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The Threat of Indoor Radon

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Operating Techniques & Products

Every year as many as 30,000 people in this country may be dying from lung cancer as a result of constant exposure to radioactive radon gas while at work and at home. The Environmental Protection Agency recently estimated that up to 1 million American homes may be contaminated.

Modern energy-efficient buildings serve as giant containment vessels, concentrating the ubiquitous gas to life-threatening levels and placing the health of inhabitants at risk. Indeed, it appears that man's attempts to control other elements of the environment may have served to escalate this particular hazard to unforeseen levels in the workplace.

Nature of radon

Radon is a naturally occurring radioactive gas that results from the decay of radium. Radium is present nearly everywhere, in rocks, soil, and products derived from earthen materials.

A member of the uranium series of elements, radon is constantly released from the soil to the air and may also enter the atmosphere through a number of other pathways, including groundwater, natural gas, volcanic gases, and air used to ventilate caves and mines.

The presence of radon and its decay products in the atmosphere adds significantly to the background radiation man experiences in the normal environment. Although the inert nature of radon limits its capacity to do direct biological damage, the gas still offers some serious implications.

The combined metallic and radioactive properties of radon, its decay products and residues, particularly in high concentrations, can result in dire medical consequences, primarily to the tissues of the respiratory tract.

Radon in the workplace

Until recently, indoor concentrations of radon have been present at levels closely in equilibrium with those in the outside atmosphere. In spite of heavy use of building materials which contain radium-226, such as concrete, brick, and tile, the exchange rate of indoor and outdoor air was generally high (one to four complete exchanges per hour). This was enough to keep the indoor concentrations of radon roughly equal to natural outdoor background levels, even in areas with high natural radon levels.

Recent developments in insulation and ventilation techniques have caused some remarkable changes to occur in the indoor environments, however.

A good way of visualizing the indoor concentration problem is to consider a building as a container for radon gas. The gas may enter the container from the outside or it may arise from emanations within the building itself. If trapped indoors, radon will continuously decay, effectively increasing the concentration of radioactive inhalants.

Energy loss due to high air exchange rates can be significant when HVAC systems must deal with the fluctuation of unconditioned outside air. About one-third of the energy used to heat or cool buildings is used to make up for these losses.

In commercial buildings, the short-term solution has been to reduce mechanical ventilation rates and to inhibit infiltration rates with more efficient insulation. Exchange rates were reduced to levels of 0.5 exchanges per hour. While this resulted in substantial energy savings, it usually boosted indoor concentrations of a host of industrial pollutants, elevated human exposure to radon, and presumably increased the incidence of radon-related lung cancer.

An inverse relationship appears to exist between the reduction of air exchange rates and the concentration of radon. For example, a 50 percent reduction in the air exchange rate will result in a doubling of the indoor radon concentration.

Sources of radon

Property managers who wish to begin a preliminary assessment of the radon risk in their buildings first need to understand the three major sources of radon and radon residuals in the outdoor environment. These are:

- building materials;
- underlying soil and rock; and
- available utilities (water and natural gas).

• *Building materials.* Surveys have shown that ordinary concrete and cement contain moderate levels of several radionuclides, including radium-226. Radionuclide levels in brick are slightly higher on average; natural plaster is several times lower.

Non-crustal building materials such as wood are much lower in radionuclide levels, but other natural materials, especially granite and shale from the southeastern United States, may have much higher concentrations.

Residues from industrial processes frequently are incorporated into buildings materials and may result in considerably higher radionuclide concentrations. Blast-furnace slag is used to make construction blocks, and the wastes derived from phosphate processing are incorporated into wallboard into the form of phosphogypsum. Both are high in concentrated radium-226.

In the U.S., the major industrial byproduct in building material is phosphate slag incorporated into concrete blocks. These blocks retain and concentrate most of the radium-226 and uranium-238 originally present in the phosphate ore.

A final, and poorly understood, example of incorporated byproduct material is the use of fly ash in certain cements. This ash, produced by coal-powered electric plants, may contribute significantly to the radionuclide content of the cement, but accurate studies still need to be completed.

