



Exacerbation of chemical sensitivity: a case study

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We report exacerbation of symptoms and chemical intolerances in three of four self-described chemically sensitive women following relocation to a newly constructed office building. Levels of total volatile organic compounds (TVOCs) in this building prior to occupancy were approximately 200 $\mu\text{g}/\text{m}^3$ (toluene equivalent units) with a myriad of individual components present. By day 50 after occupancy, the concentration of TVOCs in the building dropped to approximately 50 $\mu\text{g}/\text{m}^3$. Nevertheless, three women reported significant worsening of their symptoms with spreading of their sensitivities to previously tolerated chemical exposures. One woman relocated to another building, while the other two managed their symptoms by reducing time spent in the building or by using a room air cleaner. By day 600 following occupancy, although TVOCs had increased significantly (perhaps due to cleaning agents), there were fewer individual VOCs present in the air, and some of the women were able to tolerate the air in the building. We conclude that complex mixtures of VOCs at very low levels tolerated by the majority of building occupants may pose problems for persons who report pre-existing chemical sensitivities. TVOC measurements may not correlate with symptoms in these individuals. Reasonable accommodations by an employer can reduce problem exposures, making it possible for some affected individuals to continue productive employment.

Keywords: *environmental illness, indoor air, multiple chemical sensitivity, questionnaire, volatile organic compound.*

Introduction

Multiple chemical sensitivity (MCS) is a perplexing illness of unknown etiology. We present a case study involving several women with self-reported chemical sensitivity who attributed worsening of their symptoms and sensitivities to relocation to a new office building. These individuals' chemical sensitivities began at various ages, following different types of exposures (Table 1). Because some of the women had expressed concerns about air quality in the new building prior to move-in, an industrial hygiene evaluation with air sampling was conducted both before and after occupancy. Such baseline air sampling data in a new building rarely is obtained and this is the first published case report we are aware of involving a new building with sensitive occupants who reported worsening symptoms following move-in. A standardized questionnaire was used retrospectively to help characterize and quantify the changes in symptoms and intolerances reported by the women.

The office building, a new one-story structure (now 5 years old) has multiple partitions in the center in order to increase occupant density while affording some privacy. This core is surrounded by small offices (each approximately 20 m^3). During early occupancy, nonsensitive office staff described air in the building as having a slight new construction odor that was not objectionable. The number of building occupants has varied between 170 and 200, with a preponderance of women (gender ratio of 5:3).

Methods

VOC Measurements

Standard three-stage charcoal traps were used to sorb volatile organic compounds (VOCs). From 10 to 100 l of air were sampled at rates of 200 to 1000 ml/min. VOCs were extracted with carbon disulfide and analyzed using a gas chromatograph equipped with a flame ionization detector. Peak areas were summed and expressed in toluene-equivalent units. Infrared spectral analyses of the air in selected areas were also performed. In addition, limited microbial sampling was conducted.

Questionnaire

Subjects completed the Environmental Exposure and Sensitivity Inventory (EESI), a questionnaire with demon-

1. Abbreviations: CO₂, carbon dioxide; CFU, colony forming unit; EESI, Environmental Exposure and Sensitivity Inventory; MCS, multiple chemical sensitivity; TVOC, total volatile organic compounds; VOC, volatile organic compound.

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**Table 1.** Case summaries.

