Multidisciplinary approach in risk assessment of office buildings with indoor air problems

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SUMMARY
Indoor air of high quality does not cause health hazards or discomfort. In many buildings, workers suffer from building-related symptoms associated with exceptional exposures. Solution of indoor air problems requires co-operation of an employer, users of the building, occupational safety personnel and representatives of property management, building maintenance personnel, indoor air experts and occupational health care. Organized indoor air group (IAG) with representatives of all interested parties is useful tool in solving complicated indoor air problems. Each member of this group has his/her own role in contributing to successful outcome of the process. IAG is a forum for equal communication and distribution of information, decision making, and supervising the process. An indoor air expert is often used as a consultant to ensure that comprehensive risk assessment by multi professional group will be made. Preliminary assessment of the nature of indoor air problems determines what kind of expertise is needed.

KEYWORDS
building, multi professional co-operation, indoor air group, risk assessment

1 INTRODUCTION
Indoor air of high quality does not cause health hazards or discomfort, and ventilation is a crucial factor in maintaining air quality high (Seppänen and Fisk 2004). There are buildings, however, where workers suffer from building-related symptoms associated with exceptional exposures. Earlier, mostly employers ordered expert services to measure some exposing agents, like microbes or man-made vitreous fibers what they thought to be relevant. In best cases, this led in fixing one problem, but left several other unsolved. Also, many contributing factors affecting the consequences of the problem were ignored. We know now that the ventilation greatly affects the concentrations of chemical and microbial exposures in water-damaged buildings (Godish 1989). We are also aware of the fact that detection of microbial damages in a building does not lead to appropriate remedial actions unless the cause of moisture stress to the structures is defined. Complex nature of indoor air problems requires wide viewing angle and multidisciplinary approach. Conditions for solution of complicated indoor air problems are seamless in-workplace teamwork of different interested parties and multi professional co-operation conducted by a consultant. These procedures were applied in an office building having serious indoor air problems. The objective is to evaluate the usefulness of this approach.
2 METHODS

Process of indoor air problem solving often starts by workers' complaints about the poor quality of workplace air. Minor technical problems can be solved by the intervention of building maintenance personnel. Occurrence of irritation symptoms, recurrent infections or allergies requires the involvement of occupational health care. In case there is exceptionally high prevalence of building-related symptoms, situation is usually prolonged and atmosphere at the workplace is deteriorated. Gathering of an indoor air group (IAG) at workplace may help in dealing with complicated indoor air problems (Figure 1). It is recommended that IAG includes representatives of all interested parties: an employer, users of the building, occupational safety personnel, property management, building maintenance personnel, occupational health care, and an indoor air expert.

Figure 1. Operations model for complicated indoor air problems (Lahtinen et al. 2008).

Multi professional indoor air survey

The indoor air expert as a member of IAG ensures that on-site building assessment includes all the necessary elements. ACGIH (1999) has recommended outline of an investigation strategy for buildings with bioaerosol problems. That procedure is applicable to other indoor air problems as well. The steps in risk assessment include: 1) gathering of background information about building (year of construction, frame material, thermal insulation, risk constructions, basic data of ventilation, observed water leakages and moisture or mold problems etc.) and about people's experiences (perceived air quality and building-related symptoms), 2) preliminary evaluation consists of walk-through survey of the building and collection of data with measuring devices (detection of moisture structures, indoor air temperature and relative humidity) as well as making visual observations (staining or peeling of surface materials), and 3) comprehensive survey is based on hypothesis constructed from background information and the results of preliminary evaluation, and consists of structural engineering survey, ventilation engineering survey, exposure assessment including the source recognition of microbes, chemicals and fibres.
Assessment of exposing agents is done by source sampling, but more accurate risk assessment is done by surface or air sampling. Most common exceptional exposures and their sources are:

- microbes (moisture damaged structures, more rarely ventilation system)
- mites (moisture damaged structures)
- endotoxin (flood of sewage water)
- allergens (mite or fungal allergens from moisture damaged structures)
- asbestos (old pipe insulation or carpet glues)
- mineral fibres (acoustic insulation of ventilation system or indoor surfaces, or thermal insulation)
- volatile organic compounds (VOCs) (deterioration of plastic carpets because of alkaline moisture)
- formaldehyde (old materials)
- polycyclic aromatic hydrocarbons (old elastic patties)

In risk assessment all the factors of prioritization index described by Kujanpää et al. (2006) are also used. The recommendations are based on the risk assessment combining structural and ventilation engineering with exceptional exposures and subsequent symptoms.

3 CASE REPORT
In our case, a senior indoor air expert and a construction engineer worked as a team attending the meetings of IAG three times, and being in charge of on-site building surveys.

Background information
This office-building has four stories and a basement. Walls are concrete sandwich elements with mineral wool as thermal insulation. Building has a flat roof with roof felt. Mechanical ventilation system has been cleaned and adjusted in 2008. The building has a history of water leakages from the roof. Information of perceived indoor air quality and building related symptoms has been gathered twice, in 2009 and in 2011, using indoor air questionnaire. The results suggest a severe indoor air problem. Situation is difficult especially on 3rd and 4th floors, where more than half of the employees have building-related symptoms. The prevalence of symptoms has doubled during the last year. The profile of the symptoms has changed: cough, joint pain and fever are more common than before, especially among the employees on the 3rd floor. The employees also complained about stuffiness of indoor air and from exceptional odours.

