Assessment of Indoor Radon Exposure for Marion County

2015

An Assessment of the indoor radon issues for Marion County including an analysis of current available data, potential public health issues, and a summary of findings and recommendations for the county.

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I. Basic Information Regarding Radon

a. Physical and Chemical Data

Radon is a radioactive, colorless, odorless, and tasteless gas represented by symbol Rn and atomic number 86[1]. It occurs naturally as an indirect decay product of uranium. Radon is one of the densest substances that remains a gas under normal conditions. It is also the only gas that under normal conditions has only radioactive isotopes. Radon is considered a human health hazard due to its radioactivity[2]. Additionally, Radon is measured in picocuries per liter of air (pCi/L), the standard measurement for radiation in the air used in the United States[1].

Uranium is naturally present in the environment and as it breaks down to radium, and subsequently radon, some of that radon moves to the air, surface soil, and ground water. Radon also undergoes radioactive decay and has a radioactive half-life of about 4 days, meaning that one-half of a given amount of radon will be changed or decayed to other products in about 4 days. When radon decays, it divides into two parts: radiation and a radon daughter. The daughter, unlike radon, is a solid and may stick to dust particles in the air[2]. If the contaminated dust is inhaled, these particles can stick to airways of the lungs and increase risk for developing lung-cancer[3]. Additionally, the radon daughter is not stable; it will continue to divide into more radiation and daughters until the remaining product is a stable, nonradioactive daughter[2].

Also during the decay process, alpha, beta, and gamma radiation are released[2]. Alpha and beta rays are relatively non-penetrating so external exposures are only associated with localized damage. Gamma radiation, on the other hand, can penetrate the human body and cause severe damage to internal organs with prolonged exposure[4].

b. Geology of Radon

Because radon is a gas, it has much greater mobility than uranium, which remains fixed in rocks and soils. Radon can more easily leave the rocks and soils by escaping into fractures and openings and into the pore spaces between soil particles eventually making its way up into the home where it collects. The efficiency with which radon moves in the pore space affects the amount of radon that enters a house. If radon is able to move easily in the pore space, then it can travel a great distance before it decays, and it is more likely to collect in high concentrations inside a home or dwelling[5]. Radon from soil gas is the primary cause of radon problems[1].

Radon gets into homes and dwellings through[1]:

a. Cracks in solid floors.
b. Construction joints.

[1] Environmental Protection Agency (2012) *Citizens Guide to Radon: A Citizen's Guide to Protecting Yourself and Your Family from Radon*
[2] Agency for Toxic Substances and Disease Registry (1990) *Toxicological Profile for Radon*
[3] Executive Office of Health and Human Services (2011) *Public Health Fact Sheet on Radon*
[4] King County (2012) *Radiation Facts and Health Effects*

c. Cracks in walls.
d. Gaps in suspended floors.
e. Gaps around service pipes.
f. Cavities inside walls.
g. The water supply.

Most houses draw less than one percent of their indoor air from the soil; the remainder comes from outdoor air, which has generally low levels of radon. Houses with low indoor air pressures, poorly sealed foundations, and several entry points for soil air, however, may draw as much as 20% of their indoor air from the soil. Even if the soil air has only moderate levels of radon, the radon may accumulate over time leading to high levels inside the home or dwelling[5].

Because radon is a product of uranium decay, higher amounts of uranium in a specific area can indicate greater chances for indoor radon exposure. However, dwellings in areas with high amounts of uranium in the soil may have low levels of indoor radon and vice versa[5], and radon levels vary greatly from house to house[6]. It is estimated that nearly 1 in 15 homes in the United States contain elevated radon levels[2].

c. Biological and Health Concerns

Radon is largely regarded and classified as a carcinogen[7]. Exposure to radon primarily occurs through inhalation of both radon and its progeny. While radon is present in all air, levels are fairly low outdoors averaging at about 0.4 pCi/L, compared to the indoor average of 1.3 pCi/L[6]. Similarly, ingesting radon in water does not pose the same type of threat as inhaling concentrated amounts for a prolonged period of time. Radiation exposure from radon is indirect as the health hazard does not primarily derive from radon itself, but rather from the radioactive products created in the decay of radon. Both human and animal studies indicate that the lung and respiratory systems are the primary targets of radon daughter-induced toxicity. When radon is inhaled, alpha particles from the radioactive decay impact the lung tissue cause damage with the potential to develop into lung cancer[2]. While not all exposures will necessarily lead to cancer and the onset of disease may occur many years after an exposure[1], the Environmental Protection Agency (EPA) maintains that any level of exposure carries some risk. Indoor levels at 2.0 pCi/L or higher, however, should be prioritized for mitigation[6].

