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A case of indoor air pollution of ammonia emitted from concrete in a newly built office in Beijing

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ABSTRACT

A case of suspected indoor ammonia contamination from concrete was investigated in an airline company office in Beijing. A standardized questionnaire on indoor environment perceptions, medical symptoms and psychosocial work environment was distributed to all staff, and compared with a reference group of office workers from the same company in Stockholm. Temperature, relative humidity, formaldehyde, volatile organic compounds (VOC), ammonia, and carbon dioxide were measured both in Beijing and Stockholm. In Beijing mould and bacteria were also measured. Totally 95% ($N = 14$) participated. The Beijing staff reported a higher rate of complaints regarding poor work satisfaction, and work stress as compared to the Stockholm reference group. In the total material ($N = 203$) the psychosocial environment was related to general symptoms (headache and tiredness) but not odour perception or mucous membrane symptoms. Controlling for age, smoking habits, and psychosocial work environment the Beijing staff had more complaints on unpleasant odour and mucous membrane symptoms. An increased indoor concentration of ammonia (3–6 ppm) and benzene (26.8 $\mu g/m^3$) was measured in the indoor air in the Beijing office, as compared to the office in Stockholm (<0.1 ppm ammonia and 0.4 $\mu g/m^3$ benzene). The ammonia contamination in the Beijing office was confirmed, the probable source being additives in the concrete. The ammonia level was well below the Swedish threshold limit values (TLV) (25 ppm). In addition the exposure to benzene, an indicator of traffic exhaust pollution was high both indoors and outdoors in Beijing, possible related to increased levels of odour complaints and mucous membrane irritation.

1. Introduction

Chemical emissions may cause indoor air pollution leading to odour perception and mucosa membrane irritation. A relation between indoor volatile organic compounds (VOC) and medical symptoms has been shown in some cross-sectional studies [1,2], in case studies [3,4], and in a follow-up study [5]. The levels of different VOC concentrations may differ between Sweden and Asia [6]. However, there s little information the significance of inorganic volatile compounds for symptoms and environmental perceptions in the indoor environment.

One recent study from Japan has shown that ammonia and VOC can be emitted from concrete, the source of ammonia being amine additives. It was concluded that these compounds might lead to decalcification of the cement concrete [7]. Chinese building constructors add an additive urea-based mixture to concrete in the wintertime in order to influence the freezing point of the water and accelerate the hydration rate. This can cause a smell of ammonia indoors, which takes a very long time to disappear [8]. One field study has been performed in China on indoor air pollution of ammonia from concrete [9].

In north Europe, there has been concern about indoor ammonia and possible health effects [5], due to different reasons. During the 1980s there were cases of smell of ammonia in new buildings, the reason being that casein in floor putty decomposes to ammonia by means of microbial processes in the presence of humidity at the high pH encountered in concrete [10]. In geriatric hospitals with such dampness in the floor construction, the level of ammonia under the floor coating was 3 ppm, while comparable dry buildings had low ammonia levels (<0.5 ppm) [11]. During the 1990s, there were occasional problems with exposure of ammonia in newly water-based painted buildings. Ammonia was used to stabilize the binder and the paint at a pH of 8–9 [12,13].

In 2004, staff from a Swedish airline ticket office in Beijing reported smell of ammonia and irritative symptoms to the occupational health services of the company. The office was situated on

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18th floor in a newly built upper part of the office building. This initiated a study to evaluate possible causes of these indoor environmental problems. A combination of indoor and outdoor technical measurements and a questionnaire survey was used, comparing with an external reference group from the same company, applying multiple regression analysis to control for confounding by personal factors and psychosocial work environment. The main aim was to study the pattern of complaints and symptoms in the exposed group in Beijing, compare exposure and perceptions with the referenced group, and evaluate if it was likely or unlikely that ammonia emissions from the concrete was the cause of the problems.

2. Subjects and methods

2.1. Questionnaire study

To study medical symptoms, and perception of indoor air quality, a standardized questionnaire was distributed in May–June 2004 to all employees on duty in a Beijing city center office (14 participants), and to all employees on duty in an office in a suburban area of Stockholm (189 participants). The questionnaire has been developed by the Department of Occupational and Environmental Medicine in Örebro [14]. It has been used in many previous studies in Sweden (MM 040 NA). Participation was voluntary and the staff gave their informed consent. Information on age, gender, smoking habits and hay fever was obtained from the questionnaire. Reports on the psychosocial work environment were defined in terms of work satisfaction, work stress, influence on working conditions, and social support from colleagues. There were four response alternatives for cases: "no, never = 0", "no seldom = 1", "yes, sometimes = 2", and "yes, often = 3". The values were then divided by 3, in order to obtain four psychosocial variables ranging from 0 to 1[15]. These four scores were added into one total psychosocial dissatisfaction score (0–4).

