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Health complaints and annoyances after moving into a new office building: A multidisciplinary approach including analysis of questionnaires, air and house dust samples

Hans-Peter Hutter[a,*], Hanns Moshammer[a], Peter Wallner[b], Bernhard Damberger[c], Peter Tappler[c,d], Michael Kundi[a]

[a]*Institute of Environmental Health, Center for Public Health, Medical University of Vienna, Kinderspitalgasse 15, 1095 Vienna, Austria*
[b]*Medicine and Environmental Protection, Vienna, Austria*
[c]*Austrian Institute for Ecological Buildings, Austria*
[d]*Center for Architecture, Construction and Environment, Danube University Krems, Austria*

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Abstract

After moving into a new office building, employees complained about eye irritations, sore throats and unspecific symptoms. They were concerned about visible dust as a potential cause of adverse health effects. An external working group was appointed to investigate indoor air pollution and health complaints and to suggest measures to improve the situation.

Air samples and floor dust samples for analysis of organic compounds were collected in three offices. Bimonthly during 8 months, measurement campaigns were conducted to assess the trend of air pollutants. A questionnaire was administered concerning environmental conditions at the work place and complaints before and after moving into the new office building.

Overall the concentrations of volatile organic compounds (VOC) and formaldehyde were fairly low. However, initially high concentrations (4300–7800 mg/kg) of tris-(2-butoxyethyl)-phosphate (TBEP) and diethylhexylphthalate (DEHP: 980—3000 mg/kg) were found in dust samples. The coating of the rubber floor was identified as the source of TBEP, while no single predominant source of DEHP was found.

Results of the questionnaire demonstrated an increased irritation of the mucous membranes and a reduction of well-being after the employees had moved into the new building. Perception of low relative humidity and high temperature as well as unpleasant odors were associated with respiratory complaints.

After removal of the coating of the rubber floor throughout the whole building, a reduction up to 90% of TBEP in the dust samples was found. In spite of several attempts, no such marked reduction was achieved with the concentration of phthalates.

Although there was no significant association between visible dust exposure and increase of complaints after moving in, room climate conditions that could increase the deposition of dust in the airways were associated with the

*Corresponding author. Tel.: +43 1 4277 64727; fax: +43 1 4277 9647.
E-mail address: hans-peter.hutter@univie.ac.at (H.-P. Hutter).

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complaints. Hence it cannot be ruled out that fine dust containing TBEP together with unfavorable indoor factors were responsible for the development of the complaints.

Keywords: Building related symptoms; House dust; Questionnaire; TBEP; DEHP

Introduction

After the construction of a new office building the employees of a large hospital moved in successively during a period of several months. Although employees participated in the selection of furniture and equipment, and despite improvements concerning comfort and space compared to the former offices, complaints were reported to the occupational physician and workers' council soon after moving in.

These complaints concerned dust, bad smells, room climate, and health problems. There were observations of a white powdery dust that stuck to shoes, garments and furniture, and that continued to occur despite daily wet cleaning. With respect to health complaints, particularly irritation of eyes, nose and throat were reported.

Employees were concerned about adverse health effects. Mistrust of the employees in the management initially hampered the assessment of the problem and endeavors to find a solution.

In a coordinated and cooperative initiative delegates of the employees, workers' council, management, occupational and environmental health specialists and measurement technicians, aimed at a solution based on (additional) measurements and investigations.

Materials and methods

Visual inspection

Initially the building, including the ventilation system, was scrutinized by a team consisting of occupational and environmental medicine experts and technicians. During For this inspection the rooms where measurements should take place were chosen. Additionally, personal interviews with employees working in different parts of the building were conducted to examine the general pattern of complaints. This information was used to design a questionnaire that was delivered to all employees.

Because of the unspecific character of symptoms reported and no characteristic odors perceived upon inspection, it was decided to analyze common indoor air pollutants (volatile organic compounds (VOC), formaldehyde) and to conduct a screening of house dust samples. After first results were obtained, samples of all surface materials were taken to identify the source(s) of the increased concentrations.

