

# **SBS and chemical sensitivity in residents of renovated multi-family apartment buildings**

Anita Gidlöf Gunnarsson<sup>a,b,\*</sup>, Birgitta Berglund<sup>a,b</sup>

<sup>a</sup>*Institute of Environmental Medicine, Karolinska Institute, Sweden;* <sup>b</sup>*Department of Psychology, Stockholm University, SE-106 91 Stockholm, Sweden*

## **ABSTRACT**

Current remedial actions to buildings with indoor-environmental problems do not seem to decrease efficiently residents' symptoms typical of the sick building syndrome (SBS). Apart from potentially unsuccessful renovations (cases), the cause could be that residents already have persistent symptoms due to sensitization mechanisms. The questionnaire study showed few significant differences in critical variables (e.g. SBS symptoms or indoor-environmental perceptions) between the cases and a referent random sample. In the total sample ( $n = 1622$ ), 15% fulfilled criteria for being SBS sensitive and 22% reported that they were chemically sensitive (CS). A configural frequency analysis of residents' response pattern in five variables [apartment renovation, signs of dampness in apartment, SBS sensitivity, CS and psychological susceptibility (somatization)] revealed four response patterns (types) that were significantly more frequent than that which could be attributed to chance. The results show that the co-occurrence of one of the adverse building factors of the apartment and somatization in the resident is a prerequisite for SBS and/or CS to be reported by that resident.

## **INDEX TERMS**

SBS sensitivity; Chemical sensitivity; Renovation; Psychological factors

## **INTRODUCTION**

The main causes of indoor environmental problems and of SBS include chemical and physical contaminants of indoor air and inadequacies of the ventilation system (Mendell, 1993). The primary suspected origin is dampness in concrete (e.g. Wieslander *et al.*, 1999; Bornehag *et al.*, 2001). For high levels of dampness, floorings bonded by adhesives may undergo chemical degradation giving rise to secondary emissions (e.g. Weschler *et al.*, 1992; Sjöberg, 2001). Concrete-dampness problems may, for example, be remedied by removing floorings and adhesives (in some cases the upper part of the concrete as well) and introducing other materials in installing so-called 'ventilated' floors and/or barriers that prevent dampness from affecting the bonding materials. Secondary emissions have, however, also been shown to migrate rather deep down into the concrete and permanently contaminate it (Sjöberg, 2001). Thus, new more 'permeable' floorings may allow the emissions to migrate upwards and, consequently, the emission into the air may increase and potentially worsen residents' SBS symptoms. Residents hosting general and/or transient susceptibility to physiological or psychological symptoms or symptoms of any other nature may particularly be at 'risk' for developing persistent symptoms.

In order to be able to study the effects on SBS symptoms of renovating so-called 'sick' buildings, comparable potentially 'sick' and potentially 'healthy' building areas were sought. Since remedial actions had been undertaken in the 'sick' building areas, it was predicted that the amount of time spent in these would hypothetically result in (a) less SBS symptoms because of successful removal of sources; (b) invariant SBS symptoms because of pervasive mechanism of sensitization; (c) invariant SBS symptoms because of unsuccessful remedial

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\* Corresponding author. E-mail: ago@psychology.su.se

actions; and (d) more SBS symptoms due to new symptom-aggravating sources accompanying the renovation.

The objectives of the present field study were (i) to determine prevalence of SBS sensitivity, chemical sensitivity, and allergy/asthma among residents in multi-family apartment buildings; (ii) to assess the prevalence of SBS symptoms in these three 'sensitive' groups of residents; (iii) to explore potential associations between residents' 'host' sensitivities (SBS, CS), building-related factors and psychological susceptibility (somatization).

## METHODS

During November 2000 to February 2001, a case-referent questionnaire study was conducted in the Greater Stockholm area. The selected apartment-building areas (44 cases and 44 referents) comprised 80–300 apartments, which for the cases, but not for the referents, had undergone renovation during the last 10 years. Referent areas were a random sample of the same population of apartment-building areas (size 80–300 apartments), cases excluded. For the cases, remedial actions had been undertaken because of suspected SBS or associated indoor-air problems. A majority of the renovated cases had had problems with casein-containing smoothing compounds in floors and/or damp in concrete. Remedial actions of buildings had been to install so-called 'ventilated floors' (most common), to add a floor barrier layer, and/or to adjust the building-ventilation system. No information on which apartments had actually been renovated was available. However, in the case sample, 41% of the residents subsequently reported that their apartments had been renovated as compared to 24% in the referent sample.

