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DOES AIR CONDITIONING IMPACT ON HYGIENIC QUALITY OF INDOOR AIR ON SEAGOING VESSELS ?

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ABSTRACT

Background: According to observations by occupational health physicians, nearly 50 % of the seamen on German vessels will get diseases of the upper respiratory tract. An impact of the air-conditioning systems on these diseases has been suggested.

Objectives: To examine the hygienic quality of indoor air on seagoing vessels, a pilot study was initiated by the See-Berufsgenossenschaft.

Methods: Air samples were taken on-site at different sampling sites and analysed for the occurrence of microorganisms.

Results: Bacteria showed the highest cell numbers and the highest distribution in indoor air on vessels, whereby the maximum level was determined in the air of crew cabins. The identification of bacteria showed that beside common airborne species, pathogens existed.

Conclusions: Air-conditioning seems to influence the quality of indoor air on seagoing vessels. Interim results of the study indicate that regular maintenance of air-conditioning systems is essential.

Key words: air-conditioning system, bacteria, fungi, indoor air, seagoing vessel

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INTRODUCTION

During regular inspections, occupational health physicians of the See-Berufsgenossenschaft (institution for statutory accident insurance and prevention in the maritime industry, Germany) observed that nearly half the seamen on-board of German vessels will come down with diseases of the upper respiratory tract. A potential relationship between these diseases and air-conditioning systems (AC) was assumed.

With support from the BG-Institute for Occupational Safety and Health of the German Social Accident Insurance in Sankt Augustin, Germany, the See-Berufsgenossenschaft started a pilot study to analyse the hygienic quality of indoor air on seagoing vessels. To this end, the presence of microorganisms in the air at the work site and living quarters on ships and their distribution by AC was determined. Investigations were conducted under different climatic conditions and on different types of vessels. Interim results will be presented below.

MATERIAL AND METHODS

Air samples were taken on-site on 16 ships: six ferries, five container vessels and five bulk carriers. On each vessel, the following sampling sites were chosen: the wheelhouse, the mess room, a crew cabin and the engine control room. Outside air was used as reference.

Air was sampled by filtration and by impaction (1,2). By impaction, microorganisms of the airflow were directly collected on sterile agar plates, while by filtration microorganisms were captured on filters, which were transferred to sterile media.

Microorganisms were cultivated on special media and incubated at 25°C (fungi) or at 30°C (bacteria), so that cell numbers of potential bacteria and fungi could be enumerated (1,2).

Parallel to air sampling, filter layers of AC were examined for the occurrence of bacteria and fungi.

RESULTS

Which group of microorganisms dominates ?

Cell numbers of bacteria varied from 14 to 1800 cfu/m³ air and cell numbers of fungi from 14 to 914 cfu/m³ air (Table 1). Compared to fungi, bacteria showed the

highest cell counts, mean value and median. Consequently bacteria tended to dominate the indoor air on seagoing vessels. Due to low contents, fungi were not represented in the following tables.

Table 1: Analysis of air samples taken on 16 vessels

	minimum (cfu/m³ air)	maximum (cfu/m³ air)	mean value (cfu/m³ air)	median (cfu/m³ air)
Bacteria	14	1800	216	86
Fungi	14	914	37	14

cfu/m³ air – colony forming units per m³ air

Are there any differences between sampling sites ?

In Table 2, the different sampling sites are compared with regard to their content of bacteria. The median of enumerations of 16 vessels is shown.

The lowest cell numbers were detected in the outside air and in the air of the engine control room. Obviously, crew cabins contained more bacteria than the other sampling sites. Furthermore, there was no difference between inhabited and uninhabited cabins.

Table 2: Bacteria counts at different sampling sites

sampling site	Median (cfu /m³ air)
outside air	25
Wheelhouse	57
mess room	57
engine control room	29
cabin (inhabited)	282
cabin (uninhabited)	219

cfu/m³ air – colony forming units per m³ air

Do any differences between types of vessels exist ?

