PRELIMINARY STUDY OF POLLUTANTS IN TWO UNOCCUPIED NEW HOMES

Prepared for

National Association of Home Builders
Subcommittee on
Indoor Air Quality

by

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1.0 BACKGROUND

In recent years, indoor air quality (IAQ) has become one of the more significant issues facing the building industry. The heightened awareness of IAQ issues can usually be traced to several factors, including the emergence of indoor radon as a health risk, the trend toward tighter homes to promote energy efficiency, and improvements in measurement technology.

Studies by EPA (1) and others have identified a number of volatile organic compounds (VOCs) and other indoor pollutants in public buildings. A limited number of studies have also been conducted in residences (2,3). Reports in the media and even the scientific literature often seem to exaggerate the extent of indoor air pollution problems in homes, apparently without due consideration of the limited and often contradictory data on the subject. Recent studies in Canada (4) suggest that concerns over IAQ are often exaggerated, particularly theories that indict modern "energy-efficient" homes as indoor pollution traps. Advances in measurement technology have helped fuel IAQ issues by identifying trace quantities of pollutants that could not previously be detected.

Although there are many unwarranted fears over IAQ, there are also valid concerns that need to be addressed. These include concerns over radon, which appears to be the most widespread pollutant; formaldehyde in bonded wood products; VOCs in paints and sealants; and build up of SO_2 and CO from unvented or faulty combustion equipment.

Theoretically, source control (not using certain products) would be the most effective way to reduce pollutant exposures, although this is not always practical. Another option is to increase ventilation in order to dilute pollutants with outdoor air. In any case, more must be known about the types and concentrations of pollutants in homes before credible mitigation recommendations could be seriously considered. The objective of this project was to screen newly constructed, unoccupied homes to gain further understanding of pollutant types and strengths attributable to building products and materials. Subsequent post-occupancy tests are now proposed to identify pollutants attributable to occupants and the products they introduce into homes. This report summarizes the results of initial pollutant measurements in two homes.

2.0 TASKS

The project consisted of four tasks: 1) Identify target pollutants; 2) Specify measurement methods; 3) Select test homes; and 4) Monitor pollutants.

Task 1: Identify Target Pollutants - An extensive review of the existing literature was conducted by the Research Center to establish a list of potential pollutants to be monitored in the test homes. The list comprises the more publicized pollutants (eg. formaldehyde, carbon dioxide, NOx, etc.), as well as other pollutants that, although uncommon at elevated levels, have been identified in similar testing programs. The list of target pollutants was divided into four sets according to the type of measurement. Individual pollutants from the first three sets are shown in Table 1. The fourth set of measurements consisted of a qualitative screening test to identify medium VOCs in the test homes. Due to the virtually unlimited number of possible medium VOCs, a target list was not developed although a list of those VOCs identified is provided in the section on monitoring results.

Task 2: Specify Monitoring Methods - This task consisted of examining measurement methods and equipment for detecting various substances in indoor air. Methods and equipment deemed most appropriate for the screening tests proposed under this project were selected for pollutant monitoring. A discussion of the methods, equipment, and procedures used to measure pollutants is provided in Section 3.0.

Task 3: Select Test Homes - Two builders were solicited from the NAHB Subcommittee on Indoor Air Quality. The first builder's site is located in Fredericksburg, Virginia, about 30 miles south of Washington, D.C. The second is located near Richmond, Virginia.

Task 4: Pollutant Monitoring - Pollutant measurements on the test homes were conducted by a team from the Research Center and air quality specialists from Lancaster Laboratories, Lancaster, PA, an analytical testing laboratory with extensive gas chromatography/mass spectrometry (GC/MS) capabilities. Samples were analyzed by Lancaster and Azimuth, Inc., Charleston, SC.

TABLE 1
TARGET POLLUTANTS

Set A

Ammonia	Sulfur Dioxide	Nitrogen Dioxide
Formaldehyde	Ethylene Oxide	Hydrogen Sulfide
Radon		

Set B*

Lead	Pesticides/PCBs	Carbon Monoxide
Yeast and Mold	Carbon Dioxide	Respirable Particulates
Aerobics		

Set C
(Highly Volatile Organic Solvents)

Acetone	Benzene	Butanol
Butyl Acetate	Butyl Cellosolve (2-Butoxyethanol)	Carbon Tetrachloride
Cellosolve Acetate (2-Ethoxyethyl Acetate)	Chloroform	Chlorobenzene
		Cyclohexane
Isooctane	Isopropylnol	Isopropyl Acetate
Methyl Cellosolve (2-Methoxyethanol)	Methyl Ethyl Ketone	Methyl Isobutyl Ketone
	Methylene Chloride	Octane
Petane	1,1-Dichloroethane	1,2-Dichloroethane
Ethanol	Ethyl Acetate	Ethyl Benzene
Ethyl Cellosolve	Freon 113 (1,1,2-Trichloro-1,2, 2-trifluoroethane)	Heptane
Hexane		Isobutanol
n-Propyl Acetate		n-Propyl Alcohol
Stylene	Tetrachloroethylene	Toluene
1,1,1-Trichloroethane	1,1,2-Trichloroethane	Trichloroethylene
Xylene		

Set D

Medium Volatile Organic Compounds

*Relative Humidity and Temperature were also measured as part of Set B.

