of the most important health risks in the immediate environment rather than a list that attempts to be comprehensive.

The U.S. Environmental Protection Agency (USEPA) has compiled a ranking of health risks in three of its regional offices. Although not strictly limited to the immediate environment, their analysis category of human health risks associated with the environment provides some helpful insight. To briefly summarize, all three regions consistently rank indoor radon, other indoor air pollution, pesticide residues on food, and drinking water contamination as high health risks (USEPA, 1989a). By contrast, underground storage tanks and waste sites--hazardous and nonhazardous--are ranked as low health risks.

Others have also attempted to prioritize indoor environmental risks (Yocum, 1982; Mage and Gammage, 1985; and duPont and Morill, 1989). Included among prominent indoor pollutants are volatile organic compounds including formaldehyde, radon, biogenic particles, drinking water contaminants, and lead; asbestos is not seen as a significant problem in homes unless and until it is damaged or otherwise disturbed (Godish, 1991).

The objective of this study is to review hazards in the home that might impair the safety and well-being of its occupants. The first section examines safety issues. Analysis of data relating to unintentional injury in the home reveals the types of accidents causing the greatest number of deaths; this, in turn, identifies the circumstances and systems/products most deserving of attention. The data also reveal which age cohorts are at greatest risk from fatal accidents; at-risk populations can be specially targeted for educational outreach.

The selection of high priority environmental risks is necessarily somewhat subjective since hard data on fatalities is rarely available. Should the selection of such risks be based on the highest number of fatalities, or on the potential for serious health problems among the most people? In the present study, selection has been based, in part, on the author's estimation of the combined impact of these effects, and substantially influenced by other research (Yocum,1982; Mage and Gammage, 1985; USEPA, 1989a; and Berry 1991).

Safety Issues

In this study, the consideration of safety issues in and around the home is divided into two categories: the behavior and action of occupants as they perceive and react to risks (demographic breakdown of accident frequency provides useful perspectives), and the inherent safety of devices and systems that are used in the home.

Behavioral Aspects: Demographics

It seems reasonable to suggest that many of the precautions and safety measures taken by individuals in their daily routines are based largely on instinct. We quickly learn, for example, of the hazards posed by height, high temperatures, and high speed. In a technologically complex society, however, instinct alone is not always sufficient to identify all hazards. The risk judgments that are formulated by lay persons and based on complex psychological processes (Slovic, 1987), should be useful for everyone--residents and those providing information to them--to examine accident data that has been compiled. Such an examination can assist in the prioritization of efforts to reduce risks. It can also point out risks that are not otherwise evident. Moreover, it can identify high-risk categories of the population and reveal emerging trends in accidents.

In 1989, some 94,500 persons died in accidents; nearly half of these deaths involved motor vehicle accidents, whereas 22,500 occurred in the home (National Safety Council (NSC), 1990). In addition, it has been estimated that home accidents caused some 3,400,000 disabling injuries (NSC, 1990). Among accidental deaths in the home, falls are the predominant cause of death, (see Figure 1).

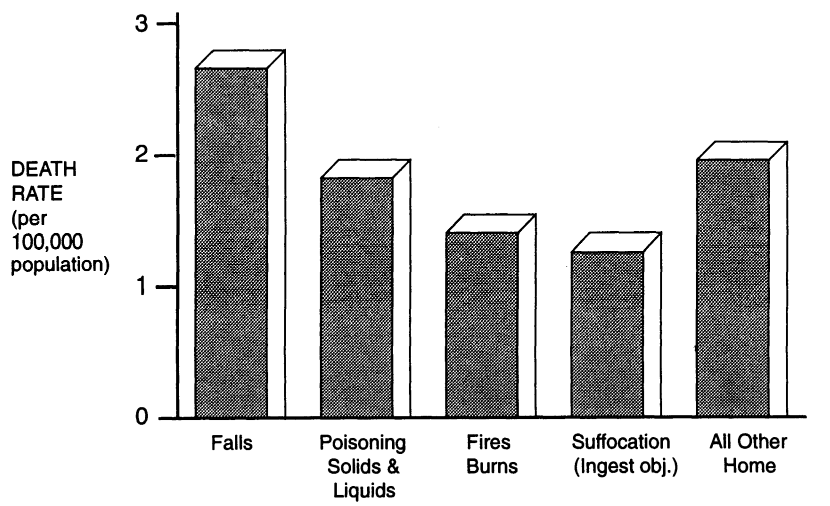

Figure 1. U.S. death rate from home accidents, 1989. Source: National Safety Council.

Further analysis of this data shows that 1) most fatal falls occur in the over-70 age group, 2) drowning and death in fires are major causes of death among young children, and 3) at-home deaths in the 25-44 year age group are attributed mainly to poisoning by solids and liquids (mainly drugs) (NSC, 1990). Deaths in this latter category have increased substantially over the last decade. Suffocation from an ingested object is the second most common cause of accidental death in the home for older persons (after falls), and this cause, along with "suffocation-mechanical," is also prominent in deaths in the 0-4 years age category. The elderly are also particularly vulnerable to fires and burns (NSC, 1990).

The farm represents one of the most dangerous of all workplace environments, and the rate of fatal accidents in farm homes is slightly more than 10 percent above the overall national rate for home accidents (NSC, 1990).

