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 — December 12, 2003
Prepared by Bruce Cooper, MD and Polly Anderson

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.

Radon in Fort Collins

Average indoor radon levels from long term tests:

Fort Collins	National	EPA Threshold
3.0 pCi/L	1.25 pCi/L[2]	4 pCi/L

The Fort Collins level is the mean level from a survey using first-floor, long-term tests conducted in 1989 (Borak, Woodruff and Toohey, 1989). Short-term tests are often conducted in the lowest level of house (i.e. a basement or crawl space).

The average of 6,900 short-term tests in Fort Collins have yield a higher average (7.1 pCi/L).

The City's New Proposal: Active Radon Reduction Systems in New Construction

In May of 2003 the City Council considered a proposal to require **passive** radon mitigation systems in all new construction. At the May 13 study session, Council directed City staff to look into an **active** mitigation system proposal. As with the passive system, City staff are soliciting public comment to help formulate their recommendation to Council.

The Council is now considering the radon-resistant new construction as part of a major building code update (International Residential Code or IRC). The schedule (subject to change) for the IRC changes is:

- December 16, 2003 — public hearing on the IRC (including radon)
- February 10, 2004 — IRC discussion by Council
- March 2004 — adoption

The new radon proposal under discussion is to require active radon mitigation systems for all new construction. The basic component of this system is identical to the passive system, with the addition of an electric fan. The passive system consists of a PVC pipe running from the gravel or dirt beneath the slab to the roof for gas venting. A polyethylene or plastic gas-retardant layer is placed and sealed between the slab and gravel or over the exposed soil or rock. The passive system also includes installation of an electric supply, should the homeowner or builder desire to install a fan. [Note: staff did not describe this component of the passive system in the March analysis, though this piece was included in the cost estimates.]

The passive system was estimated in March 2003 to cost $522 per dwelling.[3] New estimates from September 2003[4] are:

Foundation Options	Passive System Cost
Sub-slab depressurization with gravel (most common – described above)	$590
Sub-slab depressurization with perforated pipe loop	$1,101
½ slab, ½ crawlspace depressurization	$494

Activation of the system requires installation of a $310 fan.[5] The annuatized cost for maintenance and operation of the active system is $40/year (electricity is $4.75/year and fan replacement is expected every eight years).

The City of Fort Collins estimates that radon levels are reduced as follows with each system:

Passive: 47% reduction in radon levels
Active: 87% reduction in radon levels

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. Sixty percent of these (14,000 homes housing 24,000 people) will be single-family units and therefore subject to the proposed radon regulation.

The EPA recommends testing homes with the passive system and if the radon level in elevated above 4 pCi/L, activating the system by adding a fan.

Cost Effectiveness Analysis (CEA)

City cost estimates

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 56 first floor Fort Collins dwellings conducted in 1988. The City's estimated that in a hypothetical community of 14,400 dwellings and 35,300 (the predicted capacity for new single family dwellings in Fort Collins):

Passive: Cancer reduction 146 cases (range 75 to 300) at a cost of $51,000 per case (range $25,000 to $100,000)
Note: The March analysis reported that the City concluded 200 cases would be averted with the passive system.
Active: Cancer reduction 270 cases (range 150 to 600) at a cost of $42,600 per case (range $20,000 to $80,000)

Health District cost estimates

Expressing costs per lung cancer case averted does not fully reflect the savings and costs of resulting outcomes. Nor can this measure of cost be compared to cost-effectiveness ratios of other interventions with different purposes and outcomes. To make estimates more comparable, we conducted a cost-effectiveness analysis of the same hypothetical population using outcomes of years of life saved (YLS) and disability adjusted life years (DALYs). The analysis of the passive system uses the current approach as the comparison; the analysis of the active system uses the passive system as the comparison.

Table 1 — Incremental cost per life year gained

	Cost (per life year gained)	**Estimated Lung Cancer Deaths**	**Lung Cancer Deaths Averted**
No Program	-	151	-
Current	$21,900	148	3
Passive	$17,400	130	21 (18 over current)
Active	$58,900	115	36 (15 over passive)

Because the costs and outcomes of these interventions 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 a lifetime, 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 the BEIR VI study. 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).

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 range as follows:

Current: $12,800 - $35,600 per life year gained
Passive: $10,300 - $28,000 per life year gained
Active: $35,400 - $93,000 per life year gained

Table 2 — Comparison of Select Health Interventions

Life-saving intervention	Cost per life-year saved (1993 dollars)	Reference
Radon Control		
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 2 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 passive radon intervention has a more favorable cost-effectiveness ratio than both the current radon remediation strategy and the active system. Comparing both the passive and the active regulations with other prevention strategies shows that the passive falls within the range of cost considered "a good buy" and that the active is quite a bit more.

An alternative intervention targeted at primary prevention of lung cancer—smoking cessation treatment—is 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 proposals to require passive or active 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)
6. Targeted radon-reduction intervention for smokers

Reasons to support the City's *active* mitigation system proposal:

- Residential radon exposure is a known health risk in Fort Collins.
- The active system is more effective at reducing radon levels than both the passive system and the City's current program of voluntary testing and mitigation and will save more lives.
- Active 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.
- It is easier and less expensive to install the active (and passive) system during construction rather than after.
- Public comments appearing on the City's web page solicited as part of the public input process include the following ideas (note: most were written in response to the City's original proposal for a passive system):
    - Costs for the system are nothing compared to cancer.
    - Passive requirement is better than requiring active.
    - Passive systems don't do enough to lower levels so active is better (from an anonymous radon professional).

Reasons to oppose the City's *active* mitigation system proposal:

- The active system is less cost effective than the passive system and is expensive when compared to other prevention strategies. [The passive system compares favorably with other strategies.]
- The added expense of the fan for the active system is unnecessary for homes with low radon levels.
- Public comments appearing on the City's web page (some on the active system some on the passive system) include the following ideas:
    - It is the City's responsibility to educate on this issue, not regulate.
    - Additional regulations will increase the already high cost of housing in Fort Collins.
    - The addition of the fan should be the responsibility and choice of the homeowner, not the builder or government.
    - Radon levels vary too dramatically to mandate one system for all new construction.

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:

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 meta-analyses of epidemiologic studies of residential radon exposure using 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).

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.

Board of Directors position:

On December 12, 2003, the Board of Directors of the Health District of Northern Larimer County voted to uphold their March 2003 decision to **recommend that the City of Fort Collins require installation of passive radon-reduction systems in new construction**. This recommendation is made over both the City's current education program and over the current proposal to require installation of active radon-reduction systems in new construction.

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[4] Construction Cost Estimate City of Fort Collins: Radon Mitigation Program New Single-Family Dwellings, B & C Project Services for the City of Fort Collins, Natural Resource Department. September 22, 2003.
[5] Ibid

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 at (970) 224-5209 or panderson@healthdistrict.org.