Case no.	Symptoms and exposure history prior to move-in	Symptoms after move-in	Comments
1	Confusion, amnesia, difficulty concentrating, 'seizures,' cardiac arrest. Sensitivities began in early childhood. In previous work location (an older building), only fragrances affected her.	Distinct worsening of symptoms. Increased frequency of short-duration (few seconds) 'seizures,' severe asthma attacks, and burning sensation in lungs.	Initially left building; returned and was able to work in office with continuously operating air cleaning unit with charcoal/high efficiency particulate filter. Symptoms subsided with use of air cleaner. Reports severe symptoms in other new buildings.
2	Dizziness, disorientation, headaches, heartbeat irregularities. First became ill 5 years prior to occupancy while staying in a new motel room, although had experienced transient symptoms over a 35-year period in certain stores and trailers.	Severe frontal headaches with feeling of drunkenness, increased heartbeat irregularities. Lessening of symptoms with time. Worked in respirator or at home for 2 months, then without respirator for gradually longer periods of time.	After a year, was able to work normally in building. Experienced re-emergence of sensitivity problems while working part-time at another renovated office building. Increased sensitivity around vapors from copiers, fax machines, perfumes, cleaning products, and stores selling insecticides.
3	Recalls frequent contact with xylene and sensitivity to trichloroacetic acid while working in a biochemistry lab in 1960s. In 1970s became increasingly sensitive to vapors from wet-process photocopying machines, with burning sensation of facial skin, disabling headaches, and fatigue.	Unsteadiness, lightheadedness, problems with concentration and memory, irritability, and fatigue. Burning sensation in feet progressing upward toward knees, and pronounced erythema of facial skin. Unable to continue working in building after a few days. Sensitivities worsened after this short exposure.	Transferred to older building. Later worked mostly at home because of reactions to office air contaminants. Sensitivities worsened and spread. Even brief visits to the office building continued to trigger skin irritation, unsteadiness, and lightheadedness for years afterward. Currently, revisiting the building for 1 h is associated with eye irritation, but no other symptoms.
4	Frontal headaches, nausea, dizziness, vertigo. Attributes onset and exacerbation of sensitivities to home remodeling (1977-1990) and relocation to a new home (1991).	Began work in office building in August of 1995, after it was 1-year-old. No symptoms attributed to building air.	Worked in office building without difficulty except for reactions to vapors from copying machines. Outside of workplace, sensitivities worsened, with new reactions to perfumes, vehicle exhaust, petroleum and paint vapors, and air contaminants in stores selling tires, carpeting, pet supplies, and insecticides.

Exacerbation of chemical sensitivity, April 6, 1999.

strated high validity and reliability for measuring MCS-associated symptoms and chemical, food, and drug intolerances (Miller and Prihoda, 1999a). The instrument contains five scales:

Symptom Scale Subjects rate on a 0–10 scale the severity of their symptoms in ten categories: musculoskeletal, airway/mucous membrane, heart-related, gastrointestinal, cognitive, affective, neuromuscular, head-related, skin, and genitourinary. Maximum possible score=100.

Chemical (Inhalant) Intolerance Scale Subjects rate (0–10) the severity of symptoms they commonly experience in response to ten chemical inhalants: diesel/gas engine exhaust, tobacco smoke, insecticides, gasoline vapors, paint and paint thinner, cleaning products, fragrances, fresh tar, nail polish/remover or hair spray, and odors (outgassing) from new furnishings. Maximum possible score=100.

Other Intolerance Scale Subjects rate (0–10) the severity of their symptoms in response to ten other common exposures including foods, drugs, alcohol, caffeine, and skin contactants. Maximum possible score=100.

Life Impact Scale Subjects rate (0–10) the degree to which their sensitivities impact ten aspects of daily living: diet, ability to work or go to school, home furnishings, clothing, travel/driving, choice of personal care products, social activities, hobbies/recreation, family relationships, and ability to clean/maintain home. Maximum possible score=100.

Masking Index Subjects indicate (yes=1, no=0) whether they routinely use or otherwise are exposed to any of ten items including tobacco, environmental tobacco smoke, caffeine, alcoholic beverages, fragrances, pesticides, combustion products, or other substances that might reduce their



awareness of a relationship between symptoms and particular exposures. Maximum possible score=10.

Results

Environmental Evaluations

Pre-occupancy environmental evaluations were conducted on June 22 and 23, 1994, and post-occupancy evaluations on August 11 and 29, 1994, and again on February 27, 1996. The total volatile organic compounds (TVOCs) in two office rooms over this 600-day period are plotted in Figure 1. Mass spectral analyses revealed small quantities of hydrocarbon vapors. Dominant compounds were toluene, xylene, several alkanes, and a chlorofluorocarbon (identified by infrared analysis). As would be expected, the number of different VOCs in the air declined gradually over time (Figure 2). Notably, however, by day 600 following occupancy, TVOC concentration had increased substantially, despite there being fewer individual VOCs present in the air. The increase in TVOC was the result of a few VOCs that were present at relatively high levels, which may reflect the use of certain cleaning chemicals.

Carbon dioxide (CO₂) levels and ventilation rates (derived from occupant-generated CO₂ decay rates) were in the ranges of 670–850 ppm and 7–60 ft³/min, respectively. Although the minimum damper setting for fresh make-up air originally had been set at 10%, it was recommended that this be increased to 20%. Microbial sampling for total viable aerosol in two offices on the August 11 and August 29 visits revealed counts of 229±36 CFU/m³ (colony forming units per cubic meter of air).

