatine tapes [10]
[h] Requirements for specific qualification (classes K and N) and experience to inspectors before they are authorised to inspection work
[i] Requirements for qualification and experience of inspectors before they are authorised to inspection work

More detailed requirements for single components and ducts are given in a Finnish guideline [2]. Limit value for oil residues in ducts and the components manufactured by cutting, bending or jointing the limit value is 0.05 g/m^2, for parts that needs deep drawn the limit is 0.3 g/m^2. The amount of surface dust shall not exceed 0.5 g/m^2.

The emissions of new filters are controlled according to odour emissions and it is stated that low polluting new filters shall be used. Naturally, the efficiency of filter is most important feature and it shall be tested according to [11].

Control of cleanliness is a part of maintenance of **existing ventilation systems**. The majority of national maintenance guidelines do not include cleanliness inspections, rather they presents intervals for checking and maintenance. The hygiene of moist surfaces, such as humidifiers and cooling coils, needs to control to avoid or detect microbial contamination of the surfaces or water reservoirs. Criteria for the quality of humidifier water are specified, e. g., in the German guideline [12].

Cleanliness target values for existing air ducts are presented in Table 2. In the guidebook gives more detailed cleanliness control instructions for filters, heating and cooling coils, humidifiers and cooling towers.

RECOMMENDED DESIGN PRACTICES

Ventilation system design should be a "design for lifetime" rather than a "design for construction". This means that the cleanliness criteria should be defined and documented so that the maintenance of the system allows maintaining of cleanliness during the whole lifetime of the building.

Table 2. Current target values on the hygiene of air ducts presented as amount of accumulated dust.

Country	Application	Prior to clean ducts	After cleaning	Evaluation method	Reference
USA	(1)		0.1 g/m²	Filter with vacuum	[13]
Great Britain	Supply Air	1 g/m² 60 µm	0.1 g/m²	Filter with vacuum	[14]
	Recirculation Air	1 g/m² 60 µm		Filter with vacuum	
	Exhaust Air	6 g/m² 180 µm		Filter with vacuum	
Sweden	Supply Air	1 g/m²		not mentioned	[5]
Japan	Supply Air		1 g/m²	Wiping with cloth	[15]
Finland	Supply Air	2g/m² 5 g/m²		Scrape/Filter with vacuum	[2]
Germany	general	20 g/m²	10 g/m²	Scrape/Filter with vacuum	[9]

For new buildings the required standards for the indoor air quality (IAQ) should be high. This means that all designers have to consider the IAQ in their design solutions. In aiming at high IAQ the ventilation system, the designer should plan sufficient air-flow rates, adequate cleaning of the supply air, i.e. filtration, and ensure the system is constructed using clean components and a clean installation technique.

Design should also include sufficient guidance and instructions for

- assessment of cleanliness and need for cleaning
- default cleaning intervals
- cleaning method
- checking after cleaning, both for cleanliness and system functioning.

Guidebook presents design principles for different parts in ventilation systems. For example space for maintenance needs to be taken account in design of lay out in AHU room, Figure 2.

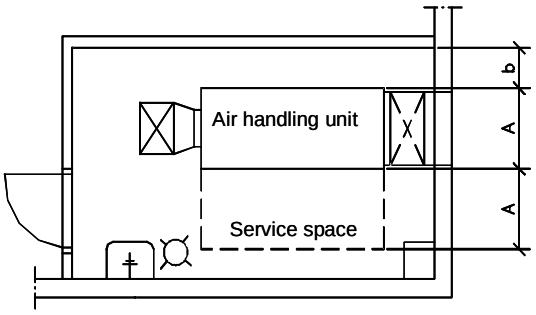


Figure 2. Sufficient space is required for maintenance access

INSTALLING CLEAN VENTILATION SYSTEMS

Ventilation systems are exposed to dust and debris during some phases of the system's history. The building process and installation are the most critical phases when dust from the building construction is likely to contaminate the system. Prevention of dust entering the partially built ventilation system is an effective technique for ensuring a clean system in the new building.

The best results are obtained by implementing the following actions:

- install the system during construction phases when no dust producing work is being carried out
- store uninstalled ducts and components under a cover or in a shed to prevent dust and debris from entering the components (Figure 3a)
- remove the packing materials or coverings just before installation
- check that the environment remains clean during the installation work
- cap or recap the installed openings, duct ends or airways during breaks in the installation
- only use cutting methods that do not produce metal shavings or powder
- where contamination has occurred, clean before closing the system
- check the cleanliness before commissioning of the system.

According to field studies the protection methods to keep the system clean during the installation process are very advantageous. In figure 3(b) the amount of accumulated dust is presented after each construction phase; P1 refer to technique in which attention is paid on the cleanliness during construction process and P2 refers to the method in which the installation is carried out without special care. At its best the amount of accumulated dust found in the duct work has been around the detection limits of the measuring methods.

