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VENTILATION AND INDOOR AIR QUALITY: REGULATIONS, CODES, AND VOLUNTARY CONSENSUS STANDARDS

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ABSTRACT

Indoor air quality (IAQ) has recently been a subject of increased concern, because (1) indoor contaminant levels and exposures frequently exceed those encountered outdoors; (2) many new products are being introduced into the indoor environment that provide increased levels of exposure; and (3) energy conservation measures that reduce ventilation rates can elevate indoor contaminant concentrations. As the need to maintain acceptable indoor air quality has become a public issue, policymakers have had to develop strategies to address this need based upon the best available information.

This paper addresses some of the policy options that have been taken by various organizations and levels of government, including regulations, codes, and voluntary consensus standards, to provide acceptable indoor air quality in buildings. Not intended to provide a complete list, this paper rather uses examples of IAQ regulations, codes, standards, etc., to indicate (1) the spectrum of alternative approaches that have been taken to promote indoor air quality (e.g., information dissemination as opposed to regulation); (2) the range of contaminant levels considered acceptable by different organizations for the same contaminant (e.g., radon); and (3) the different types of methods chosen to achieve acceptable indoor air quality (e.g., performance as opposed to prescriptive strategies; contaminant as opposed to ventilation approaches).

INTRODUCTION

Within the last decade, concern about the quality of indoor air has become a major environmental factor in the design, construction, and operation of buildings. Indoor air quality (IAQ) has become a subject of increased concern because (1) indoor contaminant levels and exposures frequently exceed those encountered outdoors; (2) many new products are being introduced into the indoor environment that provide increased levels of exposure; and (3) energy conservation measures that reduce ventilation rates can elevate indoor contaminant concentrations. (Note: The term "contaminant" is used to indicate unwanted constituents that may or may not be deleterious to human health; the term "pollutant" is used to indicate the subset of contaminants that do present a potential health risk.) As the need to maintain acceptable indoor air quality has become a public issue, policymakers have had to develop strategies to address this need based upon the best available information.

The first portion of this paper is devoted to summarizing the major steps that should be followed by the various levels of government and other organizations (e.g., the American Society of Heating, Ventilating, and Air-Conditioning Engineers [ASHRAE]) to address indoor air quality issues before developing policy responses. For a more complete overview of IAQ policy and regulatory issues, readers are referred to Sexton (1986). The second portion of

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and soil and infiltrates into houses in response to pressure differences between the inside of a house and its surrounding soil. Primary entry sites for radon include below-grade cracks in the building envelope, construction joints at walls and floors, loose-fitting pipe penetrations, and sump pump wells.

Indoor radon levels are primarily determined by the rate of entry of radon from surrounding soil; the influence of ventilation (achieved by infiltration in most residences) on indoor radon levels is significant but secondary (Nero et al. 1983). Radon entry rates are, in turn, determined by the concentration of radium (the precursor of radon) in the soil, the soil permeability, and house characteristics (e.g., construction type -- basement, crawl space, etc.). Therefore, the probability of a given home having a high indoor radon level is greatest in geographic locations with radium-rich, highly permeable soils. In addition, it cannot be generalized that tight (i.e., low infiltration rate), energy-efficient houses will have high indoor radon levels and loose, less energy-efficient homes will not.

The four immediate decay products of radon-222, commonly called radon progeny or daughters, are radioactive isotopes with short half-lives. Two of the radon progeny decay by emitting alpha particles. Some of the radon progeny attach to other small particles in the indoor air, giving rise to the terms "attached" and "unattached" fractions, and resulting in a radioactive aerosol. When this radioactive aerosol is inhaled, radon progeny can be deposited and retained in the respiratory tract, causing the epithelial cells to be irradiated by alpha particles. The potential effect of this irradiation of the lung is the induction of lung cancer.

Concern for indoor radon exposures stems from epidemiological evidence of excess lung cancer among uranium and other miners who were exposed to high concentrations of radon progeny at work, levels usually higher than those experienced in dwellings. In addition, there is also evidence that radon and smoking interact in the induction and promotion of lung cancer, potentially in a multiplicative manner. Experimental exposure of animals to radon progeny support these results. Finally, small epidemiological studies of groups of persons exposed to elevated concentrations of radon progeny in dwellings are indicative of excess lung cancer, but not conclusively so.