Epidemiology

Mean age of the four women was 45.5 years, and their average educational level was 15 years. Three of the women reported distress when they first went to work in the new

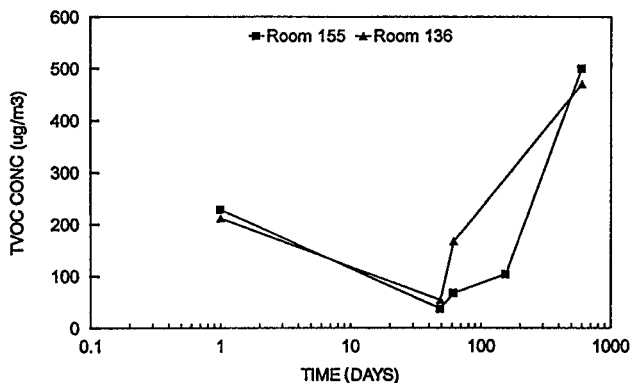


Figure 1. TVOC concentrations vs. time.

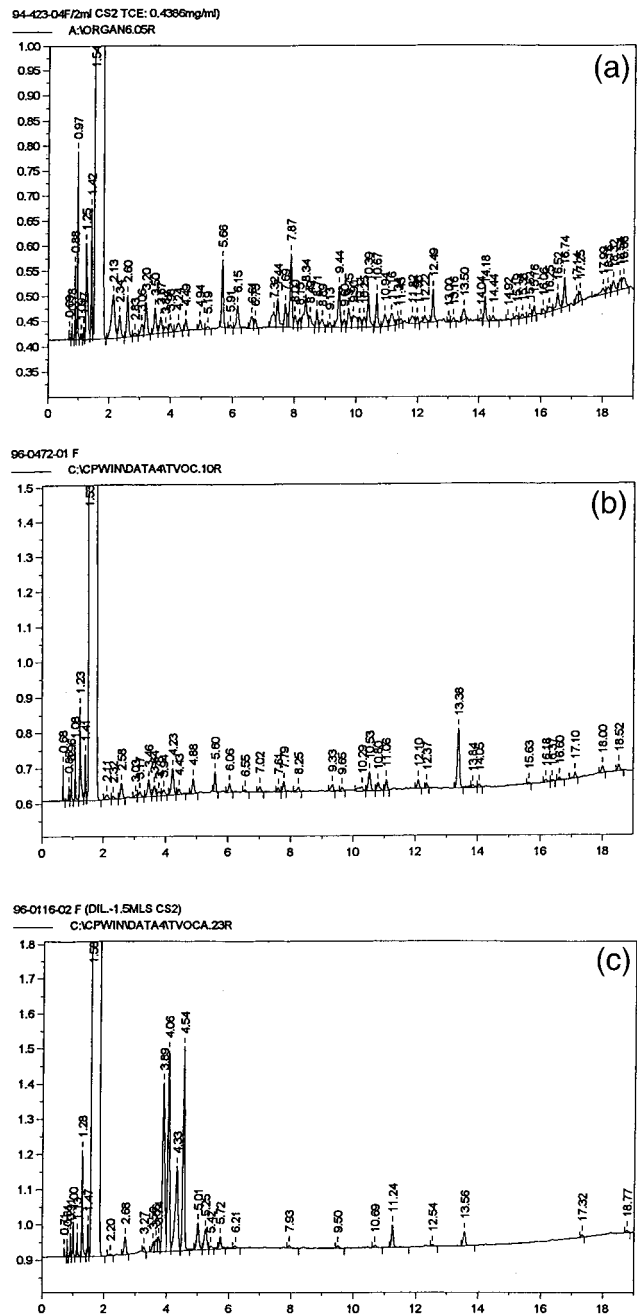


Figure 2. Results of air analyses in one office on days 1, 50 and 600. Although TVOC concentrations increased following occupancy, it can be seen that the number of individual VOCs in the air decreased greatly over time, corresponding with decreased symptoms in some of the women.

building. The fourth did not begin working in the building until after it was a year old. She experienced no difficulty with air in the building. The symptoms and experiences of all four individuals are summarized in Table 1. All were nonsmokers with histories of classical allergic reactions to pollens (four women), dust (four), mold (three), and animal



der (three); intolerances for foods or food additives such as monosodium glutamate (two); self-reported sensitivity to various skin contactants such as fabric dyes, soaps, fragrances, and metal jewelry (four); sensitivity to caffeine or other xanthines (four); intolerance for small amounts of alcoholic beverages (four); and histories of moderate to severe adverse reactions to various drugs or medical materials, such as antibiotics, pain-relievers, oral contraceptives, nasal steroids, contact lens solution, or sutures (four).

