Workshop on Radon Occurrence, Health Risks and Policy, With an Emphasis on Radon in Ground Water Drinking Supplies

Wednesday October 4, 2006

Session 1: Occurrence

Radon and Radioactivity Occurrence in Ground Water Resources in the United States
Zoltan Szabo

- RN-222 occurs more readily, has a longer half-life, decays from Uranium 238, while RN-224 decays from Thorium 232,, and Radium 224
- Average sources of total radiation dose is 87%, and naturally occurring Radon is the largest percentage of this dose, at 32% (Artificial 13%)
- Radionuclide health effects: Ionizing Radiation Damage which means long-term cancer risk
- EPA subscribes to the maximum contaminant level of no threshold, linear dose model, meaning any amount is bad and can lead to cancer
- Tissue retention controls dose, where time = dose
- Uranium attributed to kidney toxicity; radium attributed to bone cancer, sinus cancer, and bone fracturing; radon poses great complications and causes 80%+ of risk from degassing from water to lung cancer, can also be attributed to stomach cancer
- Water monitoring scheme since 2000 entails monitoring individually for 222 and 224, though until 2000, it was the combination of the two that was measured, non compliance was greater than 5 pCi/L for the combination
- Should there be an MCL/AMCL for Rn-222? Goal is 0 because of its carcinogenic nature, however, difficult to treat in water, thus….MCL is 300, so if < 300, no action needed, if >300 but less than 4000, MMMP or Treat, AML of 4000, and greater than 4000 must treat
- Approaches: Targeted Regional Survey Design and a Statewide design, both of which work together in a feed-back loop; need to use existing data and generalized models
- In terms of characterizing aquifers, first question is necessarily, where is the Uranium? High concentrations in West and in the Appalachian mountain range
- EPA assembled a map of states mean radon in groundwater, NC had from 450 to 2,000 pCi/L, as a mean….not necessarily a helpful way of looking at actual quantities of Radon
- Used river basins, each of which has its own sampling program…can look at radon occurrences on a more local scale…in draft form from USGS
- Level of Radon according to aquifer type – much greater concentration in crystalline rock samples…other groups, including unconsolidated sand, sedimentary rock, and basalt, don't even come close
- Crystalline rock aquifer data, all median levels of radon greater than 1000 pCi/L, and some up to 10,000

- 66% of all water samples greater than proposed MCl of 300 pCi/L; 63% of all water samples between 300 and 4000 pCi/L
- New Jersey's draft approach: Combine science and Policy plans; compile data, map water potential and mix into policy
- NJ Law states that homes have to be built with radon proofing and to buy or sell a house must know levels of radon
- Many of the areas of highest potential already have laws, but the areas that fall between MCL and the extreme levels do not necessarily have limits

Chemical model for Radon Enrichment in Ground Water from Fracture Rocks
Warren Wood

- Models for how radium leaks into groundwater – hydrothermal uranium mineralization; diffusion
- Evidence of diffusion include iron-oxide bands, indicating oxygen diffusing from a fracture and iron diffusing, creating iron oxide; diffusion coefficient of 7mm/300 days; is there radium on the fractious surfaces? Suggestive evidence, but no conclusive
- Conclusions from sodium ion diffusions: radium diffusion for the origin of radon in ground water of fractured rocks appears to be a viable model

Radon in Ground Water Supplies of NC
Ted Campbell

- Radon 222 a radioactive gas produced by the decay of uranium 238
- Health risk is not the radon, but the decay of the daughter products
- Is a human carcinogen, the 2nd leading cause of lung cancer; is found everywhere, very mobile; migrates from rock and soils into atmosphere and indoor air; tends to occur at higher levels in private wells than in public supply wells
- Degasses during showering which can increase exposure over ambient levels
- Ongoing debate about safe levels in water because of background and ambient conditions
- Health risks from radon in water are believed to overshadow those caused by all other radio nuclides in the nation's water supply
- In most cases, main source is underlying rock and soils; radon in water results in new pathways of exposure
- 10,000 :1 rule of thumb…10,000 pCi/L in Water equates to in air; does not account for acute daily doses
- Radon Standards: Indoor Air, Epa action level – 4 pCi/L; water EPA proposed standard for radon in water is 300; proposed alternate standard for radon in water is 4,000; in NC monitoring radon in public water supply wells is voluntary
- Some states have begun to establish their own standards/advisories such as NJ (300)
- Radon in NC: 8 counties in Western NC are EPA Zone 1, indoor radon levels above the Action level of maximum contamination