To determine the risk per unit exposure to radon progeny from the miner epidemiological data, it is appropriate (i.e., the best guess) to adopt the conventional assumption of a linear relationship, without threshold (i.e., radiation exposures contribute cumulatively to risk). Alternatively, the dose equivalent to lung tissue per unit exposure may be determined from a model of the deposition and retention of radon progeny in the lung, and then translated into risk. Both approaches, yield fairly congruent results (NRPB 1986).

Agency (EPA) are among the organizations conducting research to identify and evaluate mitigation technologies to reduce indoor radon levels. These research efforts are investigating both source control techniques to minimize radon entry and ventilation strategies to dilute indoor radon levels. Although source control is the preferred technique whenever feasible, in some instances, increased ventilation is the easiest and most cost-effective mitigation approach.

Research devoted to radon mitigation is studying the following mitigation strategies: sealing cracks and holes at below-grade building envelope surfaces; house ventilation with heat recovery; substructure ventilation; basement pressurization; and crawl space sealing and ventilation. Preliminary results indicate that all of these techniques, properly applied, are capable of reducing indoor radon levels (Turk et al. 1986; Henschel and Scott 1986). For additional information, readers are referred to EPA's technical guidance document on radon reduction techniques (EPA 1986a).

Nero (1986) estimated the frequency distribution of radon levels across the United States by combining the results of unbiased radon field studies. The resulting frequency distribution curve is shown in Figure 1.

ventilation requirements from 10 cfm per room to 0.35 air changes per hour.

ASHRAE Standard 62-1981, although admittedly not comprehensive, remains the most generally recognized standard in the United States for providing ventilation for acceptable indoor air quality. It is, therefore, appropriate to discuss how the standard should be used to achieve its purpose of specifying minimum ventilation rates and indoor air quality that will be acceptable to human occupants, which are intended to avoid adverse health effects.

While the traditional prescriptive "Ventilation Rate Procedure" provides design criteria that can be reviewed and evaluated both during design and construction, this procedure provides no assurance that indoor pollutant concentrations will not exceed recommended levels. Conversely, while the "Indoor Air Quality Procedure" provides measurable performance criteria to evaluate indoor air quality, it offers little guidance on how to design and construct buildings that will provide and maintain acceptable indoor air quality.

In standards such as ASHRAE 62-1981, which contain both prescriptive and performance criteria, it is not intended that compliance with both criteria be demonstrated. Rather, it is intended that compliance with one alternative imply compliance with the other (Woods et al. 1986). To minimize potential conflicts with other standards and codes, which may specify only one method of compliance, it is recommended that codes and standards be used as minimum recommended guidelines for the design, construction, and operation of buildings to provide and maintain acceptable indoor air quality.

CONCLUSIONS

As the need to maintain acceptable indoor air quality has become a public issue, policymakers have had to develop strategies to address this need based upon the best available information. These policy options have included a spectrum of alternative approaches to promote indoor air quality, ranging from dissemination of information to regulation; different contaminant levels being considered acceptable by different organizations for the same contaminant (e.g., radon); and different methods being chosen to achieve acceptable indoor air quality (e.g., performance as opposed to prescriptive strategies; contaminant as opposed to ventilation approaches).

The following conclusions can be drawn from the experiences of various organizations and levels of government to formulate indoor air quality policy (1) increased awareness and education about indoor air quality and energy- efficient techniques to control the indoor environment are needed; (2) responsibility for acceptable design and operation of buildings needs better definition; and (3) government standards that prescribe contaminant levels in indoor air are difficult, if not impractical, to enforce.

REFERENCES

ACGIH. 1985. "Threshold limit values and biological exposure indices for 1985-86." American Conference of Government Industrial Hygienists.