Analysis of trends in overall accidental death rates reveals a 21 percent decline for the last decade, but fatal home accidents have decreased by only 16 percent (NSC, 1990). Thus, the decline in home accidents has not kept pace with the overall reduction in accidents.

Another noteworthy feature of fatal home accidents is that they increased with age. Overall, the home accident death rate for those aged 75 years and above is more than four times as great as for the group with the next-highest rate. This predominance is broadly based among accident types. This age category has the highest death rate in seven of the nine home accident classifications described by the National Safety Council (1990), accounting for more than 60 deaths per 100,000 persons each year in this age category.

Products and Systems

Improvements in products and systems in and around the home over the last several decades have done much to enhance the safety of the home environment at minimal added cost. Electrically grounded circuits and double insulation on appliances, for example, provide an added degree of protection against electrical shock. Ground fault circuit interrupters, required by the National Electrical Code (Foley, 1981) in certain high risk locations, provide a new level of human protection at nominal cost. These devices are designed to trip in response to current leakages before serious injury can occur.

In 1989, some 802 deaths were attributed to "electric current;" 146 of these were specified as "domestic wiring and appliances," one-third were not related to the home, and about half were "other and unspecified" with regard to location (NSC, 1990). While this death rate is relatively low on a per capita basis, further advances in electrical safety are continually sought. A systems approach to safety--electrical and otherwise--is incorporated in the "Smart House," a novel, high-tech enterprise spearheaded by the National Association of Home Builders and a consortium of product manufacturers (Brody, 1988). Added protection from electrical hazards would be provided by "closed loop" electrical wiring. In such a system, appliances and fixtures would communicate with a central power controller; electricity would be supplied to an outlet only in response to a signal when a compatible device is plugged in or turned on (thus, a foreign object inserted into a receptacle could not be electrically "livened") (Brody, 1988). Moreover, the signal from the device would define the current limit for normal operation; malfunctions that would otherwise cause an overcurrent condition would not draw additional current. Likewise, gas appliances would be fueled only during appliance operation and would shut off under emergency conditions (Geremia, 1987). Such homes would also include advanced fire alarm and security systems.

Another development that may have some important spin off impacts on safety in the home is the 1988 Fair Housing Amendments Act. The portions of this bill dealing with barrier-free accessibility would require some housing construction to include units accessible to the disabled (Binsacca, 1989). While most of the emphasis of these modifications focuses on accommodating those in wheelchairs, incorporation of elements such as grab bars should help in reducing falls. Standards for these elements have been developed by the American National Standards Institute as ANSI Standard 117.1-1986 and have also been published by the Federal Government (General Services Administration, 1984).

An analysis of seniors' housing inadequacies in the areas of safety, function, and comfort was conducted by Brent, Phillips, Brent, Gupta, and Degges (1991). Not surprisingly, the highest number of safety problems was found in the kitchen and bathroom; 11 categories relating to gross-motor safety inadequacies (primarily related to the potential for falls) were identified. Eight inadequacies were listed in the lighting, fire and electrical safety categories (Brent, et al., 1991). This sort of analysis, based on a detailed set of rules for identifying hazards, can serve as a useful guide to those helping seniors make their surroundings safer. Recent rules established by building code organizations call for revised standards for residential staircase dimensions (Codes, 1992). Proponents believe that a wider tread dimension and reduced riser height will provide greater safety on stairs. Critics (mainly from the building industry) disagree, citing a lack of hard evidence and added costs affecting affordability.

Challenges to Designers and Educators

Design professionals should note conditions throughout the home that might contribute to falls, such as lighting intensity, stairway dimensions, handrail and grab bar characteristics, and floor coverings, and identify improvements that could reduce this type of accident. Educators, especially those working with older audiences, should call attention to the frequency and severity of such accidents in later years.

The Environment

It was but a few decades ago that the outdoor environment received little attention from health officials, and even less from the general public and regulatory bodies. Some landmark events shortly after World War II provided dramatic evidence of the finite capacity of the environment to dissipate toxic pollutants.

In Donora, Pennsylvania (1948), and later in London, England (1952), unusual atmospheric conditions served to trap locally produced pollutants close to the ground (Mage and Gammage, 1985). In both cities, smog created many health problems and fatally injured hundreds of residents. During these episodes, the home was considered a refuge of sorts from outdoor air, and the elderly and infirm were among those advised to remain indoors (Mage and Gammage, 1985).

But what about indoor air? Is it, indeed, a benign environment, a safe escape from outdoor pollution? The end of World War II heralded the beginning of a series of events that were to have a significant impact on housing in general and the indoor environment in particular.

The returning troops created a large demand for housing as they established new households in the postwar years. Because of the high cost of solid wood, development of pressed wood products and plastics was accelerated, and many novel materials and products were incorporated into residential construction (Mage and Gammage, 1985).

From the design perspective, little thought was given to indoor air quality needs; in fact, for the early part of this century, the main basis for ventilation requirements was the control of body odor in occupied buildings (Kreiss, 1989). Even as recently as the early 1970s, there were those who believed that indoor pollution levels were primarily dependent on outdoor pollution; about this time, however, the awareness that indoor pollution sources could have important and deleterious effects, emerged (Mage and Gammage, 1985; Kreiss, 1989). In a major review of the literature on indoor and outdoor pollution levels, Yocum (1982) concluded that for several pollutants, outdoor levels substantially underpredict indoor exposures; and further, that for the prior decade, "the degree of improvement in outdoor air quality has not been matched by a corresponding improvement in indoor air quality."