3.0 TARGET POLLUTANTS

Pollutant Set A - Tests on pollutant Set A from Table 1 were conducted by the Research Center using commercially available monitoring devices purchased from Rad-Elec, Inc., and Pro-Tek Systems, Inc.

Passive electret monitors from Rad-Elec were used to measure indoor radon. Electrets consist of a charged teflon disk inside a small canister of known volume. The voltage on the disk is measured in the field before and after deployment. Radon levels are proportional to the voltage drop.

Pro-Tek badges are liquid sorbent diffusion devices that passively sample pollutant gases by diffusion into a liquid. Badges were deployed in three locations in the home for an eight-hour sampling period and then forwarded to Azimuth for analysis. *Formaldehyde* samplers were analyzed using chromotropic acid color development UV-VIS spectrophotometry in accordance with Pro-Tek Method 1985/National Institute for Occupational Safety and Health (NIOSH) Method 3500. *Ethylene Oxide, Ammonia, Nitrogen Dioxide, Sulfur Dioxide, and Hydrogen Sulfide* samplers were analyzed using UV-VIS spectrophotometry in accordance with Pro-Tek Method 1982.

Pollutant Set B - Monitoring of pollutant Set B from Table 1 was conducted by the Research Center with the cooperation of Lancaster Laboratories. Temperature and relative humidity were also monitored with this set of pollutants. Air samples were collected at the test homes and returned to Lancaster for analysis. Measurement and analysis methods are described below.

Lead - Samples for airborne lead were collected in accordance with NIOSH Method 7082. A known volume of air is drawn through a 0.8 micron pore, mixed cellulose ester membrane filter using sampling pumps. The filter is contained in a three-piece cassette. The lead content of the dust collected on the filter is analyzed using atomic absorption spectrometry.

Pesticides/PCBs - Samples for airborne pesticides and PCBs were collected in accordance with NIOSH Method 244 (second edition). A known volume of air is drawn through Florisil sorbent tubes that are then desorbed with hexane and analyzed using electron capture gas chromatography. Quantitation for PCBs is based on Aroclor mixtures, the pesticides are determined as the pure materials.

Respirable Particulates - Airborne concentrations of respirable particulate were collected by drawing a known volume of air through an SKC cyclone onto a tared, 5 micron pore size, PVC, 37 millimeter diameter membrane filter, in accordance with NIOSH

Method 600. Air is drawn by a personal sampling pump calibrated at a flow rate of 1.7 liters per minute. The sample media was reweighed upon return to the laboratory and the total weight of airborne particulate matter was calculated.

Yeast and Mold, Aerobics - The concentration of airborne colony forming units (CFU) is determined by collecting airborne microbes on agar using an Anderson sampler. Potato dextrose agar plates are used in the collection and incubation of yeast and mold. Plate count agar plates are used in the collection and incubation of aerobic bacteria. A known volume of air is drawn through the sampler and is impinged directly onto the specific agar plate using an electric high volume air sampling pump. Separate samples are collected for the determination of yeast and mold and aerobic bacteria. Upon returning to the laboratory, the plates are incubated and the number of CFU on each plate are counted. The concentration in air is calculated from the colony counts and air volume sampled.

Carbon Monoxide - Airborne concentrations of carbon monoxide (CO) were determined using Mine Safety Appliance (MSA) detector tubes and the MSA Universal Sampling Pump. A finite quantity of air is drawn through the chemically specific detector tube. Each tube contains a packing which changes color in the presence of the specific airborne contaminant. The length of the color change in the tube is directly proportional to the specific contaminant concentration in air. The concentration in air is determined using the calibration chart supplied by the manufacturer.

Carbon Dioxide (CO_2), Temperature, and Relative Humidity - Measurements of airborne carbon dioxide (CO_2), temperature (°F), and relative humidity (RH) were made using an AQ501 monitor. Readings of the airborne CO_2, temperature, and RH are based on a preprogrammed time interval. The AQ501 CO_2 sensor is calibrated with a known concentration (1000 ppm or 5000 ppm) of CO_2. The zero scale for the CO_2 sensor is set using a nitrogen span gas.