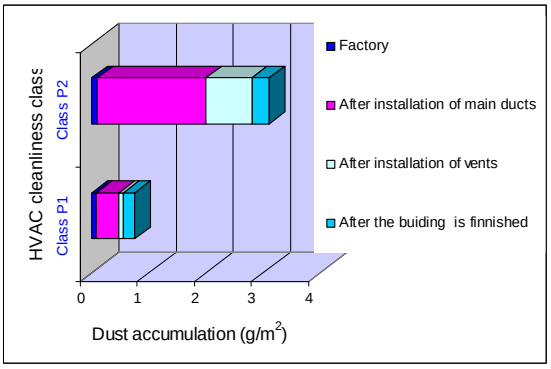
(a)  (b) 

Figure 3. (a) An example of protection of air ducts during storage at building site (left). (b) Effect of different installation processes on dust accumulation on ventilation ducts. Class P1 and P2 are cleanliness classes expressed in [2].

VERIFICATION OF CLEANLINESS

In newly installed ventilation systems, the verification of cleanliness is required during the commissioning process to confirm that the building contractor has built a system that is as clean as the building owner has demanded. In existing buildings, the periodic inspection of cleanliness is most often done to evaluate the need for cleaning. The verification process is shown in the schematic of Figure 4(a).

The evaluation of cleanliness begins with an inspection plan. The content of the plan depends on the size and design features of the system. Firstly the evaluation is done visually, aided by a source of light, possibly also using a mirror and some tools. The level of cleanliness is compared against a cleanliness scale (Figure 4(b)) which contains six illustrations showing different amounts of dust accumulation.

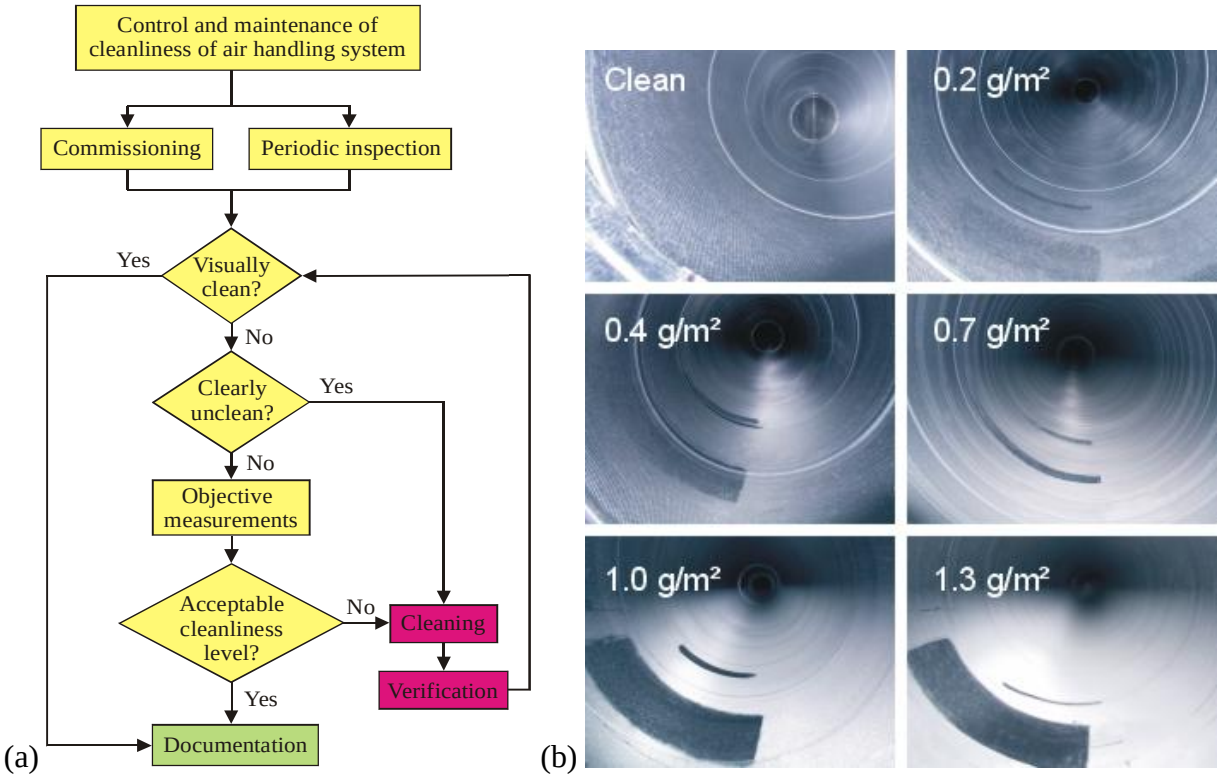


Figure 4 (a) A pathway for verification of cleanliness. (b) A reference scale for visual inspection of new installations [7].