In what may now be considered a landmark series of studies, Wallace and associates set out to compare indoor (residential) and outdoor air quality in urban areas with and without intensive petroleum/chemical industries, and in a rural town (Wallace, Pellizzari, Sheldon, Hartwell, Sparacino, and Zelon, 1986). The investigators concluded that indoor air pollution is more important than outdoor air pollution, and more important than nearby major "point" sources (such as nearby chemical plants and refineries) with regard to personal exposures to the pollutants measured (Wallace, et al., 1986).

In addition to the overall findings of Wallace's group concerning indoor air versus outdoor air, the work also revealed that several Volatile Organic Compounds were present in 80-100 percent of all indoor air and breath samples. Because of the widespread occurrence of these pollutants, they were designated as "ubiquitous compounds" including common solvents and components of gasoline, paint, and other petrochemical products, some of which are known carcinogens (Wallace, et al., 1986).

In examining the data of Wallace's group (1986) and others who have studied indoor air pollutants (see, for example, Yocum, 1982; Levin, 1989; Girman, 1989), it is evident that residential concentrations of individual pollutants are, for the most part, extremely low in comparison to workplace standards that have been established for those pollutants. This is generally true even in homes and office buildings in which health problems have been attributed to air quality problems.

The effect of low or extremely low dosages of compounds known to be harmful in larger amounts is one of the most perplexing challenges in epidemiology. One policy approach to this issue, commonly employed for cancer-causing agents, is based on the linear, no-threshold theory. This theory assumes that the toxic effects of an agent proceed in a linear fashion according to dosage; and also, that there does not exist a threshold dosage below which harmful effects do not occur (Ames, Magaw, and Gold, 1987). Exposure standards based on this assumption tend to be quite conservative, but the validity of this assumption is questionable.

Another difficult question concerning exposure to low dosages of harmful agents involves the possibility of interaction with (low concentrations of) other pollutants. Some of these interactions involve a simple addition of effects, but others involve multiplication (or synergy), where the net effect is greater than the sum of the individual effects (Girman, 1989).

Finally, in the context of acceptable/unacceptable exposures to pollutants, one must consider the concept of standards. While there are numerous standards for workplace exposures to hazardous substances, residential air quality standards have not been established. This is partly for reasons of political philosophy and partly because of lack of epidemiological data. Whereas workplace standards can be based in part on worker epidemiology, there are some very important differences from the population in homes: The very young and the very old are excluded from the workforce, as are the chronically ill. Worker exposures to harmful agents can be quite high (relative to residential exposures) but are more or less limited to an eight hour day, compared to approximately 18 hours per day typically spent at home (USEPA, 1987).

It should be stressed that indoor environmental concerns are not limited to synthetic compounds introduced by products and materials in the home; nor are they limited to airborne contaminants. Inadvertent ingestion of "small" amounts of lead in the form of dust is now believed to cause serious impairments in young children. There is growing concern about the quality of drinking water (especially as provided by private wells). Even in the absence of synthetic pollutants, serious indoor environmental problems can be traced to pollutants from natural sources. Biological organisms (ranging from mold and mildew to insects) in the home are increasingly associated with health problems. Of all indoor air pollutants, a naturally occurring one--radon--has been associated with the largest number of deaths of any residential indoor pollutant (USEPA, 1989a).

These are the issues to be addressed in the next sections. Cigarette smoking is an issue that will not be discussed; it should, however, be pointed out that a growing body of evidence implicates secondary smoke as an important health risk factor for members of smokers' households.

Volatile Organic Compounds

This is a broad category of organic compounds which can vaporize and enter the atmosphere. As indicated above, Wallace et al., (1986) found these to be widely distributed in homes, irrespective of outdoor air concentrations, and concluded that they must derive from products, materials, and processes within the home.

Investigation of air quality complaints in commercial buildings has attributed many occupant symptoms (mucous membrane irritation of the eyes, nose, and throat; headaches; and general malaise) to Volatile Organic Compounds (VOCs), which include known toxins, irritants, and carcinogens (Levin, 1989; Girman, 1989). Specific residential sources of many of these organic pollutants have been identified. These include smoking and passive smoking (benzene, styrene, and many other chemicals), hot showers (chloroform), room air fresheners or moth crystals (p-dichlorobenzene), carpets and cushions (styrene), and aerosol sprays (1,1,1 trichloroethane) (Wallace, et al., 1986). In another study of emissions produced by building materials, 80 percent of the compounds that were identified were known or suspected mucous membrane irritants (Molhave, 1985). Because of its large surface area, newly installed carpet may be a major source of VOCs in homes (Levin, 1989).

There has been some progress concerning the impact of low concentrations and mixtures of VOCs on human health. A double-blind study in which human subjects were exposed to VOC mixtures and concentrations typical of average and peak VOC values seen in new Danish homes showed mucous membrane irritation and other sensory complaints, and some neurological signs, even at "average" exposures. (Molhave, Bach, and Pedersen, 1986). Individual VOC concentrations in these mixtures were well below industrial exposure limits. There is little information on long-term effects of exposure to low concentrations and mixtures of VOCs, although some risk projections (based on an additive model) have been reported (Girman, 1989).