Diffusion and emanation rates of radon gas out of the incorporated material dictate how effective the generation of radon inside the building will be, but for the most part, this contribution is secondary to that of the underlying soil and rock.

• *Soil and rock.* Certain types of underlying soils and geological formations have greatly elevated radionuclide contents. For example, phosphate rock formations in Florida have higher levels than average, as do shale formations in Tennessee and uranium ore bodies throughout the U.S. Indoor concentrations of radon are usually appreciably higher in structures built in these locations.

The emanation and transport of radon gas from outside soil to the interior of a building depend largely on the radon content of the air trapped beneath the foundation. This, in turn, is affected by alternations in temperature, barometric pressure, prevailing winds, and the moisture level of the soil.

Radon may enter buildings through several pathways, including diffusion through concrete basement floors, by convection through basement walls, and by general seepage through designed and undesigned openings in walls and ground floors. Once inside, radon diffuses throughout the building, becoming more diluted as it rises upward from basements.

- *Utilities.* Domestic water and natural gas supplies provide an effective pathway for the diffusion of radon gas into a building. Certain areas, Maine and New Hampshire for example, have naturally high concentrations of radon in well water. Tap water from wells and underground reservoirs have also been known to exceed occupational limits.

Natural gas poses a less serious threat but is known to contribute to higher-than-average indoor concentrations in Houston. An article in the July 22, 1985, issue of *Time* magazine cited high levels of indoor radon in New Hampshire, Idaho, Texas, California, the Carolinas, and Washington.

Radon levels inside a building will vary appreciably over time and location. Unlike outdoor levels, indoor concentrations show little seasonal variation, but they do change during the course of the day, rising to a peak in early morning. Radon levels decrease markedly as building height increases.

Detection and control

Although construction material, underlying soil, and available utilities may cause variations in indoor radon levels, property managers are cautioned not to make conclusions based on these criteria alone. The large number of variables necessitates hiring a professional for more than a preliminary assessment of radon levels.

A professional health physicist, who specializes in this type of complex measurement, will be able to apply proper analytical techniques and, more importantly, will be able to explain the results in a useful fashion.

Relatively accurate, inexpensive radon detectors are available and are suitable for wholesale screenings. For accurate results, these dosimeters need to be left in place for three months. The cost for this service may run from $50 to as much as $2,000 for a single building, depending on size.

Should this preliminary step reveal unacceptably high levels (what constitutes an "acceptable level" has yet to be positively established anywhere but in uranium mines), a health physicist or other trained professional should be consulted for more detailed analysis.

Further analysis may include studies with the low-cost screening detectors or may require more timely work with expensive portable detectors. At this point, a property manager needs to be prepared to spend anywhere from $150 to $3,000 to find out where and how the radon is entering the building. Fortunately, all detection measures are nondisruptive to building occupants.

Control techniques are limited by the mobile nature of radon gas and the widespread abundance of radium-226 in the environment. Preconstruction planning may eliminate potentially hazardous building materials or dangerous site locations, but it is difficult to correct either problem after construction is complete.

Sealants, which reduce the transport and emanation of radon, may be utilized in basements, crawl spaces, and concrete slabs. Ventilation of crawl spaces and the redesign of air transport routes around slab floors can reduce concentration levels, but both require engineering retrofits.

