Microbial analysis of Heating systems' surfaces

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Abstract**—** *An analysis of experimental investigation focused on microbial pollution of heated was carried out for heating systems installed in different types of buildings as residential houses and civil buildings. The results point on importance of maintenance and cleaning the heating systems for quality of indoor air and occupants' comfort.*

Keywords**— building environment, indoor comfort, heating systems, microbial analysis.**

I. INTRODUCTION

Good quality of indoor air is one of the most important requirements for indoor climate comfort. Especially dust concentration of microorganism growth in indoor air are closely related with respiratory problems and in final consequences with serious illnesses [1-3]. Hygienic quality of indoor air and for clearness of building surfaces as well as heating systems are key issues for the indoor climate comfort [4-6]. It has been a subject of the world-wide research programmes [7-11].

Heating systems have to be cleared and repaired. Cleaning of internal surfaces in buildings as floors, furniture, windows, indoor equipment is frequently completed their cleaning of radiators and heating surfaces is often neglected [12-17].

An analysis of experimental investigation focused on microbial pollution of heated surfaces is presented in the article. The analysis was carried out for heating systems installed in different types of buildings as residential houses and civil buildings. The results point on importance of maintenance and cleaning the heating systems for quality of indoor air and occupants' comfort.

1.1 Requirements

Microbial climate in buildings is influenced by microorganism concentration in the indoor space [18-23]. The concentration is defined for the Colony Forming Unit-CFU of bacteria or mould per m3 of indoor air. Requirements for the microorganism concentration limits are specified for the controlled built-environment recommendations of hygienic demands for chemical and physical limits for indoor climate comfort in occupied rooms:

- Non-acceptable visible mould growth on interior surfaces, it means visible mould growth and also laboratory cultivated mould growth from sampling.
- Part from the spaces with extremely clear environment the bacteria concentration maximal concentration of 500 CFU/m^3 bacteria and 500 CFU/m3 of mould in indoor air is required. Samplings are laboratory tested in microscopic studies.

TABLE 1
CATEGORY OF THE INDOOR AIR POLLUTION IN ACCORDANCE WITH EUR 14988 [22] – CONCENTRATION OF MIXED BACTERIAL POPULATION AND MOULDS IN OCCUPATIONAL AREAS AND IN RESIDENTIAL AREAS

Pollution category	Occupational areas		Rooms in residential houses	
	Bacteria CFU/m^3	Mould CFU/m^3	Bacteria CFU/m^3	Mould CFU/m^3
Very low	<50	<25	<100	<50
Low	<100	<100	<500	<200
Middle	<500	<500	<2500	<1000
High	<2000	<2000	<10000	<10000
Very high	>2000	> 2000	>10000	> 10000

Diagnostics of building state from the microbiological point of view is included into tasks of the environmental session of the European Commission. The EU document 14988 published statistics of investigation in microbiological air pollution in buildings in the EU countries. Results are summarized in Table 1, which gives an overview of the classification of mould and

bacteria concentration in indoor air volume. Microorganisms are in common dusty air atmosphere. The dust gives growth to the microorganisms. Mould concentration is from 1000 to 100 000 CFU per 1 g of dust.

Hygienic limits for many buildings are considered up to the middle pollution category of the concentration of bacteria and moulds. But results of the investigations show that in residential buildings is microbiological pollution of indoor air is really high than the hygienically permitted limits.

1.2 Microorganisms and their influence on people's health

Quality of indoor air in building is extremely important for occupants' health. Adults need about 12 000 litres of air per day.

Bacteria and microscopic moulds are allergens that because they produce toxins. They can growth and cumulate on interior surfaces. Characteristic feature of microorganisms in buildings is ability to grow in a very small concentration and during convenient hygro-thermal conditions they could significantly increase their growth. Circulated air moves the microorganisms that could be inhaled by the room occupants. In case of high concentration of bacteria and mould microorganisms in indoor air the occupants could be seriously endangered in their health. Tab. 2 gives information about negative influences of myco-toxine microorganisms on living organisms.

