MAINTENANCE OF HVAC-SYSTEMS AND COMPONENTS, DEFINITION OF CLEANLINESS!

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ABSTRACT
Maintenance of air-conditioning systems is acknowledged as an important means to run HVAC-systems properly. Although several maintenance programs and standards exist, not many systems are maintained in a proper way. Most standards and programs are not concerned with the indoor environment, they are only concerned with repair and failure-response of system components. Just now, some new guidelines come out in Europe, which contains first definition of cleanliness. These levels normally define dust concentration, or microorganism on the surface of components or the microorganism concentration in the water of humidifiers. Levels for microorganism in the air are not defined. One question that is not precise answered jet is: "Is it good enough to define cleanliness levels for surfaces, or do we need concrete definitions for the air?" First steps to answer this question are done in the presented article.

INDEX TERMS
Maintenance, Definition of cleanliness, Air quality, Guideline, HVAC-System

INTRODUCTION
In the first part of the performed investigations, we define levels for cleanliness. These investigations are done during a European project called "Airless". In the seconded investigation, we measure in a field test all parameters, like number of particles, micro-organisms etc., on the surfaces of the system but also in the air. The measurements are starting with the outdoor air then going through the HVAC-system and at the end in the connected rooms. The investigated HVAC-systems are depending to a big hospital in Berlin.

In the "Airless" project some definition for cleanliness are made. In this article, only the results for ducts are shown. The comparison of different measuring methods for defining dust loads in ducts was that it is not possible to define only limits for cleanliness. It is important to define also the method for measuring those limits. The defined limits are shown under the results.

In the seconded investigation, it is shown that the supply air is cleaner then the outdoor air. The amount of micro-organism and the number of particles is decreasing from the outdoor air to the supply air. The field study was done with one known dust measuring methods from a Japanese guideline JADCA (Japanese Air Duct Cleaners Association). The micro-organism on the surface are collected with the contact agar plate method, and the micro-organism in the air with an Anderson sampler both methods are using the same agar plates. The temperature and humidity was measured during the investigations. The numbers of particles in the air are counted over the tests.

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METHODS

Temperature and Humidity

The temperature and humidity was always measured with an instrument from the company TESTO. The metering capacity of the instrument is for the relative humidity between 0 and 100 %, and for the temperature between –20 and +70°C. The averages of the measuring error for the relative humidity is ± 2%, and for the temperature ± 0,4 °C.

Particle counter

For the particle count it was used a particle monitor form the company Deha-Haan & Wittmer GmbH (Model 28 LD) with 28,3 l/min airflow. The metering capacity is defined in different particle sizes between 0,3 µm and 10 µm.

Sampling Micro-organisms

For counting the microorganism on the surface, we used the contact plate method. An agar plate is pushed directly onto the duct surface, which causes microorganisms to adhere to the agar; the plates are then incubated and the colony forming units (CFU) are counted (Laatikainen et al., 1991; Auger, 1994).

For the microorganism in the air, an Anderson sampler was used. The Sampler is shown in figure 1. The agar plates are standing in the different steps. The airflow is coming from the top and going through the sampler. The different steps have different big holes in it so only the smaller particles are coming through the next step. In figure 1, it is shown that we are able to collect particles down to 0.6 µm.

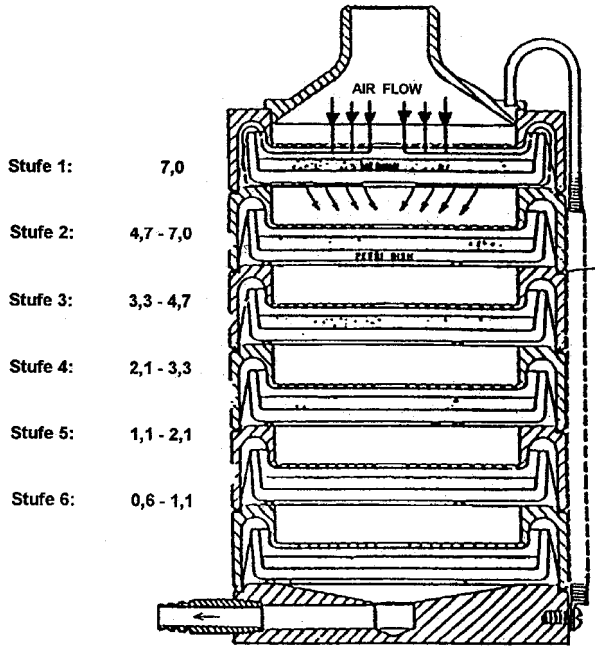

Figure 1. Anderson cascade sampler with 6 steps (7µm – 0.6µm)

In all investigations blood agar for the bacteria tests and malt extract agar for the moulds and yeasts are used.