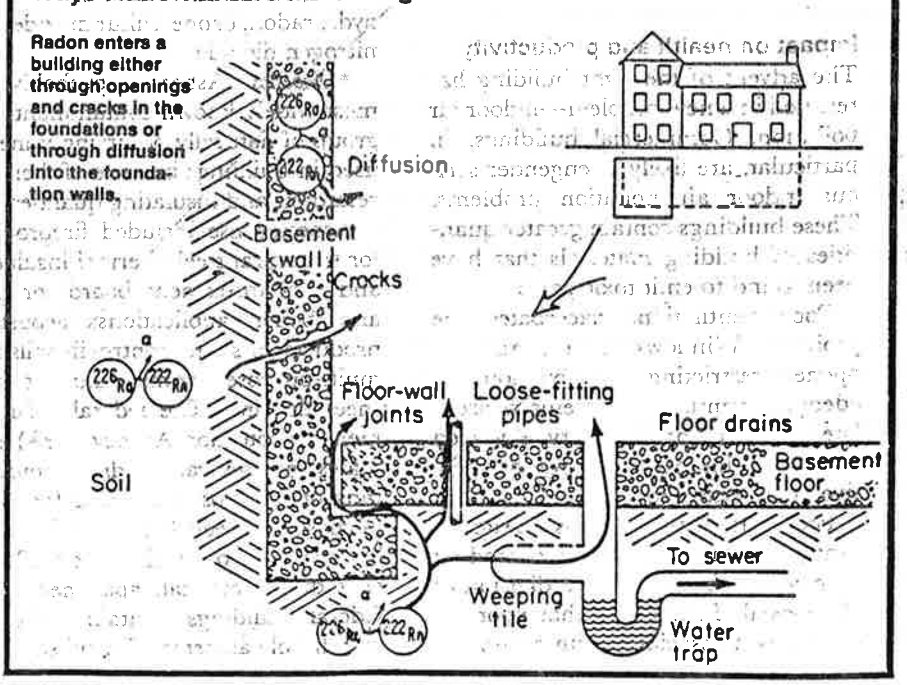
If the emanation and transport of radon cannot be controlled economically, radon and its decay products can be removed by air-mixing, ventilation, and filtration techniques requiring fairly sophisticated building subsystems. Finally, air-to-air heat exchangers remove indoor air while maintaining low energy use. This method may be applied to old and new buildings.

Whatever cure is chosen, the costs of remedial action will undoubtedly range well into five figures. However, very little disruption will occur to the activities of the building's occupants while remedial work is going on in the building's lower levels.

Conclusion

Placing the problem of indoor radon pollution in perspective first requires a thorough consideration of the relative risks posed by indoor concentrations of gas. If current figures are accurate, more than 100,000 Americans die annually from lung cancer—and as many

Ways Radon Enters a Building



as 30,000 of these may die from inhalation of airborne radon byproducts.

Health physicists have established that radon concentrations may have reached precipitously high levels in hundreds (if not thousands) of buildings and perhaps as many as 1 million homes in this country. New energy-efficient technologies only serve to exacerbate the problem.

Individual property managers have a difficult decision to make before calling in professional help. This step can result in an unjustified expense if no problems are found. On the other hand, if a serious problem does exist, the manager is then faced with a few relatively expensive solutions. In some cases, they are experimental and without an absolute guarantee of success. Competent advice and service are available and can usually be obtained through associates, trade associations, or local public authorities.

The legal and ethical questions arising from this little-known environmental pollutant could easily transcend those already posed by better-publicized hazards, such as asbestos. Property managers, plagued by a host of newly-discovered indoor public health threats, may have a new name to place at the top of that list.

Managers must become familiar with the technical aspects of the problem, and then they must take the steps necessary to establish and mitigate the present level of risk which exists in buildings under their management. Only these activities will decrease the threat of future legal battles.

Editor's note: Further information about indoor radon pollution may be found in the articles contained in Health Physics *(Special Issue on Indoor Radon), August 1983.*

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Tight Buildings and Indoor Air Quality

Since the oil crisis of the 1970s, energy usage has become an overwhelming concern for building managers. New buildings are designed with energy efficiency as a major consideration, and older buildings are retrofitted for greater efficiency.

Now buildings are designed to effectively prevent outside air from infiltrating the building envelope. Architectural design, double- and triple-pane glass, and synthetic materials for insulation and fire-prevention make environments "tight."

Impact on health and productivity

The advent of the tight building has resulted in a new problem—indoor air pollution. Commercial buildings, in particular, are likely to engender serious indoor air pollution problems. These buildings contain greater quantities of building materials that have been found to emit toxic gases.