TABLE 2
SOME MYCOTOXINS AND THEIR NEGATIVE EFFECTS

Toxin	Producent toxinu	Negative effects
Aflatoxins	Aspergillus flavus	Respiration problems and cancer
Ochratoxins	spieces Apergillus and Penicillium	Karcinogen
Patulin	spieces Apergillus and Penicillium	Affection of DNA molecules
Trichotecens	spieces Stachybotrys and Trichoderma	Karcinogen

It is not a purpose to create extremely disinfected climate in common buildings. Disinfection for liquidation of vegetative form of microorganisms or sterilization of microorganisms and spores could shave also negative impact for occupants' health. Their immune system is weaken and lose an ability of reaction on the external influences. Total liquidation of microorganisms is important for special purposes for example for operation theatres in hospitals or in special productions as pharmaceutic production etc. Microorganisms detected on surfaces are in many cases different than microorganisms in the air which also must be taken into consideration.

II. EXPERIMENTAL TESTING OF RADIATOR SURFACES

2.1 Microorganisms on radiator surfaces in school building

Testing of microorganism concentrations on heating systems surfaces was completed within the frame of a research project. The project was focused on the sampling of various systems for heating in buildings. Heating systems at a campus of the Faculty of Civil Engineering, Brno University of Technology were tested in January 2014. Positions of the sampling are shown in the scheme of Figure 1. The Dipslide Labm method was selected for the testing.

The contact sampling method is convenient because of easy and quick sampling and low risk of contamination. The sample is sealed in the test tube before and after the test. The sample cultivation is inside of the tube. In this case the cultivation process is not affected by influenced any external influences.

The samples of surface microorganisms (Figure 2) were selected for laboratory cultivation (Figure 3). Results determined from the cultivation for the constant thermal conditions (bacteria 3 days, for 30 °C; moulds 5 days for 25 °C) were evaluated for the CFU (Colony Forming Units) per m2 of the surface.

Tested heating systems:

- Radiator with lamellas – corridor E1 (about 13 years operation).
- Radiator without lamellas – corridor E2 (about 2 years operation).
- Cast iron articulated radiator – corridor to building D (more than 10 years operation).
- Floor convertor without ventilator with Al lamellas air – corridor to building D.

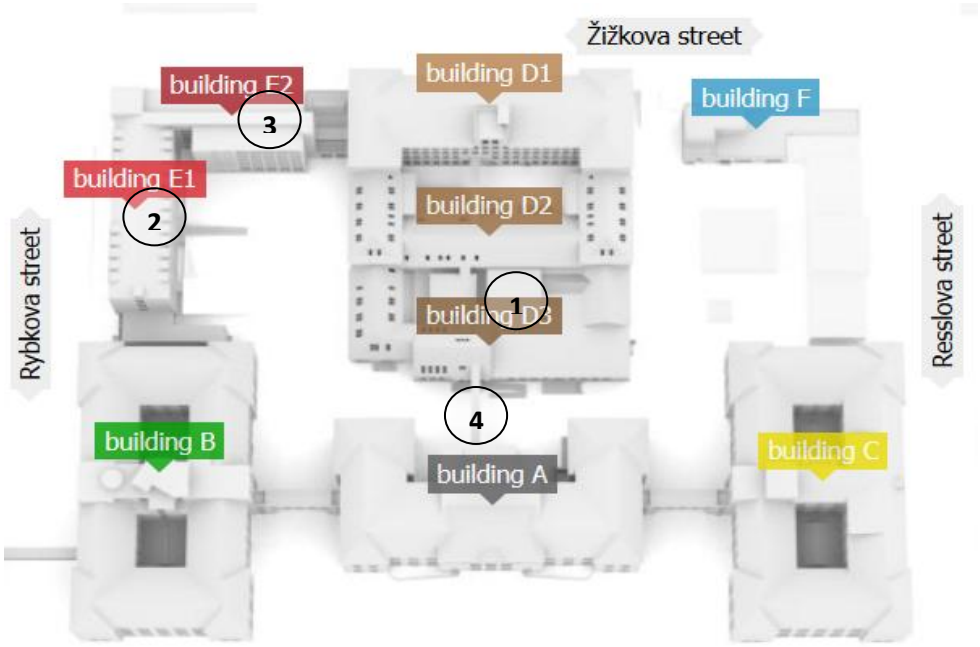
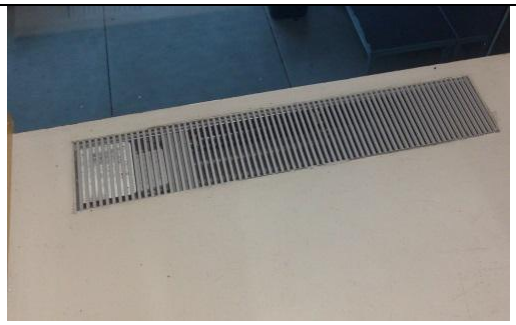


