Radon Overview and Analysis of the City of Fort Collins Proposal to Require Radon Control Systems in New Residential Construction

Health District of Northern Larimer County Board of Directors — March 25, 2003 Meeting

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Background

Radon is an odorless, gaseous radioactive element that occurs naturally in earth and rock, well water and some building materials. It has been classified by the Environmental Protection Agency (EPA) and others as a Class A carcinogen because of the known connection between exposure and lung cancer. It is found throughout the United States, with higher than average levels in Colorado. Radon is drawn into homes and other buildings through cracks and openings in basements, crawl spaces and slabs. Radon levels vary from house to house, and are higher on the lowest level of a house.

According to the EPA, exposure to radon has no immediate effect. However, over a person's lifetime, radon particles can enter the lungs, attach themselves and eventually lead to lung cancer. The EPA estimates that between 15,000 and 22,000 lung cancer deaths in the United States can be attributed to radon. Radon is the second leading cause of lung cancer in the United States, accounting for about 10% of lung cancer deaths.[1] Studies show that smokers are at a higher risk of developing radon-induced lung cancer.

The Health Effects of Radon Exposure

From what is known about the biological mechanisms involved in the development of cancer, radon is an ideal suspect. Radon is radioactive—that means that radon atoms spontaneously decay to other atoms called radon progeny, releasing alpha radiation as they change. The electrically charged radon progeny can attach to dust particles in indoor air and be inhaled into the lungs where they continue to decay and emit alpha radiation. The radiation can disrupt DNA in lung cells which can be the initiating step in the development of cancer. Since alpha radiation can only travel short distances and cannot penetrate tissues like skin, lung cancer is the only potentially important cancer hazard from indoor radon.

Evidence that radon indeed causes lung cancer comes from studies of underground miners whose high rates of lung cancer have been linked to high levels of radon exposure and higher rates of smoking. The concern is that much lower levels of radon in indoor air in homes might pose an important cancer hazard. The most direct way to assess the risk posed by radon in homes is to compare life-long radon exposures among people who developed lung cancer with exposures among healthy controls, accounting for other causes of lung cancer such as smoking. About a dozen such studies have been conducted to date, but they haven't provided a precise answer on the level of risk because the risk is very small and it is difficult to estimate exposures over a lifetime. The combined evidence from these studies suggests that the risk is about the size that has been postulated on the basis of lung cancer data from miners (Darby, 1998). The most comprehensive examination of the evidence to date is the BEIR VI study sponsored by the U.S. National Research Council completed in 1999 (BEIR VI).

City of Fort Collins Current Indoor Air Radon Reduction Efforts

Radon education and mitigation is central to the City of Fort Collins 2000-2003 Air Quality Action Plan. Efforts include:

- **Information** — Encouraging radon testing and mitigation
- **Incentive** — Low cost testing kit sales
- **Ordinances** — Radon information given at point of sale, building code standards for voluntarily installed mitigation systems and inspector/mitigator certification requirements

The Problem: Compliance with Current Recommendations

The City's current radon program, which relies both on voluntary testing and mitigation, is similar to the programs of other municipalities in Colorado and across the nation.

The problem with a voluntary system is that—even with fairly intensive public education—relatively few people test for radon, retest or mitigate when needed. A study of a community intervention radon program in the Washington, D.C. area (which has similarly high levels of radon) found the following behaviors related to radon testing and mitigation (Doyle et al, 1991):

Home owners purchasing short term-test	6.5%
Using short term-test if purchased	55.8%
Using long-term test if purchased	55.8%
Mitigating (if needed)	25%

It should be noted that the radon program in this study utilized public education to increase both testing and mitigation.

Low compliance levels can dramatically reduce the effectiveness and cost effectiveness of a voluntary program. Using the probability estimates from this Washington, D.C. study, and applying it to all Region 1 areas of the U.S., Ford et. al. estimated that a radon remediation program recommending testing and remediation at or above the current threshold of 4pCi/L would cost about $320,000 to prevent one death from radon-associated lung cancer while preventing about 1317 lung cancer deaths. In contrast, using a full compliance estimate (everyone tests and everyone with high levels mitigates), about 122,000 deaths could be prevented at a cost of about $35,000 each.