Relative Humidity (Sling Psychrometer) - Instantaneous relative humidity readings were also obtained using a sling psychrometer. A sling psychrometer measures the dry bulb and wet bulb temperatures. Relative humidity is calculated as the difference between these temperatures. These results were used to confirm readings obtained using the AQ501.

Pollutant Set C - The target pollutants in Set C of Table 1 consist of highly volatile organic solvents. Airborne concentrations of organic solvents were determined using 3M Organic Vapor Monitor (OVM) badges. OVM badges operate by diffusion. When the badge is exposed to the atmosphere, air diffuses at a constant rate through a plastic membrane to a charcoal pad within the badge. The specific contaminant being sampled is then chemically desorbed from the charcoal pad and is analyzed by gas chromatography.

Pollutant Set D - The last set of pollutant measurements were conducted using Tenax-GC/MS analysis to identify medium volatile organic compounds. Medium VOCs present special measurement problems due to their vast numbers. Consequently, quantitative analysis is impractical. Therefore, medium VOCs were identified in accordance with protocol in EPA document number 600/4-84-041, Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Method T-01, April 1984. Results from this procedure are qualitative in nature. Tests are conducted by drawing a known volume of air through a sampling tube packed with Tenax sorbent using a calibrated sampling pump. The tube is sealed in a glass jar and frozen until analysis. The analysis consists of thermal desorption of the Tenax material, sweeping the contents into a gas chromatograph/mass spectrometer. Components are identified by comparison of the electron impact spectra with those in an EPA/NIH spectral database. GC/MS conditions were set according to EPA Method 524.

4.0 TEST HOMES

Test Home No. 1

Test Home No. 1 is located in Fredericksburg, Virginia. The home is a two story, wood framed colonial on a crawlspace foundation with an attached slab-on-grade garage. It has 2,610 square feet of living space. A floor plan is shown in Figure 1. The construction is typical for the area including gypsumboard covered wood framing and vinyl siding. Floor finishes include a mix of carpet, sheet vinyl and hardwood. Interior walls are covered with flat latex paint.

The thermal envelope includes R-13 fiberglass batts and R-3 styrofoam sheathing on exterior walls of the living space, rigid insulation board in the garage, R-30 fiberglass batts in the attic, and R-19 fiberglass batts over the crawlspace. A polyethylene vapor barrier covers the ground in the crawl space.

The home is heated and cooled by a two-zoned forced air HVAC system with two separate electric heat pumps. One air handler located in the attic serves the second floor and is fitted with an AUTO-FLO humidity control. The second air handler is located in the crawlspace and serves the main floor. The house has two fireplaces equipped with ducts to the outside for combustion air. The home was in the cooling mode during pollutant monitoring.

Sampling at Home No.1 was conducted over a period from May 1 to May 4, 1990. The home had been completed approximately six months prior to sampling and had never been occupied. Several potential sources of indoor pollution were observed in the garage. These included a partial gallon of exterior acrylic latex paint, two quarts of interior latex paint , one quart of unused thinner and some left over thinner in a used container, a lawn mower, two generators, one pint of turpentine, one quart of latex grout, 3/4 gallon of muriatic acid, one gallon of joint compound, 2 1/2 gallons of polymer wall coating, one quart of stain killer, one can of foam caulk, and a five gallon can of gasoline.

Test Home No.2

Test House No. 2 is located near Richmond, Virginia. The home is a two-story, wood-framed colonial built on a crawl space foundation with an attached garage built on a concrete slab-on-grade. A floor plan is provided in Figure 2. The home has 2,376 square feet of living space. Interior walls and ceilings consist of wood framing covered by gypsumboard and a flat latex paint finish. Floor coverings are a mix of carpet, sheet vinyl, and hardwood.

Exterior walls are covered with painted wood siding over rigid insulation board and plywood corner bracing. The thermal envelope includes a 1/2" to 5/8" layer of polyurethane foam sprayed over the inside surface of the wall sheathing covered with R-13 fiberglass batts, R-19 fiberglass batts between the floor joists over the crawl space, and ten inches of blown fiberglass insulation in the attic.