Radon's radioactivity is closely associated with an increased risk of radiation-induced cancer such as lung-cancer. Analyses of pooled data from home-based radon health outcomes in multiple countries have concluded that lung-cancer patients are more likely to have been exposed to radon than people without lung cancer, concluding that radon is an independent risk factor for lung cancer regardless of smoking status[8]. There are some recent studies which suggest an association with leukemia, but they require further analysis to determine causation[9]. While it is unknown whether radon causes other types of cancer, there is sufficient peer-reviewed data to indicate that radon exposure increases risk for developing lung cancer.

[5] U.S. Geological Survey (1995) *The Geology of Radon*
[6] Environmental Protection Agency (2013) *Basic Radon Facts*
[7] U.S. Department of Health and Human Services (2014) *Report on Carcinogens, Thirteenth edition*
[8] Neri et al. (2013) *Radon Control Activities for Lung Cancer Prevention in National CCC Program Plans, 2005-2011*
[9] Smith, B., Zhang, L., and Field, W. (2007) *Iowa Radon Leukemia Study*

d. Public Health Issues

The EPA attributes an estimated 21,000 deaths from lung cancer per year due to radon exposure in the U.S. This ranks radon as the leading cause of lung cancer among nonsmokers and the second leading cause among smokers. Radon-related lung cancer deaths also account for a larger number of deaths than drunk driving[6]. Also according to the EPA, about 6% of homes in the U.S. have radon levels above 4.0 pCi/L; if those homes could reduce their radon levels to meet EPA guidelines, about one-third of the radon-related lung cancer deaths that occur each year could be prevented. Although the majority of preventable deaths would be among smokers, an estimated 1,000 non-smokers could also avoid lung cancer[10].

In September 2009, the World Health Organization (WHO) released a comprehensive global initiative on radon that recommended a reference level of 100 Bq/m^3 for radon, the equivalent of 2.7 pCi/L (Becquerels per cubic meter as compared to picocuries per liter, which is more commonly used in the U.S.)[11]. The WHO initiative also advocates for establishment and/or strengthening of radon measurement and mitigation programs in addition to building codes requiring radon prevention measures in homes and dwellings under construction. Furthermore, while several states have radon-specific policies in place, many Comprehensive Cancer Control (CCC) programs do not address radon exposure and may not be aware of radon as a public health issue[8].

e. Synergistic Characteristics of Radon

It is generally believed that exposure to radon in conjunction with cigarette smoking is synergistic; meaning that the combined effect exceeds the sum of their independent effects. This is because the radon daughters often become attached to smoke and dust particles, and are then able to lodge into the airways of the lungs and increase risk for lung cancer over the course of a lifetime[1]. Smoking and radon exposure are considered the first and second leading risk factors, respectively[8].

The charts below depict data from the EPA's *Assessment of Risks from Radon and Homes* and comparison data from the Centers for Disease Control presented in the EPA's 2012 report, *Citizens Guide to Radon: a Citizen's Guide to Protecting Yourself and Your Family from Radon*:

Radon Risk for Smokers

Radon Level	If 1,000 people who smoked were exposed to this level over a lifetime…	Risk of cancer from radon exposure compares to…
20 pCi/L	About 260 people could get lung cancer	250× the risk of drowning
10 pCi/L	About 150 people could get lung cancer	200× the risk of dying in a home fire
4 pCi/L	About 62 people could get lung cancer	5× the risk of dying in a car crash
1.3 pCi/L	About 20 people could get lung caner	(Average indoor radon level)

Note: Risk may be lower for former smokers

Radon Risk for Nonsmokers

Radon Level	If 1,000 people who never smoked were exposed to this level over a lifetime…	Risk of cancer from radon exposure compares to…

[10] National Research Council (1998) *Radon, Especially In Combination With Smoking, Contributes To Lung Cancer Deaths*

[11] World Health Organization (2009) *WHO Handbook on Indoor Radon: A Public Health Perspective*

20 pCi/L	About 36 people could get lung cancer	35× the risk of drowning
10 pCi/L	About 18 people could get lung cancer	20× the risk of dying in a home fire
4 pCi/L	About 7 people could get lung cancer	the risk of dying in a car crash
1.3 pCi/L	About 2 people could get lung caner	(Average indoor radon level)

The majority of radon-related lung cancer deaths occur among smokers. And given the strong connection between smoking and radon, a reduction in radon exposure would greatly benefit smokers more than nonsmokers, as they are more vulnerable to disease in this situation[10]. It is generally recommended that smokers cease smoking in order to lower their risk of lung cancer due to radon exposure as well as exposure to carcinogens in cigarettes and other tobacco products[1].