While analytic methodologies exist for VOCs (e.g., gas chromatography/mass spectroscopy) (USEPA, 1989b), these will be prohibitively expensive for the average household with an air quality problem. A diagnostic interview--or perhaps an interactive computer program--will likely be the more practical approach in most cases.

Mitigation of VOC problems will depend largely on whether or not the source can be identified. Increased ventilation may be a successful strategy in some situations, but is limited by energy cost and comfort considerations. "Source reduction"--which, until recently, meant removing a product or using less of a material--is another approach. In recent years, manufacturers have researched ways to reduce products' VOC emissions (in carpet, for example), and various states have set limits on VOC content for products such as paints (NYC Joins VOC Reg. Bandwagon, 1990). Combustion products, particularly carbon monoxide and oxides of nitrogen, can seriously impact the indoor environment. These products are produced by unvented, or improperly vented, fuel burning equipment. A total of 600 deaths were attributed to this cause in 1989 (NSC, 1990), although this figure includes standing motor vehicles.

Formaldehyde

Although formaldehyde is a volatile organic compound, it is treated separately because of the large number of complaints attributed to it, both in office buildings and especially in homes.

This compound is used in a wide variety of materials and products that are incorporated/found in buildings. It is a component of resins, adhesives, and binders; urea formaldehyde, a relatively unstable compound, is used as a binder/adhesive in particle board, fiberboard, and hardwood plywoods, and has been used as a component of insulating foam (Yocum, 1982). The latter use was banned by the Consumer Product Safety Commission in 1982, and although the order was reversed shortly thereafter, this insulation has virtually disappeared from the marketplace (Anderson, 1983).

Formaldehyde usage in these products is a particular problem partly because it can be hydrolyzed (broken down), releasing formaldehyde as a function of indoor relative humidity and temperature (Godish, Fell, and Lincoln, 1984). Thus, unlike many other VOCs, formaldehyde offgassing can be expected to persist indefinitely, although release falls substantially in the first few months; pressed wood products may have an emissions half life of months or years compared to days for "wet" products such as adhesives. Pressed wood products are generally recognized as the major contributors of indoor formaldehyde (Girman, 1989). Indoor formaldehyde levels can also be raised by combustion from unvented gas appliances and, to a lesser extent, from cigarette smoke (Yocum, 1982).

Formaldehyde has a pungent, characteristic odor and causes irritation of the eyes, upper respiratory system, and skin; headaches, fatigue, and abnormal thirst have also been observed (Godish, 1989). Sensitive individuals react to levels of formaldehyde that do not affect most individuals (duPont and Morrill, 1989). Because of wide variations in individuals' sensitivity, it has been concluded that there is no concentration threshold for the irritating effects of formaldehyde (Mage and Gammage, 1985). The question of the long-term effects of formaldehyde exposure remains controversial. Following an earlier report of nasal cancer in rats exposed to very high levels of formaldehyde, Blair et al., (1986) studied some 26,000 workers with occupational formaldehyde exposure and found no statistical correlation between exposure and lung cancer. Another study showed a "strong and significant association" between living in a mobile home for ten or more years and nasopharyngeal cancer, but not other cancers (Vaughan, Strader, Davis and Daling, 1986).

Formaldehyde problems in houses are generally more serious than those in office buildings (Girman, 1989); the most serious problems frequently occur in mobile homes (duPont and Morrill, 1989). There has been progress in reducing the formaldehyde content of pressed-wood products (reductions as high as 75 percent have been realized in the past decade) (duPont and Morrill, 1989). Nevertheless, the formaldehyde release potential of many of these products is still potent enough to cause a variety of problems (Godish,1989).

Two types of moderately-priced passive formaldehyde detectors are available for home use (duPont and Morrill, 1989). In homes whose occupants experience serious problems that are traced to formaldehyde, steps must be taken to reduce this pollutant. Godish (1986) has listed a variety of strategies for the treatment of buildings with formaldehyde problems. Of these, source treatment is probably the most widely applicable and practical. This involves coating exposed surfaces (cabinets, paneling, the underside of countertops, etc.) with a sealant that blocks formaldehyde passage (Godish, 1986). Ammonia fumigation can inactivate formaldehyde, but this procedure can cause its own problems and is of limited practicality (Godish, 1986). Spider plants are among plant species that have been identified for their abilities to remove formaldehyde and other pollutants from the air (Wolverton, Mcdonald and Watkins, 1984; Research update: House plants for clean air, 1991). However, others claim that such an approach is ineffective in dealing with the continuous release of formaldehyde that occurs in homes (Godish, 1986). In most existing homes, application of coatings, perhaps combined with ventilation increases, will probably remain the most practical approach to formaldehyde mitigation.

