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Case st. 1/

[Fig. title]

CASE STUDIES THREE CALIFORNIA BUILDINGS

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This presentation of three "problem building" case studies provides a sample of some indoor pollution problems in new buildings. It illustrates some methods of investigating problems, describes some of the key actors, explores some of the potential causes of the problems, and analyzes some of the potential causes of "building sickness." It attempts to identify the role of the architect during investigations. Measures which can be taken during design to minimize problems are discussed. Recommendations are made regarding the building 'launching' or move-in process.

The first case studies concerns the <u>San Francisco Social Services Building (SFSSB)</u>
[Fig: slide of building name on wall]

[Fig: Photo(s) of exterior}

A new, design award-winning building for a city agency was the subject of employee complaints almost immediately upon occupancy in the Fall of 1979. Complaints of upper respiratory problems, headaches, eye irritation, drowziness, and other symptoms of "tight building syndrome" were registered by many occupants.
[Fig. symptoms]

BLDG. IS LOCATED DOWNWIND FROM A MAJOR BI-LEVEL FREEWAY

A worker survey conducted in the following months showed that the problem was widespread. The following summer and fall, after almost a year had passed, epidemiology and air quality surveys were conducted. This was unique in that most problem building investigations do not benefit from the conduct of both air quality monitoring and epidemiology studies. In many ways, this is a typical tight building syndrome case study. However, it is rare in that both epdiemiology and air quality studies were done. The combination of both investigatory methods in a single building allows more effective determination of the nature, location and targets of the problems.

Since epidemiology identifies patterns in large populations, it is often an effective tool in narrowing and focusing the physical, biological and chemical parameters measured, or helping to focus the investigation on specific portions of the building or the population within the building. It also is a valuable tool in establishing whether the complaints are related to a building-related phenomenon or not. Thus, epidemiology results in saving time, money and effort in problem buildings.

[Fig: cover of epi study]

[Fig. epi study results

[Fig: generalizations of findings]

Findings included confirmation that the problem was building-related, that no single contaminant could be blamed, that certain functions such as operation of copying machines required improved ventilationthat ventilation system functioning should be improved, and that air quality indoors was far worse than outdoors but could be worsened b;y outdoor air carrying auto exhaust emissions when traffic was busy.

LESSONS

1. Short Circuit of ventilation
2. Long delay obscures problem
3. Aair quality is extremely ventilation rate dependent
4. Outdoor air source s of pollutants should be identified and avoided. Design, operational protocols can both reduce problem.
5. Indoor/outdoor ratios generally greater than unity, often higher.
6. LOSS OF CONTROL

Oakland High School, (OHS)

When staff arrived to prepare for the Fall Semester in this new building, formaldehyde odors filled the air. Health problems and complaints were met with little sympathy from site and district personnel resulting in adversary relations. Air sampling detecting ver high formaldehdye levels were characterized by health officials as meeting legal limits for occupational exposure although they were far above levels known to cause the reported problems.

After school began, teachers and students continued to complain while school district staff hesitated to acknowledge the existence of the problem. Four teachers and ten students left the building due to their health problems and fears about the consequences of exposure. An epidemiology study found that the complaints and health problems were building related.

Six months after school began, the district engaged consultants to evaluate the air quality. By this time, foru teachers had left the school and filed workers compensation claims, and ten students had transferred to other schools, all for reasons related to health problems related to the school environment.

Ventilation system operational protocols were determined inadequate to clear the air of contaminants produced by building materials, furnishings, and occupant activities. Solvents and other materials used in science and photography classes were not provided ventilation adquately. Modifications were recommended and implemented.

These included, among others, the need to extend the hours of operation of the building ventilation system. The system was being started up shortly before occupancy in the morning and turned off atthe end of the school day. Thus, approximately a nine hour cycle, five days a week. This was found to be inadequate to remove the poooll utants emitted by new building materials and furnishings.

