A Survey of Public Drinking Water Systems on Wells in Colorado

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Abstract

In 1998 and 1999, the State of Colorado conducted a survey of radon in water in public drinking water systems. This survey was established in order to estimate the number (percentage) of public drinking water systems (using ground water sources) that could be expected to be out of compliance once a maximum contaminant level (MCL) for radon in water is proposed and promulgated by the United States Environmental Protection Agency (EPA). On the basis of the 613 tests successfully completed, it is estimated that approximately 70 % of Colorado's wells used in public drinking water systems would be out of compliance should a MCL of 300 pCi/L be promulgated, with an average radon concentration, in the wells tested, of approximately 1000 pCi/L, and 4% of the wells would be above an AMCL of 4000 pCi/L.

Acknowledgments

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Introduction

The Safe Drinking Water Act (SDWA), as amended in 1996, requires the EPA to propose a maximum contaminant level (MCL) and an alternative maximum contaminant level (AMCL) for radon in drinking water by August of 1999 (which has not happened at the time of this writing). Once the MCL and AMCL are promulgated, it is clear that each state will be affected by these regulations in direct proportion to the incidence of radon in the community water systems (and non-transient non-community water systems).

In anticipation of the establishment of the MCL and the AMCL, the State of Colorado decided to test as many public drinking water systems (using ground water or a mixture of ground water and surface water) as possible, for radon in the water. Then, using the results of this survey, the State will be able to project the number (percentage) of wells that will need to be mitigated once the MCL and the AMCL are made official. More importantly, the State will have information sufficiently detailed to allow them to make a considered decision on whether to accept the final MCL or to opt for the AMCL. Adopting the higher AMCL will, of course, reduce the number of wells that need to be mitigated. However, since adopting an AMCL will automatically increase the amount of time and expense that the State will have to bring to bear on a multimedia mitigation effort (MMM), there is a trade off. The efficacy of that trade off can only be decided upon when the decision makers have a realistic appraisal of the impact that the MCL and AMCL have on the number of wells that will be targeted for mitigation under the two different contaminant levels.

Definitions

A community water system (CWS) is defined as a public water system that has at least 15 service connections or that regularly serves 25 year round residences. A non-transient non-community water systems (NTNCWS) is a public water system that is not a CWS and that regularly serves at least 25 of the same persons for at least 6 months per year. Under the proposed rule, all CWS and NTNCWS relying on ground water would be required to monitor radon levels quarterly at each point of entry to the distribution system. Compliance monitoring requirements will probably be based on the arithmetic average of the four quarterly samples.

Limitations of the Survey

The present survey was designed to test each compliance point (sometimes, more than one compliance point per water system) only once. As a consequence, this survey is not able to make any predictions of radon occurrence in ground water on an annual basis nor is it able to make any predictions concerning radon variability over time.

Also, although the MCL and AMCL have not been announced at the time of the writing of this report, there is a reasonable probability that the MCL will be established at, or near, 300 pCi/L (radon in a liter of water) and an AMCL of 4000 pCi/L. The latter AMCL logically follows from the NAS report, "Report on the Risks of Radon in Drinking Water", September 1998 (NAS 1998B). The former number, 300 pCi/L, follows logically from the fact that the EPA has historically defended this number as a health based MCL. Therefore, this report will look at the impact of an MCL of 300 pCi/L and an AMCL of 4000 pCi/L, although it is not difficult to categorize the data contained within for any MCL and AMCL that may be promulgated.

Survey Details

Preliminary Work

Public water systems were contacted and testing dates arranged prior to the shipment of the water test kits. The date of sampling for each well was arranged to guarantee a return rate to the state lab that could be accommodated by the personnel and equipment available at the state lab.

1,130 tests were originally scheduled. Site specific data necessary for the logistics of the survey were collected during the spring of 1998. Such information included site location (city, county, latitude and longitude), plant operator(s) name(s) and address(es), number of wells at each site, depth of well and aquifer.