Radon

Radon, a colorless, odorless, radioactive gas produced as naturally occurring uranium, undergoes radioactive decay (USEPA, 1987). Since uranium is one of the most widely dispersed elements in the earth's crust, it poses a contamination potential for homes throughout the world. This potential was realized in dramatic fashion in 1984 when a worker at a nuclear plant in Pennsylvania set off radiation alarms upon entering the plant; the contamination was subsequently traced to his home, in which peak radon levels were about 100 times greater than levels currently permitted in uranium mines (duPont and Morrill, 1989). It was later learned that this home was situated above a uranium-rich geologic formation spanning several states (the Reading Prong); while such areas pose high risks, it is important to recognize that some nearby homes had little or no problem (duPont and Morrill, 1989). Since that time, USEPA surveys have found homes with elevated levels throughout the country, and this agency recommends that all homes be tested for radon (USEPA, 1987).

Radon gas--or, more precisely, its radioactive-breakdown products--is a well-known carcinogen. The link between radon and lung cancer has been amply documented through studies on a large number of mine workers (USEPA, 1987; Committee of the Biological Effects of Ionizing Radiation, 1988). Extrapolation from mine worker data to residential exposures and risk factors is difficult and, to some degree, controversial. Direct epidemiological evidence linking residential radon exposures (which may greatly exceed workplace exposures) and lung cancer is sparse, in part because the appearance of this disease requires exposure and latency periods that may span two or more decades (New Jersey State Department of Health, 1989). Studies comparing median radon levels (in a large number of U.S. counties) with the incidence of lung cancer were unable to show a linkage (and, in fact, showed a negative correlation; such data question the validity of the linear, no-threshold assumption about radon's effects) (Cohen, 1988). A case-control study of New Jersey lung cancer victims with lengthy tenure in individual homes showed increasing risk of lung cancer with increasing residential radon exposure. The relationship was consistent with that calculated for miners exposed to higher dosages, although the small number of qualifying high-radon homes in the New Jersey study limits its statistical strength (New Jersey Department of Health, 1989). Another case-control study dealing with female lung cancer victims with (long term) residency in rural Chinese villages was unable to show a correlation between indoor radon levels and this disease (Blot, Xu, Boice, Zhao, Stone, Sun, Jing and Fraumeni, 1990).

Most of these residential studies involve radon levels that exceed the USEPA's action level of 4 pCi/l air by only a modest amount. Indeed, the large majority of tested homes that exceed this level are nevertheless close to the action level. Raw data for the United States show that, of a sample of more than 60,000 radon measurements, about 30 percent were in excess of the action level, with 5.5 percent in excess of 20 pCi/l. These values are slightly biased toward the high side since radon "hot spots" (Pennsylvania, New Jersey, and Maine) are represented by a relatively high number of measurements (Alter and Oswald, 1987). Nevertheless, even if the 4 pCi/l level is found to be harmless, there is still a percentage of homes with radon levels at and above concentrations that have been associated with lung cancer in mine workers.

Radon is not the major cause of lung cancer; most lung cancer deaths are attributed to cigarette smoking; some 85 percent of the 130,000 lung cancer deaths in 1986 were attributed to cigarette smoking, with most of the remainder-about 5,000 to 15,000 lung cancer deaths attributed to radon (USEPA, 1987). These "radon deaths" may not be the only major impact of this element on public health. There is growing suspicion that radon exposure may also multiply the risk of lung cancer among cigarette smokers.(Committee of the Biological Effects, 1988.)

Fortunately, simple and inexpensive tests (some costing as little as $10 to $20) are readily available for occupants to measure radon in their homes (duPont and Morrill, 1989). Unfortunately, radon tests have only been conducted in, at most, about two percent of homes nationally (Bierma and Swartzman, 1990), and in only slightly more homes in high risk areas, in spite of heavy publicity campaigns by federal and state health officials and others.

There has been a great deal of progress in understanding the dynamics of radon entry into buildings and in the development of mitigation techniques in recent years (duPont and Morrill, 1989; USEPA, 1990b). It is anticipated that the recently established regional radon training centers will provide radon mitigation professionals with the ability to select and install the most appropriate and economical mitigation measures in homes and other buildings.

Biological Agents

Included in this category is bacteria, mold, mildew, fungi, and organisms such as dust mites and roaches. Most of these organisms have several characteristics in common: they thrive in conditions of relatively high moisture, and (except for dust mites) they can cause damage to building contents and sometimes the structure itself. There is a growing awareness, moreover, that these organisms can have a significant impact on the health of building occupants (Burge, 1991; duPont and Morrill, 1989). The population of dust mites, for example, which can cause childhood asthma, is directly related to humidity levels (duPont and Morrill, 1989). Bacteria and other organisms that grow on wet surfaces or standing water can cause allergic reactions and more serious illnesses, especially when ventilation or humidification equipment disperses these organisms or their spores, body parts, or waste (Burge, 1991). Problems can also result when humidity levels are too low (Sterling, Arundel, and Sterling, 1985) so optimal moisture levels are defined by a relatively narrow range. Because of the important link between building moisture levels and the growth of disease-causing organisms, moisture control is a vital element in managing the indoor environment.

