SMALL PLANTS AND THEIR MEDICAL PROBLEMS— THE FURNITURE INDUSTRY

The Environmental Problems of Urea-Formaldehyde Structures— Formaldehyde Exposure In Mobile Homes

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Over the past few years, the Department of Environmental Health, School of Public Health and Community Medicine of the University of Washington has been receiving an increasing number of complaints of illness from persons who reside in mobile homes; the problem is also appearing to a lesser extent in conventional homes. Our investigations have pointed to atmospheric concentrations of formaldehyde as the most likely cause of these complaints.

Formaldehyde is utilized in the manufacture of a variety of commercial products, the most significant of these involves the production of phenolic, melamine and urea formaldehyde resins (1). Formaldehyde is also used in agriculture, for chemical analysis, in concrete and plaster, in cosmetics and deodorants, in disinfectants and fumigants, in dyes, in hydrocarbon products for leather tanning, in paper manufacture, in photography, in solvents and plasticizers for rubber production, in starch, in wood, in textiles and in embalming fluid. It is also a product of combustion found in automotive exhaust and in cigarette smoke.

TOXICITY

Recently, three important documents have been published that deal with the health effects of formaldehyde (1-3). Table 1—taken from the NIOSH criteria document—summarizes the human responses to exposures of less than 3 ppm of HCHO in the ambient air.

TABLE 1 -- Dose-Response Relationship Following Human Exposure to Airborne Formaldehyde (below 3 ppm)

Concentration	Exposure	Number	Responses
0.3-2.7 ppm	8 hr/d	Many	Annoying odor, constant prickling irritation of the mucous membranes, disturbed sleep, thirst, heavy tearing (odor subsided during day, but returned at start of next shift)
0.9-2.7	hrs	Many	Tearing of eyes and irritation of nasal passages and throat (irritant effects were greatest at very beginning of workday and after lunch)
0.9-1.6	8 hr/d	2	Itching eyes, dry and sore throats, disturbed sleep, and unusual thirst upon awakening in the morning
1.4	mins	12	Eye sensitivity to light lowered in unacclimated group
1.0	mins	Many	Increased worker complaints
0.8	mins	12	Altered functional state of cerebral cortex
0.8	daily	?	Equilibrium and olfactory sensation shifts; irritation of upper respiratory tract and eyes in most sensitive individuals; enhancement of alpha-rhythms
0.3-0.5	5 min	12	Increased blink rate, rhythms proportional to formaldehyde concentration
0.05-0.5	5 min	12	Eye irritation range in unacclimated group
0.13-0.45	?	Many	Complaints of temporary eye and upper respiratory tract irritation

A report prepared for the Environmental Protection Agency (1) details the known toxicity of formaldehyde to humans and other mammals:

Toxicity to Humans

Epidemiology
Non-lethal doses of formaldehyde vapors generally irritate the mucous membranes of the eyes and upper respiratory tract. Skin irritation can occur in sensitive individuals. Both severity of irritation and types of symptom relate to formaldeyde concentration as well as the individual's sensitivity.

Toxicity to Mammals

Subacute/chronic Toxicity
Some long-term exposure studies suggest definite non-physiological changes, including slight variations in vitamin C metabolism and changes in neurons.

Concentrations below 1 ppm may result in biochemical and tissue changes in animals even though no outward signs of illness are apparent.

Teratogenicity and Mutagenicity
Present data do not adequately demonstrate that formaldehyde is teratogenic or mutagenic in animals; however it is expected that some histological changes of unknown significance may occur to the embryo exposed to formaldehyde in utero.

Carcinogenicity
Animal data indicate that formaldehyde is unlikely to be a strong carcinogen. Bacterial strains for current tests, however, have shown formaldehyde to be a mutagen in a number of systems.

Behavior - Symptomology
Sublethal atmospheric concentrations of formaldehyde have elicited coughing, sneezing, eye irritation, salivation, slowed respiration and loss of appetite.

Possible Synergistic Effects
Guinea pigs exposed to a combination of formaldehyde and sodium chloride aerosol showed a response that was greater than that for formaldehyde alone. Aerosol inhalation in the absence of formaldehyde evoked no response.

Formaldehyde and a number of other aldehydes are considered to be important constituents of photochemical smog (3). Typical concentrations of both formaldehyde and higher aldehydes have been reported as high as 0.04 ppm.

Furthermore, the National Research Council (4) reports that peroxyacyl nitrate (PAN) and peroxybenzoyl nitrate (PBzN) (both photochemical oxidants) together with photochemically produced formaldehyde and acrolein are the primary eye irritants. NRC concluded that aldehyde exposure in Los Angeles has been high enough to cause non-disease effects.