Additionally, it was found that solvents used in the photo lab were resulting in elevated concentrations within that space. The photography instructor was one of those most severely affected.

LESSONS

Problems not limited to offices. Schools can be plagued.

Significance of exposure of children. Since children have higher metabolism than adults and, for younger children, are still developing, exposure to toxic substances can be more significant. Furthermore, due to the greater expected longevity of children, exposure can result in adverse outcomes which older members of the population avoid by shorter life.

Solving one problem, finding another. Removal of asbestos hazard; exposure elsewhere.

Failure to contemplate problem of timing of move-in.

Long delay in investigation, difficult to find problem.

Adversarial relationships reduced potential to solve it.
LESSONS

LESSONS

1. Investigtions must be done promptly
   to identify the problem,
   to reduce the exposures of occupants
   to avoid unecessary stress due to worry, stress which can worsen sypmtoms

2. Ventilation investigation should be done before air quality work

3. Ventilation measurements should be done along with air qulaity work

4. Indoor outdoor ratios, and vent./concentration relationships can usefully demonstrate problem

5. Long delays will obsucre findings

indoor pollution problems often result from improper or inadequate mainenance of the mechanical system. Maintenance of fans, replacement of filters, lubrication of moving parts such as fans and vane operating rods, cleaning of moist or damp areas, etc.

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{fig: photo of building name]

California Veterans Memorial State Office Building, Long Beach (CVMSOB-LB)

[fig: photo of building exterior]

The state's energy efficient office building program included this southern California building using daylighting strategies to reduce energy consumption. The innovative design called for a glu-laminated timber structure.

[fig: photo of ext. showing beams, shading]

Wood beams projecting outside the building to support the sunshades were treated with the wood preservative, Pentachlorophenol (PCP) to protect the wood from the marine environment.

[fig: photo of interior beams prior to sealant]

Exterior beams which were continuous on the interior accounted for 40% of the interior beams. The size of these beams and the treatment method used resulted in a substantial penta content indoors. Penta emissions resulted in measured levels of PCP above levels reported to have caused irritation and illness in residential environments.

[fig: photos of monitoring equipment]

Measurements of indoor air quality prior to scheduled occupancy resulted in a decision to attempt to reduce airborne levels of Penta before occupancy to protect workers' health.

[fig: photo of ventilation hood measurements]

Efforts to evaluate air quality resulted in the finding that ventilation system design and installation were flawed.

[fig: photo of vav box]

Stops for Dampers in the vav boxes to hold air supply at 50% of designed values had not been installed, and dampers were closing completely in some instances, providing virtually no ventilation.

[fig: test results from stockholm paper]

Remedial measures were successfully employed to improve ventilation as well as to seal treated beams in order to reduce airborne Penta.

These measures were effective in reducing airborne penta from 30 ug/m3 to around 7 ug/m3, with ventilation improvements contributing a substantial

improvement, sealing the beams was only partially effective due to the inaccessibility of the upper portion of the beam above the sealing which constituted 40% of the beam surface area.

[fig.: photo of roof configuration of vent system}

design and layout are critical, remedial measures to improve vent and avboid potential cross-contamination of intake air by exhaust. This is not uncommon, although it is extremely important.

[fig: lighting photo]

Use of high intensity sources must be coordinated with location in building. Ceiling height was reduced to economize; This reduces the effectiveness of the daylighting scheme by reducing the depth

of penetration of daylight into the building. As a result, also, fixutres are now to low, and present a potential source of glare, discomfort, and veiling relflections.
[fig: photo of worker with desk lamp]
This can be solved by lowering levels and providing individuals with desk lamps which they can control, and utilize as needed.

Design and construction procedures are recommended to avoid future incidents of chemical contamination as well as ventilation system problems.