FIG. 1: SCHEME OF THE FACULTY CAMPUS OF BRNO UNIVERSITY OF TECHNOLOGY POSITIONS 1 TO 4 ARE THE TEST SAMPLING PLACES



FLOOR CONVECTOR IN THE CINEMA

FLOOR CONVERTOR IN THE UNIVERSITY STUDY ROOM

FLOOR CONVERTOR IN RESIDENTIAL BUILDING A

SLAB RADIATION IN RESIDENTIAL BUILDING A

FLOOR CONVERTOR IN RESIDENTIAL BUILDING B

SLAB RADIATION IN RESIDENTIAL BUILDING B

FIG. 2: TESTED HEATERS, RADIATORS AND FLOOR HEAT CONVERTORS

Samplings were selected on all heaters and were compared with samplings of interior surfaces. The sampling selection is documented in Figure 3.

FIG. 3: POSITIONS OF SAMPLINGS ON THE TESTED HEATER

The example of a microbiological sample and its cultivation of bacteria (yellow) and mould (red) of sample 2 (new radiator in school building corridor) is shown in Figure 4.

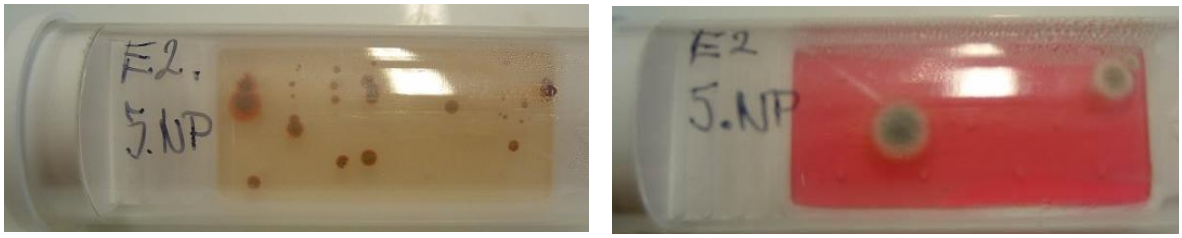


FIG. 3: THE SAMPLES LABORATORY CULTIVATION

Bacterial pollution of the heaters is adequate to other tested surfaces in interior. More intensive pollution is on the floor convertor, where there were three types of moulds detected. Results of the laboratory tests of the samplings are shown in Table 3 a Figure 4.

TABLE 3

RESULTS OF THE HEATER MICROBIOLOGICAL SAMPLES TESTING

Heating system	Bacteria CFU/m^2	Mould CFU/m^2	species
Desk radiator – building E1	10600	undetected	
Desk radiator - building E2	18100	3125	Penicillium
Sectional heater - building D	4375	1800	Penicillium Rhizopus
Floor convertor - corridor to building D	58750	11900	Aspergillus Penicillium Rhizopus

Type Rhizopus is thermophile – it means moulds of this type could grow even for temperature of 50 °C. The mould types do not produce mycotoxines, but spores have highly allergenic potential. Type Aspergillus grows under conditions of temperatures 10 to 45 °C, type Penicillium grows from 4 °C. Type Aspergillus produces aflatoxins with carcinogenic effects.