II. Data Research

a. United States

As aforementioned, the national indoor radon level averages at 1.3 pCi/L and homes with high levels of radon have been found in every state[6]. The highest levels of radon tend to occur in the Northern portion of the country. States such as Iowa, North Dakota, South Dakota, Maine, Minnesota, Illinois, Kansas, Montana, Idaho, Wyoming, Colorado, Pennsylvania, and Virginia have a recorded average of 4.0 pCi/L or higher categorizing them as Zone 1. States with moderate radon levels of 2.0 – 3.9 pCi/L, or Zone 2 states, include Alaska, Arizona, Nevada, Missouri, Utah, and Wisconsin. Significant parts of California, Oregon, and most of New England also fall in the Zone 2 category. And Zone 3 states are considered low risk, with average recorded indoor radon levels of less than 2.0 pCi/L[12].

b. Oregon

New data released by the Oregon Health Authority (OHA) show that many regions of the state are at moderate risk of having high concentrations of radon. These high-risk areas are generally relegated to the Willamette Valley and eastern and southern Oregon. Specifically the cities of Scappoose, Banks and North Plains, as well as Boring, Parkdale, Dundee, Turner, and La Grande carry the largest recorded concentrations of radon in the state. Portland has also been documented as having high risk areas, particularly in the North, Northeast, and Southeast sectors of the city[13].

c. Marion County

According to Oregon's state radon officer, Marion County has an average indoor radon level of 3.1 pCi/L. That is over two times higher than the national average. While the majority of results (about 52%) represent households and dwellings with less than 2.0 pCi/L, about 22% of households tested between 2.0 and 3.9 pCi/L and 26% tested at over 4.0 pCi/L[14]. Thus, almost half of all homes in the county test well within the realm for mitigation as recommended by the EPA and the U.S. Surgeon General. Lung cancer risk rises 16% per 2.7 pCi/L increase in radon exposure[15]; therefore it is especially important to target the

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[12] Agency for Toxic Substances and Disease Registry (2013) *Radon Toxicity*
[13] Oregon Health Authority (2015) *State Data Show Areas of Oregon at High Risk for Dangerous Radon Levels*
[14] State Radon Officer, Brett Sherry (no date available) *Marion County Radon Information*
[15] Kansas State University (2009) *National Radon Program Services*

households with dangerously high concentrations of radon, which represent about 1 in every 4 homes in Marion County.
As shown in the table below, the Aurora, Salem, Silverton, and Turner areas in Marion County tested the highest for radon (>4.0 pCi/L) according to data collected by Portland State University's Department of Geology in 2013[16].

III. Tables and Maps

Table 1: Long and Short Term Radon Test Results for Marion County by Zip Code, 2013

		Long Term Testing Results					Short Term Testing Results				
Zip Code	**City**	***n***	**Max**	**Avg.**	**%>4**	**Radon Potential**	***n***	**Max**	**Avg.**	**%>4**	**Radon Potential**
97002	Aurora	7	4.4	1	14		22	11.1	3.5	36	**High**
97026	Gervais	4	11.2	6.5	100		4	6.2	3.5	50	
97032	Hubbard	1	0.8	0.8	1		3	1.8	0.9	0	
97071	Woodburn	30	5.5	1.3	7	Low	24	3.3	1.5	0	Low
97301	SE Salem	136	15.8	1.5	6	Moderate	82	47.4	2.5	6	Moderate
97302	S Salem	258	14.4	2.4	23	Moderate					
97303	Salem	316	39.8	2.2	2	Moderate	46	39.8	2.2	4	Moderate
97304	W Salem	699	160.2	4	18	Moderate	153	114.3	7.1	33	**High**
97305	Salem	39	5.7	1.3	8	Low	18	5.7	2.2	4	Moderate
97306	Salem	99	25.2	3.9	18	Moderate	83	22.7	4.2	31	**High**
97308	Salem	33	1.6	0.6	0	Low	1	1	1	0	
97309	Salem	7	6.3	1.6	14						
97310	Salem	25	1.7	1	0	Low					
97317	Salem	1	0	0	0		13	6	2.6	23	Moderate
97325	Aumsville	15	4.9	2.9	33	Moderate	9	1.6	0.5	0	
97342	Detroit	2	0.9	0.5	0						
97346	Gates	1	0.7	0.7	0						
97352	Jefferson	12	21.5	3.2	25	Moderate	2	2.7	1.6	0	
97359	Marion	2	0.6	0.6	0						
97360	Mill City	1	0	0	0						
97362	Mt. Angel	6	7.4	2	20		8	9.8	4.3	38	
97375	Scotts Mill	8	12	3.9	38		1	1.9	1.9	0	
97381	Silverton	43	14.4	5.1	56	**High**	80	22.4	4.2	41	**High**
97383	Stayton	4	17.3	4.7	25		4	17.3	6	50	
97385	Sublimity	10	8.4	2.5	20	Moderate	7	6.9	3.1	29	
97392	Turner	11	12.6	3.6	27	Moderate	14	15.6	5.2	43	**High**