[Stockholm paper follows]

PCP is used as a pesticide, herbicide, and fungicide worldwide. Current annual production is estimated at 5 x 10^7kg, 23 x 10^6kg in t USA (4). General population exposure is substantial. In a sample o the U.S. population, 85% had urine PCP averaging 6.3 ppb.(7) Human exposure to PCP results from residues in food, from exposure in buildings containing PCP-treated wood or other materials, and from exposure to PCP in numerous consumer products such as paper, cleanin products, soaps, skin medication, leather and cotton; and, from PCP formation as a metabolite of many common pesticides (3, 4, 5, 8).

Elevated PCP body burdens were found in urine and blood samples residents in homes constructed with PCP-treated logs. Serum levels w 7 times those of individuals living in conventional homes (2). The California Department of Health Services has investigated reported illness in homes with PCP air concentrations of 10 to 30 ug/m^3.

PCP use in buildings is widespread: to treat foundation lumber timber, structural members exposed to the weather, and in finish materials and coatings. Eighty percent of U.S. PCP consumption is a wood preservative (8). PCP use is common in residences, commercial structures, and public buildings. PCP is used in paints, wood stain and sealers. Recently, two office buildings in California were constructed with PCP-treated glu-laminated timbers exposed on the interior. Occupant complaints of irritation and respiratory illness the smaller building led to application of brush-applied polyurethan varnish and to increased use of natural ventilation. These remedial measures resulted in decreased complaints. The larger building requ more extensive remedial work as reported below.

Experimental work

Background

Indoor air quality was monitored in several new, energy-efficie California state office buildings including one in coastal southern California which contained PCP-treated wood. Sampling found PCP air concentrations of 30.7 ug/m^3 without ventilation and 27.2 ug/m^3 with very low ventilation (02/19, 06/04, Table 2). Although these concentrations are <6% of US occupational limits (1), public health officials agreed that illness might occur. A health risk assessment state officials established a "safe" level at <20 ug/m^3.

The four story structure contains 14,500 m^2 of conditioned floo area, 50,750 m^3 conditioned volume. The structural system consists glu-laminated Douglas fir columns, girders and purlins. To conserve energy, extensive glazing provides daylight on the interior. The structural wood extends outside the exterior walls to support an elaborate sun shading system which reduces direct sun entry. Forty percent of the interior horizontal structural members extend outside were PCP pressure-treated. PCP treatment was by the Cellon process carrier) for wood installed in the first floor and the remainder was treated using an oil carrier. A surface material sample of treated contained 0.185 percent (1850 ppm) PCP by weight.

Discoloration, and "blooming" of PCP crystals on the surface of treated wood, and exuding pitch were deemed unacceptable. Cleaning attempted using a solvent containing aromatic hydrocarbons (88.9%), aliphatic hydrocarbons (5.2%) and ethanol (5.3%). Hot water washing brush scrubbing were completed prior to application of a semi-transparent stain containing PCP as a biocide.

Evaluation of air sampling results (02/19, 06/04, Table 2) led remedial work. Data on sealing PCP pressure-treated wood to reduce vaporization indicated that polyurethane varnish might be 80% effect (1 coat) and 95% effective (2 coats) in reducing emanation rates. Tw coats of polyurethane varnish were spray-applied only to exposed are of treated wood. Portions of the purlins above the ceiling could no economically sealed (Fig. 1).

Table 1. Data on Wooden Beams

Wood surface/ surface Member	Dimensions (cm)	Spacing (m)	PCP-treated wood Interior volume (m^2/m^3)	% Seal
Purlins	27.3 x 38.1	1.37	0.11	60
Girders (paired)	27.3 x 76.2 2 @ 1.37 o.c.	9.45	0.05	100
Total			0.16	72.5

Testing methods

Personal monitoring pumps were used to collect samples in midget impingers filled with ethylene glycol and submitted to the laboratory for analysis by NIOSH approved methods. Sampling times ranged from 8 hours at 0.7 liters/minute and were usually taken one per location. Some duplicate samples were submitted to the state's Air Industrial Hygiene Laboratory for validation of results.