All of the women reported multisystem symptoms. Symptom scores for two of the women more than doubled during occupancy, going from 23 to 57 (on the 0–100 Symptom Severity Scale) in one case and from 28 to 58 in the other. Scores on the Chemical Intolerance Scale (0–100) nearly tripled for the three women (Cases 1–3) who were affected, increasing from an average of 20 prior to occupancy to 61 following occupancy. Scores on the Other Intolerance Scale (0–100) increased in only one individual, from 6 to 34. Scores on the Life Impact Scale ranged from 71 to 98 (average = 87). The average Masking Index was three out of a possible ten items. A score of 2–3 is typical for MCS patients, while 5 is average for the general population (Miller and Prihoda, 1999b).

Discussion

This case study is noteworthy on several fronts. The initial industrial hygiene evaluation revealed low levels of both TVOC and total viable aerosol, and concluded that the indoor environment of this new building was unlikely to induce chemical sensitivity in persons not previously sensitized. This proved to be the case. However, three of four women with pre-existing sensitivities reported considerable distress with worsening of their sensitivities when they first occupied the building. Case 1 was able to work in her office with the help of an air cleaner. Case 2 gradually became able to tolerate the building air over a 1-year period. Case 3 was unable to continue working in the building. Case 4, who did not begin working in the building until a year after it was opened, reported no adverse reactions to the building air, but did experience more severe reactions to perfumes, vehicle exhaust, insecticides, and other exposures outside the workplace.

The low TVOC levels and the composition of the major VOC components in the building ordinarily would be viewed as unremarkable. For unknown reasons, but possibly related to the use of cleaning chemicals, the TVOC concentrations increased in later occupancy. One of the authors (RBG) noted a persistent, slight odor in some of the isolated rooms and that air in the office with the air cleaner seemed subjectively 'fresher' than air in the remainder of the building. The specific nature of the VOCs that appear to have exacerbated these occupants' sensitivities remains

unknown, but it is clear that the complexity of the mixture of low level VOCs (shown in Figure 2) decreased with time. Perhaps the initial more concentrated and complex mix of VOCs was an important factor in exacerbating the symptoms of chemical sensitivity. The observations that Case 2's sensitivity to the building air waned over a 1-year period and that Case 4, who began working in the building a year after it was built, tolerated the air, suggest that some of the offending air contaminants decreased significantly over time, consistent with analyses of the air which showed a marked decrease in the number of different VOCs over time (Figure 2). On the other hand, Case 3 reported that even brief entry into the office building continued to trigger the same adverse central nervous system effects for several years after construction. However, she stated that her symptoms resolved after one of the building's ventilation units was repaired and placed back in service.

Findings from this study suggest that among persons with self-reported chemical sensitivities, there is a wide range of tolerance for the low levels of VOCs associated with new construction. Successful accommodation may be possible in some cases and difficult in others. No new cases of chemical sensitivity attributed to the building were observed, in contrast with reports from other studies (Miller and Mitzel, 1995), possibly because (1) VOC levels in the new building in this investigation were relatively low at the time of occupancy, or (2) sensitivity-initiating substances were absent.

Now, four years since construction, two of the women continue to work for the same employer, one in this building and the other in an older building. A third woman works at her home, and the fourth is no longer employed outside the home. The employer accommodated these individuals through a variety of mechanisms, such as providing office space in another area or building even if separated from the employee's workgroup, purchasing a room air filtration unit and replacement filters for office use, providing disposable respirators with charcoal-impregnated filters for use in meetings or other situations as needed, performing painting and other maintenance activities at times when the employee was away, closing air intakes on the roof during tarring, providing prior notification of remodeling activities and pesticide applications, avoiding use of pesticides in immediate work areas, removing air fresheners from restrooms, using well-tolerated cleaning agents, and scheduling meetings in better-tolerated conference rooms.

We conclude that complex mixtures of VOCs at very low levels tolerated by the majority of new building occupants may pose problems for persons who report pre-existing chemical sensitivities. TVOC measurements may not correlate with symptoms in these individuals. Reasonable accommodations by an employer can reduce problem exposures, making it possible for some affected individuals to continue productive employment.



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