The above table depicts data provided by Portland State University's Department of Geology. The data indicate potential radon hazard by zip code in Marion County with Aurora, Salem, Silverton, and Turner testing at the highest levels. Additionally, it should be noted that zip codes with fewer than 10 results (*n*=<10) were not categorized because of insufficient data[16].

Table 2: Oregon Radon Program Test Results for Marion County by Zip Code, 2014

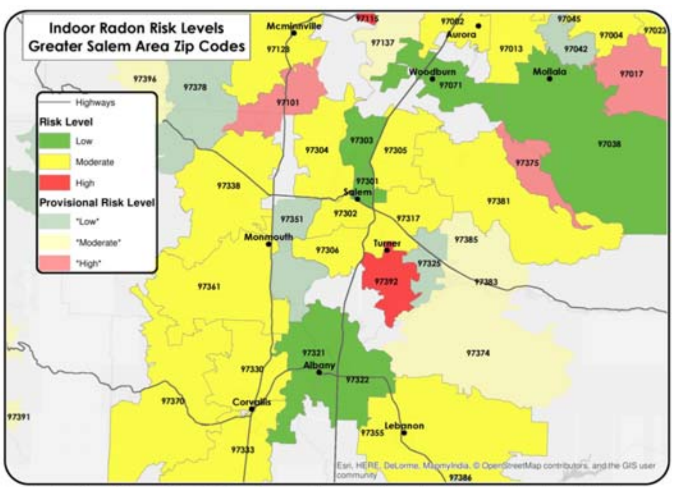
Zip Code	City	Risk Level	*n*	Maximum Result	Average Result	%>4

[16] Lindsey, K. et al., Portland State University Department of Geology (2013) *Radon Test Results in Oregon by Zip Code*

97002	Aurora	Moderate	5	11.1	2.0	16.0
97026	Gervais		4			
97032	Hubbard		4			
97071	Woodburn	Low	27	6.7	1.5	3.7
97301	SE Salem	Low	80	15.8	1.7	6.3
97302	S Salem	Moderate	303	36.4	3.4	30.4
97303	Salem	Low	49	39.8	1.7	8.2
97304	W Salem	Moderate	385	114.3	4.0	26.0
97305	Salem	Moderate	33	9.9	2.2	15.2
97306	Salem	Moderate	142	22.7	3.1	27.5
97317	Salem	Moderate	61	36.1	3.5	26.2
97325	Aumsville	Low	9	5.2	2.0	22.2
97342	Detroit		0			
97346	Gates		3			
97352	Jefferson		4			
97360	Mill City		0			
97362	Mt. Angel		4			
97375	Scotts Mill	**High**	9	11.1	5.2	60.0
97381	Silverton	Moderate	213	40.1	3.8	32.9
97383	Stayton	Moderate	10	17.3	2.6	10
97385	Sublimity	Moderate	9	6.9	2.9	33.3
97392	Turner	**High**	24	23.1	4.6	41.7

Additional data, provided by the Oregon Health Authority, show 2014 test results for the Oregon Radon Program. The data categorize radon risk level using three factors, maximum radon test result, average radon result, and the percentage of locations within the zip code that had a test result of over 4.0 pCi/L[17].

Figure 1: Indoor Radon Risk Levels for Greater Salem Area by Zip Code, 2014



This map, provided by the OHA, shows the distribution of indoor radon risk by zip code in the greater Salem area[18].

Regardless of zip code risk, it still remains important that householders test for radon as levels can vary from home to home. Living in a low-risk zip code does not mean that risk for exposure is low in a given home or dwelling[6].

IV. Summary of Data

a. Hypothesis of Marion County Data

[17] Oregon Health Authority (2014) *Oregon radon Program: Indoor Radon Test Results Summary*

[18] Oregon Health Authority (2014) *Indoor Radon Risk Levels for Greater Salem Area by Zip Code*

Current legislation in Oregon requires that new public construction projects address radon by utilizing construction methods that inhibit radon from accumulating in buildings. Furthermore, Baker, Clackamas, Hood, River, Multnomah, Polk, Washington, and Yamhill Counties adopted additional legislation extending radon prevention standards to certain types of new residential and public building construction[19]. As of early 2015, Marion County has not adopted any additional radon regulations to address residential construction or existing structures to prevent radon exposure.