A test kit, consisting of two 50-ml VOC bottles, a Tygon tube and connector, and an instruction set, was sent to all participants by the coordinator for the entire survey (S.L. Kladder).

The number of tests originally scheduled was 1,130. However, 417 wells did not participate as requested or failed to perform the tests correctly or failed to return the tests in a timely fashion. This left the number of successful tests at 713, with the following breakdown in distribution:

Number of wells tested (primary tests).....613
Number of duplicate tests completed:........52
Number of field blanks completed:...........24
Number of spikes completed: 24
Number of tests successfully completed:...**713**

Methodology Used to Measure Radon in Water

The methodology which would be used for the sampling and reading of the water samples was tested in the spring of 1998. The methodology used by the Colorado Department of Public Health and Environment, Laboratory and Radiation Services Division requires the water to be collected directly (at the water plant) into a 50 ml VOC bottle with tapered Teflon lining inside a plastic cap. At the lab, 10-ml of water is transferred to a 22-ml clear glass liquid scintillation vial containing 10-ml of liquid scintillant. The radon in water is then read in the usual way using a 100-minute counting time. This results in a reported lower level of detection (LLD) of between 50 to 200 pCi/L, depending upon shipment times and holding times in the lab.

In order to have an independent verification that the above described sampling and transfer methodology would give repeatable results, Mr. Harrison, of the Colorado Radiation Lab and one of us (J.F. Burkhart) conducted 25 simultaneous paired samples of a well at the Woodman Water District in northern Colorado Springs. The comparison was made with another laboratory, Radon Measurements Lab (RML) at the University of Colorado-Colorado Springs, which employs a different sampling technique wherein the water at the site is slowly extracted using a 10ml syringe and then expelled directly into the liquid scintillant, by-passing the additional step of transferring the water into the scintillant at the lab. The 25 cross-comparisons showed no difference in the results for the two methods, indicating that the methodology used by the state laboratory could be verified, if necessary, and that cross-comparisons between the two labs (necessary when comparing spikes) would result in data that could be meaningfully compared.

Quality Control Measures

In addition to the 613 primary tests, 100 tests were conducted as part of the quality control (QC) program that accompanied the primary tests. These QC tests consisted of duplicate tests, which were blind to the analysis lab, field blanks (aged, bottled water as the water source), which were blind to the analysis lab and spiked water samples, which were also submitted to the lab in a blind fashion.

A representative number of wells were targeted for being the source of the duplicate tests by the survey coordinator (S.L. Kladder). The water plant operators were requested to take two separate samples simultaneously and send both back to the state lab, with a false name or false well name on the second sample so that the fact that they were duplicates would remain blind to the state lab. The compliance condition for the duplicates was set so that a relative percent difference of 10%, or less, was expected for duplicates which had an average radon value above the lab's LLD (approximately 200 pCi/L). Four of the 52 duplicates were out of compliance. It is impossible to determine the cause although it is expected that water plant operator error is the most likely explanation for those duplicates with large errors and too long of a holding time is the most likely explanation for the smaller errors. A pass rate of 48 out of the 52 duplicates was considered acceptable.

Field blanks, blind to the state lab, were provided by one of us (S.L. Kladder), drawn from a bottled water source with a demonstrated low radon concentration (below 25 pCi/L). These blanks were shipped to the water plants and, in turn, shipped to the state lab for analysis. The criteria set up for compliance of the field blanks were that the blanks were expected to be reported at, or below, the lower level of detection for the state lab. Twenty two of the 24 field blanks were in compliance. A careful review of the raw data suggested that plant operator error (in mislabeling one of the field blanks) and excessive holding time (causing a very large theoretical measurement precision error) are the most likely explanations for the two field blanks which were not in compliance

Spikes were introduced into the survey at a 3% rate. They were sent to the state lab for analysis with false site names or false well names. A duplicate spike was analyzed by RML and NAREL. (It was arranged for the water lab at the EPA National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, AL to do an independent verification of spike samples which would be taken by one of us (J.F. Burkhart) and measured by RML.)

