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Practical Research Briefs

VOC "Patterns" in Sick and Healthy Buildings

Investigations of sick building syndrome (SBS) or other occupant complaints may involve extensive — and expensive — air quality measurements. These measurements usually fail to identify the causes of the complaints and thus do not point to effective remedial measures. Sometimes investigators obtain large amounts of data from air sampling, questionnaire surveys, or other environmental measurements. But unless they can identify patterns in the data that suggest possible causes, or at least directions for further investigation, their measurements are useless. In this article we describe the results obtained in a Swedish study by Elliot Noma and his colleagues. They employed a sophisticated statistical technique that may identify patterns of air pollutants in buildings where sufficient measurements of chemical concentrations or other relevant data are obtained.

A recent article in the journal ***Atmospheric Environment*** describes Noma's application of correspondence analysis to chemical concentration data from one sick and one healthy Swedish preschool. The results have important implications: the researchers may have found some clues to causes or indicators of sick building syndrome, and they certainly have demonstrated a valuable way to analyze chemical data. We think the technique used could be beneficially applied in investigations of sick buildings, in indoor air audits, and in pre-occupancy monitoring of new or remodeled buildings.

Background

In many other studies of sick building syndrome, differences of chemical occurrence and concentrations between sick and healthy buildings have been investigated in the hope of finding specific chemicals present in sick buildings and absent in healthy buildings. Yet no consistent pattern has emerged from such studies.

In this study, the researchers not only measured chemicals present in the two buildings, they also compared selected locations within the buildings. They compared the gross chemical levels between buildings and also the distribution of chemicals within the buildings. This "within-building" analysis of variation is useful in assessing the effects of people within spaces and of ventilation system components on the air chemistry within a building.

The Study

1. The researchers analyzed data from two identically constructed Swedish preschools, one known to be a "sick building" and the other a "healthy building." 170 air samples collected at 17 locations inside and outside the two schools were analyzed for volatile organic compounds (VOC) by GC/MS (gas chromatography/mass spectrometry).

2. On all 170 gas chromatograms 158 peaks were defined. Of these, 33 VOC could be positively identified and quantified by GC. These compounds were typical of those found in many indoor air studies (such as the EPA study reported in ***IAQU***, December 1988).

3. The locations were chosen to represent distinct spatial volumes within the schools, with emphasis on locations where differences in the heating and exhaust systems might be important.

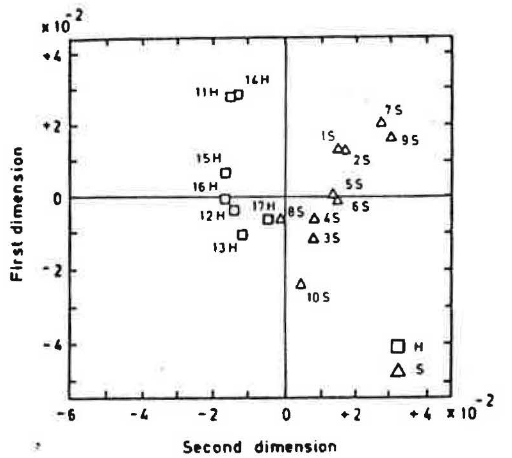
4. The relationships between the chemical concentrations and their locations in the two preschools was represented spatially by correspondence analysis and other statistical techniques to determine the "patterns" of occurrence.

Correspondence Analysis

According to research collaborator Elliot Noma, correspondence analysis was first developed in 1941, and seems to be lost and rediscovered every five years or so. He has applied it to the data available from the investigations of the schools.

The technique involves simultaneously representing chemicals and building locations as points in geometric space. Correspondence analysis places each chemical as close as possible to the location where it has the highest concentration. This is done by arbitrarily placing all the chemicals in the space and then placing the building locations close to the chemicals congregated at that particular site. Then the locations are used to rearrange the chemical positions (on the spatial plot) so that they occur as close as possible to the location of their highest concentration. The process is repeated until a stable position for both chemicals and locations is achieved (by computer, of course).

According to Noma, the key is that correspondence analysis allows one to see which locations have



Location #	Location Name	Location #	Location Name
	S Locations		*H Locations*
1S	Supply air before heat exchanger	11H	Outdoor air
2S	Supply air after heat exchanger	12H	Exhaust air — room
3S	Exhaust air before heat exchanger	13H	Exhaust air — staff room
4S	Exhaust air after heat exchanger	14H	Supply air in ventilation system before fan
5S	In the room at ceiling level	15H	Supply air in ventilation system after fan
6S	In the room at floor level	16H	Exhaust air in ventilation system on roof
7S	Outdoor air at building S	17H	Exhaust air — room, transferred to mobile laboratory adjacent to the building
8S	Room air — with persons in the room in S		
9S	Outdoor air at building C		
10S	Room air — with persons in the room in C		

Figure 1

similar chemical profiles and also permits a grouping of chemicals. Comparing the plots of the chemicals and the plots of the locations, one can easily see which chemicals have the highest concentrations in which locations.