Figure 1
Floor Plan of Test Home No. 1

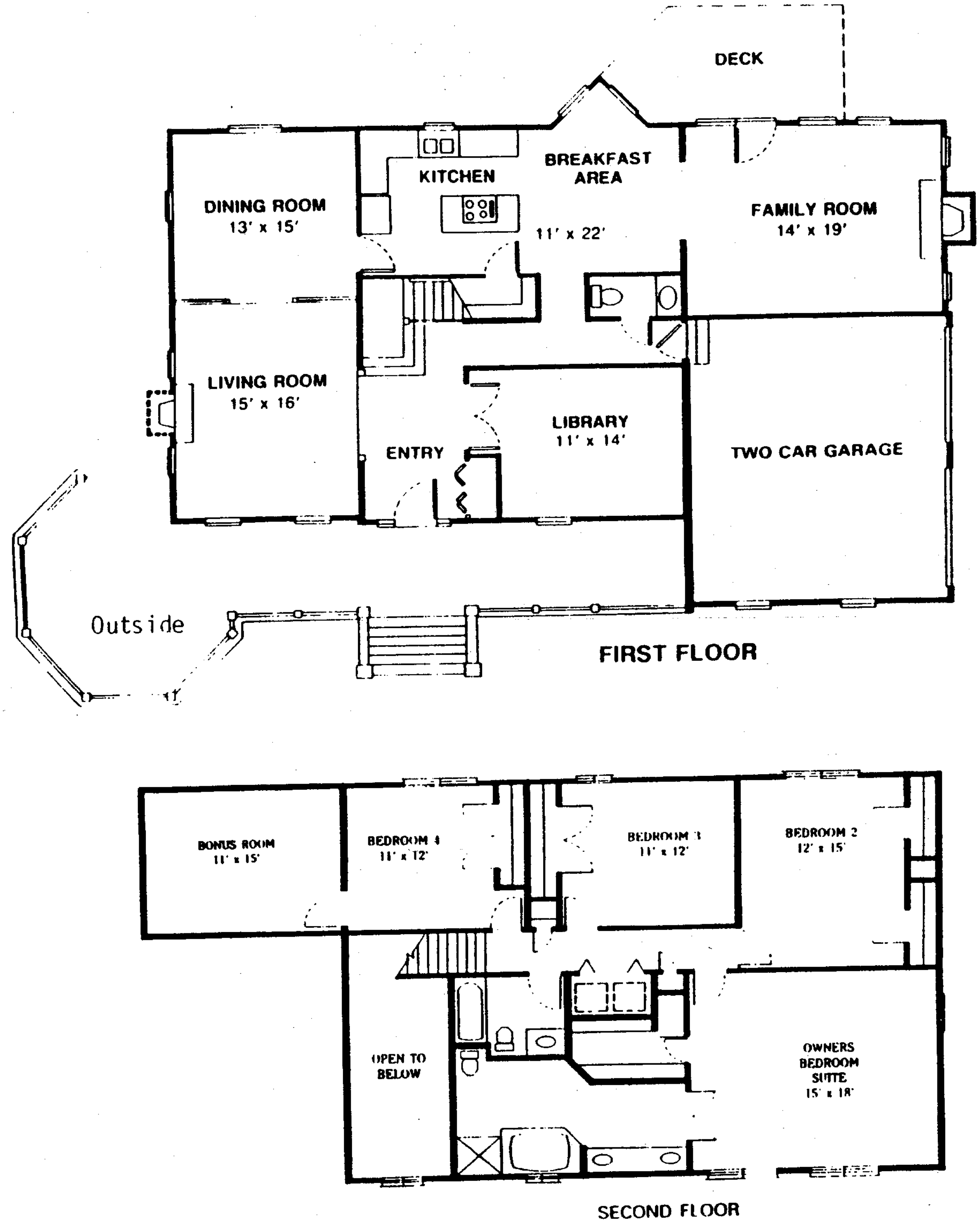
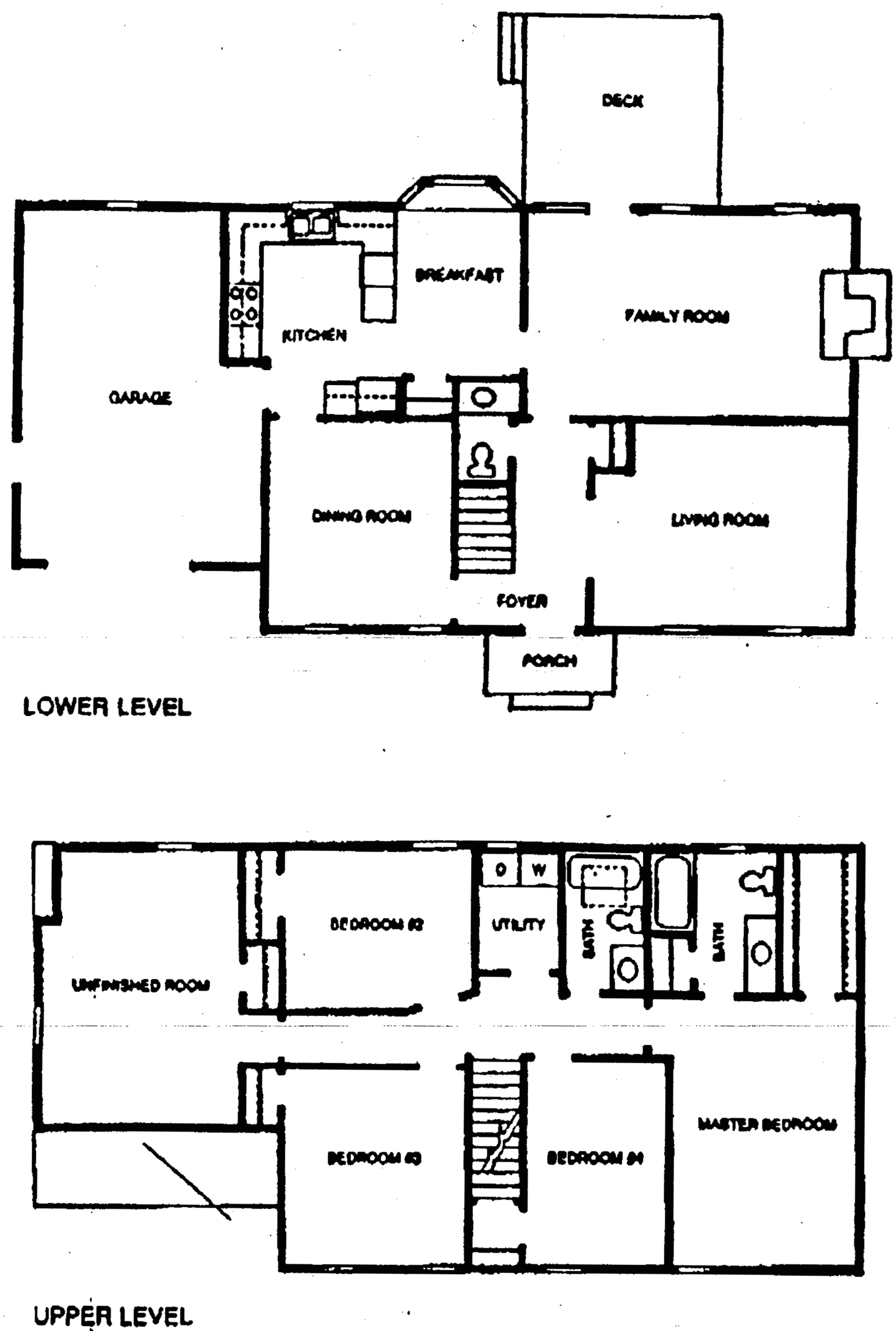


