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# Shelter for the Twenty-First Century

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**Housing for the twenty-first century will be shaped by the changes that are occurring in society. These include the demographics of the occupant, the products and materials used for construction and furnishing, and the basic use of the structure. An aging population will have different demands on design and function. The health concerns of an aging population encompass chronic degenerative diseases as well as injury. The lessons of the past must make us mindful that chronic, low-level exposures to substances can occur at home. Products and materials used in homes can release vapors that may affect immunologic and neurologic function. Manifestations of dysfunctions will be more important as our population ages and if there is a continued reliance on new chemical formulation for products used in homes and workplaces. The future portends changes in functional use of residences. Electronic communications and robotics will decentralize our work force. Manufacturing or office functions will occur at home. This will present new challenges for health and safety for both monitoring and prevention.**

## Introduction

Housing is central to the promise of America. It distinguishes us from most of the world's population. Even among developed cultures our homes are more spacious and offer more comfort features. However, these benefits are not equally shared across our society. Safe shelter will be critical to millions of Americans going into the twenty-first century.

To anticipate how housing might affect future generations, one must examine the factors of change. Changes will occur in housing. For ethnic and economic reasons, these changes will play out differentially across our diverse population. There are three elements to examine. First is the demographics of future occupants. Second is the materials and products used in construction and furnishings. Third is the functional use of living space. Anticipating changes in these elements will provide insight into the health and safety issues of shelters for the twenty-first century.

## Occupants

Beginning with demography, it should be recognized that America is an aging population. The average age is currently about 32, and by 2020 it will be 41. An aging population will expect different amenities from housing. In a word, they will expect security; that is, health security, financial security, and protection, as well as comfort (*1*). We can expect these demands because this generation of Americans were the children of the 1960s. They are educated, accustomed to the benefits of our society, and fully aware of their contributions to social security. Also they will be politically active. They will create a demand for housing that differs from the conventional housing that currently exists. These structures must consider the perils of aging. They must be designed to accommodate loss of mobility and eyesight and the prevention of accidents, because falls and burns are presently the most common among the elderly. If housing is not specifically designed to fit the ergonomics of the elderly, then by default, they will live in dilapidating conventional structures, and we might expect an epidemic of injuries (*2*).

Another challenge to housing in our society will be to provide for low-income families. It is imperative to address the issue in the 1990s, before the twenty-first century. Without radical alteration in our nation's public housing and low-income housing, we will condemn another generation to the hazards associated with decaying, ghetto-style housing. To house the nation's poor in urban high-rises will not be a viable option. Poor maintenance often leaves the population without heat, adequate lighting, and security. Insect and rodent infestation contributes, in part, to the doubling of asthma rates. The stove becomes the space heater, leading to the highest nitrogen dioxide and carbon monoxide concentrations among any indoor residential environment. Crowding and sanitary conditions add to the transmissions of respiratory infection.

Radical departures from our traditional housing policies are needed, along with an estimated $300 billion investment. Low-income housing, transportation, and employment options must be integrated. Suburban communities must share the responsibility. There should be a shift from federal standardized programs to those controlled by states and the tenants themselves.

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Yet, a federal program must maintain basic standards for comfort, security, and health-related amenities.

## Materials

The construction of housing responds to market forces. Since the 1980s builders have constructed more energy-efficient housing. Today it is estimated that 85% of the 1.5 million new homes built annually have more insulation and vapor barriers and offer less air exchange than older homes. These trends, along with the building of more multi-unit dwellings, will continue. Most northern metropolitan areas have the majority of their housing predating 1940. We might expect homes constructed in the last half of the twentieth century to be with us well into the twenty-first century.

The lessons of lead-based paints, mercury fungicides in latex paint, asbestos pipe and furnace insulation, chlordane termiticides, and urea formaldehyde foam insulation should not be forgotten. What are the hidden problems contained in the materials and products within our present and future homes? Again, we must look to demographics. The chronic diseases of an aging population include cancer, heart disease, degenerating neurological disorders, and impaired immunological functions. A diverse array of chemicals will enter our home environments with construction materials, furnishings, appliances, solvents, and pesticides. We already know that the calculated cancer risk for many air toxins are higher indoors in conventional home settings than for most hazardous waste sites. Also, indoor particulate samples are more mutagenic than outdoor samples. Further, it is recognized that specific antibodies are formed from chronic exposures to various organic compounds that are off-gassing from electronic equipment, plastics, and petroleum products.