Poor ventilation exacerbates the problem. Windows often cannot be opened, restricting air circulation. Inadequate ventilation systems recirculate stale air and humidity. Reduced ventilation increases the level of "passive" cigarette smoking.

Poor office air quality poses a significant problem. A survey conducted by Honeywell Technologies, a division of Honeywell, Inc., found that poor air quality was associated with a number of physical ailments experienced by office workers. Some of the most common symptoms include drowsiness, headaches, nausea, dizziness, respiratory ailments, chronic coughs, lethargy, and eye and respiratory irritation.

Another effect is a drop in productivity. According to Honeywell, poor ventilation and cigarette smoking are the top air-quality problems that disrupt the productivity of office workers. Therefore, complaints about office air quality should be taken seriously.

Indoor air contaminants

Pollutants of major concern to building managers include asbestos, formaldehyde, radon, ozone, sulfur dioxide, and nitrogen dioxide.

• *Asbestos.* Asbestos, probably the most widely known contaminant, is a group of naturally occurring minerals used in buildings because of their fire retardant and insulating qualities.

Asbestos use included fireproofing for structural steel, thermal insulation and asbestos-cement board for pipe and boiler applications, acoustical products for sound control in halls and multi-purpose rooms, and tile and sheet flooring. The federal Environmental Protection Agency (EPA) estimates that several hundred thousand tons of asbestos were used for these purposes between 1940 and 1973.

According to the EPA, about 20 percent of commercial, apartment, and federal buildings contain materials with friable asbestos. The substance is most often found in pipe and boiler insulation (75 percent), and in sprayed or trowelled-on materials (25 percent). Fifty-nine percent of all residential rental buildings with 10 units or more contain some friable asbestos materials; 39 percent of all federal buildings and 16 percent of private nonresidential buildings also have such materials.

Asbestos that is friable, or with the potential to become airborne, poses significant health dangers. Exposure to airborne asbestos can cause asbestosis, a serious form of lung cancer; mesothelioma, a cancer of the lung and the abdominal cavity lining; and other laryngeal and gastrointestinal cancers.

The Consumer Product Safety Commission (CPSC) has banned the use of asbestos in certain products. Molded wet-applied insulation, if it can be crushed, pulverized, or reduced to powder by hand pressure after drying, cannot be used, as well as patching compounds and artificial embers and ash for home fireplace use. Fireproofing or insulation products that contain more than 1 percent asbestos have also been banned.

There are several methods of correcting the hazard of asbestos. The first option is "encapsulation," or applying EPA-tested sealants to control asbestos fiber release. The "barrier" method allows a physical barrier to be placed between contaminated asbestos areas to contain the problem.

Removal and replacement may be necessary in some cases, although it is the most expensive method of handling the problem. According to the Safe Buildings Alliance (SBA), unless properly done, removing asbestos can increase the level of friable asbestos.

Proper maintenance and inspection procedures are generally the best means of assuring that asbestos-containing materials pose no significant health risk, according to John Welch, president of SBA. In most cases, asbestos can be properly controlled by a combination of improved custodial control, special maintenance, and minor patching and repairs.

• *Formaldehyde.* Formaldehyde is used in building materials, insulation, furniture, carpets, cosmetics, deodorants, solvents, disinfectants, and fumigants. It is a known irritant.

Gas emitted from formaldehyde and related products has been found to affect the mucous membranes of the eyes, nose, and throat. Urea formaldehyde foam insulation (UFFI), the main culprit in the formaldehyde family, was used in the early 1970s for its high insulation factor and low cost, mainly in residential buildings.

UFFI was banned in 1982 by the CPSC. The ban has since been lifted because of a disagreement between the CPSC and the EPA over its carcinogenic risk. Nevertheless, UFFI is still a problem product.

Some city, county, and state health departments will conduct tests at a modest fee to check for formaldehyde. A commercial laboratory also can determine the level of formaldehyde, which varies with temperature, humidity, and other factors. UFFI has been found to decrease in risk over time. The CPSC suggests that after a three-year period, little risk exists except for someone with unusual sensitivity to formaldehyde.