Dust measuring method

Determination of dust concentration by means of the method as described by the Japanese Air Duct Cleaners Association (wiping of a 100 cm² area with a pre-weighed polypropylene cloth

[Kimtex, Kimberly Clark Co.]), without use of solvent (Kumagai et al., 1997); additionally as an own variation the same method with solvent (propanol, 70 %), three parallel samples, respectively. (This method was used in the both investigations. Airless was also investigated other method, which are not describe in this article).

After the measurements, the samples were transported to the laboratory. At the laboratory the samples were weighed to determine the level of dust per unit area [g/m²] (the samples with solvent were stored 24 hours at a temperature of 20 ± 2 °C and rel. humidity of 40 ± 5 % to ensure that the solvent to be completely evaporated. The weighing was undertaken with a Satorius Balance with a resolution of 0,1 mg. Each sample was packaged into aluminum foil, which is rigid enough to ensure a calm weighing procedure on the one hand and to avoid electrostatic influences between balance windshield and the cloth on the other.

RESULTS

Definition of cleanliness in Ducts

In practice, HVAC-systems are aimed to improve air quality compared to outdoor concentrations, which is usually (under normal operation and proper maintenance) the case with regard to airborne microorganisms and particles due to filtration (Müller, B., 1998; Küchen, 1998). However, the following three major contaminants from ducts may deteriorate IAQ and should be limited:

1. residues of lubricant oils from duct manufacture (Björkroth 1999, Pasanen, 1995)
2. dust accumulated during operation or debris from construction
3. deposited microorganisms, particularly when toxigenic species are present and conditions are favorable for their survival and growth

The acceptable amount of oil residuals in new ducts is specified in the Finish (FISIAQ 2001) guideline with 50 mg/m².

The VDI 6022 part 1 (VDI 6022, Part 1, 1998) uses the word “Broom clean” to define cleanliness in ducts.

Table 1. Approximate corresponding target values for duct cleanliness referring to various existing dust measurement methods (Küchen, 1998)

Method	description	Detection efficiency	**Dust surface concentration [g/m²]**		
		(Faktor)	**low standard**	**medium standard**	**high standard**
Total dust	solvent	1	20.0	10.0	5.0
Vacuum	with blade	0.9	18.0	9.0	4.5
Wiping	JADCA	0.5	10.0	5.0	2.5
Tape	gravimetric	0.35	7.0	3.5	1.8
Vacuum	with brush	0.15	3.0	1.5	0.8
Vacuum	Wintest	0.1	2.0	1.0	0.5
Vacuum	NADCA/HVCA	0.02	0.4	0.2	0.1

In the "Airless" project we looked for a definition of what amount of dust "Broom clean" actually refers to. Therefore it is substantial to know something about the dust measuring methods in ducts. Volker Küchen (Küchen 1998) compared in his diploma work the commonly used measuring systems for dust under. The differences of the used measuring systems is shown in table 1. The question about the definition of "Broom clean" was not answered, so we made different tests with different brooms and a scrubbers. The result:

4 g/m² JADCA with solvent (table 2)

Table 2. Definition of "Broom clean" for different dust measuring methods in ducts (Müller et al. 1999)

Method	Description	High Standard BROOM CLEAN
Total dust	solvent	5.0
Vacuum	with blade	4.5
Wiping with solvent	**JADCA with solvent**	**4.0**
Wiping	JADCA	2.5
Tape	gravimetric	1.8
Vacuum	with brush	0.8
Vacuum	Wintest	0.5
Vacuum	NADCA/HVCA	0.1

That means "Broom clean" is the high standard after table 1. In the new VDI 6022 part 3 a part of table 1 is implement. In the VDI 6022 part 3, it is defined that you have to clean when the amount of dust is over the low standard and after cleaning it must be cleaner then the medium standard. They leave out the high standard.

Field study

The field study takes place in a big hospital in Berlin. Different HVAC-systems are investigated. The shown results are from an HVAC-system that serves the operation theater and surrounding rooms. Like describe above, all parameters are measured through the whole system.

In figure 2 the comparison of the number of micro-organisms in the air and on the surface of an HVAC-system is shown. It is obvious to see that the amount of air microorganism are decreasing over the system. In this figure it looks like that there is a relation between the surface and air microorganisms but it was not possible to find that correlation in all tests. Important is that at the end of the measurement (after the second filter, that is not the Hyper filter) the numbers of microorganisms are nearly zeroed.

In figure 3, it is shown that in the same system also the number of particles decrease. In the operation theater no particles coming out of the system, like it is required.