ASHRAE. 1973. ASHRAE Standard 62-1973, "Standards for natural and mechanical ventilation." New York: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE. 1975. ASHRAE Standard 90-1975, "Energy conservation in new building design." New York: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE. 1981. ASHRAE Standard 62-1981, "Ventilation for acceptable indoor air quality." Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE. 1986. "ASHRAE Standard 62-1981R: Ventilation for acceptable indoor air quality." American Society of Heating, Refrigerating, and Air-

Conditioning Engineers, Atlanta, Public Review Draft (July 15).

BPA. 1984. "Record of decision for the expanded residential weatherization program." Bonneville Power Administration, 49 Federal Register 40959.

California Administrative Code. 1982. Title 25, Housing and Community Development, Part 1, Chapter 1, Article 5, Section 32.

49 Code of Federal Regulation 155. 9 August 1984.

EPA. 1986a. "Radon reduction techniques for detached houses: Technical guidance." Report by the U.S. Environmental Protection Agency, Report No. EPA/625/5-86/019, Washington, D.C. (June).

EPA. 1986b. "A citizen's guide to radon: What it is and what to do about it." Pamphlet by the Environmental Protection Agency, Washington, D.C.

EPA. 1986c. "Radon reduction methods: A homeowner's guide." Pamphlet by the U.S. Environmental Protection Agency, Washington, D.C. (August).

47 Federal Register 23360. 1982.

Federal Register. 8 December 1986. pp. 44258 - 44259.

Henschel, D.B. and Scott, A.G. 1986. "The EPA program to demonstrate mitigation measures for indoor radon: Initial results." Presented at the Air Pollution Control Association Specialty Conference on Indoor Radon, Philadelphia, PA, February 25-26.

NCRP. 1984. "Exposures from the uranium series with emphasis on radon and its daughters." National Council of Radiation Protection and Measurements, NCRP Report No. 77, Washington, D.C.

Nero, A.V. 1986. "Estimated risk from exposure to radon decay products in U.S. homes." Lawrence Berkeley Laboratory, Report No. LBL-21642, Berkeley, CA (May).

Nero, A.V.; Boegel, M.L.; Hollowell, C.D.; Ingersoll, J.G.; and Nazaroff, W.W. 1983. "Radon concentrations and infiltration rates measured in conventional and energy-efficient houses." Health Physics, Vol. 45, No. 2 (August), pp. 401-405.

NIBS. 1986. "Standards, regulations, and other technical criteria related to indoor air quality." Report by the National Institute of Building Sciences, Washington, D.C. (February).

NRPB. 1987. "Exposure to radon daughters in dwellings." National Radiological Protection Board, Report No. NRPB-GS6. Chilton, Didcot, Oxon, United Kingdom (January).

Oatman, L. 1985. "Minnesota's response to indoor problems." Paper 85-46.3, 78th Annual Meeting of the Air Pollution Control Association, Detroit, MI.

Sexton, Ken. 1986. "Indoor air quality: An overview of policy and regulatory issues." Science, Technology & Human Values, Volume 11, Issue 1, pp. 53-67 (Winter).

State of Massachusetts. 1984. "Regulations concerning repurchase of banned hazardous substances." 105CMR, 650.221, paragraph 1, 650.222, effective 1 June.

Turk, B.H.; Prill, R.J.; Fisk, W.J.; Grimsrud, D.T.; Moed, B.A.; and Sextro, R.G. 1986. "Radon and remedial action in Spokane River Valley residences." Lawrence Berkeley Laboratory Report No. LBL-21399, Berkeley, CA.

U.K. DOE. 1987. "Radon in houses." Pamphlet by the Department of the Environment, United Kingdom (January).

Woods, J.E. "Air quality," In Encyclopedia of Architecture: Design, Engineering, and Construction (forthcoming).

Woods, J.E.; Janssen, J.E.; and Krafthefer, B.C. 1986. "Rationalization of equivalence between the 'ventilation rate' and 'indoor air quality' procedures in ASHRAE Standard 62." Managing Indoor Air for Health and Energy Conservation, Janssen, J.E., ed. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, pp. 181 - 191.

