UNEXPECTED LEVELS AND MOVEMENT OF RADON IN A LARGE WAREHOUSE

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Abstract

Alpha-track detectors, used in screening for radon, identified a large warehouse with levels of radon as high as 20 pCi/l. This circumstance was unexpected because large bay doors were left open for much of the day to admit 18-wheeler trucks, and exhaust fans in the roof produced good ventilation. More detailed temporal and spatial investigations of radon and air-flow patterns were made with electret chambers, Lucas-cell flow chambers, tracer gas, smoke pencils and pressure sensing micrometers. An oval-dome shaped zone of radon (>4 pCi/L) persisted in the central region of each of four separate bays composing the warehouse. Detailed studies of air movement in the bay with the highest levels of radon showed clockwise rotation of air near the outer walls with a central dead zone. Subslab, radon-laden air ingressed the building through expansion joints between the floor slabs to produce the measured radon. The likely source of radon is air within porous, karst bedrock that underlies much of north-central Tennessee where the warehouse is situated.

Introduction

The Indoor Radon Abatement Act of 1988 mandated that all federally owned buildings be evaluated for radon. This paper reports on the findings of radon measurements made in a very large, general-purpose warehouse, located in north central Tennessee. The four bay building is well ventilated, and during the day, has large openings to the outside. As such, one anticipated that radon levels would be rather low; it turned out not be so. The building subsequently required extensive remediation [subslab depressurization] to bring the radon down to acceptable levels.

This study reports on the radon levels found, and their temporal and spatial distribution.

Some explanations are provided that are guided in part by our previous studies of houses with radon problems that are located in the southeastern states[1].

Methodology

Instrumentation

Initial screening measurements for radon were made alpha-track detectors (ATDs) made of CR-39, and using the commercial services of Landauer, Inc. Single ATDs were located at 8 measuring points (2 per bay) for 3 months. Short-term measurements were made collocated electret, S-Chamber from Rad Elec Inc. Some real-time radon measurements were made with a Pylon (Model AB-5), Lucas-cell flow chamber.

Air-circulation patterns were measured by injecting tracer gases at selected locations; movements of tracer gas were followed by measuring its concentration Miran IR spectrometer (Model A-1). Smoke pencils were used to identify locations where soil gas was ingressing through the floor. Soil-gas pressure was measured using a micrometer (Model: EDM) via tubing inserted through a 3/8 in hole drilled in the floor.

Building Description

The rectangular building is composed of four separate high bays, Bays A through D (82 m X 42 m), with a total floor space of 55,300m^2. The height is 10 m. Trucks (18 wheelers) are driven inside through bay doors (4 m X 7 m) that are usually left open during the work day in virtually all weathers. There are six doors to each bay, three each on opposite walls. The outer two bays, including Bay A, have an additional two doors in the end walls.

Exhaust fans on the roof operate continuously during the work day to provide the good ventilation rate of 2 h^{-1} by the walls.

This general warehouse was built in 1955 on floating concrete slabs. Metal pillars support the roof. The original fibrous materials in the expansion joint between the floor slabs has decayed and become filled with debris, through which soil-gas laden with radon can pass easily (Picture 1). Rows of windows beneath the roof are in leaky conditions and contribute to the natural ventilation of the building.

The building complex is located in north-central Tennessee, and area known for its geology of porous limestone [karst].

Picture 1: Expansion joints around pillars and between slabs

Results and discussion

Initial screening for radon was done with 8 ATDs (2 per bay). Placement was on the outer walls and pillars, and exposure was for 3 months from January to April, 1997. The measurements were consistently higher on the central support pillars (> 4pCi/L) than against the walls (1 to 2 pCi/L). The highest ATD measurement was 20.1 pCi/L. Confirmation of these surprisingly high radon levels was required. To this end, measurements were made for 48 hours with collocated, duplicate electret, E- perms in nearly identical positions to the ATD`s, with a similar result. These two sets of data are shown in Table 1.

