

direct the research is required. Based on the findings from the team effort, decisions about the causes of the building problems can be made and appropriate actions for retrofits to improve conditions can be designed.

Based on the case study example, it is clear that, irrespective of media pressure, professional investigators must take care to avoid the unnecessary intensification of occupant anxiety. We believe that this can be best achieved by the development and implementation of a systematic research methodology, and by coordinated multidisciplinary teamwork (5,6).

References

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CURE OF A SICK BUILDING: A CASE STUDY

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Abstract

Following allegations that faculty and students were being poisoned by high levels of CO and CO₂ in a five-year-old school, a multidisciplinary study was initiated to assess 1) available records of health and academic achievement of students, 2) actual levels of CO and other contaminants in the air, and 3) measurable ventilation characteristics of classrooms. No excess absenteeism, illnesses, or lack of academic achievement were found, nor were any significant levels of CO, HCHO, or SO₂ found. However, there was insufficient fresh air supply to some classrooms, and a large percentage of students exhibited classic symptoms of "sick building syndrome", i.e. headache, eye burning, and fatigue. Correcting the ventilation problems resulted in a reduction of symptoms to approximately equal those of students in other schools in the county.

The legendary fury of a woman scorned is mild compared to the wrath of a mother who thinks someone threatens her child. When a faculty member of Northern Middle School in Hagerstown, Maryland issued a report in December 1984 alleging that dangerous levels of CO, CO₂ and SO₂ existed in the school, the local newspaper picked up the story with such statements as "Faculty and students are working in an environment that could be detrimental or even fatal" and "There are many citizens out there who are enraged over this - - frightened". The PTA and the Citizens' Advisory Board then demanded that the situation be corrected or the school, only five years old, be closed.

A multidisciplinary team was quickly assembled to:

1. Investigate records of health-related behavior of students and teachers.
2. Measure air quality and air quantity in problem areas.
3. Conduct an assessment of symptoms among faculty and students.
4. Make recommendations and follow up after corrective measures have been taken.

Investigation

1. Even before equipment could be obtained to monitor the air, there were existing records which could quickly show how serious the health hazard might be. A search of records of absenteeism among the students in the five years before and the five years after moving into the new school in January of 1980 showed essentially no change, or if anything a slight decrease in absenteeism rate since the move, as seen in Table 1.

Table 1: Annual mean percentage absenteeism of Northern Middle School students, 1975 - 76 to 1983 - 84.

Year	1975-6	76-7	77-8	78-9	79-80	80-1	81-2	82-3	83-4
Per Cent	6.0	6.7	6.4	6.4	5.9	5.8	6.0	5.9	5.9

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A comparison of student absenteeism with other schools of the county showed no excess among Northern Middle School students, and faculty absenteeism for illness was also no higher among Northern faculty than in other schools.

Existing academic records were also available to permit investigation of the allegation that the learning ability of the students had been impaired by the school environment. Two types of tests were on record for all the middle schools in the county - I Q tests and academic achievement tests. A careful analysis of mean I Q's of students in all schools in the county showed Northern Middle to be consistently at the top or second every year for the five years before and the five after the student body was moved into the new building. Similarly, academic achievement records of eighth graders in all the schools showed that Northern Middle School eighth graders had a lower percentage of under-achievers and a higher percentage of over-achievers in one or more subject areas than eighth graders in any other middle school in the county. At this point the Health Department concluded that there was no evidence that the school environment was causing physical or mental harm to the students, and discarded any thought of closing the school.

2. During the search and analysis of existing records, equipment was being installed to monitor continuously the levels of CO and SO₂ in various areas of the school, mainly because of the insistence by faculty and parents that CO was the cause of the problems, and they would not settle for anything less. Over a two-month period the CO level stayed well below 5 ppm except for one episode when a trucker delivering food to the kitchen left the door to the loading dock open and his diesel engine running; the CO level indoors reached 35 ppm for about five minutes and quickly dropped again when the door was closed. SO₂ levels never exceeded 0.03 ppm, indicating no problem from smokestack emissions. Periodic checks for formaldehyde in various parts of the school showed no levels above 0.08 ppm even in the library after a week-end with the ventilation system shut off. Investigation of cleaning materials used by the custodial staff found none except those supplied for use in all schools in the county, and "grab samples" of air in the school showed nearly all detectable organics to be well below one part per billion. Tests of CO₂ sometimes approached but never exceeded 0.25 per cent.

A smoke test of the sewer system, however, disclosed three potential sources of sewer gas into the building -- two three-inch openings to untrapped sewer lines in the kitchen and a large gap in the vent piping above the girls' locker room, a room which had been a source of constant complaints. It was also found that a "pocket" at the front of the building occasionally trapped exhaust fumes from the school buses, and the locker room air handling system had the air intake and exhaust openings side by side on one wall of the pocket so that discharged air would tend to recirculate. A similar situation was found on the west penthouse, where the air exhaust from the school's bathrooms was adjacent to grilles opening into the penthouse which acts as a plenum for a main air handling system. Prevailing west winds would tend to blow the bathroom exhausts right back into the building.

Air flow tests were conducted in several classrooms that had recorded numerous complaints. Total air flow in these rooms was marginal, with calculated fresh air supply often falling far below the 5 cfm (2.36 l/s)

per occupant recommended for school classrooms. In addition, tracer gas dilution studies showed that there were times when the mixing factor K was as high as 4, signifying that as little as 1/4 of the air supplied to the room was effectively mixing within the room. One result of the poor mixing is that even less of the already inadequate fresh air supply was reaching the students seated at their desks.

3. A physical examination of faculty and staff showed no evidence of common infection or allergy, and carboxyhemoglobin levels reflected only the normal smoker/nonsmoker status of the subjects. Pulmonary function studies were normal. However, five of every six faculty members reported headaches which tended to occur at work, late in the day, and to be associated with another highly prevalent symptom, fatigue. Dizziness was also reported by a large number of the faculty, associated with fatigue.