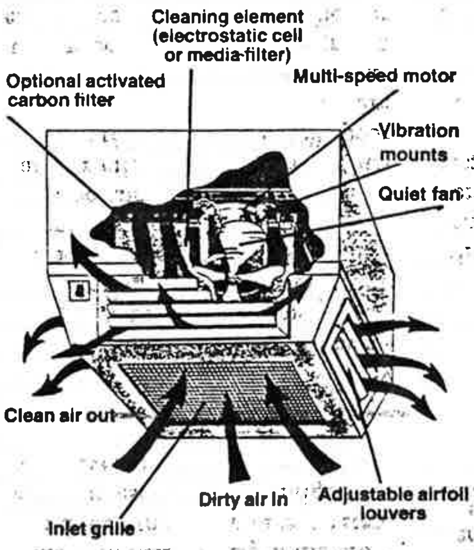
Increasing ventilation reduces the formaldehyde level. It is advisable to repair all holes, cracks, or gaps in the wall and finish with caulking, spackling, or special vapor-barrier paints. Mylar or vinyl wallpaper or a good grade of canvas-backed vinyl wallpaper are also effective corrective sealants, according to the National Research Council of Canada. Removal should be a last resort.

• *Involuntary smoking and combustion byproducts.* Cigarette smoke is one of the most common indoor pollutants. Nonsmokers working in an environment with smokers have been found to passively inhale cigarette fumes. In a low-ventilation environment, they risk the same health hazards as active smokers, though at a lower level.

Other fumes that impede human health result from gas stoves' and space heaters' emissions. These combustion products emit carbon monoxide, nitrogen oxide, and formaldehyde, all of which cause respiratory problems.

Managers will often find that poorly tuned gas stoves and space heaters disperse very high levels of contaminants through an apartment. Concentrations of these contaminants can be reduced by placing a range hood over the stove in conjunction with a fan to direct exhaust outdoors.

Air Filters Reduce Indoor Pollution



Establishing a pollution-free environment

An effective HVAC system can noticeably improve the quality of air. It establishes the correct balance between oxygen and carbon dioxide so that the air is breathable. It removes humidity to ensure comfort and to decrease microbiological risks. (The outburst of Legionnaires' disease, for instance, was traced to bacteria growing in the water of an air conditioning system.) The HVAC system dilutes odors to acceptable levels and removes contaminants produced by human activity, building materials, and other sources.

Property managers should check ventilation systems to make sure that they are working efficiently. One of the major reasons for poor air circulation is faulty equipment installation.

Correct vent placement will ensure good air circulation. Most vents are near outer walls, leaving inner offices poorly ventilated. Increase the amount of ventilated outdoor air to improve air quality, rather than recirculating indoor air—except at street level, where car exhaust fumes can easily enter. New buildings can be adjusted to do this; older buildings may have to be retrofitted.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has developed standard recommended and minimum ventilation rates for many types of building spaces. These standards help to ensure safe and habitable living and working environments.

Building managers should consider retrofitting their properties with devices to improve the quality of the air. Air cleaners are an efficient and economical means of controlling pollution indoors, by removing up to 95 percent of all airborne particles. Additional charcoal filters eliminate up to 75 percent of all air odors. Together, they are effective in offices, conference rooms, computer rooms, and other areas where air circulation is low.

Careful selection of building material also reduces indoor air pollutants. Furniture, carpets, partitions, wall coverings, and cleaning materials may emit toxic substances. Property managers must become familiar with the chemical composition of products and materials used in the buildings they manage and avoid using those that pose significant health risks.

Conclusion

Ensuring the comfort and safety levels of office and residential tenants takes on greater significance in light of recent findings. As more is learned about the consequences of indoor air pollution, property managers who are responsible for the selection of office products face a greater risk of liability.

Thus, managers should attempt to make informed choices—cost cannot be the only consideration. As one expert surmised, "Indoor air pollution may be the greatest environmental challenge facing business and health care professionals in the next 10 years."

—Karen McManus