From each of the 44 cases and the 44 referent apartment-building areas, the Statistics Sweden created a random sample of households based on the Register of the Swedish Total Population (RTB). Only one resident (at least 18 and at most 74 years old) from each household was allowed to participate. For each apartment, one eligible respondent was selected randomly from the two or more residents who had answered the questionnaire. The questionnaire was completed by 823 out of 2003 eligible residents in the case-sample (41%), and by 799 out of 2045 in the referent-sample (39%)—altogether 1622 respondents out of 4048 eligible residents (or households). The most common reason for not participating was refusals (91 and 88% in cases & referents, respectively). An external response-loss analysis showed that women, Swedish citizenship, Sweden as country of birth and higher income groups (>SEK 159 999) were over-represented (both samples). Unmarried respondents, those aged between 25 and 34 years old, and low-income groups (SEK 0–159 999) were under-represented (both samples). For further details on the method, see Gidlöf Gunnarsson (2002).

The self-administered SBS questionnaire (postal distribution) was an adjusted version of a previously tested inventory, which had been found to be a psychometrically sound tool i.e., for identifying and diagnosing SBS sensitive and SBS non-sensitive persons (e.g. Berglund *et al.*, 2002a,b; Berglund and Zheng, 2002). The innovative part of this questionnaire is that it focuses not only on building-related factors but also on person-related factors (e.g. life-style, sensitivity and personality). Both kinds of factors are assumed to be associated with reports of physical symptoms (see e.g. Pennebaker, 1982; Berglund and Gidlöf Gunnarsson, 2000).

## Methods of Data Treatment

Chi-square tests ( $\chi^2$ ) or *t*-tests were used to determine differences in proportions of categorical variables or in mean scores of continuous variables, respectively. A stepwise screening procedure, developed in an earlier study (cf. Berglund *et al.*, 2002b) was employed for identifying SBS sensitive and SBS non-sensitive persons. Given the high power of the present analyses ( $n=1622$ ), the *p*-value was set at  $\leq 0.01$  for multiple comparisons exceeding 50

(Howell, 1992). Otherwise, the  $p$ -value was set at 0.05. All tests of significance were two-tailed. The Statistical Package for the Social Sciences was used (SPSS, 2000, version 10.0). Central to this article is a Configural Frequency Analysis (CFA) (Bergman and El Khouri, 1998) which was used to group residents according to their response value profiles. It was thus applied to test if a selected variable pattern (configuration) occurred more frequently ('type') or less frequently ('antitype') than expected by a chance model (e.g. von Eye *et al.*, 1996).

## RESULTS

### Case and Referent Samples and a Total Sample

Few significant differences in demographic, individual, life style and building-environmental variables were found between cases and referents. For the three pre-determined inclusion criteria for the cases, significantly higher frequencies were reported by the cases than the referents: building renovation (27 versus 10%; respectively,  $p < 0.001$ ), apartment renovation (41 versus 24%;  $p < 0.001$ ), and building-owner responsibility for these renovations (92 versus 79%;  $p < 0.001$ ). Although this result supports the proper choice of cases versus referents, our cases' renovations were much more infrequent and the referents' renovations more frequent than we had expected. A striking similarity between cases and referents existed as regards both the profiles of symptom prevalence and the profiles of the indoor-environmental factors. Taken together, we found this evidence convincing enough for pooling the data from the cases and referents to represent one group of residents. Therefore, all subsequent analyses were based on this total sample.

The total sample of responding residents (case and referent samples combined) consisted predominantly of women (61%). The respondents' mean age was 39 years ( $SD = 12.94$ ). More than one-third had university education or the corresponding. Roughly half lived alone with or without children. Unexpectedly many reported that they have or have had some kind of allergy (hay fever, eczema) or asthma (42%). One-third (32%; 41% of the case sample) reported apartment renovation, and 22% reported signs of dampness in their apartments.