Table 1

Summary of the Major Steps in the Process of Addressing Indoor Air Quality Issues

I. Problem Definition

Contaminant Sources, Dilution Mechanisms, Indoor Concentrations, Activity Patterns, Indoor Exposures (and their contribution to Total Exposures), and Health and Comfort Consequences

II. Health Risk Assessment

Number of People Exposed, Severity of Exposures, Sensitive Populations, and Dose-Response Relationships

III. Applicability of Mitigating Measures

Source Removal, Source Modification, Behavioral Adjustment, and Local and General Ventilation, including Air Cleaning

IV. Resolution of Policy Issues

Voluntary vs. Non-VoluntaryRisks, Publicvs. Private Responsibility, Building "Publicness," ConservationBenefits, and Appropriate Responses

V. Alternative Responses

No Action, More Research, Public Information, Economic Incentives, Moral Suasion, Legal Liability, Guidelines, Voluntary Standards, Codes and Regulations

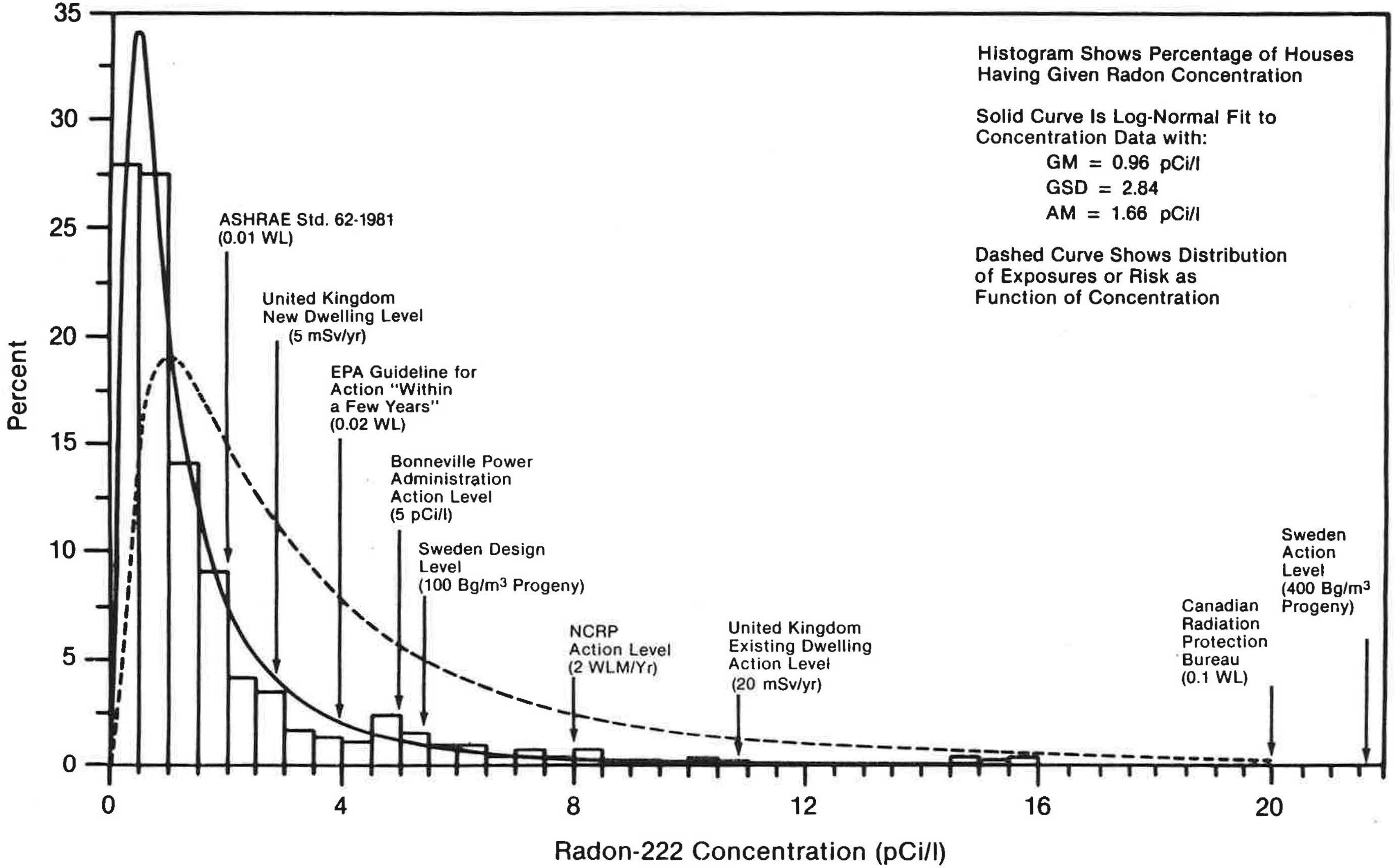

Figure 1. Distribution of radon concentrations and lung-cancer risk in 552 homes

Discussion

C.W. BAYER, Georgia Tech Research Institute, Atlanta: How were levels established of 1/10 TLV OSHA as a guideline for indoor air contaminants? This sets the acceptable guideline level of toluene at 10 ppm for chronic exposure. At this level toluene odor is detectable. Toluene, as are many other of the VOCs, is a CNS depressant. Also, it seems that the synergistic effect is more important than individual compounds in the most general case. What total level of indoor contaminants will be considered accpetable? If, as is commonly detected, 50 or more VOCs are detected, and 1/10 TLVs are considered to be acceptable, the total VOC concentration can be quite high. The guideline being set at 1/10 TLV seems to be much too high. The following is a list of 1/10 OSHA TLV acceptable concentrations for some commonly detected VOCs:

COMPOUND	ACCEPTABLE GUIDELINES (1/10 TLV)
*Toluene	10 ppm
*Tetrachloroethane	5 ppm
*Trichloroethane	5 ppm
*Benzene	1 ppm
*Methylene chloride	10 ppm
Propanol	20 ppm
*Chloroform	1 ppm
Butyl acetate	15 ppm
Acetaldehyde	10 ppm
Acetone	75 ppm
Cyclohexane	30 ppm
Ethyl acetate	40 ppm
Dioxane	2.5 ppm
Heptane	40 ppm