Preliminary evaluation
In walk-through survey, roof seemed intact, exterior wall tiles were partly fallen off, and element seams were open widely in several places, especially on 3rd and 4th floor. Windows were original and air leakages were detected from window-wall joints, as well as from element seams. Expansion joints were open up to insulation space. Ceilings of 3rd and 4th floor were discoloured because of water leakages from the roof and drains. Plaster and paint was peeled off here and there. No exceptional moisture was detected in any construction. Mineral wool was used on suspended ceilings in corridors to improve acoustics. Deteriorated plastic carpets had been replaced by new ones in two upper floor offices where strong odour was detected. Although ventilation ducts were recently cleaned, there was visible dust on the bottom of the ducts. Uncoated mineral wool was used as acoustic insulation in ventilation system. Hollows in concrete slab in ceilings act as air ducts. Offices were underpressurized compared with outdoor air and with corridors.
**Comprehensive survey**

Air, surface and material samples were taken to analyses for microbes, VOCs and fibres. Samples from settled dust on horizontal surfaces were taken for composition analysis. Microbes indicating water-damage (*Aspergillus (A.) niger*, *A. ochraceus*, *A. penicillioides*, *A. versicolor*, *Chaetomium*, *Oidiodendron*, *Ulocladium* and *Streptomyces*) were found in air, on surfaces as well as in materials. Microbiological damages were found in insulation space of outer walls, expansion joints, ceiling, and in ventilation chamber. Microbes were detected to have transported from damaged materials onto walls in offices, on suspended ceilings and ventilation ducts. On the 3rd floor airborne fungal spore concentrations were highest, up to 1500 cfu/m³, on other floors they were at normal office level.

VOC concentrations in air and emissions from carpet samples were low.

Exceptional amount of fibres were found on horizontal surfaces in offices, although fibres were found in ventilation system within normal range.

**Risk assessment and recommendations**

In this building, both the quality and the quantity of microbes were exceptional. Many microbes detected are potential toxin-producers. Exposure to microbes, their metabolites or toxins may cause e.g. irritation symptoms, increased frequency of respiratory infections or even allergies. Certain parts of the ceilings and their insulation materials are mould-damaged. Outer wall constructions, especially insulation materials near expansion joints, are mould-damaged. These structures have to be opened to remove all damaged materials.

All element seams and expansion joints have old patties that have lost their elasticity, and have to be renewed. Also other routes for uncontrollable air leakage have to be sealed in order to prevent the transport of microbes or microbial impurities into indoor air.

Settled dust in offices contained concrete dust, mineral fibres and exceptional microbes. Exposure to any of these may cause irritation symptoms. Dust and microbes accumulated on suspended ceilings are transported with air currents to indoor air. They have to be vacuum cleaned or to be replaced by new ones. Uncoated acoustic insulation materials in ventilation system are sources of mineral fibres found on interior surfaces, and they have to be replaced by coated mineral wool. Ventilation ducts are source of dust and fibres, but not microbes. Because hollows in concrete slab are used as ducts for incoming air, impurities including concrete dust are transferred to indoor air. Ventilation system is old-fashioned, unbalanced, and does not fulfil the criteria of present regulations, thus it has to be renovated thoroughly.

Simultaneous exposure to several impurities may enhance the health consequences, thus it is important to eliminate all the causes of water-damages as well as the sources of different particulate impurities.

**4 DISCUSSION**

Risk assessment has earlier often been based on detection of only a few exposing agents, like microbes (ACGIH 1999) or man-made vitreous fibers. Nowadays, awareness of the complex nature on indoor air problems requires wider viewing angle and multidisciplinary approach.

We highly recommend the multidisciplinary survey comprehending the following components: on-site assessment, symptom survey, technostructural survey, ventilation survey, microbiological measurements and analyses, chemical measurements and analyses, antibody analyses and work group consultation.

Information obtained in the survey is used to improve working conditions by, for example, planning and executing structural renovations. This also reduces the building-related
symptoms and occupational diseases caused by impurities, and improves well-being and productivity at work.

5 CONCLUSIONS
Successful solution of indoor air problems at work place calls for open-minded co-operation of an employer, users of the building, occupational safety personnel, a representative of property management, building maintenance personnel, indoor air experts and occupational health care. IAG helps in dealing with complicated indoor air problems and ensures sufficient communication on each phase of the process. The experienced indoor air expert as a member of IAG ensures that on-site building assessment is made by relevant professional skills.

Multidisciplinary team is capable of diagnosing structural moisture damage, evaluating the qualitative and quantitative exposure to impurities and making preliminary assessment of the functioning of ventilation system. The content of on-site building surveys can be custom-tailored to each building’s specific needs. Advantage of multidisciplinary approach is that different aspects of indoor air problem are simultaneously taken into consideration.

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6 REFERENCES