### SBS Sensitivity

A procedure recently developed by Berglund *et al.* (2002b) made it possible to identify 242 SBS sensitive residents in the total sample, the remaining 1166 residents being SBS non-sensitive. Close to three times as many women as men were found in this identified SBS sensitive unit (73% versus 27%, respectively). Compared to the SBS non-sensitives, SBS sensitives were more likely to report general health and allergy problems, sensitivities to food or chemicals and general sensitivity to environmental factors. Moreover, the SBS sensitive unit was more dissatisfied with their building environments, indoors and outdoors, had more adverse indoor-environmental perceptions, perceived less indoor-air control, and had frequently more intentions to move to another building because of the indoor air ( $p < 0.001$ ). The apartment or its building was not reported by the SBS sensitives to have been renovated significantly more often than for the SBS non-sensitives. The only exception was that prevalence of dampness in the apartments was more frequently reported in SBS sensitives than in SBS non-sensitives.

### Chemical Sensitivity

Approximately one-third of the general population is known to self-report chemical sensitivity (CS) in questionnaire studies. There is evidence that CS is significantly associated with enhanced SBS-symptom reporting (Norbäck *et al.*, 1990; Wallace *et al.*, 1993). In the total sample, 22% reported that they were sensitive to chemical products (e.g. perfume, paints, cleaning agents, tobacco smoke, car exhaust). More women than men reported that they had

acquired CS (25% women and 16% men;  $\chi^2_2 = 24.17$ ,  $p < 0.001$ ). This figure confirms an earlier estimate of 28% made by Berglund and Zheng (2002) based on a random sample of 3424 women in the Greater Stockholm Area.

### SBS-Symptom Reporting

The residents had been asked to assess how often they had experienced each of the 14 SBS symptoms during the last 3 weeks when being in their apartments: fatigue; heavy head; headache; nausea/dizziness; difficulty in concentrating; itching/burning or irritation in eyes; irritated/stuffy or runny nose; hoarse/dry sore throat; cough; dry facial skin; dry skin on hands; flushed facial skin; irritation/peeling in scalp/ears; and itching/stinging/tight or burning sensations in face without visible rash. A 4-point category response format was used ('never/don't know', 'sometimes', 'often', or 'always'). Scale values were added to form an SBS-symptom sum-score of 'often' and 'always' responses (coded as 1, other responses and missing values were coded as 0) (Cronbach's  $\alpha = 0.86$ ,  $n = 1622$ ).

### Gender

The average number of the 14 SBS symptoms reported in the total sample differed significantly between women and men (mean = 2.66, SD = 3.12: mean = 1.64, SD = 2.61 respectively;  $t_{1591} = -6.8$ ,  $p < 0.000$ ). Except for two of the skin symptoms (irritation/peeling in scalp/ears and itching/stinging/tight or burning sensations in face without visible rash), the proportion of symptomatic residents was significantly larger for women than for men (smallest  $\chi^2_1 = 4.33$ ,  $p < 0.05$ ). Approximately twice as many women as men reported dry skin on hands, dry facial skin and headache. The top three most prevalent symptoms ( $\geq 29\%$ ) for women were fatigue, dry skin on hands and dry facial skin; for men, only fatigue reached a high frequency (31%).

### SBS sensitivity

The proportion of symptomatic residents in the total sample was significantly larger for the SBS sensitive unit than for the SBS non-sensitives (smallest  $\chi^2_1 = 73.02$ ,  $p < 0.000$ ). In SBS sensitives, symptom frequencies ranged from a low of 21% for nausea/dizziness to a high of 74% for fatigue. In SBS non-sensitives, the symptom frequencies ranged from a low of 2% for itching/stinging/tight or burning sensations in face without visible rash to a high of 35% for fatigue. The average number of the 14 SBS symptoms reported was significantly higher for SBS sensitives than SBS non-sensitives (mean = 6.27, SD = 3.53, and mean = 1.51, SD = 2.14, respectively;  $t_{1406} = 27.68$ ,  $p < 0.000$ ).

**Allergy/asthma (atopy)** Except for nausea/dizziness, the proportion of symptomatic residents in the total sample was significantly larger (smallest  $\chi^2_1 = 4.03$ ,  $p < 0.05$ ) for atopics than non-atopics, and the average number of SBS symptoms reported also differed significantly between these two groups of residents (mean = 2.79, SD = 3.15, and mean = 1.86, SD = 2.76, respectively;  $t_{1620} = 6.3$ ,  $p < 0.000$ ).