To recognize the pervasive nature of chemicals in our homes, offices, and schools, we examine studies conducted in the U.S., Holland, Germany, Denmark, and Italy (*3*). Using different methods, these studies reached a similar conclusion: many volatile organic compounds emit by-products and materials that result in higher concentrations indoors than outdoors. Halocarbons and aromatic and aliphatic organic compounds are emitted from products that are familiar to most of us. Table 1 provides a partial list for a few of these compounds that are known or suspected human carcinogens and their sources. The sources that emit organic compounds are numerous and can be commonly found in homes and office products. So common is the household use of many of these compounds that they can be readily detected in residential waste water. As seen in Table 2, analysis of water at the West Point sewage treatment plant in Seattle, WA, attributed a significant fraction of the commonly detected organic compounds to the residential discharge.

**Table 1. Volatile organic compounds typically found in higher concentration indoors.[a]**

| Compounds | Uses |
|---|---|
| *p*-Dichlorobenzene | Deodorizers |
| 1,1,1-Trichloroethane | Dry-cleaned clothes, pesticides, some household cleaners, spray-can propellants |
| Chloroform | Outgases from chlorinated water (washing clothes, showers) |
| Trichloroethylene | Adhesives, tape, cosmetics, insulation, photographic equipment, opaquing fluid |
| Tetrachloroethylene | Dry-cleaned clothes, degreaser |
| Formaldehyde | Fabrics, presswood, insulation, cosmetics |
| Carbon tetrachloride | Cleaners, paint remover |
| Benzene | Smoking, stored gasoline, filling gas tank, power-mower exhaust |
| Styrene | Adhesives, foam, lubricants, plastics, carpets, insulation |
| Methylene chloride | Furniture stripper |

[a]According to Ozkaynak et al. (*4*) and Wallace (*5*).

**Table 2. Common organic compounds found in residential waste waters, West Point, Seattle, WA.[a]**

| Compound | Pound/day[b] | Percent[c] | Uses and products |
|---|---|---|---|
| Phenol | 15 | 47 | Disinfectants, antiseptics, ointments, glues |
| Naphthalene | 10 | 68 | Pesticides, bathroom deodorants, detergents, upholstery and rug cleaners |
| Diethylphthalate | 8.1 | 83 | Food packaging, perfumes, insect repellents, glues, cosmetics, polishes |
| Di-*n*-butylphthalate | 33.8 | 64 | Lubricants, insect repellents, cosmetics, fragrance, gasoline, plasticizers |
| Butyl benzyl phthalate | 30 | 59 | Lubricants, insect repellents, cosmetics, fragrance, gasoline, plasticizers |
| Methylene chloride | 18.6 | 59 | Oven cleaners, tar removers, waxes, spray deodorant, brush cleaners |
| Chloroform | 2.3 | 44 | Liniments, degreasers, water supply |
| Trichloroethylene | 7.9 | 30 | Upholstery cleaners, degreasers, waxes, tar removers |
| Tetrachloroethylene | 21.7 | 84 | Contact cements, degreasers, wax removers, shoe dyes and polishes, upholstery and rug cleaners, pesticides, home and auto parts cleaners |
| Benzene | 2.8 | 63 | Adhesives, deodorants, tar removers, solvents, thinners |
| Ethylbenzene | 2.3 | 19 | Petroleum products |
| Toluene | 2.3 | 29 | Contact cements, detergents, brush cleaners, perfumes, degreasers, shampoo |

[a]After Cooley et al. (*6*).
[b]Pound/day = amount of compound received at West Point Sewage treatment plant in Seattle, WA, from residential sources per day.
[c]Percent of total amount of compound received at treatment plant that was generated from residential sources.

It should not be surprising then to learn that for many of these organic compounds the highest exposure risk is not from manufacturing sources discharging to the ambient air. Rather, the products that are produced and distributed to millions of indoor environments are used, spilled, left to evaporate, discarded, or poured down the drain. Thus, the important exposures often result from everyday-type activities that put us in contact with these chemicals.

We can expect an increasing population of chemically sensitive people. In addition, the role of metals in neurological disorders is recognized without a clearly established route of exposure. The medical profession will have to be more discerning of both the home and work environments in its investigations of the etiology of these diseases.