If the contractor, duct cleaner or building owner is not satisfied with the results of the visual inspection, a more objective method of assessment should be used; this is carried out by collecting and weighing the dust deposited on a known area of the duct surface. For round ducts the dust is collected from the lower half or side quarter (as seen in figure 4(b)), and in rectangular air ducts from the bottom of the duct.

During the sampling notes from visual observations shall be done and also photographs e.g. with digital camera will aid the reporting and decision making if the system shall be cleaned or not. Finally, the results of the evaluation should be documented, with photographic evidence.

Different parameters or contaminants need different methods. Several methods for dust deposits are developed; vacuum sampling with loosening the dust by scraping is recommended in the guidebook. Microbial contamination on surfaces is useful to sample by swiping technique followed by cultivation of the sample. The microbial concentration in water samples are analyzed with the cultivation techniques as used in water hygiene control.

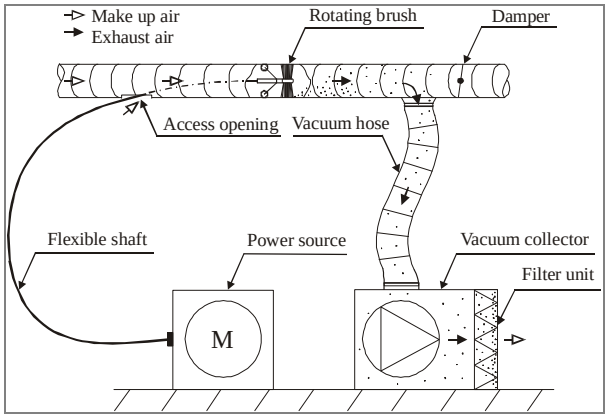
CLEANING OF VENTILATION SYSTEMS

The ventilation system should be cleaned according to a cleaning plan. The plan consists of a selection of methods suitable for the different components and surface materials. The methods should be selected so as to avoid damage to surfaces and components being cleaned.

A basic distinction is made between dry and wet cleaning. Compressed air cleaning, mechanical brushing, hand vacuuming are examples of dry cleaning methods. Compressed air

is used e.g. for cleaning narrow gaps, e.g. between the fins of heat exchangers, or for irregular surfaces of other parts of ventilation systems. Mechanical brushing with a vacuum technique to remove the loosened dust is the most common cleaning method for spiral seamed ducts. With proper equipment the mechanical dry cleaning method is an effective technique to remove loose dry dust from the surface of air ducts (Figure 6).

Hand vacuuming is suitable for small areas like filter banks or the surfaces of silencers.

(a) 

(b) 

Figure 6. (a) A schematic picture of mechanical brushing with a vacuum collector. (b) Duct cleaning with mechanical brushing.

Wet cleaning methods are used, for example, for cleaning terminal devices after they have been removed from the duct work. Wet cleaning methods can also be used for the cleaning of heat recovery units if they are installed in a location where water can be drained from the air handling unit.

Cleaning robots are also useful in both in round and rectangular air ducts. The robots are usually equipped with a camera which provides an opportunity to see the progress of the cleaning work.

EDUCATION TO MAINTAIN CLEANLINESS

Guidebook gives a brief introduction to the education programs for hygiene inspections and maintenance of ventilation systems. However, as training procedures and legislation vary from country to country it is difficult to harmonize training practices. As training is imperative it is important to focus on local codes and guidelines, although an international training programme would be beneficial.

Another REHVA Guidebook “Hygiene Requirements for air-conditioning systems and units” presents an example of a training system established in Germany, Austria and Switzerland. EVHA guidebook states the training demands from point of view of cleaning professionals.

RELATIONSHIPS TO OTHER GUIDEBOOKS AND STANDARDS

The REHVA guidebook (nr8) is not an official guideline or regulation; but recommends the best proven practices for maintaining hygienic and clean ventilation systems. However, this guidebook does present some recommended minimum or maximum values for different parameters, such as default values. National regulations, which may require more stringent values should always be followed. The guidebook is useful for practitioners who like to

follow the recent international practices. It offers a wide approach to the factors affecting indoor air quality and is aiming to conform to the European standards of HVAC maintenance. Standard EN 12097 gives requirements for ductwork design and construction in order to ensure the cleanability of the system, focusing on the size and location of access openings.

The other REHVA guidebook "Hygiene requirements for ventilation and air conditioning systems and units" (nr 9) goes in more detail to hygiene and health issues of the systems and components. The European Ventilation Hygiene Association guidebooks "EVHA Guide to cleaning and hygiene management of ventilation systems" and "EVHA Good practice document for grease extract cleaning" are targeted to cleaners.

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