- Do not have data for every county
- Know that uranium rich rock exists across the whole region
- About half of the population in NC uses ground water as principle drinking supply; elevated radon and radio nuclides have been found in ground water of piedmont
- 1974 study samples 204 PWS wells found 60% with radon above 2000 pCi/L; lowest levels in Coastal plain and highest in Mountains
- 1983 study from 2000 suppliers found 2.4% of suppliers exceeded EPA MCL's for gross alpha (15 pCi/L) or combined radium (5)
- 1987 study, 96 suppliers, found rock type effects radon levels and Is highly variable within subtypes
- 1993 UNC Study 277 well sample, 83% contained radon above 2000 pCi/L
- 1975 to current many counties have limited data
- Wake County data: median 2800 pCi/L, Max, 32,000, had 27 wells above 10,000, 60 wells above 4,000
- Western NC study addressing 3 q's: levels, and policy implications
- Throughout the area, saw high levels of radon, levels frequently exceeding EPA proposed 300 standard
- Factors controlling occurrence: Geology predominantly, three formations had the highest levels; Dissolved oxygen, most wells had high oxic levels associated with high levels; radionuclides do not necessarily co-occur, high indoor radon was not an obvious predictor of other radionuclides
- Many constraining factors and variables affecting radon in the house, including way house is built and ventilation within house
- Radon levels were not correlated with hydrologic setting, well depth, casing depth, well yield, Fe, Mn
- Elevated radon associated with meta-igneous rocks
- Geochemistry controls radionuclide solubility and occurrence
- Degassing from water results in an acute daily short term dose
- Main source of indoor radon from underlying rock and soils
- Testing is easy and inexpensive
- Radon can be removed from water supply fairly easily with aeration or GAC filter, though disposal may be costly
- One should consider the combination of inputs of indoor radon air and radon in groundwater when considering mitigation
- Indoor air radon levels do not account for acute indoor daily exposure, many homes already have levels of 3 or 4 pCI/L

Relationship between radon in water and indoor air
David Vinson

- Radon exposure mechanisms include inhalation, from shower, dishwasher, laundry and mixed into rest of house
- 1:10,000 Radon in air to radon in water ratio assumes radon is mixed throughout house at time of exposure and does not consider short-term acute exposures

- Objective to quantify the immediate contribution of airborne radon from showering, and estimates of what this means in terms of exposure
- In NC, private well usage is widespread outside of major towns
- Sampled well water and indoor tap water
- Measured radon in bathroom air before during and after shower
- Range of RN in well water, from 4,280 to 20,386, all exceeding the proposed EPA standards of 300 and 4,000
- Airborne Rn increased up to 120 pCi/L during water running and door closed in room
- Found that room with good mixing and escape have an earlier and smaller peak of radon levels while rooms with poor mixing and escape have a later and higher peak
- Exposure estimation, its more important the level of decay rather than the radon being present
- Alpha energy exposure caused by radioactive decay, not the mere presence of Rn useful for exposure estimation; radon and decay products not in equilibrium and minimal decay products in shower water, radioactive decay in room air creates progeny; shower exposure is time dependent, average shower time and time spent in bathroom before opening door…an important length of time for estimating exposure
- Less exposure during shower and highest exposure after water turned off but before door opened
- Exposure per unit of Radon in water, exposure has linear increase with radon in water; exposure has non-linear increase with exposure time
- Conclusions: showering causes a few percent increase in exposure relative to existing models showing radon being mixed equally throughout a home
- Info most pertinent for homeowners at the borderline of the EPA action level of 4 pCi/L
- Rn progeny exposure may exceed expectations even if house-averaged airborne Rn remains below the nominal limit

Session 2: Health Risks

Residential Radon Exposure and Lung Cancer
William Field

- Cancers with highest incidence in men and women are prostate and breast, however, lung cancer has the highest cause of death from cancer for both, primarily from smoking, probably
- More men develop lung cancer, among both sexes, lung cancer incidence decreasing
- Before the age of 40 usually seen as a secondary cancer, generally develops later in life
- Why is Radon a concern?