Furthermore, about 22% of all homes in the county test in the moderate risk range (2.0 – 3.9 pCi/L), and about 26% of all homes in Marion County test at the high risk level (>4.0 pCi/L)[14]. Thus, almost half of the county tests well within the realm for mitigation as recommended by the EPA and the U.S. Surgeon General. Radon test results for the county are also twice as high as the national average, making radon a valid health concern for the area.

While lung cancer rates for the county remain comparable to the national average[20], continued and unmitigated exposure in high risk dwellings may contribute to a higher incidence of radon-induced lung cancer over time. Without additional prevention and mitigation efforts in place, in conjunction with smoking cessation efforts, householders who smoke and/or have high concentrations of radon in their homes will be most at risk for developing radiation-induced cancers[10].

b. Possible Mitigation

The most common method for radon mitigation is to install a vent pipe system or exhaust fan, which pulls radon from beneath the house and vents it to the outside. Known as sub-slab depressurization, this mitigation technique increases under-floor ventilation and moves radon-laden air from homes to the outdoors where it can dissipate[21]. Other mitigation approaches include installing a radon pump system in a basement, improving general ventilation in a dwelling, or installing a positive pressurization or positive supply ventilation system[22]. However, the radon mediation process is a largely individual endeavor. Testing for radon is the only way to know if a home is at risk for radon exposure[1]. Thus, it becomes the responsibility of the householder to pursue testing and possibly mediation, which takes time and resources.

In a cost benefit analysis performed in 1986, the report indicates that an action level of 4.0 pCi/L or above results in a cost of about $700,000 per lung cancer death saved. If the action level was set at 3.0 pCi/L, the cost would be $1.7 million, and if set at 2.0 pCi/L, the cost would be $2.4 million per lung cancer death saved. Accordingly, it becomes more cost effective to target the homes with very high recorded levels of radon[15]. Although, as aforementioned, the burden falls to the householder to pursue testing in order to see if action is warranted. Typically, testing consists of relatively simple procedure of placing a commercially available radon testing device in the lowest livable floor of a home. A short-term test usually takes about 3-7 days, or up to 3 months, and a long-term test may take up to a year to get an accurate measurement[1].

[19] Oregon Building Codes Division (2011) *Adopting Radon Gas Mitigation Standards Amending 2008 ORSC & 2010 OSSC*

[20] National Cancer Institute (2014) *Age-Adjusted Death Rate Due to Lung Cancer by County*

[21] Blaine, D. (2011) *New Oregon Standards for Radon Control*

[22] World Health Organization (2014) *Radon and Health Fact Sheet*

Lack of resources, such as perceived difficulty and expense combined with the perception that radon is not an immediate health hazard, have kept many householders from pursuing testing and/or radon mitigation. Many studies on the barriers to testing have found that perception of radon as a health risk was positively correlated with planning to conduct further radon testing and to employ radon mitigation methods[23]. In order to address the disparity in radon testing, it is fundamental that the county invest in risk communication techniques that sufficiently describe the adverse health effects of radon exposure to adequately display the hazards. In combination with smoking cessation programs and increasing access to cheap or free radon test kits, education campaigns aimed at changing risk perceptions around radon exposure will reduce indoor radon exposure and greatly benefit the county.

[23] Duckworth, L. et al. (2002) Relationship of Perception of Radon as a Health Risk and Willingness to Engage in Radon Testing and Mitigation

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Glossary of Terms

Concentration: The activity of radon gas in terms of decays per time in a volume of air. The unit of radioactivity concentration is typically given in picocuries per liter (pCi/L) in the U.S. or Becquerel per cubic meter (Bq/m3).

Exposure: The amount of time a person spends in any given radon concentration. It is determined by multiplying the radon concentration, measured in pCi/L or Bq/m3 of each area by the amount of time spent in that area.

Homes or dwellings: These terms are used interchangeably and refer to all detached and attached structures used for non-occupational human residency. The term "house" refers to a detached single-family dwelling.

Householders: This is a term of convenience used to collectively describe those living in a home or dwelling. It refers to occupants of the home, including owners of the property as well as tenants.

Long-term measurement: A measurement of radon concentrations that takes place over period of 3 months up to 1 year.

Mitigation or remediation: These terms are interchangeable and refer to steps taken in an existing building to reduce radon entry.

Prevention: In this context, measures installed during construction of new homes or dwellings aimed at preventing the entry of radon.

Short-term measurement: A measurement of radon concentrations that takes place over a period less than 3 months.