The sealant's efficacy was tested in selected locations. Sampli 13 days after application indicated a threefold reduction in PCP air concentrations compared with unsealed wood in unventilated spaces. Unsealed wood in a low-ventilated space produced air levels similar t sealed wood in unventilated spaces (09/23-24, Table 2). It was decid to seal all exposed, treated interior wood members.

The building's office spaces are ventilated and cooled by eight roof-mounted units serving vertical zones. The restrooms, cafeteria auditorium are separately ventilated. Maximum Variable Air Volume (V design supply rates are 305 liters/min/m^2 (1 cfm/ft^2). This results 5.2 ACH at 100% supply and outside air conditions. Normal operation introduces approximately 20 percent outside air with VAV supply rates from 50 to 100% of design values. Actual outside air change rates va from 0.6 to 1.1 under normal conditions and 2.6 to 5.2 with 100% outside air conditions. Return air registers collect air from multip zones, combine it and redistribute it to the roof units. Heating is fan coil units located in perimeter zones only and mounted just below the ceiling. Air is drawn past water-heated coils and distributed downward at the windows.

Results

Twelve days after the second sealant coat was applied, 4 consecutive days of testing (10/29 - 11/01) under varied ventilation conditions confirmed the efficacy of the sealant. An average of 5.9 ug/m^3 PCP was found in 68 air samples at 0.8 to 5.2 outside air chang per hour. Necessary ventilation equipment corections were made and further testing (11/17) found PCP levels of 3.2 ug/m^3 at normal ventilation rates (1.1 ACH). On this date, some HVAC equipment was bstill malfunctioning. Subsequent tests at different locations found 7.2 ug/m^3 average PCP levels at 1.6 ACH (02/07/83).

Table 2. Air concentrations of PCP

Date	PCP Conc. (ug/m^3) #	Range	Mean	Temp °C	R.H. %	Vent Rate ACH	HVAC System Units	VAVs	*
02/19/82	6	15.1-50.0	30.7	21	51	0.4	Off		T
06/04/82	7	7.1-44.5	27.2	25	54	0.5	On	Variable	T
09/09/82	7	4.6-26.1	10.5	25	64	0.1	Off		T
09/12/82	2	25.1-29.8	27.4	25	62	0.1	Variable	Variable	T
09/23/82	6	10.0-13.5	11.7	24	54	0.1	Off		S
	3	31.2-49.0	38.0	24	55	0.1	Off		T
	3	10.1-13.2	11.2	23	54	n.a.	Variable	Malfunct	T
09/24/82	6	7.2-13.6	11.3	23	66	1.0	Variable	Variable	T
	6	4.2-11.5	7.4	23	66	1.0	Variable	Variable	S
10/29/82	15	1.0-8.2	4.6	23	48	3.4	Open	Minimum	S
	5	3.2-15.3	10.4	24	48	n.a.	Open	Malfunct	S
10/30/82	16	1.9-5.8	3.1	23	61	5.2	Open	Maximum	S
	2	6.1-8.9	7.5	23	66	n.a.	Open	Malfunct	S
10/31/82	19	3.06-14.4	7.1	24	59	1.1	Minimum	Maximum	S
	1	10.01	---	24	65	n.a.	Minimum	Malfunct	S
11/01/82	18	3.2-17.0	8.0	26	61	0.8	Variable	Variable	S
	2	10.5-26.4	18.5	27	55	n.a.	Variable	Malfunct	S
11/17/82	18	0.9-8.5	3.19	23	57	1.1	Variable	Variable	S
	2	7.6-14.2	10.9	27	54	n.a.	Variable	Malfunct	S
02/07/83	6	4.6-9.9	7.2	23	56	1.6	Variable	Variable	S

* Condition of Beams: T=PCP Pressure-Treated; S=Polyurethane Sealed

Discussion

PCP concentration determinations in indoor air

Gebefugi explored the effects of temperature and absolute humidit on PCP concentrations in indoor air. Investigations conducted in a te room lacking controlled ventilation did not adequately address the impacts of ventilation on experimental results. The results were inconclusive, although the effect of temperature was clearer than that of water vapor (6).