Hexane	50 ppm
Methyl cyclohexane	40 ppm
Octane	30 ppm
Styrene	5.0 ppm
*Freon	50 ppm
*1,1,1-Trichloroethane	35 ppm

*Possible human carcinogen

These are the most commonly detected VOCs. They are usually detected in all office buildings and work stations. The total VOC acceptable level would be 332 ppm. AIHA based on Molhave's work is setting a guideline at 5 mg/m^3. Molhave found that the majority of people were affected with mucous membrane irritation at this level. If the 1/10 TLV guideline is followed, the majority of the people would be suffering mucousal irritation.

TEICHMAN: Charlene, the question you raise concerning the use of TLV's in ASHRAE Standard 62-1981R (ASHRAE, 1986) is a very important one, which would perhaps be better directed to and answered by the members of the ASHRAE Standard 62-1981R committee. Modestly assuming the omniscience to know how the 62-1981R committee might respond to your question, I would cite Appendix C of the ASHRAE Standard 62-1981R Public Review Draft (ASHRAE 1986), which states:

> "As a preliminary guideline for (residential, office, or retail) spaces **it has been customary** (emphasis added) to assume that a concentration of 1/10 of the TLV would not produce complaints in a non-occupational population in residential and office environments. If a concentration of 1/10 of the TLV cannot be provided, the designer or building operator should seek expert help in evaluating what level of such a chemical or combination of chemicals would be acceptable."

Therefore, I would presume the committee's response to be that 1/10 of the TLV is to be used as a **preliminary** guideline, and that, in situations in which designers or building operators predict or experience concern, they should seek "expert help" to evaluate the acceptable concentration for a given chemical or combination of chemicals.

I am familiar with the work of Molhave you cite in your question, and to the best of my knowledge, this work has not been replicated to date. Until this research is replicated or similar research conclusively relates total organic compound concentrations to potentially deleterious health effects, I would not anticipate the revision of the ASHRAE 62-1981R in this regard.