The questionnaire contained 3 questions on the perception of workplace air quality (stuffy air, dry air, and unpleasant odour), four questions on general symptoms (fatigue; feeling heavy-headed; headache; and difficulties concentrating), three questions on mucous symptoms (irritation of the eyes; irritated, stuffy or runny nose; and hoarse, dry throat), and three questions on dermal symptoms (dry or flushed facial skin; scaling/itching scalp or ears; and dry, itching hands, with red skin). For each perception and medical symptom, there were three response alternatives for cases: "no, never = 0", "yes, sometimes = 1", and "yes, often = 2" ("often" meaning every week). In each symptom category (general, mucous, dermal symptoms), subjects with at least one weekly symptom were assigned the value 1, and subject with no weekly symptom was assigned 0. A recall period of three months was used for these questions.

2.2. Measured parameters

Sampling was performed from April through June 2004 in both Beijing and Stockholm. Measurements were performed in two office rooms at each office and outside the window. Temperature, relative air humidity, and carbon dioxide (CO_2) concentration were measured by a direct reading instrument with in-built data logger (Q-Trak IAQ) monitor (TSI Incorporated, USA). Measurements of volatile organic compounds (VOC) were performed with air pumped through a charcoal filter (Anasorb 747), 250 ml/min for 4 h. Formaldehyde was measured during one week with diffusion sampler SKC UMEx100 (SKC, PA, USA), based on chemosorbtion on 2,4-dinitrophenyl hydrazine. The samplers were analyzed by liquid chromatography. Ammonia was measured with Kitagawa Precision Gas Detector Tubes (Tube No. 105SD). Airborne micro-organisms were sampled on 25 mm nucleopore filters with a pore size of 0.4 nm and a sampling rate of 2 l/min for 4 h. Moulds and bacteria were sampled during 4 h outside the window on floor 18 in two rooms. The total concentration of airborne moulds and bacteria, respectively, was determined by the CAMNEA method [16]. Viable moulds and bacteria were determined by incubation on two different media. The detection limit for viable organisms was 30 colony forming units (cfu) per m^3 of air.

2.3. Statistical analysis

Statistical analysis was performed by descriptive statistics and multiple logistic regression analysis using Statistical Package for Social Sciences (SPSS). The difference in prevalence between the office in Beijing and the office in Stockholm was determined by Fishers exact test (two-tailed). In the multiple logistic regression analysis, all office staff was grouped together. The influence of age, gender, smoking, hay fever, psychosocial dissatisfaction index (0–12) and workplace (Beijing = 1 or Stockholm = 0) on perception of indoor air quality and medical symptoms was analyzed by multiple logistic regressions. In this analysis, weekly complaints were dichotomized to value "1", and both "yes, sometimes", and "no, never" were dichotomized to a zero value. Moreover, general, mucous or dermal symptoms were assigned a value of 1 if any of each individual dichotomized medical symptom in the group had a value of 1 and all others had a zero value. Two-tailed tests and a p-value of <0.05 were considered to be statistically significant.

3. Results

Totally, 14 subjects (95%) participated in Beijing and 189 (77%) in Stockholm. Among office staff in Beijing, 86% were females, 14% were current smokers, 14% had hay fever, and the mean age was 32 year (SD = 7). In the crude analysis (Fishers exact test), there were significant differences between the two offices with respect to stuffy air, dry air and unpleasant odour, general symptoms and mucous symptoms (Table 1).

Among staff in Beijing, 30–60% of all types of individual medical symptoms were perceived as work-related. The highest proportion of work-related symptoms (60%) was found for nasal symptoms. Using the same crude analysis, significant differences were found with regard to the psychosocial work environment, including work satisfaction, work stress, and influence on working conditions, with a more unfavorable psychosocial work environment in Beijing (Table 2).

In the multiple logistic regression analysis, controlling for age, gender, smoking habits, and workplace, the psychosocial dissatisfaction index was related to general symptoms ($p < 0.001$) but not to stuffy air, dry air, unpleasant odour, mucous membrane symptoms or dermal symptom. Beijing staff reported significantly more

Table 1
Prevalence (%) of at least weekly complaints concerning different aspects of indoor air quality (IAQ) and symptoms, reported for the past three months.

Variable	Office staff in Beijing, $n = 14$ (often) %	Office staff in Stockholm, $n = 189$ (often) %	p-Values[a]
Stuffy air	71	22	0.000
Dry air	64	32	0.013
Unpleasant odour	79	9	0.000
General symptoms	79	20	0.000
Mucous symptoms	57	14	0.001
Dermal symptoms	14	16	NS

NS, no significance.
[a] Calculated by Fishers exact test (two-tailed).