**Chemical sensitivity (CS)** The proportion of symptomatic CS residents in the total sample was significantly larger than the proportion of symptomatic non-CS residents (smallest  $\chi^2_1 = 8.28$ ,  $p < 0.05$ ). The average number of SBS symptoms reported differed significantly between CS and non-CS residents (mean = 3.46, SD = 3.52, and mean = 1.94, SD = 2.72, respectively;  $t_{1586} = 8.6$ ,  $p < 0.000$ ).

### Associations among SBS sensitivity, CS, building-related factors and somatization

An explorative CFA was applied to identify groups of persons with unique patterns of various response profiles among a selected set of five important building-related and person-related variables: apartment renovation, signs of dampness in the apartment, SBS sensitivity, CS and

psychological susceptibility (somatization). The great advantage with CFA is that it will jointly take into consideration the whole pattern of values in these variables instead of one variable at a time. Every variable was dichotomized for the total sample and each resident was then designated the scale value 1 (present) or 0 (absent) for the five variables. For every five-variable pattern the observed frequency of responding residents was compared with the expected frequency under the null hypothesis of independent variables. In total, 32 unique patterns of the set of five variables exist.

Table 1 summarizes the CFA-results for the six significant residents' patterns for which adjusted probabilities fell below 0.05 [i.e. out of 32 possible five-variable patterns, six were significant types or antitypes (four or two, respectively) after correction for statistical mass significance]. The highest frequency ( $n = 477$ ) was observed for pattern (00000). This pattern is most common (type) in the present study and characterizes those individuals who lacked both building-related (apartment renovation and signs of dampness in the apartment) and person-related variables (SBS sensitivity, CS and somatization). The CFA gave two antitypes with the two building-related variables absent. In one of these, 47 residents were *somatizers* only (00001), and in another 35 residents had CS only (00010). This particular finding indicates that patterns reflecting the presence of psychological susceptibility or CS combined with the absence of building-related factors are unlikely to occur if the independence assumption holds true. Accordingly, a small number of individuals would be expected to show these variable combinations. The most interesting finding of the CFA is that *SBS sensitivity* was only present in the two types (10111) and (01111), which each shows joint presence of one of the two *building-related factors* (apartment renovation or signs of dampness), CS and *somatization* ( $n = 26$ ). It seems logical that the remaining type that reached significance (01011) had CS (but not *SBS sensitivity*) jointly with *signs of dampness* and *somatization*. After all, earlier research has shown that damp in buildings is a cause of health problems in indoor-air environments.

**Table 1** Four types and two antitypes resulting from a CFA ( $n = 1293$ )

Pattern*	Type/ Antitype**	Observed frequency	Expected frequency	Chi-Square	Binomial probability	Adjusted probability
00000	T	477	388.53	20.15	0.0000	0.0000
00010	A	35	62.43	12.05	0.0001	0.0026
00001	A	47	79.66	13.39	0.0000	0.0011
01011	T	15	3.57	36.59	0.0000	0.0002
10111	T	10	1.58	44.72	0.0000	0.0002
01111	T	16	0.92	254.76	0.0000	0.0000

\*Position of assessed variables in pattern is given in the following order: Apartment Renovation, Signs of Dampness in the Apartment, SBS Sensitivity, CS and Somatization.

\*\*T = Type; A = Antitype.

## CONCLUSIONS

A considerable proportion of the residents studied were found to have some kind of sensitivity (allergy/asthma, CS and/or SBS sensitivity). Such sensitivities commonly accompany enhanced SBS symptom reporting, a result which agrees with earlier findings (e.g. Norbäck *et al.*, 1990; Wallace *et al.*, 1993). The result of the CFA analysis showed four significant patterns of occurrences of two building-related and three person-related variables. Three of the patterns show that building problems co-occur with SBS sensitivity or CS as well as with residents' psychological susceptibility (somatization). Moreover, in SBS sensitive residents or residents reporting CS, one of two building factors *and* psychological susceptibility has to

significantly co-occur. These findings would suggest that both SBS and CS primarily would be linked to building-related causes. Somatization may indicate that personality characteristics influence residents' responses to questionnaire questions or, alternatively, indicate the psychological consequence of being exposed to an adverse indoor environment (that is, of having acquired SBS or CS). The above conclusions are strengthened by the fact that neither apartment renovation, nor dampness in the apartment co-occurred with somatization alone.

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