Table 1. Initial screening and confirmation results

Bay Location	**Long-term (pCi/L)**	**Short-term (pCi/L)**
A Pillar 4	20.1	8.1
B Pillar 3	8.1	6.4
C Pillar 5	6.2	4.2
D Pillar 3	8.5	6.1

Bay A, which had the highest radon level of the four bays, was chosen for more detailed study; the interior layout is shown in Picture 2. Two-day measurements during October of 1999, made with collocated duplicate electrets at 24 locations, produced the results shown in Figure1. Distinctly higher levels of radon exist along the center line of pillars numbered 3 through 6. Real- time measurements were made at each of these 4 pillars during the period February-March of 2000. The data obtained for Pillar 3 are reproduced in Figure 2. The radon level varied by only a factor of two, even as the bay doors were being opened and closed during the workday, or closed for the night with the exhaust fans turned off. Some of the lower radon readings coincided with outside temperatures of 0°C or less; marked as <0 in Figure 2.

Picture 2: Pillar 4 in Bay A

0.5	1.1	1.4	0.8	0.5	0.4	0.1	1.0
2.2	2.5	4.4 (3)	20.4 (4)	17.5 (5)	8.4 (6)	2.1	2.8
0.3	0.3	0.5	0.8	0.9	1.5	1.0	0.8

Figure 1: Short-term testing results (pCi/L) for Bay A: pillars are numbers 3 through 6

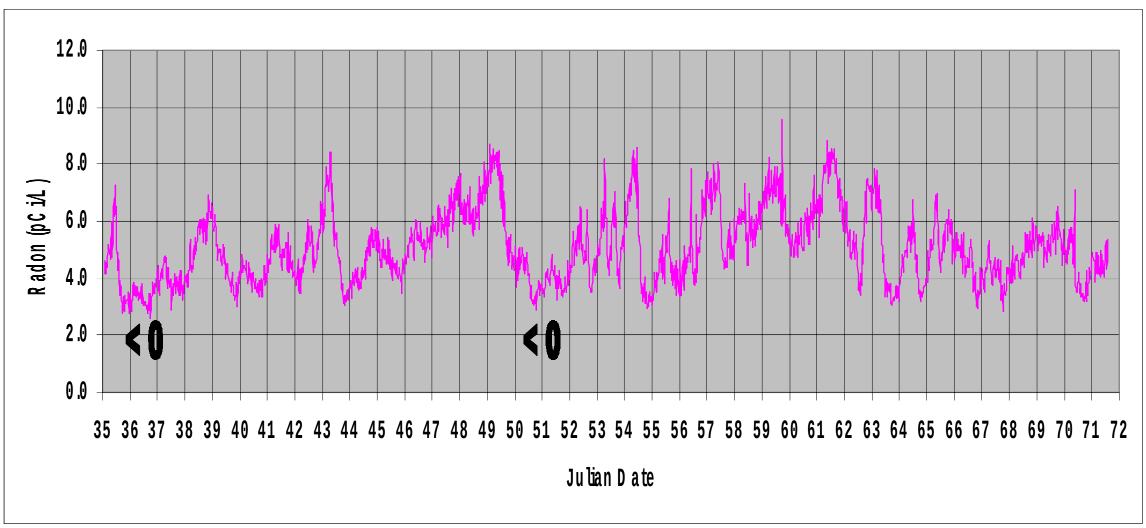
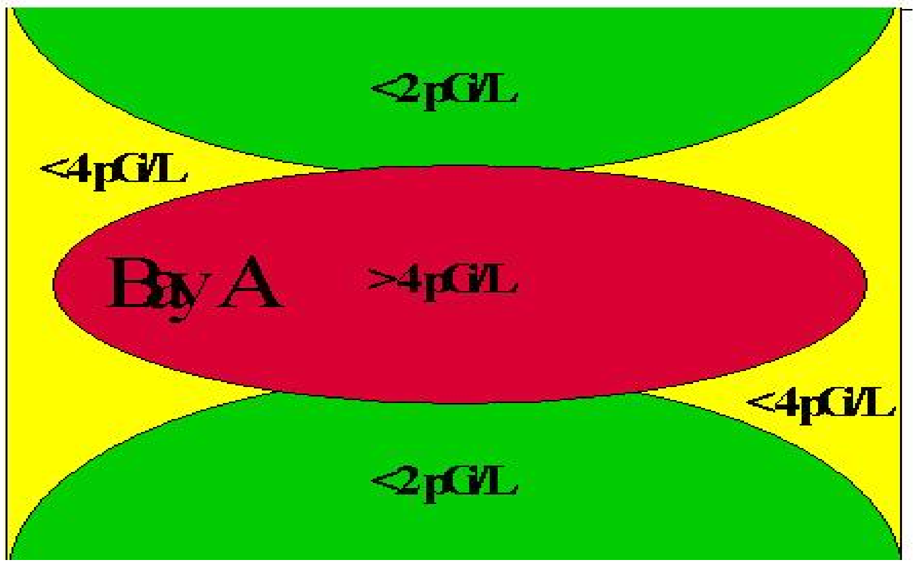