In Table 3, the median is shown of bacteria counts at different sampling sites on ferries, container vessels and bulk carriers. The largest cell counts were determined in the air of crew cabins, especially on container vessels in worldwide operation. In addition, mess rooms of bulk carriers showed high cell numbers. Consequently an inter-relation between the type of vessel, the route of the voyage and the quality of indoor air could be suggested.

Table 3: Bacteria counts on different types of vessels

sampling site	ferries (cfu/m³ air)	Container vessels (cfu/m³ air)	bulk carriers (cfu/m³ air)
outside air	20	44	108
wheelhouse	58	88	68
mess room	86	60	272
cabin	236	587	188
engine control room	30	72	56

cfu/m³ air – colony forming units per m³ air

What could be the reason for the large bacteria contents in indoor air ?

Parallel to air sampling, filter layers of AC were examined for the occurrence of bacteria and fungi (Table 4). Similar to indoor air, more bacteria than fungi were enumerated. As a result, air conditioning filters seemed to be the source of large bacteria contents in indoor air.

Table 4: The count of bacteria and fungi on filter layers of the AC

Bacteria (cfu/g filter)	Fungi (cfu/g filter)
1200	266
1333	133
1214953	220238
7333	1333
46667	25167
851851	740
5722	222
3666	400
3833	267

cfu/g filter – colony forming units per g filter

Which bacteria species were found ?

Colonies of bacteria, which occurred frequently, were isolated from agar plates and cultivated as pure culture. Afterwards strains were identified physiologically (3). Beside common airborne species like *Micrococcus luteus* and *Micrococcus lylae*, pathogens such as *Staphylococcus aureus*, *Staphylococcus epidermidis, Pseudomonas aeruginosa, Pseudomonas stutzerii* and *Aeromonas hydrophila* were detected. Their distribution by AC could not be excluded.

DISCUSSION AND CONCLUSIONS

The interim results of our study showed that bacteria dominated in indoor air on seagoing vessels. In contrast, more fungi than bacteria were found in outside air ashore (4). Furthermore, highest cell numbers of bacteria occurred in crew cabins, especially on container vessels in worldwide operation. A relationship between type of vessel, the route of the voyage and quality of indoor air was assumed.

Up to now, hygienic air quality of seagoing vessels has not been analysed. Investigations in automobiles and mass transport buses demonstrated an impact by AC on the quality of indoor air (5,6,7,8). Moulds were detected in the indoor air of automobiles (7). The inside air of buses contained high levels of bacteria (8).

Upper respiratory symptoms occurred concurrently with air conditioning (9,10). Especially in artificially ventilated office buildings, an increase of work related respiratory diseases was observed (11,12,13). A relationship between these diseases and the distribution of airborne microorganisms by AC was suggested (9,10).

Kodama and McGee (14) compared the airborne microbial community of naturally and artificially ventilated Hawaiian homes. While there was no significant difference in quality and quantity of microorganisms between outside and indoor air of naturally ventilated houses, larger cell numbers of bacteria and Gram positive cocci occurred in air-conditioned residences.

Based on analyses of filter layers of AC on seagoing vessels, it could be supposed that airborne bacteria increased on filter materials and were afterwards distributed by air flow. Moritz et al. described that bacteria proliferated on air filters and were subsequently released into the AC of an office building (15). In a review by the International Centre for Indoor Environment and Energy in Denmark, a relationship between used ventilation filters and air quality was suggested (16). Loaded particle filters seemed to have an adverse impact on indoor air.

In our study, pathogens were identified in addition to common airborne bacteria. Especially the species *Pseudomonas aeruginosa*, *Pseudomonas stutzeri* and *Staphylococcus aureus* are frequently associated with infections of the respiratory tracts in humans (17), while *Pseudomonas aeruginosa* is known to cause pneumonia (3,17).

Our results indicated strong evidence that the air-conditioning system impacts on the hygienic quality of indoor air on seagoing vessels. Proper maintenance of the AC thus appears to be essential.