The USDA's annoted bibliography (5) concerning formaldehyde in wood products indicated possible effects on human performance as reported by Freeman and Grendan.

Formaldehyde Emission - Particle Board - Plywood

Particle board and chipboard are formed by impregnating wood chips or sawdust with a synthetic resin, usually urea-formaldehyde, and subjecting the mixture to high pressure.

Plywood is produced by bonding various layers of wood veneer with a synthetic adhesive under increased temperature and pressure. More than 95% of the hardwood plywood production utilizes urea-formaldehyde as the bonding agent (6). In addition, some of the finishes that are applied to the plywood panels may also contain formaldehyde.

Formaldehyde emissions from UF-bonded chipboard and particle board stem from unreacted formaldehyde that remains in the product after manufacture, as well as from the subsequent breakdown of the urea-formaldehyde resin by their reaction with moisture and heat (7). Some gaseous formaldehyde escapes from plywood during its pressing; small amounts are, however, given off afterwards during subsequent storage, sanding, trimming, etc, of the material (8). The extent of emissions and degree of concentration build-up of formaldehyde from both particle board and plywood depend upon a number of factors; for example,

the amount of free formaldehyde remaining in the panels,

the volume of panels in an enclosed space relative to the volume of that space,

the area of exposed surface of the panels,

the temperature and humidity and rate of diffusion of formaldehyde from the panel and

the amount of ventilation available to the enclosed space.

Evidence that particle board and chipboard could give off formaldehyde gas came to light in March of 1961 (9) when a number of investigations were conducted in response to complaints of eye and upper respiratory irritation.

Then about five years ago, an investigation was prompted by an infant that experienced chronic irritation of the eyes and respiratory tract as soon as it was taken from the maternity ward to a mobile home. Formaldehyde concentrations of 0.76 ppm in the bedroom and 1.41 ppm in the bathroom were evident.

Later, a request for assistance was received from a man also living in a mobile home; he had been having irritation of the eyes and a general feeling of ill health, which symptoms abated when he left for a weekend and reappeared shortly after his return. Environmental samples collected on three different occasions indicated the following:

Date	Sample Location	Concn.
10-7-75	Kitchen	1.3 ppm
	Master bedroom	1.3
12-19-75	Living room	0.87
	Master bedroom	0.87
7-27-76	Kitchen	0.64
	Master bedroom	0.93

Recalling the past problems associated with formaldeyde emissions from particle board and plywood and with the rapidly increasing sales of mobile homes and recreation vehicles adding additional impetus, a more extensive investigation of this problem was begun.

Various methods of sampling and analysis for formaldehyde were reviewed and it was decided to utilize the chromotropic acid method recommended by NIOSH (2).

Samples were collected in a midget impringer containing 10 ml of distilled water at a sampling rate of 1 Lpm. Sampling times ranged from 35 to 60 minutes. In most mobile homes, two samples were collected—one in a bedroom and the other in the living room or kitchen. It should be mentioned that the NIOSH method recommended the use of two impringers in series since the collection efficiency of one impringer is approximately 80%. For this study only one impringer was used and no corrections were made in the results.

To date, 334 mobile homes in which one or more individuals have experienced health problems have been surveyed. Formaldehyde concentrations (Table 2) ranged from a high of 1.77 ppm down to 0.03 ppm. Of the 608 samples collected, 66% were between 0.1 and 0.49 ppm while 21% were 0.5 ppm or greater.

A total of 523 individuals, including 240 adult females, 184 adult males and 99 children (under 19 years of age) were affected. The most prevalent symptoms (Table 3) were eye (58% of the adults and 41% of the children) and throat (66% of the adults and 62% of the children) irritation. In addition, 33% of the children were reported to experience chronic cough or cold symptoms. Of particular interest are the relatively large numbers of persons reporting chronic headache and memory lapse or drowsiness and to a lesser extent chronic nausea. A smaller number of the elderly experienced chest pains and heart attacks after having moved into mobile homes.