    - Decay products – Polonium 218 and 214, which decay and attach themselves to the lung – can irradiate sensitive cells
- Comparing radon related cancer to other cancer types, causes most frequently lung cancer
- Several challenges to measuring and controlling radon exposure concentration
- Pooled summary of studies found the 11% estimated risk is consistent
- Radon concentration leads to exposure leads to progeny dose
- Have the risks been under reported?
    - Poor quality control, studies performed in low radon areas, failure to link radon concentrations with where people spend time; inadequate consideration of temporal radon variations, high percentage of proxy respondents
- Subject mobility interview, Iowa study, obtains mobility patterns within/outside the home using seasonally adjusted task linkage
- Found in Iowa that radium was coming from the pipe scale
- Outdoor exposure of radon – if its so high indoors, how high is it outdoors – some places outdoors have very high concentrations
- Exposures in other buildings – work place, first floor concentrations
- Looked at tissues from non-smokers
    - Genotype GSTM1, null in 38-62% of Caucasians; higher risk for greater effects of radon on those individuals with null gene, which works as a natural defense
- Summary: Now have direct evidence that prolonged residential radon is one of our eliding public health risks and a leading cause of cancer
- WHO's International Radon Initiative to provide information and action at the international level; what is the worldwide burden of the disease? Exposure guidelines, cost effectiveness, risk communication, measurement and mitigation

Health Risks Associated with Radon in drinking water
Debra Falta

- Challenges – majority of environmental causes of disease that we research today are associated with small to moderate risks, ~ 10 to 50 increase in chances of getting cancer, indoor air radon risk roughly 30%
- Environmental exposures typically small and or low dose
- Small risk not the same as small impact, simply means not a huge risk such as smoking
- Environmental exposures typically a mixture of plausible hazards
- Involuntary and ubiquitous nature of env exposures makes it difficult to quantify the exposure and determine the exact dose
- Ethics prevents from doing a clinical trial type of study
- Evidence for Risks associated with radon: solid data links radon inhalation exposure to lung cancers; Iowa studies show evidence for lung cancers associated with radon inhalation at moderate levels; no data available to show cancer resulting from exposure to radon in water

- Concern with radon is with internal exposure, getting it into body
- Moving from figuring out dose and then risk estimation
- Radon is not thought to be toxic any other way than as a carcinogen, inhaling risk and ingestion risk
- At a level of 20 pCi/L for never smokers, 36 out of 1,000 have a lifetime risk of lung cancer death per person from radon exposure in homes; at same level for current smokers, the risk is 26 out of 100
- Stomach: studies of other noble gases suggest that alphas may reach the stem cells in the stomach lining – a lot of uncertainty with risks and impacts
- Comparing radon concentrations to actual stomach cancer deaths (many known risk factors associated with stomach cancer) – finding actual stomach cancer risks associated with radon ingestion is unlikely; important to focus more on the larger lung cancer risk that may be associated with breathing radon released from household water

Exposure and Risks from Showering with Radon-Rich Water
Philip Hopke

- An experimental program of measurements in a controlled lab env as well as an actual occupied home, looked at emanation of 222Rn from the shower water, role of ventilation, behavior of the aerosol present in the home; work performed in a shower stall constructed in the lab and in a domestic bathroom in a normally occupied home
- In Lab
    - Measured fraction of radon emanating from shower water at various temps and various shower head configurations
    - Despite variations, found consistent emanation rates around 70%
- In normal house
    - At times when water had not been used for several hours, radon levels below pCi/L
    - Highest concentrations came from washing machines, radon concentrations lower for showers, but depended on length of shower
    - Depending on ventilation rates, radon levels peaked and then dropped off, also depends on turbulence in the room, shower encourages mixing, particular house did not have a central ventilation system
- Modeling Studies
    - Source term for radon is time dependent, radon enters from water droplets when shower is turned on
    - Removal of activity from air takes place from ventilation and wall deposition, a function of the size of the particles
    - Even with identical concentrations in water, can differ depending on bathroom and ventilation
- Conclusions: the concentration of radon during showering is considerably higher than the background level; however, the short shower duration and the lower dose rate per unit radon concentration during showering make the showering dose only 10-15% of the incremental background dose; at the same time, showering is only

one of the dynamic components and the total dynamic contribution could be significant – use vent fan!!