REFERENCES

1. BGIA-Arbeitsmappe - Messung von Gefahrstoffen. Verfahren zur Bestimmung der Schimmelpilzkonzentration in der Luft am Arbeitsplatz. Kennziffer 9420. Erich Schmidt Verlag Bielefeld, 30. Lfg. IV/2003. www.bia-arbeitsmappedigital.de/9420
2. BGIA-Arbeitsmappe – Messung von Gefahrstoffen. Verfahren zur Bestimmung der Bakterienkonzentration in der Luft am Arbeitplatz. Kennziffer 9430. Erich Schmidt Verlag Bielefeld, 32. Lfg. IV/2004. www.bia-arbeitsmappedigital.de/9430
3. Brock Biology of Microorganisms. Madigan MT, Martinko JM & Parker J. 10th edition 2003. Pearson Education LTD., London. 1019 p.
4. Innenraum-Arbeitsplätze – Vorgehensempfehlung für die Ermittlungen zum Arbeitsumfeld. Report der gewerblichen Berufsgenossenschaften, der Unfallversicherungsträger der öffentlichen Hand und des Berufsgenossenschaftlichen Instituts für Arbeitsschutz – BGIA, 2nd edition, Hauptverband der gewerblichen Berufsgenossenschaften, Sankt Augustin, 2005, 263.
5. Rose LJ, Simmons RB, Crow SA & Ahearn DG. Volatile organic compounds associated with microbial growth in automobile air conditioning systems. Curr Microbiol 2000; 41(3); 206-9.
6. Simmons RB, Rose LJ, Crow SA & Ahearn DG. The occurrence and persistence of mixed biofilms in automobile air conditioning systems. Curr Microbiol 1999; 39(3); 141-5.
7. Kumar P, Lopez M, Fan W, Cambre K & Elston RC. Mold contamination of automobile air conditioner systems. Ann Allergy 1990; 64; 174-7.
8. Luksamijarulkul P, Arunchai N, Luksamijarulkul S & Kaewboonchoo O. Improving microbial air quality in air-conditioned mass transport buses by opening the bus exhaust ventilation fans. Southeast Asian J Trop Med Public Health 2005; 36(4); 1032-8.
9. Parat S, Perdix A & Baconnier P. Relationships between air conditioning, airborne microorganisms and health (in French). Bull Acad Natl Med 1999; 183(2); 327-42.
10. Rossi GL, Corsico A, Roggeri A & Moscato G. Human health and air conditioning systems. G Ital Med Lav 1991; 13(1-6); 51-4.
11. Graudenz GS, Kalil J, Saldiva PH, Latorre MR & Morato-Castro FF. Decreased respiratory symptoms after intervention in artificially ventilated offices in Sao Paulo, Brasil. Chest 2004; 125(1); 326-9.

12. Graudenz GS, Oliveira CH, Tribess A, Mendes C, Latorre MR et al.. Association of air-conditioning with respiratory symptoms in office workers in tropical climate. Indoor Air 2005; 15(1); 62-6.
13. Graudenz GS, Kalil J, Saldiva PH, Gambale W, Latorre MR et al.. Upper respiratory symptoms associated with aging of the ventilation system in artificially ventilated offices in Sao Paulo, Brazil. Chest 2002; 122(2); 729-35.
14. Kodama AM & McGee RI. Airborne microbial contaminants in indoor environments. Naturally ventilated and air-conditioned homes. Arch Envrion Health 1986; 41(5); 306-11.
15. Moritz M, Peters H, Nipko B & Ruden H. Capability of air filters to retain airborne bacteria and molds in heating, ventilating and air-conditioning (HVAC) systems. Int J Hyg Envrion Health 2001; 203(5-6); 401-9.
16. Clausen G. Ventilation filters and indoor air quality: a review of research from the International Centre for Indoor Environment and Energy. Indoor Air 2004; 14; 202-7.
17. Medizinische Mikrobiologie und Infektiologie. 5th edition. Hahn H, Falke D, Kaufmann SHE & Ullmann U. Springer-Verlag Berlin Heidelberg 2005. 1050 p.