Figure 2
Floor Plan of Test Home No. 2



Note: Reverse floor plan used with test home.

This home is heated and cooled with a central forced air HVAC system that includes a conventional air conditioning unit and a heating unit that extracts heat from a gas-fired domestic water heater located in the garage. The home also has a fireplace in the family room equipped with a duct to the outside for combustion air.

All sampling other than for pesticides at Test Home No. 2 was conducted on June 20 and 21, 1990. The home had been completed a few days before and was unoccupied. Pesticide sampling was conducted on July 17, 1990. The home was occupied during the pesticide sampling.

5.0 MONITORING RESULTS

Results from measurements of the target compounds in sets A, B, and C in Table 1 are shown in Tables 2 and 3 for Test Home Nos. 1 and 2, respectively. Tables 4 and 5 show the medium VOCs (Pollutant Set D) present in the homes at the time of sampling.

6.0 ACCEPTABLE LIMITS

Acceptable levels for residential pollutant exposure have been well established for a small number of pollutants. For instance, EPA has set an action level for radon, while other groups have established guidelines for CO_2, relative humidity, yeast and mold, and formaldehyde.

Widely recognized guidelines are not available for most other indoor air pollutants, although attempts have been made to extrapolate guidelines from existing industrial or occupational standards. One type of "guideline" often quoted by indoor air quality practitioners is the 1/10 permissible exposure limit (PEL). PELs, set by the U.S. Occupational Safety and Health Administration (OSHA), are time weighted concentrations averaged over an eight-hour period. The 1/10 PEL is determined by multiplying OSHA requirements for occupational exposures by 0.10. Without official guidelines, the 1/10 PEL has been unofficially adopted by some practitioners as a conservative action level.