- Modeling found increasing ventilation rate useful, but reducing duration of the shower best over mitigation scheme
- Questions regarding including public wells versus private wells in data

The Comparative Effectiveness of Health Risk Reduction by Alternative Mitigation Methods for Radon

Douglas Crawford-Brown

- EPA and AWWA – cost and uncertainty effectiveness of limits
    - How do we figure out how to spend money to get best average reduction in risk and reduction in uncertainty in risk?
    - Radon is an aggregate risk problem, comes from air (ambient, indoor), soil, food, water (ground, surface)
    - From Safe Drinking Water Act perspective, really needed to address radon, however from the perspective of the air side problem, not a big risk
    - Radon a cumulative risk, because combined with PM and arsenic creates bigger risk
    - Guided by a Multimedia Mitigation Program: Water MCL of 300 pCi/L or Alternative MCL of 4,000 pCi/L as long as there is an indoor air mitigation that reduces health impacts to at or below 300 pCi/L health effects
    - Sets forth parameter values for ingestion of water, radon in home air,
    - Average radon in US Homes, 1.3 pCi/L in air, 130 pCi/L in water
    - Lifetime excess probability of risk, includes inhalation and ingestion
    - Various mitigation methods for Home Air, including natural ventilation, heat recovery ventilation
    - Mitigation for private wells, including aeration and granular activated carbon
    - Point of use at tap, granular activated acron
    - Home water for public supplies, granular activated carbon and aeration, only supplies above the MCL or AMCL would be mitigated
- Risk mitigation needs to be in at least a context of aggregate risk if not cumulative risk, which is allowed under the Multimedia Mitigation Program, but is constrained by the Safe Drinking Water Act
- Risk mitigation for indoor air characterized by a 10 fold lower cost per cancer case avoided than water mitigation
- Risk is 9 times higher for smokers than non-smokers
- For water, mitigation of public supplies is most cost effective
- For individual homes, point of use devices are most cost effective but offer lower reduction in risk
- Questions: Costs do not include disposal costs, because unclear what costs will be, though will not be insignificant; cost of point of use is lower, but don't get devices for shower heads

Session 3: Policy Implications

EPA's National Risk Reduction Strategy for Radon in Residential Indoor Air: Inhalation versus Ingestion Risk – US EPA Indoor Radon Policy, Two Decades of Experience
Phil Jalbert

- EPA's Indoor Radon Program – Voluntary and National, 4 pCi/L action level; Partnerships with Federal Agencies, states and counties, ngo's and industry; outreach and education programs
- General population's risk for lung cancer from radon is 23 in a 1,000, in 2003 about 21,000 radon related lung cancer deaths annually
- Scope of radon risk in homes: 60,000 new homes built each year with high levels, above 4, same number as homes which are mitigated each year
- Risk reduction endpoints, with new homes, code adoption by states, counties and localities, and RRNC (voluntary) adoption by builders
- Goals for 2012, have 3.9M homes with reduced risk (8.4 M homes have greater than 4 pCi/L)
    - 1.5 M with operating mitigation system, and 2.4 M built radon-resistant (RRNC)
- US New Homes built from 1990 thru 2004 build with RRNC shows an unexplained sawtooth pattern, some years more than others
- Lives saved and lung cancer deaths prevented
- Principal public policy guidance – www.epa.gov/radon, citizen's guide to radon, home buyer's and seller's guide to radon, EPA map of radon zones, several other documents
- Major outreach tools to real estate, consumers, builders, schools, public service announcements
- Public service announcement won an Emmy award in 2001, for "Man on the Street"
- Challenge remains in getting people to take action – new public service campaign looks like a US Surgeon General Warning, plays off tobacco warning
- Challenges and Opportunities: Educating professionals, thru education, health and medical, press , industry, real estate and state/local and tribal governments; getting builders and subcontractors to install radon-resistant features correctly; finite state indoor radon grant (SIRG) funding; balancing state-tribal requests for SIRG funds, because one necessarily takes away from the other
- Including radon in green/healthy building programs; measuring results at the state-tribal level; perception that concentrations below pCi/L are safe, in other words low or no risk; explaining the differences in risk between radon in air and drinking water
- Audience Q's – States adopting codes?
    - Collating info on how extensive adoption at state level has been, seems to be growing, but very slowly; for every 5,000 houses mitigated, one house is safe; 75 year exposure at 1.3 pCi/L, average household level results in x number of deaths per year