Measurements of indoor air pollutants

All rooms were furnished equally. Therefore samples were taken from each of three types of offices (two to four workplaces per room). In these rooms air samples as well as dust samples were taken in the morning, before office hours. Bimonthly during eight months, measurement campaigns were conducted to assess the trend of air pollutants.

VOC air samples were taken by using adsorption tubes containing a special activated charcoal (SKC, Anasorb 747). Sample flow rates were about 2 l/min. VOC were extracted from activated carbon with 1 ml of CS_2 and analyzed by gas chromatography/mass spectrometry (Shimadzu QP 5000), using a 60 m fused silica capillary column (HP-VOC) following the Austrian Standard ÖNORM M 5700-2, proposal (Austrian Standard Institute, 2002). Fifty target VOC were selected for analysis. As internal standards cyclooctane and toluene-d8 were used.

Formaldehyde was measured using active air sampling in accordance with the German Standard VDI 4300 part 3E (VDI, 1997), followed by application of the acetylacetone photometric method (Austrian Standard Institute, 1995).

Analysis of house dust and assessment of sources of exposure

House dust samples were taken after 1 week of sedimentation without wet and vacuum cleaning. Samples were collected by using a vacuum cleaner with an inserted particle filter. House dust samples were tested four times during a period of eight months (measurements 3 and 4 were conducted after removal of the floor coating and wet cleaning). Samples were analyzed for semivolatile to nonvolatile organic compounds (55 biocides including PCP, lindane and pyrethroids, phthalates and trisphosphates, PAHs, and polychlorinated biphenyls). Dust samples were sieved (pore size 2 mm) and weighed out into 50 ml graduated flasks. Extraction was performed using *n*-hexane (10 ml) and a preliminary purification step (silicagel, SPE). Aliquots of the extract were analyzed by capillary gas chromatography with an electron-capture-detector/

flame-ionization-detector (GC/ECD/FID). α-HCH and 2,4,6-tribromphenol served as internal standards for quantification.

Specimen of wall-papers, the extended ceiling, curtains, rubber floor tiles and coating were taken and analyzed for the same substances found in house dust samples. The materials (rubber floor tiles, etc.) were reduced into small pieces and homogenized. Afterwards the samples underwent the analytical procedure mentioned above. Additionally, material safety data sheets of coating and of all cleaning agents, which were used in the office building, were checked for trisphosphates and phthalates.

Questionnaire

The questionnaire consisted of three parts: items about the environmental conditions in the room the subject occupied; questions about symptoms (respiratory symptoms and unspecific ones like headaches, fatigue, etc.) before and after moving in, spells of illness during this period, and earlier chronic diseases (allergies and asthma); the third part was about proposals and suggestions for improving working and environmental conditions. Additionally, socio-demographic data were collected.

Statistical analysis

Comparison of the symptoms before and after moving in were done by sign tests and McNemar tests. To determine the contribution of the evaluation of environmental factors by employees to the symptoms after moving in, and for the change in these reported symptoms, a score was computed for all respiratory symptoms as well as for unspecific symptoms. This score was area transformed to obtain normal distribution. Scores were subjected to regression analyses with room temperature, humidity, draught, visible dust, bad smells, environmental tobacco smoke and sex and age as predictors. For all statistical tests a p-value below 0.05 was considered significant.

Results

Indoor air pollutants and dust samples

Formaldehyde levels were 0.046, 0.047 and 0.051 ppm in the three rooms selected initially. Total VOC levels ranged from 360 to 740 $\mu g/m^3$. In dust samples initially high levels of tris(2-butoxyethyl) phosphate (TBEP) (4300–7800 mg/kg) were detected. The coating of the floor tiles was identified as the source of TBEP: the product used for coating the floor contained 10 g TBEP/kg.

Table 1. Concentrations of diethylhexylphthalate and TRIS(2-butoxyethyl)phosphate (TBEP) in dust floor samples (average of three rooms) over the 8-month period (in mg/kg dust)

Measurements	Diethylhexylphthalate	TRIS(2-butoxyethyl) phosphate (TBEP)
1 (February)	3000	4300
2 (April)	980	7800
3 (July)*	2800	410
4 (October)*	790	90

*Measurements 3 and 4: conducted after removal of the floor coating and wet cleaning.