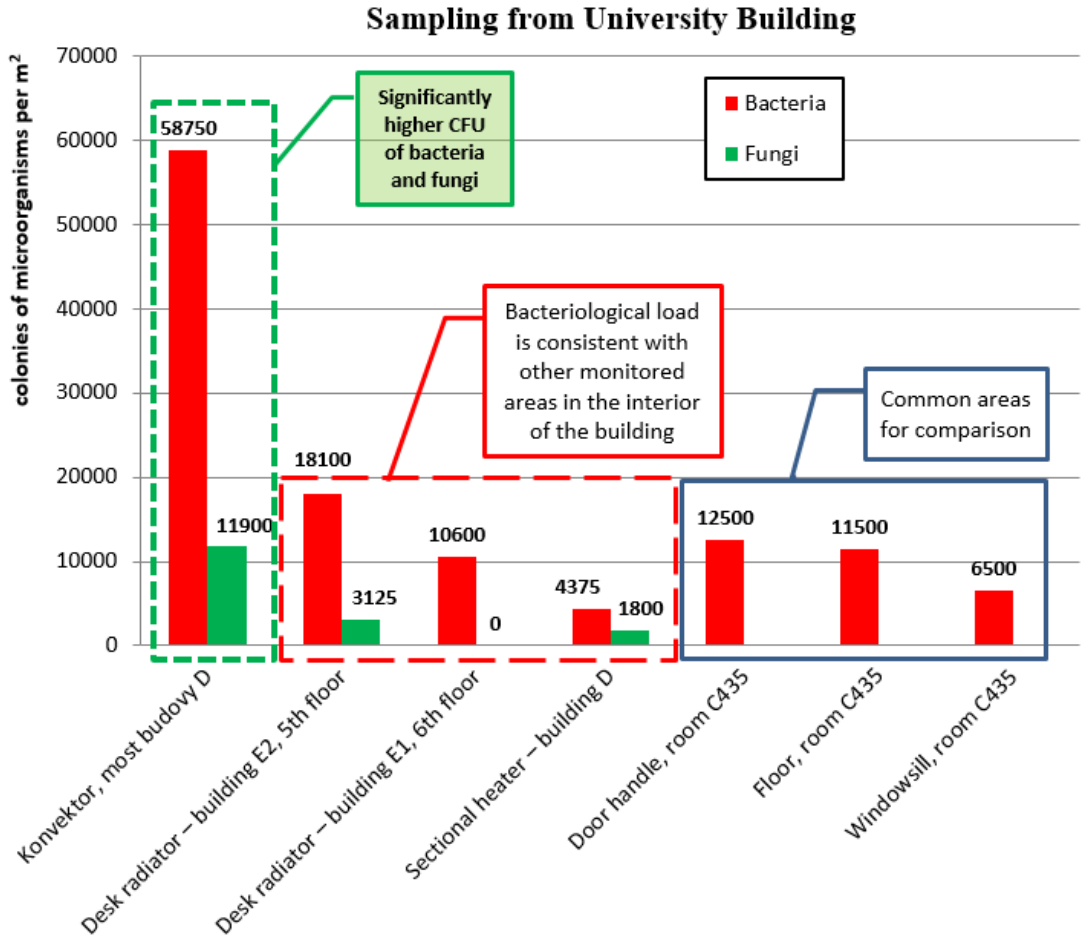


FIG. 4: RESULTS OF MICROOGRANISM CULTIVATION ON VARIOUS SURFACES

2.2 Microorganisms in floor convertors

The above mentioned results show that the microbial pollution is the most problematic for the floor convertor. It is certainly because of its shape and uneven surface that are and difficult to clean. Especially in dwellings and places with pets as cats or dogs the convertors are very often "dust and hair accumulators", Figure 5. Dust with organic compounds is a convenient base for the mould growth. For this reason the next research has been focused on the floor convertors.

FIG. 5: FLOOR LAMELLAE CONVERTOR OF ROOM OF A FLAT WITH A CAT (TWICE A YEAR CLEARED); DISTANCE OF THE CONVERTOR LAMELLAS IS 3 mm

On the basis of the above mentioned experiment samples of floor heating convertors were tested. The testing was carried out for the following floor heaters:

1. Floor convertor without ventilator located in circulation area in a cinema building in the city centre (new building – only two years in operation).
2. Floor convertor in a study room of a university library (four years' operation).
3. Floor convertor in a residential building A (ten years' operation).
4. Slab radiator in a residential building A.
5. Floor convertor in a residential building B (two years' operation).
6. Slab radiator in a residential building B.

Both of the residential buildings are occupied by four-member families there are no pets in the families. Low-temperature heating systems are in service in those buildings. Results of the tests are presented in Table 4 and Figure 6.