Results compared to predicted values

Theoretical values were calculated as equilibrium concentrations (Raoult's Law) of PCP in room air based on measured concentrations in

the treated wood (1850ppm) over the measured temperature range during sampling (20-28 °C). The values are 3.5-11.5 ug/m^3 compared with 3.1- ug/m^3 measured values. The deviation might derive from variations in wood PCP content or room temperatures. Higher temperatures at the ceiling than in the sampling zone would increase PCP vapor pressure.

Ventilation data reported here support a relationship between PCP concentrations and ventilation rates (Fig. 2) although ventilation system malfunctions encountered during sampling limit ventilation rate estimate reliability. The present work also supports the relationship between temperature and PCP concentrations in air; but no clear relationship to relative humidity is evident (Fig. 3).

Conclusions

1. Use of Pentachlorophenol indoors should be limited to essential purposes and only where alternatives are clearly unacceptable. Treatec wood should be sealed before treated wood is installed or concealed.

2. Sealing PCP-treated wood can be effective in reducing airborne concentrations, particularly where ventilation is also used to control levels in air. Polyurethane varnish appears suitable but the duration and extent of its effectiveness should be investigated.

3. Ventilation data is significant in interpreting air sampling results due to the wide variability of actual air change rates in the field, particularly in newly-constructed buildings. Air change rates and ventilation are important determinants of contaminant levels and must k considered routinely during sampling as well as design.

4. Further research on PCP air concentrations determinations in buildings should include characterization of ventilation rates, surface material PCP concentrations, the effects of temperature and humidity, and the absorption of PCP on the surfaces of building contents.

INTRODUCTION TO THE CASE STUDIES PRESENTATIONS AND OVERVIEW OF BUILDING INVESTIGATIONS

The presentation will be an introduction to the case study presentations which follow.

These case studies will be presented in 3 separate talks:

First, case studies in 3 public buildings in California, two of them offices, one a high school, which I will present.

Phil Morey will describe investigations of biological contamination including Legionnaires disease and Pontiac fever.

Barry Wasserman will describe efforts by the State of California to reduce indoor pollution in several recent California State office buildings designed as state of the art energy efficient buildings.

This introduction and the 3 talks which follow will provide an overview of indoor pollution as it manifests in the completed "problem" building or sick building syndrome.

It will provide some details and illustrate the concepts described in the previous talk. And it will provide some practical examples as references for the afternoon talks which present the sources of indoor pollution and details about various air pollutants, noise, and lighting in buildings.

We will begin by discussing the various types of indoor pollution problems as they have been characterized by investigators,

Typology of Problems of indoor pollution in buildings:
[fig: List of problems types: tight, Phys, Chem, Bioiol, General]
Tight building syndrome, building sickness
[fig: symptoms]
Physical contamination: asbestos, lead [list of physical contaminants]
Chemical contaminants
[Fig: gases, aerosols, mists, surface coatings or emissions on surfaces]
Biological contaminants
[Fig: legionaires, etc.]
General (non-specific) indoor pollution problems - combination of a variety of factors such as ...[fig: factors]

Types of investigations:
Problem solving: bldg operators, occupants (or reps - unions)
Legal compliance: local, state or federal agency, complaint, request

Research: owners, architects, scientists, public health officials

Post occupancy evaluation: owners, architects, occupants

Methods of conducting investigations:

Various approaches to studying problem buildings are described as follows:

1. Formal survey of occupants - questionnaires
2. "Walk-through inspection"
3. Informal interviews with occupants
4. Take history from affected occupants, engineers, managers, supervisors
5./Epidemiology: includes case controls
6./Clinical investigation of occupant parameters - not often done, but warranted were severe chronic or acute consequences are observed or feared.
7. Indoor air quality monitoring
8./Lighting evaluation
9. Acoustic evaluation
10. Thermal performance parameters

/What disciplines/professions can assist in investigations
Types of disciplines to study problem buildings:

* mechanical system maintenance personnel:
* air balance engineer
* mechanical engineer
* controls system engineer
* general and specialty contractors
* acoustics consultant
* electrical engineer/lighting consultant
* epidiemiologists
* industrial hygienists
* chemical engineers
* behavioral scientists
* medical clinicians
* medical investigators
* survey research scientists (psychologists, sociologists, anthropologists)

The course of events related to a building pollution problem contains a number of critical components which usually include the following:

1. COMPLAINTS
- the way complaints are received, problems are discovered, identified
- the types of complaints/problems which are most common (distinguish between a problem and a complaint)

2. CHARACTERIZATION OF BUILDING
- building types, construction types
- description of building design, use, location

3. CHARACTERIZATION OF ENVIRONMENTAL QUALITY
- air sampling data
- ventilation data

- lighting levels and system characteristics
- space use patterns: density, privacy

4. CHARACTERIZATION OF HEALTH AND COMFORT OUTCOMES
- survey results from health studies
- observed absenteeism, change in performance or behavior

5. PROBLEM MANAGEMENT
- occupant committee, formal safety committee
- management team (technical, administrative, legal, medical)

Major Steps in Conducting an Investigation:
- assembling the team
- getting an approach developed
- implementing the investigation
- assessing findings and their usefulness
- documentation of changes in building operation, use or climate

We will provide some guidelines for conducting an investigation during the workshop tomorrow afternoon on Investigating Problem Buildings.

The results of some which have been documented, an analysis of the results, and a review of the remedial actions which have been taken.
[figures from NIOSH, Dean Baker]

Summary of results: Types of findings, remedies.
Summarize findings.
[Fig: NIOSH results]

This will include:
- air sampling data
- survey results from health studies
- summary of causes and remedial measures
- recommendations of measures architects can take to improve the effectiveness of building investigations

The implications of past case studies for architects, occupants, and investigators:
1. There is often a long lag time between the onset of problems and the initiation of formal, systematic investigations. This can result in hostility and mistrust bewteen occupants and building management, owners or employeers. It can also result in changes in the building environment which will confound investigators when they do arrive.
2. Multi-disciplinary teams of investigators including a variety of experts can most effectively address problem building investigations. Multi-disciplinary investigations, even in the rare instances where they do occur, are frequently not coordinated to derive the maximum benefit from the independent, disciplinary results. Such coordination and communication are essential to effective problem solving.
3. Air sampling is often expensive and does not always result in identification of the causal factors. Ventilation system inspection and monitoring can be quicker and more economical and

may often result in problem identification.
4. Ventilation system malfunction or dysfunction is often found where complaints are received.
5. New buildings often require a certain break-in or launching period to work correctly.
6. Many building materials and furnishings will release a large fraction of their chemical emissions during the first few weeks after exposure to the environment. Investigations conducted subsequently will not determine air levels associated with complaints.
7.

The role of the architect in past and future investigations will likely expand. The architect is well suited to assemble and lead a team of investigators resolving problems in new or remodeled buildings.

What the architect can do:

- in the design and building process to avoid problems

- to provide information/documentation that will facilitate resolution of problems when they occur:

- documenting design intents, (assembling a briefing book or guide to the building for users, operators, investigators) specifications (performance)

- review shop drawings

- field inspection (observation) reports

- measures of building performnance

- measures of environmental quality

- measures of user satisfaction

- the way complaints are received, problems are discovered, identified
- the types of complaints/problems which are most common (distinguish between a problem and a complaint)
- description by building type
  description of building design, use, location