Furthermore, in areas of heavy use of the floor, floor coating caused visible and atypically high amounts of dust. After removing the coating, dust concentration of TBEP was reduced to an average of 410 mg/kg and after another three months to 90 mg/kg (Table 1). Diethylexylphthalate (DEHP) was also found in considerable amounts of 980–3000 mg/kg. DEHP was identified in PVC material used for floor ledges. Despite removal of this material, dust concentration of DEHP declined only slightly (Table 1).

All other compounds (semivolatile to nonvolatile organic compounds including PCP, lindane and pyrethroids, PAHs, and polychlorinated biphenyls) were below the limit of detection.

Questionnaire

Overall 65 subjects returned the questionnaire (63% of employees in the new building). Distribution of respondents did not deviate considerably from the total work force with respect to age, sex and occupational categories of the work force.

Upper and lower respiratory tract diseases did not increase significantly after moving into the new building. However, symptoms of irritation (sore throat, burning eyes, dry nose) as well as unspecific symptoms (tiredness, exhaustion, headaches, decreased alertness) showed marked and significant increases.

Room climate was rated uncomfortable by approximately half of the employees (in particular humidity and air velocity), and by about 20% concerning air temperature. Air quality was described as stale and odors as annoying. More than half of the employees rated visible dust as a nuisance.

Regression analysis revealed a significant influence of humidity, high temperature and a tendency for smoking in office rooms on the increase of respiratory symptoms. No influence of visible dust but a tendency for bad smells on increase in unspecific symptoms was noted.

Discussion

Overall the concentrations of total VOC and formaldehyde were fairly low. The highest values of formaldehyde were about 0.05 ppm, the WHO level of no concern (WHO, 1983). VOC levels were within interquartile range of those in a random sample of Viennese households (Hutter et al., 2003). Comparatively high levels of TBEP and DEHP were found in dust samples. The expert group advised removal of rubber coatings and floor tiles as well as frequent wet cleaning of the surfaces. During the following 4 months after this intervention, complaints at the worker's council were drastically reduced.

Organophosphate esters are frequently applied as flame retardants and softeners in building products and other materials for indoor use. They can be found in house dust and indoor air. In our study, TBEP concentration in dust was rather high (Hansen et al., 2000; Federal Environmental Agency, 1998), but could be reduced significantly by removing the floor coating.

In the German Environmental Survey (Federal Environmental Agency, 1998) house dust specimens were also analyzed for phthalates. Diethylhexylphthalate had a median concentration of 416 mg/kg and a 90 percentile of 978 mg/kg, maximum was 7530 mg/kg. Concentrations measured in our study in the dust of offices were in the upper range of the distribution obtained in households (980–3000 mg/kg). Although one source of phthalates had been detected and removed, concentration did not decline significantly. This points to the broad range of usage of phthalates in materials used in the office environment. Furthermore, it shows the limitation of interventions because of the widespread usage of phthalates (Moriske, 2004).

More attention should be dedicated to the coating of floors, particularly those in constant use and to the concentrations of TBEP and other organophosphate esters in offices.

Subjective symptoms could not be attributed to visible dust. Strongest relationship to increase of symptoms after moving in was observed for dry air. Whether these symptoms were due to psychological factors associating the unpleasant feelings with visible and communicable factors like the odd occurrence of a white powdery dust or to irritation by contents of the dust cannot be firmly established. Although there was no significant association between visible dust exposure and increase of complaints after moving in, room climate conditions that could increase the deposition of dust in the airways were associated with the complaints. In fact, TBEP has not been associated with irritation upon inhalation; however, skin reactions can be produced by prolonged exposure to flame retardants (WHO, 2000). For phthalates only few investigations addressed respiratory effects (Hollund, 2001; Hoppin et al., 2004). The problem in these studies is associated with the fast metabolism of these substances while the respiratory effects seem to need some time to build up.

According to our experience we further emphasize the importance of early involvement of the employees and thorough information concerning the planned interventions. In this study, employees were informed about measurement campaigns as well as measures recommended at each step of the procedure. This led to a strong decrease of complaints to the worker's council.

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