Results and Interpretation

In Noma's analysis, chemicals and locations are plotted within a "common space." To clarify the presentation, the building locations and the chemicals are shown in separate plots (Figures 1 and 2 respectively) although they actually occur in a common space created by the correspondence analysis.

For the non-statistician, it is less important to understand the process by which the analysis is done than to examine its results. For the statistician, the published article contains more methodological details and some references which describe the statistical techniques that were used.

Very clear patterns emerged for "within building" and "between building" plots. These patterns show significant differences between the sick and the healthy building.

Figure 1 is a two-dimensional plot (from the correspondence analysis) of the peak heights showing the locations within the healthy (H) and sick (S) buildings.

Figure 2 is a two-dimensional plot (from the correspondence analysis) of the peak heights of all 33 chemicals that were present in at least one sample at each of the 17 locations plotted in Figure 1. The investigators had identified 15 of the chemicals as either "indoor" or "outdoor," on the basis of previous studies and published literature. These are also indicated in Figure 2.

The Healthy Building

Figure 1 shows outdoor air for the healthy building near the top (11H), supply locations next to and immediately below outdoor air (14H and 15H), and exhaust locations near the bottom (12H, 13H, 16H, and 17H). Note the large distance between supply air before (14H) and after the fan (15H). This suggests that air chemistry changes as it passes the fan, perhaps from lubricants used for the fan itself or emissions from electrical components such as wire insulation.

All 33 VOC showed increases at this point in the circulation system and generally at all subsequent stages in the air flow. This was revealed by comparing the distance of each location from the air intakes and the chemical concentrations in these locations. However, not all substances increased to the same degree.

differentiate sick and healthy buildings.

We will not describe the details of that work here, but the findings supported and reinforced the correspondence analysis. And it was found that no single chemical class was capable of distinguishing sick from healthy buildings. Also, chemicals in the same class lacked common origins or circulation patterns.

Light Aromatic Hydrocarbons Might Trigger SBS

In the sick preschool, light aromatic hydrocarbons (HC) increased with distance from the air supply, but no such gradient was seen in the healthy building. The authors do not venture to guess whether the concentration gradient of light aromatic HC is a key to sick building syndrome or only symptomatic of other problems.

They do suggest that the light aromatic HC could trigger the syndrome by preventing people from adapting completely to their presence. The lack of sensory adaptation "could lead to a persistent awareness of these chemicals together with a heightened sensory awareness of other annoying factors (agents)." They add: "In a related vein, although the formaldehyde levels in the present study were extremely low, this chemical might interact detrimentally with one or several volatile organic compounds."

Commentary

The mathematical analyses do not show that sick building syndrome is caused by the differences in contaminant concentrations. Rather, they seem to show that there is a significant difference in the way the air handling systems are controlling (or not controlling) the contaminant concentrations in one building compared to the other. The change in concentrations within the sick building may be only an indicator of some other environmental differences in the building which elicit the complaints and symptoms characteristic of sick building syndrome.

We think the usefulness of applying sophisticated mathematical and statistical analysis to sampling results is clearly demonstrated by the study. We would like to see the technique extended to other nonchemical factors in a multifactorial sick building study. It provides researchers and investigators of sick building problems with a valuable tool for analyzing their data. In light of the failure of simpler methods and the clear results in the Swedish preschool study, we think the extra effort is worth considering

For More Information

Elliot Noma, Birgitta Berglund, Ulf Berglund, Ingegerd Johansson, and John C. Baird, 1988. "Joint representation of physical locations and volatile organic compounds in indoor air from a healthy and a sick building." ***Atmospheric Environment*** Vol. 22, No. 3., pp. 451-460.

To obtain correspondence analysis computer software:Elliot Noma has developed a PC-based software package (which can also be run on a mainframe) with documentation for the use of correspondence analysis. He can be contacted at Statistical Modelling Associates, 234 Lawrence Avenue, Highland Park, NJ 08904; (201)246-4876. He sells the software package for $500/copy. ♦

Formaldehyde Sealants Evaluated

Researchers at Ball State University in Indiana have tested various sealants for reducing formaldehyde emissions from particleboard subflooring. The tests showed that sealants could be effective in reducing formaldehyde emissions, both in the short run and after more than six months.

Treatment reduced emissions as much as 95% in one test, although most sealants tested did not perform that well. Several were less than 50% effective. And the sealant which produced the highest single reduction (Hyde-Chek) was not as effective in two other tests. Another sealant, Valspar formaldehyde sealant, was more consistently effective, from 78-86% reduction. The complete results are shown in Table 1.

The researchers did not evaluate the sealants on other formaldehyde-emitting products (such as paneling and plywood) or on other uses of particle board (such as for cabinets or furniture). However, in general the levels of reduction achieved in these tests are proba-bly a good indication of the general effectiveness of the sealants for formaldehyde-resin-bound composite wood products.

Note: It is important to remember to use adequate ventilation when applying materials like the sealants. Ventilation should be maintained well after the sealant is applied, until the strong odor has disappeared. If upon reclosing the house the strong odor returns, continue to maintain good ventilation.