TABLE 2
RESULTS OF MONITORING
IN TEST HOME NO. 1

Set A

Parameter	Concentration (ppm) Kitchen/ Dining Room	Family Room	Master Bedroom
Ammonia	<0.83	0.88	<0.83
Sulfur Dioxide	<0.9	<0.9	<0.9
Nitrogen Dioxide	<0.3	<0.3	<0.3
Formaldehyde	0.5	0.9	0.07
Ethylene Oxide	0.6	0.6	0.6
Hydrogen Sulfide	<0.7	<0.7	<0.7
Radon	1.1/1.0*		

Notes: *Duplicate three-day tests, results in pCi/l.
Values with a less than sign (<) indicate the amount was below the established reporting limits.

Set B

Parameter	Concentration Kitchen/ Dining Room	Family Room	Master Bedroom	Outdoors	Garage
Airborne Lead (ug/m³)	<0.4	<0.4	<0.4	---	---
Pesticides/PCBs	ND	ND	ND	---	ND
Respirable Particulates (mg/m³)	<0.1	<0.1	<0.1	---	---
Yeast and Mold	570	1,700	---	1,500	---
Aerobics	430	1,100	---	200	---
Total CFU/m³	1,000	2,800	---	1,700	---
Carbon Dioxide (PPM)	500	530	500	360	---
Carbon Monoxide (PPM)	<5	<5	<5	<5	<5
Relative Humidity (Percent)	50	52	52	52	---
Temperature (°F)	68	67	68	80	---

Notes: ND = None Detected

Set C
(Highly Volatile Organic Solvents)

Area	Concentration
Family Room	ND
Master Bedroom	ND
Kitchen/Dining Room	ND
Outdoors	ND
Garage	ND

Notes: ND = None Detected

TABLE 3
RESULTS OF MONITORING
IN TEST HOME NO. 2

Set A

Parameter	Concentration (ppm) Kitchen/ Dining Room	Family Room	Master Bedroom
Ammonia	1.5	1.8	*
Sulfur Dioxide	<0.9	<0.9	<0.9
Nitrogen Dioxide	0.9	0.9	1.0
Formaldehyde	0.2	<0.2	0.2
Ethylene Oxide	1.2	0.9	0.9
Hydrogen Sulfide	<0.7	<0.7	<0.7
Radon	1.8/1.4**		

Notes: * The ammonia badge was damaged and was not deployed in the master bedroom.
**A duplicate two-day test, results in pCi/l.
Values with a less than sign (<) indicate the amount present was below the established reporting limit.

Set B

Parameter	Concentration Kitchen/ Dining Room	Family Room	Master Bedroom	Outdoors	Garage
Pesticide (Dursban)(mg/m³)	<0.00008	---	<0.00008	<0.00008	<0.0008
Respirable Particulates (mg/m³)	<0.3	<0.3	<0.3	---	
Yeast and Mold	700	300	70	<30	---
Aerobics	300	100	100	540	---
Total CFU/m³	1,000	400	170	540-569	---
Carbon Dioxide (PPM)	702	818	779	417	---
Carbon Monoxide (PPM)		<5	<5	---	<5
Relative Humidity (Percent)	52	52	48	57	---
Temperature (°F)	74	74	74	86	---

Notes: Values with a less than sign (<) indicate the amount present was below the established reporting limit.

Set C
(Highly Volatile Organic Solvents)

Area	Concentration (PPM)
Kitchen/Dining Room	0.056 (Toluene)
	0.17 (Acetone)
Family Room	0.16 (Acetone)
Master Bedroom	0.13 (Acetone)
Garage	ND
Outdoors	ND

Notes: ND = None Detected

TABLE 4
MEDIUM VOCs (SET D) IDENTIFIED IN TEST HOME NO. 1

Compound	Location Where Identified
Pentane	G, M
$C_{10}H_{16}$ Isomer	G, F, K
Toluene	O, G, M, F, K
Hexanal	O, G, M, F, K
Dimethyl Benzene Isomer	O, G, M, F, K
Decane	O, G, M, F, K
Undecane	O, G, M, F, K
Dodecane	O, G, M, F, K
Carbon Disulfide	O, M, F, K
Pentanal	M, F, K
Octane	O, M, F, K
$C_{10}H_{14}$ Isomer	O, G, M, K
Nonanal	O, M, F, K
Tridecane	O, M, F, K
Heptane	M, F, K
Aliphatic Hydrocarbon	O, G, M, K
Trimethyl Benzene Isomer	O, G, M, F, K
Alpha Pinene	M, F
1-Ethyl Methyl Benzene Isomer	G, M, F, K
Ethyl Dimethyl Benzene Isomer	G, F
Tetradecane	F, K
2-Methylheptane	G
1,1,2-Trichloro - 1,2,2-Trifluoroethane	O
Dichloromethane	O, B
Benzene	O, G
Heptanal	O
C_9H_{12} Isomer	O
Octanal	O
Decanal	O
Ethylbenzene	G
Unknown Siloxane	O
Unknown Hydrocarbon	G
$C_{10}H_{12}$ Isomer	G
$C_{11}H_{14}$ Isomer	G
Unknown Ketone	K
Trichlorofluoromethane	B
2-Propanone	B
Hexane	B