Beyond the hazards, what promises do technically advanced societies offer? The National Association of Home Builders (NAHB) Research Center has built the "smart house" (*7*). This "smart house" is a revolutionary approach to energy distribution and control in a home. Integrated systems through a single hybrid cable combines power, communication entertainment, security, and safety functions in every room. The use of gas, either directly or by on-site efficient co-generation to electricity, is a future energy source. Currently NAHB is exploring conventional energy sources (gas and electricity from external suppliers). However, the use of solar, geothermal, on-site cogeneration, and storage (thermal mass or batteries) offer self-sufficient energy sources constructed in more remote areas.

The next generation of advancements will come with inexpensive and reliable sensing systems, according to Coates (*8*). Currently, smoke, methane, carbon monoxide, and nitrogen dioxide detectors exist that can be integrated into environmental controls. Infrared and ultraviolet spectrophotometry and gas chromatographic separation will make inexpensive multicompound detectors possible that can be integrated into home-based computing systems. From chemical and elemental signatures, the biological and chemical contamination of homes can be identified.

Beyond controlling the physical environment, advances in sensor technology should provide the opportunity for bioefficient monitoring. From chemical signature of biological samples (breath, urine) or other vital signs, physiologic baselines and the early stages of pathologic deviations could be detected. In addition, many laboratory analyses could be replaced by home-based sensors, linked by telecommunications to medical diagnostic centers. Thus, the home with advanced detectors, monitors, and communication systems becomes the triage center.

## Function

Finally, we come to the future uses of homes. They will not merely be places of shelter. As we currently see the explosion in robotics, microprocessing, and communications, we can envision altered activity patterns (*9,10*).

Because these changes have lower capital investitures, they will alter American life at a rate much quicker than changes in transportation. We have had a century of investment in automobile and aviation transportation, with perhaps another 20 years of expansion before us. With super-conductor technology, land-based fixed-rail rapid transit will reemerge as fast, quiet, and safe travel. Nodes of residential populations 100 to 200 miles from employment centers will disperse our populations to areas that are currently ecologically attractive or are cheaper to develop.

But the transportation revolution that is occurring is through the electronic transfer of information. Couple this with the advancement of intelligent machines, and we will witness the dispersion of enterprise. Smaller manufacturing operations can be established at home and in remote areas. The home can now be the workplace for millions.

Currently, there are 24 million dual-income households in the American society. Along with this income comes a new commodity—independence. Independence in the work force with a shrinking labor pool will transform our public and private bureaucracies. Management will be forced to accommodate a work force that values flexibility and workplace amenities more than financial security. The home as a workplace, the office, and the production line will modify our conventional uses of residential space. It will introduce new challenges to health and safety. How will attitudes to workplace safety be affected when those locations are as familiar to the employee as their own home? How will contaminants be managed when they are dispersed across many locations? Potentially, occupation-related exposures will affect a broad segment of our population and occur in smaller working groups. The tracking of diseases and injuries will be more difficult. How will workman's compensation or tort litigation handle work-related injuries at home? The time to address these complex issues is now, as these changes are unfolding in our society.

## Concluding Statements

For America to keep its promise of economical and safe housing along with access to affordable health care, education, and employment, it must face up to its institutional mess. We look now to government for leadership. However, we have a heritage of linear thinking. The issue-oriented organizational structures demonstrate no propensity for creating new and innovative solutions. Every institution—be it farming, education, defense, transportation, health care, or housing—has vocal, organized constituents who view their own economic interest as paramount. We need integrative national policy in using public investment to stimulate private expenditure.

The pattern of government growth in the 1960s was, in part, under the guiding policy of dispersing the popu-

lation. The location of the National Institute for Environmental Health Science (NIEHS) and U.S. Environmental Protection Agency (USEPA) and other federal facilities in the Research Triangle area of North Carolina has had a major influence on development. Highways, fixed-rail mass transit, and airports are all examples where public investment has altered the course of land development. However, it is time to explicitly recognize the interactions in the formulation of national policy. Housing should help to integrate society and not segregate it. It should provide occupants better access to education, employment, and recreation. Housing should be the haven from a hazardous environment. It should be designed for health promotion. Eventually the medical infrastructure of our society should be integrated into the home. In the home, occupants might find the biofeedback systems to moderate nutrition and lifestyles. They might find diagnostic aids for disease detection and support apparatus for coping with vision, infirmity, or aging. To keep its promise, America must apply its technology to the betterment of its citizens.

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