Lead

Lead poisoning has been a persistent problem for many years, especially among young children (Rabin, 1989). It has been called "the most common and societally devastating environmental disease among young children" (Binder and Falk, 1991). Lead is not readily excreted, so chronic ingestion has a cumulative effect. Lead poisoning in young children affects the development of the nervous system, causing learning disabilities, hyperactivity, poor motor coordination, other developmental deficits, and, in larger doses, death (Rabin, 1989). Based on recently revised standards, it is estimated that 3.5 million U.S. children may be at risk of lead poisoning. In some homes built before 1978, and more than half of those built prior to 1960, heavily leaded paint was used (U.S. Consumer Product Safety Commission, 1989). While there are other sources of lead in the home environment, paint is a major source of poisoning by this element (Binder and Falk, 1991). Scenarios include the deliberate ingestion of paint chips (by very young children) and, more importantly, consumption of lead-tainted dust as hands or objects are mouthed. Lead dust may come from paint; also from soils contaminated by lead from (prior) auto emissions. Problems can also result from rehabilitation projects when old paint is disturbed by sanding or removal (lead vapors can be produced by heat removal processes).

An official set of lead paint removal guidelines has been developed (U.S. Department of Housing and Urban Development, 1990), but such procedures are labor intensive. Lead paint remediation, much as radon remediation, is likely to be out of reach for low-income households and presents similar problems in many rental units. Solutions to such problems will likely involve a mix of political policy decisions and perhaps the development of acceptable technical measures that fall short of complete removal.

Drinking Water Quality

Approximately half the nation's population relies on ground water for drinking, via both private and municipal wells; the vast majority of the rural population depends on potable groundwater for domestic use (USEPA, 1990a). However, in 1988, over half the states identified major threats to their groundwater supplies; these threats included leaking storage tanks, poorly operating septic systems, brine intrusion, agricultural activities, and seepage from landfills and hazardous waste sites (USEPA, 1990a). The direct contribution from individual households may add to groundwater (and surface water) pollution when household products and wastes are improperly used or disposed of. The relative role of this non-point source pollution in the contamination of surface and groundwater needs to be better documented and certainly needs to be conveyed to the public.

Federal legislation (and amendments) over the last two decades have addressed the nation's water quality issue by regulating pollution sources. Moreover, in the Safe Drinking Water Act, quality standards for public drinking water supplies are set by the USEPA for state adoption, and periodic monitoring requirements are mandated for local water supply systems (USEPA, 1990a). Thus, there are some reasonable assurances of the quality of public drinking water supplies insofar as local officials comply with these regulations. Such requirements do not apply to private wells, so the burden is on private well users to conduct regular testing and make decisions concerning remediation.

Decisions in these matters can be quite difficult when a large expense is involved, even though they can be made in the context of quantitative measurements of a private well and Maximum Contaminant Levels as developed by the USEPA. Decision-making processes in these matters are basically risk-benefit judgments. Ideally, these are best rendered in the context of other risks (both accepted and avoided) encountered by those in the household. Educators who assist with decision making of this sort can do so by developing materials that provide a basis for risk comparisons.

Summary and Implications

With regard to VOCs, some very compelling questions arise. While the ubiquitous pollutants described by Wallace, et al. (1986) are likely to be found in most homes, what is their impact? Can long-term exposure to very low concentrations of known and suspected carcinogens play a role in the development of cancer? A related, and perhaps even more complex question involves the numerous VOCs present in most homes: How do these species interact, and are their effects on human health additive or multiplicative?

In contrast to long-term health impacts, the effects of indoor pollutants that get occupants' immediate attention are those which cause acute discomfort or problems. VOCs are probably major contributors in the latter category; the homeowner confronted with indoor air problems will frequently ask for information on "air testing" to identify the problem's source. Ordinarily, testing would be inappropriate and prohibitively expensive (Oatman, 1991). Health department officials and others who respond to these questions employ question-and-answer diagnostic routines to track down the origin of indoor air complaints. Such a protocol--perhaps in the form of an interactive computer program--would be a great help to householders trying to identify and reduce air quality problems.

With regard to formaldehyde, two major challenges are 1) to find new formulations or substitutes for its uses to minimize its impact on the indoor environment and 2) to develop better mitigation measures. It is likely that for existing homes the preference will be for low-cost, low-tech measures. While simple test kits are available, reduction of their cost would make them more accessible to homeowners.

There are important differences in the problems presented by radon and lead in the residential environment, but the commonalities are many. More research is needed to identify low-cost measures to mitigate residential exposures to these elements and to identify the circumstances in which partial or "low level" mitigation would be appropriate. While there are many methods to minimize radon entry in new construction (USEPA, 1988), protocols for optimum method selection are not well developed, and pre-construction site evaluation for radon potential has had little success.

Educational needs, to some degree, blend with advocacy. The public's response to the radon threat has largely been apathetic; radon tests have been conducted in a very small percentage of households (Bierma and Swartzman, 1990), even though this is considered a major health risk. Convincing the public of this danger and the need for testing presents a major challenge. With regard to lead, educational efforts are needed for all occupants of older housing, ranging from low-income households, which are not well connected to mainstream information, to upper-income households which may be unaware of less obvious hazards from dust as older homes are "gentrified." Private well owners should understand the importance of a regular testing program for nitrates and bacteria and other contaminants that may be locally important.

Besides these research and educational needs, there are also public policy issues needing the expertise of housing professionals. The fundamental question regarding both radon and lead contamination in homes involves the role of the government (federal and local) in rental and low-income housing. In principle, the various governmental bodies set minimum standards of habitation and occupancy through the various building and sanitation codes. The degree to which governmental bodies will mandate inspection and remediation for radon and lead has not been well established, nor is it clear how--or if--public monies will be used to support mitigation of such problems. While the responsibility for publicly-owned and Indian housing may be less debatable, the availability of money for this purpose remains a serious question.