The Proposal Being Considered: Requirements for Passive Radon Reduction Systems in New Construction

To further reduce exposure, the City is considering requiring radon reduction systems in new home construction. As part of their policy formation education and outreach efforts, City staff are soliciting public comment to help formulate their recommendation to the City Council. The Council is expected to consider the possible code change at their May 13 study session.

The proposal under discussion is to require passive radon mitigation system for all new construction. The basic component of the passive system is a PVC pipe running from the gravel or dirt beneath the slab to the roof for gas venting. Additionally, a polyethylene or plastic gas-retardant layer is placed and sealed between the slab and gravel or over the exposed soil or rock. The system is estimated to cost $522 per dwelling.[2]

City of Fort Collins estimates that 24,000 new homes (housing 59,000 people) will be built in the Fort Collins Growth Management area before the city runs out of land.

Radon in Fort Collins

Average indoor radon levels:

Fort Collins	Colorado	National	EPA Threshold
2.5 – 7 pCi/L	>4 pCi/L[3]	1.3 pCi/L[4]	4 pCi/L

The wide range in the Fort Collins levels is due to the method of testing. The lower figure (2.5) is the median level from a survey using first-floor, long-term tests conducted in 1989 (Borak, Woodruff and Toohey, 1989). The higher figure (7.1) is the average of 6,900 short-term tests. Short-term tests are often conducted in the lowest level of house (i.e. a basement or crawl space).

Cost Effectiveness Analysis (CEA)

Using risk estimates from the EPA based on BEIR VI risk models and exposure estimates based on radon levels measured in Fort Collins homes, staff in the City of Fort Collins Natural Resources Department constructed cost analyses using two different exposure estimates, one a worst-case exposure estimate from 6,900 consecutive short-term lower level radon tests in Fort Collins zip codes and another best case exposure estimate based on a one-year scientific survey of 90 first floor Fort Collins dwellings conducted in 1988. Cost per cancer avoided was estimated at $20,000 and $61,600 respectively. Over 200 cases of lung cancer would be prevented.

Expressing costs per lung cancer case averted does not reflect the savings and costs of resulting outcomes. Nor can this measure of cost be compared to cost-effectiveness ratios of other interventions. To make estimates more useful, we conducted a cost-effectiveness analysis using outcomes of years of life saved (YLS) and disability adjusted life years (DALYs), suing “no program” as the baseline comparison. Because the costs and outcomes of this intervention are spread over many years and because individuals prefer to receive benefits today rather than 20 or 25 years into the future, future costs and benefits were discounted at 3% per year as is standard in a cost effectiveness analysis (Siegel, 1996). We estimated that the useful life of the radon control system was 40 years, and that the latency period to the first cases of radon induced cancer is 25 years. We used estimates on effectiveness of the system from the City’s analysis. Estimates of the risk reduction were taken from 8 studies of residential radon exposure (Lubin 1997). Baseline lung cancer rates and life expectancies were derived from county and state vital statistics, respectively. Costs of treating lung cancer and estimates of lost productivity were taken from other U.S. studies (analysis available upon request). All costs were adjusted to 1993 dollars to facilitate comparison with other studies (see Table 1).

We estimate that a program requiring installation of passive radon control systems in all new residential construction in Fort Collins would cost **$12,082 per year of life saved** (1993 dollars). The most uncertain parameter in our model is the estimate of risk attributable to radon exposure in households. Using most and least favorable estimates of risk, the cost effectiveness ratio ranges from -$2,324 (cost-saving) to $141,740 per YLL. The EPA estimate taken from the two BEIR VI preferred risk models corresponds to the most favorable estimate from the residential radon studies and yields a cost-saving CEA ratio.