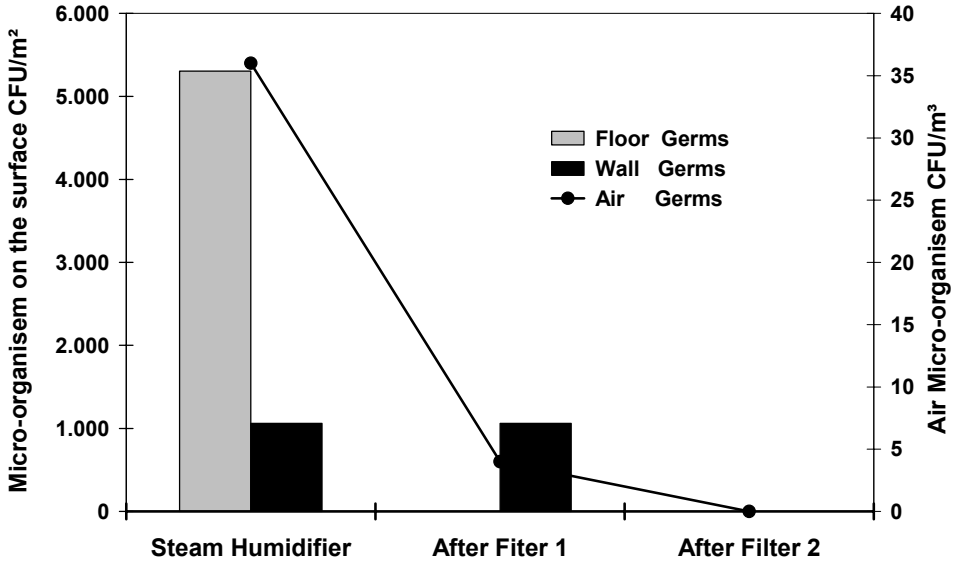

Figure 2. Comparison of the number of micro-organisms in the air and on the surface of an HVAC-system

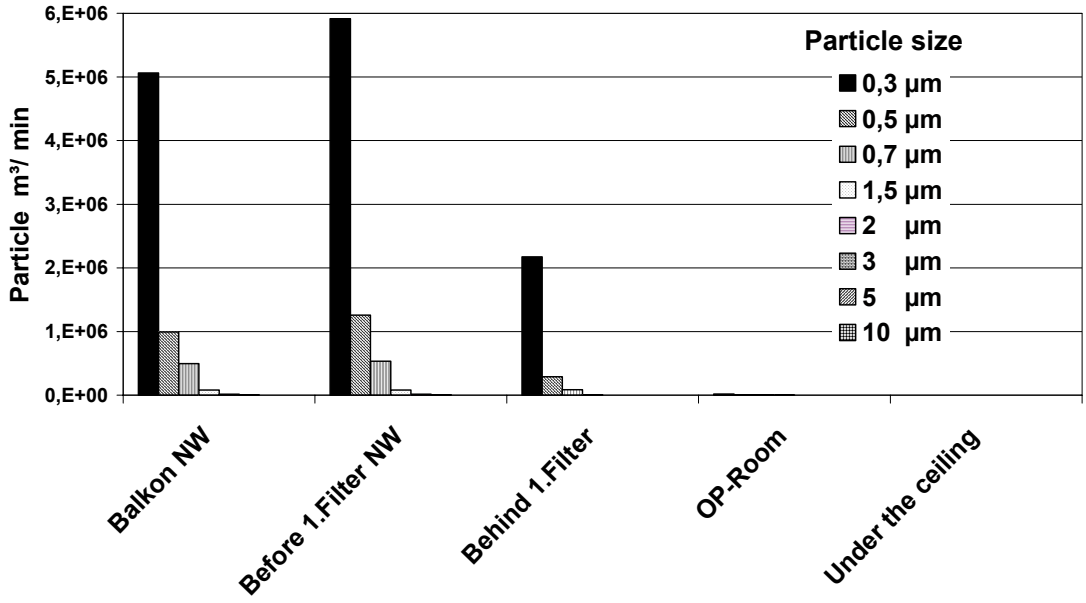

Figure 3. Number of particles in an HVAC-system from the outdoor air intake to the outlet

DISCUSSION

Until now in the existing definition of cleanliness, only limits for surface or water concentrations are given. New definition for duct cleanliness are made and presented. First results of these investigations are implemented in guidelines. Still open is the question: "Is it good enough to define cleanliness levels for surfaces, or do we need concrete definitions for the air?" The definition of cleanliness for HVAC-systems is very important for the owner and user of buildings. To define levels of cleanliness on surfaces is the first step to guarantee a good indoor air quality in buildings. More investigations on the correlation of air and surface microorganism must be done.

CONCLUSION

It is still open if it is enough to define limits for cleanliness over the surface or water concentration of microorganism and dirt in an HVAC-system.
First steps to define cleanliness, in the right direction are made. It is very important to define limits of cleanliness and cleaning procedures, which are understandable and easy to use. Non-implement able instructions and limits are not useful.

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