In a similar vein, issues such as remediation of lead, radon, and other environmental hazards are likely to become important at the time of real estate transactions. Are the interests of the buyer and seller best served by total remediation, or might there be other mutually satisfactory approaches? What will be the role of lenders, the "financial gatekeepers" in these transactions, in view of their own liabilities and interests? Housing educators, as disinterested parties, can play an important role in developing policies that deal with these issues.

As safety and environmental risks are considered and evaluated by housing educators, and especially as they are communicated to others, two important factors deserve attention. As hazards are identified, an expression of their attendant risks, relative to other, better-known risks can help to establish the priority and context of that particular hazard when such risk expressions can be made. This can be particularly difficult as general audiences may be unswayed by data and statistical arguments that seem elementary to professionals. In addition, when risk information is to be communicated, attention to the techniques of "risk communication" can reduce problems of perception.

References

Alter, H.W., & Oswald, R.A. (1987). Nationwide distribution of indoor radon measurements: A preliminary data base. *Journal of the Air Pollution Control Association*, 37(3). 227-231.

Ames, B.N., Magaw, R., & Gold, L.S. (1987). Ranking possible carcinogenic hazards. *Science*, 236, 271-280.

Anderson, C. (1983, October). Formaldehyde wins in court, but still a loser. *Builder*, 42-48.

Berry, Michael A. (1991). Assessing the risks of indoor air. In J. Laquatra and S.A. Zaslow (Eds.), *Indoor air quality in homes: Synthesizing the issues and educating consumers* (pp. 17-21). Chicago: Building Research Council - Small Homes Council, University of Illinois.

Bierma, T.J., &, Swartzman, D. (1990). "Social Marketing" and the reduction of indoor radon. Session I. In U.S. Environmental Protection Agency (Ed.), *The 1990 International Symposium on Radon and Radon Reduction Technology Proceeding.* Washington, DC: Author.

Binder, S., & Falk, H. (1991). *Strategic plan for the elimination childhood lead poisoning.* Atlanta, GA: U.S. Department of Health and Human Services, PHS, CDC.

Binsacca, R. (1989, June). How to deal with new fair housing rules. *Builder*, 56-60.

Blair, A., Stewart, P., O'Berg, M., Gaffey, W., Walrath, J., Ward, J., Bales, R., Kaplan, S., & Cubit, D. (1986). Mortality among industrial workers exposed to formaldehyde. *Journal of the National Cancer Institute*, 76, 1071-1084.

Blot, W.J., Xu, Z. Y., Boice, J.D., Zhao, D.Z., Stone, B.J., Sun, J., Jing, L. B., & Fraumeni, J.F. (1990). Indoor radon and lung cancer in China. *Journal of the National Cancer Institute*, 82(12). 1025-1030.

Brent, R.S., Phillips, R.G., Brent, E.E., Gupta, M.K., & Degges, S.R. (1991). Older adults residing in their own home: Prioritizing housing inadequacies. *Housing and Society*, 18(1), 25-35.

Brody, H. (1988, March). Companies struggle to automate homes. *High Technology Business*, 34-38.

Burge, H. (1991). Biological contamination in the home environment. In J. Laquatra and S.A. Zaslow (Eds.), *Indoor air quality in homes: Synthesizing the issues and educating consumers*, (pp 52-54). Chicago: Building Research Council--Small Homes Council, University of Illinois.

Codes okay wider doors, longer stairs (1992). *Journal of Light Construction - Easters. Edition.* 10(4), 5, 10.

Cohen, B. (1988). Correlation between mean radon levels and lung cancer rates: A test of the linear-no threshold theory. *Session II, U.S. Environmental Protection Agency 1988 Symposium on Radon and Radon Reduction Technology. Proceedings, Denver, Colorado.* Washington, DC: U.S. Environmental Protection Agency.

Committee of the Biological Effects of Ionizing Radiation (1988). *Health risks of radon and other internally deposited alpha emitters: BEIR IV.* Washington, DC: National Academy Press.

duPont, P., & Morrill, J. (1989). *Residential indoor air quality and energy efficiency.* Washington, DC: American Council for an Energy Efficient Economy.

Foley, J.H. (1981, December). Ground fault protection. *Fine Homebuilding,* 39-41.

General Services Administration (1984, Aug. 7). Uniform federal accessibility standards. *Federal Register, 49* (153), 31,528-31,617. Washington, DC: U.S. Government Printing Office.

Geremia, K. (1987). *Smart house.* Upper Marlboro, MD: Smart House Development Venture, Inc.

Girman, J. (1989). Volatile organic compounds and building bake-out. In J.E. Cone and M.J. Hodgson (Eds.), *Occupational Medicine: State of the Arts Reviews.* Vol. 4, No. 4, (pp. 695-712). Philadelphia, PA: Hanley & Belfus.

Godish, T. (1986, Summer). *Indoor air quality notes: Residential formaldehyde control.* Muncie, IN: Ball State University.

Godish, T. (1989, Summer). *Indoor air quality notes: Formaldehyde--Our homes and health.* 2nd Ed. Muncie, IN: Ball State University.