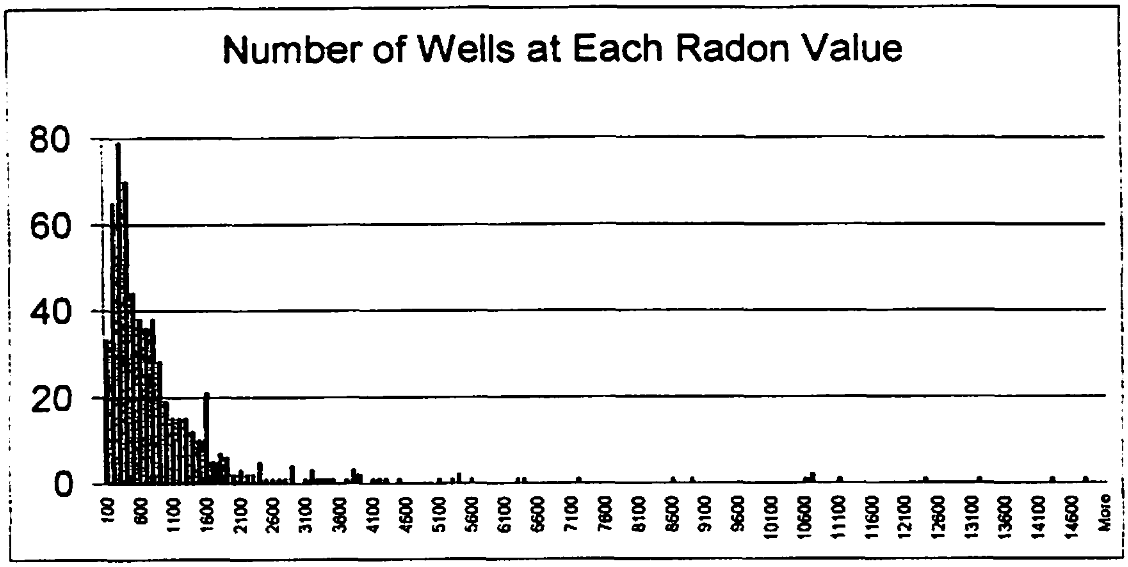
The spiked samples were drawn from various locations throughout El Paso County, CO, to assure a variety of radon concentrations. The spikes were sent to the state lab through the survey coordinator and simultaneously measured by RML and, further, sent to NAREL for an independent verification.

The compliance condition was set using the typical "acceptable" spike result with the expectation that the state lab results would be within +/- 25% of the value obtained by RML (and verified by NAREL). All of the 24 spikes were in compliance (as calculated by determining the percentage error between the state lab result and the average of the two results reported by RML and NAREL). The largest error was 14.6 %. Also, the state lab had both plus and minus error values, indicating that there was no problem with a bias that might have been caused by some (unknown) systematic error.

On the basis of these QC tests, it has been judged that the survey was reliable in that it had an acceptable level of precision, bias and accuracy. Also, as will be shown in a later section, the lognormal graph of the radon data strongly suggests that the survey included enough wells to fairly represent a reasonable sample of the true radon distribution within the State's boundaries.