- States could provide training for builders and construction and provide more information to the builders

Radon in Drinking Water Proposed Rule: Background and Status
Becky Allen

- From drinking water estimates 168 fatal cancer cases each year
- Regulating Radon in drinking water: two regulatory options, MCL of 300 and alternative MCL of 3000
- How does a state choose to develop a multimedia program? Chooses to adopt 4,000 and MMM option, which has the potential for 5,000 to 7,000 lives saved each year; however if state chooses 300 goal, fewer lives saved each year
- MM Program requirements: public participation, quantitative goals, program strategy, measure and report results
- How did the EPA set proposed MCL for Radon?
  - Analyzed relative risk to human health at various levels and associated benefits; Adjusted from 100 to 300 using radon-specific SDWA language
- Total national benefits and costs at various radon levels, both increase as MCL level decreases
- Goals for radon rule: for states to choose the AMCL/MMM option, for states to continue and enhance existing programs
- Key issues and stakeholder concerns on proposed rule: MCL and rule structure, state resource drain – requiring tight coordination between air and water programs within state, tort liability (concern over dual MCL), equity, appearance of unequal risk reduction to consumers from AMCL and MMM
- Options that EPA can consider for the final Radon Rule? Maintain option outlined in 1999; set MCL between 300 and 4,000 pCi/L with AMCL/MMM alternative available; set MCL = 4,000 pCi/L AMCL with mandatory MMM program, which would require statutory change; set MCL at 4000 AMCL with no MMM program; other alternatives would require legislative change
- January 2009 is the date projected for final Radon in Drinking Water Rule
- Interim activities and remaining work, GAO 2002 analysis of EPA's cost estimates; GAO recs include….
- Report to Congress: Congress directed EPA to consult with State drinking water, air , and radiation programs and evaluate options to implement a single drinking water standard for radon
- EPA interprets single drinking water standard as a single MCL for all systems (no MMM)
- EPA consulted with ASDWA and CRCPD in 2003, who gave similar feedback to future rules, basically that 300 is way too low, and anticipate final report to be sent to Congress by end of 2006

Maine's Radon Well Water Advice: Risk Management and Risk Communication

Eric Frohmberg

- Discussing private wells only, because majority of Maine is poor, rural and on private wells
- Well Water Guidelines…what is safe? Typical goal in risk assessment is 1/ in 1000 cancer risk (combined inhalation, GI)
- Thought they could have better standards than what they currently had, so compared to other states, both guideline and risk assessment
- This is a risk management decision
- What they did…for the air, pushed 2 pCi/L as a clean up goal, which equates to 20,000 pCi/L in water with a 20% relative source contribution
- The ultimate goal is to get people to test and act on the results, however thus far knowledge has not led to action/mitigation
- We are doing risk communication, not focusing on behavior change, including getting people to test water and air
- Not getting info to individuals at the right time and in a format they can use or act upon – 50% of US population reads at an 8^{th} grade level, need to use readability analysis, write in plain language; focus on content, and just on what is needed to know not what is nice to know; remove jargon in a conversational tone and use active voice; use graphics effectively, lots of white space
- Think of relevance, how does the reader think of the issue? The problem with beaurocracy is everyone separated into individual groups
- How do you know if well water is safe to drink? People don't want to test water several times a year for different elements
- What do the results mean ~ generally very difficult to understand for average person – simplify lab results, get baseline data, set reasonable goals, evaluate and revise