Table 1

Life-saving intervention	Cost per life-year saved (1993 dollars)	Reference
Radon Control		
Passive radon reduction systems in new construction	$12,100	See attached analysis
Radon remediation in homes with levels ≥ 4 pCi/L, modified	$80,000	Ford, SF et al (1999)
Radon remediation in homes with levels ≥ 4 pCi/L	$140,000	Pushkin JS (1989)
Radon remediation in homes with levels ≥ 8.11 pCi/L	$35,000	Mossman KL (1991)
Radon remediation in homes with levels ≥ 21.6 pCi/L	$6,100	Nero AV (1988)
Asbestos Control		
Ban asbestos in brake pads blocks	$29,000	Tengs (1994)
Ban asbestos in clutch facings blocks	$2,700,000	Tengs (1994)
Ban asbestos in roof coatings	$5,200,000	Tengs (1994)
Screening		
Pap smear screening (for cervical cancer)	$15,600	Friedenberg RM (2002)
Mammography screening (for breast cancer)	$24,100	Friedenberg RM (2002)
Colonoscopy (for colon cancer)	$127,000	Friedenberg RM (2002)
CXR and sputum cytology screening for lung cancer	$93,000	Friedenberg RM (2002)
Smoking cessation counseling	<$0 to $2,900	Tengs (1994)
Add NRT, and	$1,500-$3,500	Song F (2002)
Add bupropion SR,	$900-$2,150	Song F (2002)
Add NRT plus bupropion SR	$1,300-$2,800	Song F (2002)
Hypertension screening, age 40 (for heart disease and stroke)	Men: $23,000 Women: $36,000	Littenberg B (1990)
Public Health Initiatives		
Routine childhood vaccines and influenza in high risk adults	<$0	Tengs (1994)
Fluoridation (to prevent dental caries)	<$0	Tengs (1994)
Automobile Design Improvements		
Driver automatic (vs. manual) belts	<$0	Tengs (1994)
Dual master cylinder brakes	$13,000	Tengs (1994)
Collapsible steering columns	$63,000	Tengs (1994)
Side structure improvements to reduce door intrusion upon crash	$110,000	Tengs (1994)

Our estimate can be compared with a) other interventions to reduce exposure to residential radon, b) other prevention strategies our society has adopted, and c) alternative interventions targeted at primary prevention of lung cancer. Table 1 gives some estimates of the cost per YLL (1993 dollars) of a variety of prevention measures from published studies. First, note from Table 1, that the proposed intervention (listed first) has a more favorable cost-effectiveness ratio than the current radon remediation strategy, listed second. Comparing the proposed regulation with other prevention strategies shows that it falls well within the range of cost considered “a good buy.”

An alternative intervention targeted at primary prevention of lung cancer—smoking cessation treatment—is also very cost effective. Studies of smoking cessation advice have been conducted. Estimates of cost per life year saved range from <$0 to $2,900 (Tengs, 1994). Using pharmacotherapy (quit aids like nicotine replacement or other pharmaceuticals) roughly doubles the cost (Song F, 2002). Of course, the advantage of a requirement of new homes to include passive radon reduction systems over smoking cessation interventions is that the former does not require any behavior changes. Smoking cessation programs are only effective for those motivated to quit.

Because 70% to 90% of lung cancer deaths attributable to radon exposure occur among current and former smokers, it is more cost-effective to target radon-reduction programs at smokers than at non-smokers (Ford, 1999). Of course, if the choice were between radon reduction and smoking cessation, it would be more desirable to have smoker’s quit smoking. However, because the interaction between these two risk factors is believed to be multiplicative, lung cancer prevention will be most effective if efforts are made to reduce risk from both.