Figure 2: Real-time radon levels at the base of Pillar 3, Bay A

The final set of radon measurements were made in Bay A during the period April-June of 2000. First the floor of Bay A was divided into a grid of 50 units, each of area 250m^2. Flow-cell measurements, were made for 4 hours within each unit during the workday over a period of 40 days. The spatial distribution of radon is shown in Figure 3. It is thus firmly established that elevated radon above 4 pCi/l occurs in a centrally located, oval shaped zone. Second, the variation of radon between the floor and the roof was measured with the aid of a scissor lift, and in real-time (Pylon Lucas Cell). The radon decreased gradually upwards from the floor until it was the same as that measured by the outer walls (1-2 pCi/L). Once can thus say that the central, oval zone of radon is also domed shaped.

Figure 3. Generalized spatial distribution at floor level in Bay A



The movement of air inside Bay A was tracked by injecting the contents of a can of tracer gas into the air and monitoring the tracer gas at various positions by infrared absorption with the Miran instrument. These tracer studies in Bay A identified a slow, clockwise rotation of air close to the walls, and with a relative dead-zone in the middle. This unexpected circumstance prevails even while 4 exhaust fans in the roof are operating and some or all of the 8 bay doors are open to the outside.

Where is the radon coming from? Smoke from hand-held pencils identified upward movement of air coming up through the debris-filled expansion joints between the floor slabs and from joints between the support pillars and the floor (Picture 1). This air of subslab origin is the radon-rich source of the measured radon. The subsequently measured soil-gas pressure (micrometer) under the slab of (+) 18 Pa confirmed that air moves from underground to inside the warehouse where it lingers in an oval shaped-dome. Soil-gas measurements under the slab with Pylon Lucas Cell found on average, radon at 700 pCi/L.

The final stage of our work at this site was successful radon mitigation; it was achieved by the installation and operation of subslab depressurization units, 6 to each bay and a total of 24 systems for the whole building.

Conclusion

The study produced the counter intuitive finding that in a very large commercial building divided into 4 bays with multiple large openings to the outside, radon levels can elevate to unacceptably high levels. The radon concentrates spatially as much as 20-fold and to 20 pCi/L in the center compared to near the walls (1-2 pCi/L). Air flows in a circular pattern near the walls with a near dead zone in the middle. Radon concentrates within this near dead zone in a dome-shaped oval. This finding is surprising in light of multiple large openings to the outside and exhaust fans in the roof that operate continuously during the day to produce an air exchange rate of 2 h^{-1} near the outside walls.

The elevated radon is explained by the ingress of radon laden air from beneath the floor slabs through expansion joints between the floor slabs and where the support posts for the roof meet the floor. The local geology of north-central Tennessee includes porous limestone known as karst, which provides a nearly inexhaustible reservoir of radon-rich soil gas to buildings whose foundations abut the porous bedrock. Our previous studies of houses with radon problems in the south eastern United States have implicated radon bearing karst as a common culprit[1].

Solid-state, radiation detectors of track-etch plastic have, once again, proved their worth in the screening phase of a field study to identify buildings with problem levels of radon.

Acknowledgement

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References

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