TABLE 2 - Formaldehyde Concentration in Mobile Homes

Concentration	Kitchen	Bedroom	Other	Total
1.0 ppm	7	7	2	16
0.5 - 0.99	53	44	15	112
0.1 - 0.49	198	161	48	407
0.1	34	36	3	73
Total	292	248	68	608

TABLE 3 - Symptomatic Complaints

	Female (240)		Male (184)		Child (99)	
	No.	%	No.	%	No.	%
Irritation						
eyes	150	62	98	53	41	41
nose	18	8	14	8	11	11
throat	160	67	120	65	62	63
Chronic cold/cough	21	9	18	10	33	33
Difficult breathing	15	6	9	5	1	1
Chronic headache	103	43	65	35	16	16
Chronic nausea	25	10	13	7	5	5
Chronic sneezing	3	1	2	1	1	1
Skin rash	11	5	3	2	1	1
Allergies	7	3	4	2	5	5
Sinus problems	11	5	9	5	5	5
Emphysema	5	2	8	4	0	0
Chest pains	14	6	9	5	0	0
Heart trouble	2	1	3	2	0	0
Heart attack	4	2	3	2	0	0
Memory lapse or drowsiness	62	25	38	20	7	7

Of course, all of the above symptoms could very well result from other causes; however, all of these people indicated that they experienced relief whenever they left their homes on weekends or on vacations. Many of the respondents mentioned that they were being treated by their doctors without any significant relief; a few were accused of being hypochondriacs by either their doctors, spouses or associates. Those who had suffered over the long periods of time often developed acute mental depression.

There is no doubt that the presence of formaldehyde in living areas is an urgent medical concern. The problem may be more serious in mobile homes than conventional homes since the former utilize much more plywood and particle board per volume of space and they are of much tighter construction.

While the literature is vague about permanent health damage and long-term effects are unknown, one must keep in mind that sensitization to formaldehyde can lead to allergic reactions. For such persons, the effect or damage is permanent.

It also is important to consider the prolonged exposure of young children; especially newborn infants, for they spend most of their first year of life indoors. In addition, damage to the developing fetus by exposure of pregnant females deserves consideration.

Many of the people who live in mobile homes are retired and over sixty years of age. These individuals are highly susceptible to formaldehyde because they have an increased incidence of allergies, emphysema, bronchitis and heart disease. Also individuals who have just returned home after open heart surgery may have delayed recovery or complications if they are continously exposed to formaldehyde.

The only standards for formaldehyde to date are associated with the work place. The standard of 1967, for example, provides for a maximum peak concentration of 10 ppm for a total of no more than 30 minutes during an 8-hour work period, with an acceptable 8-hour time weighted average of 3 ppm. The American Conference of Governmental Industrial Hygienists (ACGIH) (11), on the other hand, has recommended an 8-hour ceiling limit of 2 ppm. Recently, NIOSH (2) has proposed that no employee be exposed to formaldehyde at a concentration greater than 1 ppm for any 30-minute sampling period.

On the community level, the American Industrial Hygiene Association (12) has recommended a maximum concentration of 0.1 ppm, which is similar to that adopted in July 1978 by the Netherlands (13).

Control of formaldehyde emissions is difficult. Absorbent chemicals and deodorants have been tried with little or no success, while attempts have been made to seal the plywood and particle board. Yet air samples collected before and after the treatments indicated a relatively insignificant lowering of the atmospheric formaldehyde levels. Attempts to "boil out" the formaldehyde by closing up a home for the weekend and turning up the heat failed to solve the problem. Washing down the walls with ammonia and the discharge of ozone into the interior have not provided any lasting relief. Flow-through ventilation without recirculation appears to be the only reasonable way to minimize indoor atmospheric concentration of formaldehyde in mobile homes; heating and cooling expenses would be increased.

But workplace standards cannot be used for the home environment. First of all, work standards are based on an 8-10 hour work day, 40-hour work week, while the public can be exposed up to 24 hours a day in their homes. Secondly, work standards deal with

adults who are in reasonably good health. The home environment, on the other hand, may contain newborn infants and young children, elderly people with respiratory diseases and heart trouble, pregnant females, hypersensitive and allergic individuals, and people with various other kinds of illnesses.

Attempts to set a standard that would cover all of the above conditions would be extremely complicated. More importantly, enforcement would be impossible. Even if it were possible to develop an atmospheric standard for the home environment, how would it regulate the many thousands of mobile homes that already have been purchased?

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OCCUPATIONAL SAFETY AND HEALTH SYMPOSIA

1979

Department of Environmental, Public
and Occupational Health

American Medical Association
Chicago, Illinois 60610

Contract #210-79-0009

US DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Technical Services
Cincinnati, Ohio 45226

June 1980

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These proceedings are based upon the manuscripts submitted in accordance with NIOSH Contract No. 210-79-0009 with the American Medical Association.

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DHHS (NIOSH) Publication No. 80-139