Other Options for Risk Abatement

The City’s proposal to require passive radon mitigation systems in all new construction is only one of many options the City has considered or could consider to lower the risk of radon exposure and consequent illness. A partial listing follows:

1. Status quo
    - Information at point-of-sale
    - Mitigation system installation standards
    - Mitigation/testing certification requirements
2. Increase education efforts to increase testing and mitigation by homeowners and/or builders
3. Required testing on all homes (new or new and old)
4. Required mitigation system installation on all homes (without testing)
5. Required mitigation system installation on all homes or home sites with certain actual or expected radon levels (new or new and old)

Reasons to support the City’s proposal:

- Residential radon exposure is a known health risk in Fort Collins.
- Testing and mitigation are voluntary in the City’s current Radon program and as mentioned previously, the program’s reliance on voluntary behavior change costs more and is less effective.
- Passive radon reduction requirements in new construction do not require owners to take action. Owners do not need to purchase radon-screening devices, retest their homes or mitigate in order for their families to benefit. Compared to the current program, installation of the passive mitigation system in new construction saves more lives at a lower cost.
- The cost-effectiveness of a passive radon reduction program in new construction compares favorably with other prevention strategies.

Reasons to oppose the City’s proposal:

Some who argue against mandatory (or even voluntary) radon mitigation or testing call into question the use of the linear no-threshold (LRT) model to estimate risk (see box at right). The critics of the science behind establishing radiation thresholds have suggested that background radiation — such as the relatively low-levels of naturally occurring radon — might actually stimulate our biological defense mechanisms. However, it should be noted that:

The LRT model applies the fact that a single particle of radiation hitting a single biological cell *can* initiate a cancer, and then assumes that the number of these initiating events would be proportional to the number of particles of radiation (dose and response). To simplify further, the theory uses data extrapolated from high-level radiation doses — such as the radon exposure and related lung cancer rate of miners — to calculate acceptable low-dose exposure for the general public.

Critics of this theory say that this model ignores the biological defense mechanisms that can prevent numerous exposures from developing into cancers. The alternative to use of the linear no-threshold hypothesis is a threshold hypothesis. In this hypothesis, radiation results in cancer only when there is enough radiation to overwhelm the threshold mechanism.

1. The LRT model is the scientific standard for calculating radiation risk.
2. Knowledge about the health effects of radon gas exposure has increased markedly in the last few years (Kennedy, 2002). Work such as BEIR VI and the findings of several multinational collaborative groups have provided exposure-risk estimates with greater confidence.
3. Risk measures from epidemiologic studies of residential radon exposure (case-control studies that don't rely on modeling) suggest that risk at lower levels of exposure is about that that would be predicted from extrapolating miner data using the LRT model (Darby, 1998, Stigum, 2003).

Board position:

The Health District Board of Directors supports the City's proposal to require installation of passive radon mitigation systems in new construction for the following key reasons:

1. It is estimated to save more than 200 lives over the useful life of the systems that would be required (using favorable assumptions)
2. It is more cost-effective than the City's current radon program
3. When compared with other prevention strategies, it falls well within the "good buy" range for prevention of disease and premature death.

About this Analysis
This analysis was prepared by Health District of Northern Larimer County staff to assist the Health District Board of Directors in determining whether to take an official stand on various health-related issues. Analyses are based on bills or issues at the time of their consideration by the Board and are accurate to the best of staff knowledge. To see whether the Health District Board of Directors took a position on this or other policy issues, please visit www.healthdistrict.org/policy.

About the Health District
The Health District is a special district of the northern two-thirds of Larimer County, Colorado, supported by local property tax dollars and governed by a publicly elected five-member board. The Health District provides medical, mental health, dental, preventive and health planning services to the communities it serves.

For more information about this analysis or the Health District, please contact Polly Anderson, community projects coordinator (970) 224-5209 or panderson@healthdistrict.org.

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[1] Environmental Protection Agency
[2] The Costs and Benefits of Passive Radon Control Systems in New Residential Construction, City of Fort Collins, 2/28/03.
[3] From the Colorado Department of Health and Environment, short-term, closed building measurement (http://www.cdphe.state.co.us/lr/radon/realest.htm - Radon%20in%20Colorado)
[4] Radon Frequently Asked Questions, U.S. Environmental Protection Agency (http://www.epa.gov/iaq/radon/radonqa1.html)

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