Radon Results

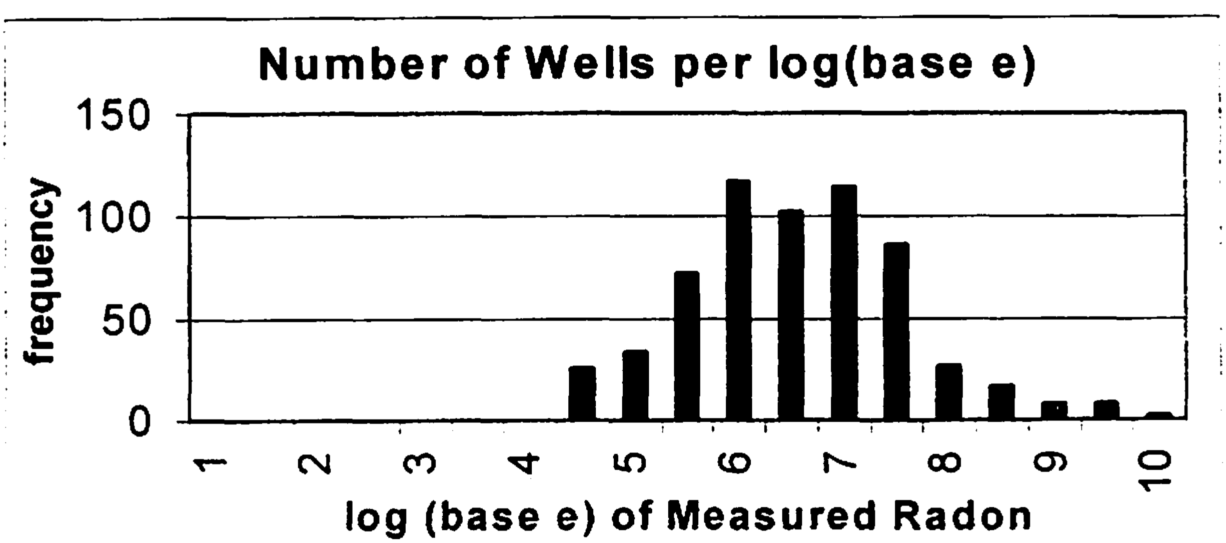
A graph of the radon results indicates a typical distribution when radon is charted for a large geographic area, with a noticeable tail to the right. This graph, which follows on the next page, has a vertical axis that represents the frequency, or number of test, with a radon value within any one class. The horizontal axis is the measured radon values, in pCi/L, with a class width of 100 pCi/L.



Measured Radon Values (in pCi/L)

The arithmetic mean is 999 pCi/L.

A plot of the log (base e) of the radon data reveals a lognormal curve, typical of radon results taken over a large geographic error, lending credence to the survey in that this curve indicates that a diversity of geographic areas were surveyed and, in sufficient number to give a representative sampling of the entire spectrum of radon results in the state. The geometric mean (the antilog of the average of the logs (base e) of the radon values) is 547 pCi/L.



It is interesting to note that these averages are above those given by the EPA in the "Health Risk Reduction and Cost Analysis for Radon in Drinking Water", 1999 (EPA-815-Z-99-002) on page 28. In this document the EPA estimates the arithmetic mean for radon in water in the Rocky Mountain region as 607 pCi/L (compared to the actual 999 pCi/L from this state survey) and the geometric mean as 361 pCi/L (compared to the actual 547 pCi/L from this state survey). This error in estimate by the EPA could result in underestimating the actual number of people at risk due to radon in drinking water in the Rocky Mountain region, although more surveys in adjoining states (averaged with the Colorado data) would be necessary to verify, or deny this concern.

Breaking down the radon results by category, the following is found:

0 to 100 pCi/L......................33 wells (5.4 %)
101 to 300 pCi/L....................144 wells (23.5 %)
301 to 400 pCi/L......................70 wells (11.4 %)
401 to 500 pCi/L......................44 wells (7.2 %)
501 to 600 pCi/L......................38 wells (6.2 %)
601 to 700 pCi/L......................35 wells (5.8 %)
701 to 800 pCi/L......................38 wells (6.2 %)
801 to 900 pCi/L...... ....28 wells (4.6 %)
901 to 1000 pCi/L...................19 wells (2.9%)
1001 to 2000 pCi/L.................108 wells (17.6 %)
2001 to 4000 pCi/L...................33 wells (5.4 %)
4001 and higher.......................22 wells (3.6 %)

Using this breakdown, one can then quickly determine the percentage of wells that would be out of compliance for any proposed MCL or AMCL

Conclusion

On the basis of 613 successful tests, it is expected that an MCL of 300 pCi/L will put approximately 70 % of the state's ground water supplies out of compliance. An AMCL of 4000 pCi/L will affect approximately 4 % of the state's ground water supplies. The 100 QC tests verify that the survey results are reliable and can be used for the type of analysis that is done in this report.