TABLE 4
RESULTS OF THE MICROORGANISM CULTIVATION OF THE FLOOR CONVERTORS SAMPLINGS

Heating system	Bacteria CFU/m^2	Mould CFU/m^2	spieces
Floor convector in the cinema	78750	39400	Penicillium Rhizopus
Floor convertor in the university study room	55700	2500	Penicillium
Floor convertor in residential building A	18500	5100	Aspergillus
Slab radiation in residential building A	7800	1500	Aspergillus
Floor convertor in residential building B	13750	undetected	-
Slab radiation in residential building B	4400	1900	Rhizopus

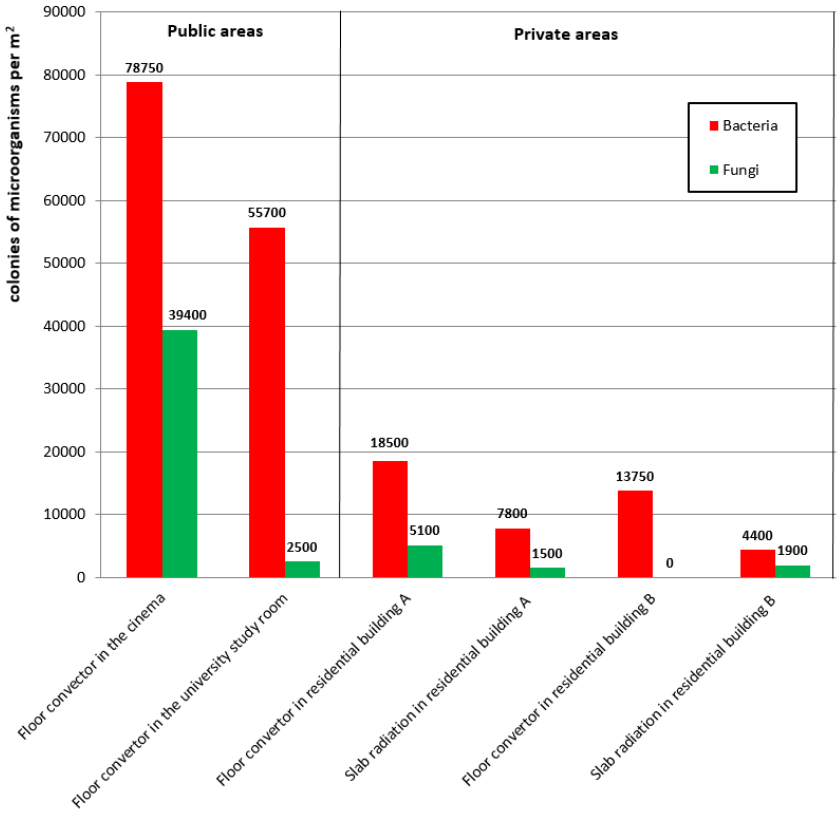


FIG. 6: RESULTS OF THE MICROORGANISM CULTIVATION OF SAMPLES OF FLOOR CONVERTORS

Microorganism growth was detected for many floor convertors in public buildings. The convertor itself is not source of microorganisms but its construction and surface area and possibility to clean it influences microorganism concentration.

Low-temperature heating systems are weak to microorganism growth. Location of these systems is problematical because of floor or very low positioning in the room places with increased concentration of microorganism. Microorganisms are moved by the air circulation inside of the internal spaces in buildings. It can be expected that in public buildings the concentration of microorganisms could be very high because of neglected regular service and cleaning of the heating systems. Moulds and fungy Rhizopus are very rare in buildings but in case that they have convenient conditions they spread and increase their allergenic potential.

2.3 Growth of microorganisms on surfaces of heating systems

The next experiment was aimed at the testing of heating surfaces that are commonly cleaned without disinfection detergents. The slab radiator was cleaned and sampled (after 14, 21, 28 and 35 days). Samplings were selected due to surface sponges (3M).

Samples were cultivated in laboratory. Two cultivation substances were used - PCA agar for bacteria cultivation and agar with antibiotics for mould cultivation. Samples for the bacteria cultivation were tested for three days at temperature of 30 °C and samples for moulds cultivation for 5 days at 25 °C.

The radiator bacterial pollution in forty days in presented in graph of Figure 7. It is clear that the bacteria contamination is exponentially increased in time.