Location Notes:

O = Outside
G = Garage
F = Family Room
M = Master Bedroom
K = Kitchen/Dining Room
B = Blank Sample

TABLE 5
MEDIUM VOCs (SET D) IDENTIFIED IN TEST HOME NO. 2

Compound	Location Where Identified
Hexane	B
Nonane	K, F, M, O, G
Xylene Isomer	K, F, M, O, G
$C_{10}H_{22}$ Isomer	K, F, M, G
C_9H_{18} Alicyclic	K, F, M, G
Methyl Nonane Isomer	K, F, M, O, G
Decane	K, F, M, O, G
Aliphatic Hydrocarbons	K, F, M, O, G
Dodecane	K, F, M, O, G
Toluene	K, F, M, O, B
C_9H_{20} Isomer	K, F, M
3-Methyl Octane	K, F, M
$C_{10}H_{20}$ Alicyclic	K, F, M
Ethyl Dimethyl Benzene Isomer	F
Octane	M, O
Dichloromethane	G, B
2-Methyl Decane	G
Hexanal	K, F, M, O, G
$C_{11}H_{24}$ Isomer	K, G
C_9H_{12} Aromatic	K, F, M, O, G
Undecane	O
Ethane, 1,1,1 Trichloro	B
Tridecane	O
Cyclohexane	B
Trichlorofluoromethane	B
Ethane, 1,1,2-Trichloro - 1,2,2-Trifluoro	B
Acetone	B
Unknown Hydrocarbon	G
Unknown Alicyclic	G
Unknown Cyclic Ketone	G

Location Notes:

K = Kitchen/Dining Room
F = Family Room
M = Master Bedroom/Bathroom
G = Garage
O = Outside
B = Blank Sample

Since peak exposures are often as important as longer-term averages, OSHA also has guidelines for short-term exposure limits (STEL). These are also non-residential standards based on exposure over a 15 minute period.

Medium VOCs represent a special case of indoor air pollution. As with most other pollutants, there are few guidelines for medium VOCs in indoor air. Some threshold limit values (TLV) for peak exposures to individual VOCs in occupational settings have been set by the American Conference of Governmental Industrial Hygienists (ACGIH). Indoor concentrations of individual VOCs are usually several orders of magnitude lower than the TLVs (5). Recently, research is beginning to focus on the combined effects of VOCs in an effort to develop a single standard for total VOC exposure.

Appendix A contains available pollutant guidelines and the group responsible for promulgating the guideline.

7.0 DISCUSSION

The results of this study show that, with the exception of total CFU (yeast and mold, aerobics) in Home No. 1 and, to a lesser extent, formaldehyde in both homes, the pollutant concentrations in the two test homes were well below existing guidelines. Furthermore, none of these pollutants were present in significant quantities, with the majority below the lower limit of quantitation.

Total CFU counts in the family room of Home No. 1 were above the ACGIH 1,000 CFU/m^3 action level. The kitchen was reported as 1,000 CFU/m^3. It should be noted that the outdoor sample also exceeded the guideline by 700 counts. The ACGIH guidelines suggest that further investigation of the area may be necessary. However, since the CFU counts in outdoor air were high, it would not be unusual for those inside to be elevated.

Formaldehyde levels throughout the test homes were below the OSHA 8-hour PEL of 1 ppm. However, levels in the kitchen/dining room area and the family room of Home No. 1 exceeded the HUD 0.4 ppm guideline and the ASHRAE guideline of 0.1 ppm. Formaldehyde levels in two rooms of Home No. 2 exceeded the ASHRAE guideline. The difference between guidelines demonstrates the need for additional research to establish reasonable, widely-recognized standard guidelines.

The qualitative assessment of medium VOCs indicated the presence of 31 different VOCs in Home No. 1 and 16 in Home No. 2. Twenty-four and 25 medium VOCs were also identified in outdoor air around Home Nos. 1 and 2, respectively. A smaller number (five in Home No. 1, eight in Home No. 2) were identified on the blank samples. Other studies (2) have found similar types of medium VOCs in homes. It is recommended that medium VOCs identified repeatedly in studies of this type be quantified in the future.