Godish, T. (1991). Overview of the issues. In J. Laquatra and S.A. Zaslow (Eds.), *Indoor air quality in homes: Synthesizing the issues and educating consumers.* Urbana - Champaign, IL: Building Research Council-Small Houses Council.

Godish, T., Fell, J., &, Lincoln, P. (1984). Formaldehyde levels in New Hampshire urea-formaldehyde foam insulated houses: Relationship to outdoor temperature. *Journal of the Air Pollution Control Association,* 34(10), 1051-1052.

Kreiss, K. (1989). The epidemiology of building-related complaints and illness. In J.E. Cone and M.J. Hodgson (Eds.), *Occupational. Medicine: State of the Art Reviews,* Vol. 4, (4), (pp. 575-592). Philadelphia, PA: Hanley & Belfus.

Levin, H. (1989). Building materials and indoor air quality. In J.E. Cone and M.J. Hodgson (Eds.), *Occupational Medicine: State of the Art Reviews,* Vol. 4, No. 4, (pp. 667-693). Philadelphia, PA: Hanley &, Belfus.

Mage, D.T., & Gammage, R.B. (1985). Evaluation of changes in indoor air quality occurring over the last several decades. In R.B. Gammage and S.V. Kaye (Eds.), *Indoor air and human health,* (pp. 5-35). Chelsea, MI: Lewis Publishers.

Molhave, L. (1985). Volatile organic compounds as indoor air pollutants. In R.B. Gammage and S.V. Kaye (Eds.), *Indoor air and human health,* (pp. 403-414). Chelsea, MI. Lewis Publishers.

Molhave, L., Bach, B., & Pedersen, O.F. (1986). Human reactions to low concentrations of volatile organic compounds. *Environment International*, 12, 167-176. Cited by Girman, 1989, op. cit.

National Safety Council (1990). *Accident Facts, 1990 Edition*. Chicago: Author.

New Jersey State Department of Health (1989). *A case control study of radon and lung cancer among New Jersey women*. Technical Report - Phase I. Trenton, NJ: Author.

NYC Joins VOC Reg. Bandwagon (1990). *Journal of Light Construction Eastern Edition*. 8(5), 6.

Oatman, L. (1991). Responding to public concerns. In J. Laquatra and S.A. Zaslow (Eds.). *Indoor air quality in homes: Synthesizing the issues and educating consumers*. Urbana-Champaign, IL: Building Research Council-Small Houses Council.

Rabin, R. (1989). Warnings unheeded: A history of childhood lead poisoning. *American Journal of Public Health*, 79(12), 1668-1674).

Research Update: House plants for clean air (1991, September). *Fine Homebuilding*, p. 102.

Slovic, P. (1987). Perception of risk. *Science*, 236, 280-285.

Sterling, E.M., Arundel, A., & Sterling, T.D. (1985). Criteria for human exposure to humidity in occupied buildings. *ASHERAE Transactions*, 91(1).

U.S. Consumer Product Safety Commission (1989). CPSC warns about hazards of "Do It Yourself" removal of lead based paint. *Safety alert*. Washington, DC: Author.

U.S. Department of Housing and Urban Development. (1990). *Comprehensive and workable plan for the abatement: of lead based paint in privately owned housing*. Washington, DC: Author.

U.S. Environmental Protection Agency (1987). *Radon reference manual*. (U.S. Environmental Protection Agency 520/1-87-20). Washington, DC: Author.

U.S. Environmental Protection Agency (1988). *Radon resistant construction techniques for new residential construction*. (U.S. Environmental Protection Agency/6 25/2-91/032). Washington, DC: Author.

U.S. Environmental protection Agency (1989a). *Comparing risks and setting environmental priorities*. (U.S. Environmental Protection Agency PM-220). Washington, DC: Author.

U.S. Environmental protection Agency (1989b). *Report to congress on indoor air quality: Volume II assessment and control of indoor air pollution*. (U.S. Environmental Protection Agency 400/1-89/00lC). Washington, DC: Author.

U.S. Environmental Protection Agency (1990a). *The quality of our nation's water*. (U.S. Environmental Protection Agency 440/4-90-005). Washington, DC: Author.

U.S. Environmental Protection Agency (1990b). *The 1990 International Symposium on Radon and Radon Reduction Technology. Proceedings*. Washington, DC: Author.

Vaughn, T.L., Strader, C., Davis, S., & Daling, J.R. (1986). Formaldehyde and cancers of the pharynx, sinus and nasal cavity: II. Residential exposures. *International Journal of Cancer*, 38, 685-688.

Wallace, L., Pellizzari, E., Sheldon, L., Hartwell, T., Sparacino, C., & Zelon, H. (1986). The total exposure assessment methodology (TEAM) study: Direct measurement of personal exposures through air and water for 600 residents of several U.S. cities. In Y. Cohen (Ed.). *Pollutants in a multimedia environment* (pp. 289-315). New York: Plenum Press.

Wolverton, B.C., McDonald, R.C., & Watkins, E.A. (1984). Foliage plants for removing indoor air pollutants from energy-efficient homes. *Economic Botany*, 38(2), 224-228.

Yocum, J. (1982). Indoor-outdoor air quality relationships. *Journal of the Air Pollution Control Association*, 35(2), 500-520.