In May of 1985 a questionnaire was mailed to parents of eighth grade students in Northern and two other comparable-sized middle schools in the county, Springfield and E. R. Hicks. The questionnaire asked, among other things, how often the child had experienced any of 17 listed symptoms, 15 of which might conceivably be environmentally caused.

Participation was 75% from Northern, 70% from Springfield, and 65% from E. R. Hicks. Table 2 shows the percentage of students reported to have experienced each symptom oftener than twice a month.

Table 2. Percentage of eighth grade students in three middle schools reported by their parents to have experienced symptoms oftener than twice a month.

Symptom N	S c h o o l		
	Northern 156	Springfield 165	E. R. Hicks 151
Asthma	1.3	0	1.3
Stomachache or cramps (1)	7.1	1.8	6.0
Sore throat (1)	4.5	0	3.3
Earache	2.6	0	2.0
Hurt all over	1.3	0.6	1.3
Fainting	0	0	0
Stiff neck or back	3.2	0.6	2.6
Headache (2)	25.0	14.5	13.2
Vomit	1.3	0.6	2.0
Loss of appetite	5.8	2.4	2.6
Eye irritation or burning (2)	12.2	1.8	1.3
Overtiredness (2)	22.4	6.1	11.3
Pain in chest	0.6	0	2.7
Dizzy spells	0.6	1.2	1.3
Blood in urine or stool	0	0	0
Nervousness	12.2	6.7	6.0
Nosebleed	3.2	1.2	2.0

(1) Difference between Northern and one other school significant ($p < 0.05$)

(2) Difference between Northern and both other schools significant ($p < 0.05$)

Headache, overtiredness and eye irritation or burning were reported significantly more often from Northern than from the other two schools. The percentage reporting sore throat or stomachache was significantly greater in Northern than in Springfield, but not E. R. Hicks.

4. In order to correct the deficiencies found, a number of changes were made. Sealing the openings to the sewer line was, of course, corrected the day they were found. Other changes, involving some engineering design and construction, were made during the school summer vacation of 1985:

- Supply fan speed in both main air handling units was increased in order to increase total air flow capability.
- In eleven of the peripheral classrooms that had been the focus of most faculty complaints, larger Variable Air Volume (VAV) terminal units were installed, permitting greater air flow than before.
- VAV control boxes for the large open interior spaces were modified so they could not open wide and take all the air available before it could reach the perimeter classrooms.
- Supply air temperature was reset to 50 F (10C) from the 58 F (14 C) setting that had been adopted as an energy saving measure.
- Air intake to the locker rooms was changed to obtain air from the gymnasium supply air duct instead of from the pocket of the building which tended to trap school bus fumes.
- A duct was built to carry bathroom exhaust air to above the pent-house roof, to avoid recirculation of that air.
- In the course of the other improvements, workers discovered and repaired two broken duct lines serving office and music areas.

Results

A tracer gas retest of Room 206, which had previously tested worst of the peripheral classrooms with only 147 cfm (69 l/s) effective ventilation at a 50-inch (1.25m) height from the floor, now tested 380 cfm (179 l/s) under the same conditions; with a minimum of 33% fresh air and occupancy of 24 students, this provides at least 5 cfm (2.36 l/s) fresh air per student, the ASHRAE (1) recommended minimum. Tests of air flow in other rooms showed that corrective measures were effective in increasing air flow to rooms needing it.

One dramatic result of the action taken was the immediate drop in faculty complaints as the 1985-86 school year began, a trend which continued all year.

A final epidemiological inquiry was made in May of 1986. The same questionnaire that had been mailed to parents of eighth grade students of Northern, Springfield and E. R. Hicks middle schools in 1985 were mailed to parents of the 1986 eighth graders of the same schools. Table 3 shows the 1985 and 1986 percentages for students of the three schools, in response rate, frequency of the five significant symptoms, and mean year-to-year change in symptom frequency. The improvement at Northern is obvious.

Table 3. Percentage of eighth grade students experiencing selected symptoms oftener than twice a month, as reported by parents in 1985 and 1986.

Symptom	Year	S c h o o l		
		Northern	Springfield	E. R. Hicks
% Participation	1985	75.4	69.6	65.0
	1986	65.6	68.4	63.0
Stomachache	1985	7.1	1.8	6.0
	1986	4.3	3.0	5.6
Sore throat	1985	4.5	0	3.3
	1986	2.8	3.0	4.2
Headache	1985	25.0	14.5	13.2
	1986	12.8	6.1	9.9
Eye irritation or burning	1985	12.2	1.8	1.3
	1986	5.0	2.3	4.2
Overtiredness	1985	22.4	6.1	11.3
	1986	14.2	8.3	7.7
Mean change, 1985 to 1986		-6.4	-0.3	-0.7

Note: None of the 1986 differences between schools are statistically significant at $p < 0.05$.

The drop in percentage of parents of Northern Middle School students returning the questionnaires in 1986 is another indication that parents were no longer as worried about the situation as were the parents in 1985.

Discussion

This investigation brought out some general information that may be helpful in other instances.

- Ignored complaints will, with time, generate exaggerated accusations and a crisis atmosphere.
- Helpful information may be immediately available; absenteeism, illness, productivity are often matters of record.
- A diligent search for obvious and easily located sources of contaminants may be surprisingly productive. Suggestions: sewer gas, exhaust recirculation (2), electrostatic copy machines and carbonless copy paper.
- Of course, check air flows, air distribution and adequacy of fresh air.
- After corrections are made, make a survey to be sure that the frequency of original complaints has been reduced and no new ones added.

References

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