8.0 REFERENCES

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APPENDIX A

GUIDELINES

SET A

OCCUPATIONAL GUIDELINES

Parameter	Guideline*	Source
Ammonia	50 ppm	OSHA
Formaldehyde	1 ppm	OSHA
Sulfur Dioxide	2 ppm	OSHA
Ethylene Oxide	1 ppm	OSHA
Nitrogen Dioxide	5 ppm	OSHA
Hydrogen Sulfide	10 ppm	OSHA

*Eight-hour permissible exposure limit (PEL)

RESIDENTIAL GUIDELINES

Parameter	Guideline	Source
Formaldehyde	0.40 ppm	U.S. HUD
	0.10 ppm	ASHRAE
Radon	4 pCi/l**	U.S. EPA

**Annual Average

SET B

Parameter	Guideline	Source
Airborne Lead	50 ug/m^3	OSHA 8-Hour PEL
CFU	1,000 CFU/m^3	ACGIH
Carbon Monoxide	35 ppm	OSHA 8-Hour PEL
Relative Humidity	30 - 60 percent	ASHRAE
Pesticides	(see page A-2)	---
Carbon Dioxide	(see page A-3)	---

GUIDELINES FOR AIRBORNE PESTICIDES

Compound	OSHA 8-Hour PEL
Heptachlor	0.5 mg/m^3
Aldrin	0.25 mg/m^3
DDT	1 mg/m^3
Methoxychlor	10 mg/m^3 T.D.* 5 mg/m^3 R.D.**
Dieldrin	0.25 mg/m^3
Endrin	0.1 mg/m^3
Chlordane	0.5 mg/m^3
Toxaphene	0.5 mg/m^3
Endosulfan I	0.1 mg/m^3
Endosulfan II	0.1 mg/m^3

*T.D. - Total Dust
**R.D. - Respirable Dust

Indoor Air Quality Supplement for Airborne Carbon Dioxide Levels*

Carbon dioxide, according to ASHRAE, is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of fresh outdoor air are being introduced into a building or work area. Indoor CO_2 levels exceeding 1000 ppm can be an indicator of a build-up of other indoor contaminants which could account for employee health symptoms such as fatigue, dizziness, headaches, etc. The outdoor, ambient concentration of CO_2 is usually 250-450 ppm. Usually the CO_2 level is higher inside than outside, even in buildings with few complaints about indoor air quality.

However, if indoor CO_2 concentrations are more than 1000 ppm (3 to 4 times the outside level), there could be a problem with inadequate ventilation. Inadequate ventilation may cause employee complaints such as headaches, fatigue, disorientation, tiredness, and eye and throat irritations.

If CO_2 concentrations are maintained below 600 ppm with comfortable temperature and humidity levels, complaints about poor indoor air quality should be minimal. If CO_2 levels are greater than 1000 ppm, employee complaints may occur and thus 1000 ppm should be used as an upper limit guideline. This does not mean that if this level is exceeded the building's indoor environment is hazardous, but rather, this level should be a guideline that helps maximize comfort for all occupants. Levels between 600 ppm and 1000 ppm may cause some of the more sensitive individuals to complain of poor indoor air quality.

In addition, elevated CO_2 levels may be an indicator of accumulations of other typical indoor contaminants. Low-level concentrations of contaminants such as various gases, vapors, microorganisms, and particulate matter are present in every indoor situation. The contaminants may be introduced from indoor activities, furnishings, building materials, and surface coatings. Poor fresh air exchange will contribute to the accumulation of any typical indoor contaminants. As the concentrations begin to increase, occupants may complain of a variety of health symptoms which may include frequent headaches, disorientation, fatigue, and eye and throat irritations.

*Lancaster Laboratories, Lancaster, PA

SET C

GUIDELINES FOR HIGHLY VOLATILE ORGANIC SOLVENTS

	OSHA 8-Hour PEL ppm
n-pentane	600
n-hexane	50
n-heptane	400
n-octane	300
iso-octane	NE
benzene	1
toluene	100
ethyl Benzene	100
xylenes	100
styrene	50
chlorobenzene	75
methanol	200
ethanol	1,000
n-propanol	200
iso-propanol	400
n-butanol	50*
iso-butanol	50
acetone	750
methyl ethyl ketone	200
methyl isobutyl ketone	50
cyclohexanone	25
methyl cellosolve	25
ethyl cellosolve	200
butyl cellosolve	25
cellosolve acetate	100
ethyl acetate	400
propyl acetate	200
iso-propyl acetate	250
n-butyl-acetate	150
carbon tetrachloride	2
chloroform	2
methylene chloride	500
1,1 dichloroethane	100
1,2 dichloroethane	200
1,1,1 trichloroethane	350
1,1,2 trichloroethane	10
trichloroethylene	50
tetrachloroethylene	25
freon 113	1,000

*OSHA Acceptable Ceiling Concentration in Parts Per Million.
NE = No established guideline