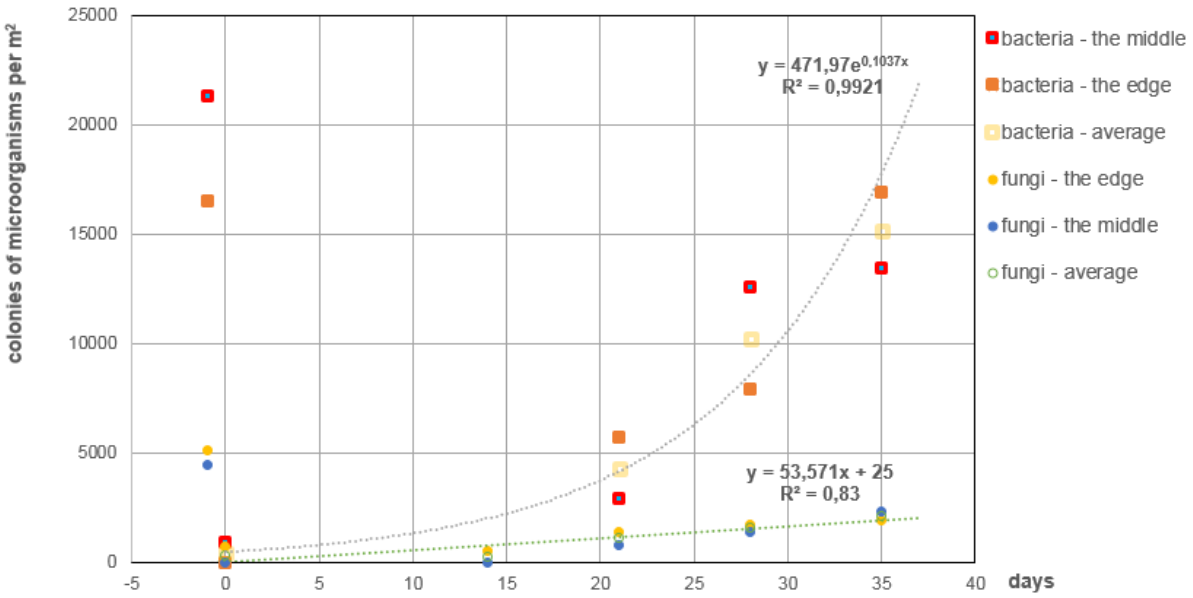


FIG. 7: BACTERIAL CONTAMINATION OF THE RADIATOR (COLOUR POINTS – DIFFERENT PLACES OF THE DUST SAMPLING ON THE RADIATOR)

III. CONCLUSION

Heating radiators a shape that gives possibility to dust settlement on them create opportunity to microorganism growth. It can be problematic in rooms with very low indoor temperature. Low-temperature heating systems with the service water temperature below 50 °C could be affected by microorganisms. It is very important to provide frequent revisions and cleaning of the heating systems in public and residential buildings.

Heaters with complicated shape and uneven surface could accumulate dust and for this reason they support the mould growth a microbial concentration. Low-temperature water heater systems (below 50 °C) give growth of mesophile types of organic pollution. For the low-temperature heating systems regular thermic disinfection is recommended for the heaters maintenance.

The heaters construction and easy-to-clean surfaces as well as convenient positioning in the building are key factor for elimination of dust concentration and organic pollution. Heaters with lamellas located in floors are directly exposed to the pollution and microbial contamination. Another problem could be uncontrolled amount of dust in places where people do not

change their shoes. In public buildings with high occupancy the dust contamination was proven much more serious compared to dwelling where people wear clear home shoes. High occupancy has also negative influence on microbial pollution.

It seems that frequent and thorough cleaning maintenance of heaters at public buildings is really necessary. Floor convertor heaters are not recommended for spaces with high hygienic demands as hospitals and care homes. Plain surface radiators positioned in easy-to –clean installations would be or convenient in these cases.

ACKNOWLEDGEMENTS

This article has been worked out under the project No. LO1408 "AdMaS UP - Advanced Materials, Structures and Technologies", supported by Ministry of Education, Youth and Sports under the National Sustainability Programme I" of the Czech Republic.

The research is supported by the Specific research at Brno University of Technology, Faculty of Civil Engineering, reg. number FAST-S-15-2620.

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