TARGETING HIGH-RISK TOWNS FOR GROUNDWATER RADON

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ABSTRACT

Over 1300 measurements have identified high groundwater radon concentrations in areas of the Reading Prong located in SOUTHEASTERN New York State. As towns most at risk had few measurements, additional concentration data were obtained through a mail-out offer to homes with private wells. Spatial coordinates were used for correlation of concentrations to bedrock geology. Indoor radon concentrations were measured in homes with >5000 pCi/L of waterborne radon. The waterborne radon contribution could not be determined in homes with a significant soil-gas component. The systematic mitigation of a home with >100 pCi/L of indoor radon will examine the contribution from the 70,000 pCi/L in the water supply.

INTRODUCTION

Radon (^{222}Rn) is a gaseous decay product of radium, a naturally-occurring radionuclide found in all rocks and soils. Inhalation of radon decay products has been linked to an increased risk of lung cancer (National 1988) . To lessen exposure, remediation has focused primarily on reducing infiltration of radon-containing soil gas into homes from the surrounding soil. Occasionally, groundwater can be a substantial source of radon in household air. All groundwater contains radon from both dissolved radium and from recoil of radon from soil and rocks. During daily water use, such as showering, cooking, or washing dishes and clothes, radon is released from the water into the home's air. It has been estimated (Gesell and Prichard 1980; Hess et al 1982) that 10,000 pCi/L of radon in a domestic water supply is needed to contribute 1 pCi/L of radon to indoor air, though the contribution varies depending on house volume and ventilation rate. Only groundwater is of concern, as surface waters have such low radon concentrations that their use does not affect indoor levels. Though waterborne radon is often a trivial component of overall indoor radon levels, use of water in areas containing high concentrations of dissolved radon will elevate indoor levels.

From an initial survey (New York 1990) of 429 community groundwater supplies in New York State (NYS), radon levels ranged from 13 to 26,800 pCi/L. As shown in Fig. 1, over half of the counties surveyed contained average groundwater radon levels above the initial Environmental Protection Agency (EPA) proposed maximum contaminant level (MCL) of radon in drinking water of 300 pCi/L. Five southeastern counties contain the State's highest levels primarily because they are partly underlain by bedrock associated with an extension of Pennsylvania's Reading Prong, a metamorphic granite known to contain areas with high radium and radon levels in both soil gas and water supplies. Private water supplies over 110,000 pCi/L of radon have been identified in these counties. As this region poses the greatest health risk from waterborne radon in NYS, this article details a concentrated survey of water supplies in these counties.

EXPERIMENTAL

To identify specific areas containing high waterborne radon concentrations, the previously-measured public water supplies were spatially located and mapped using geographic information system (GIS) software. Well coordinates provided by the State's Bureau of Public Water Supply (BPWS) occasionally misplaced sites (e.g., in rivers, adjacent states) and required all site locations be verified. Wells were separated into unconsolidated or bedrock aquifer systems using a combination of records and digital maps from the BPWS, county health departments, well operators, and the State's Low-Radioactive Nuclear Waste Siting Commission. Bedrock wells are of most interest as they are cased throughout the unconsolidated material and therefore draw water only from the bedrock. In contrast, unconsolidated wells are surrounded by glacially-transported materials which are chemically different than the native bedrock. Additionally, unconsolidated aquifers are often shielded from underlying bedrock by layers of clay. The well concentrations were correlated with the NYS Geological Survey bedrock geology maps and rock classifications were identified for further radon measurements. In areas with insufficient measurements, but suspected to contain elevated waterborne radon concentrations, a quarter-mile sampling grid system was used. Using the State's Real Property database, the housing units were plotted using the GIS. With structure type available for each property, only single- and multiple-family residents were included in the study. The house nearest the center of each gridded square was sent an offer for a waterborne radon measurement. In the hamlet of Fort Montgomery, which contains the highest waterborne concentrations observed in the State, all 230 homes are on individual wells and were sent an offer for a waterborne radon measurement. Follow-up letters and telephone calls were used to increase participation. Lastly, homes in adjacent counties located over bedrock of similar geology as in the Fort Montgomery area were identified using the Real Property database and sent an offer for a waterborne radon measurement.

Water collection kits consisted of a funnel with attached tubing, two 25-mL vials, capped using a Teflon-lined septum, and detailed directions. The two vials provided duplicate sampling and, in cases of poor collection, a choice of the better sample (less air bubbles). Groundwater samples at each site were collected from the closest spigot to the well, usually prior to any treatment or storage, and mailed to our laboratory. In many cases the collected water samples were bubble-free.

Water samples were analyzed by liquid-scintillation (LS) counting as described elsewhere (Kitto 1994). For LS, 10 mL of water is collected from the sample bottle using a syringe and injected below high-efficiency mineral oil in a glass scintillation vial. LS samples were measured for 50 min on a Packard[1] 1900CA LS analyzer with a background of 3.7 counts per minute and a relative efficiency of 340% for radon and its four short-lived alpha- and beta-emitting progeny.

A total of 56 homes with waterborne radon concentrations exceeding 5000 pCi/L were examined for indoor radon levels under closed-house conditions. Charcoal canisters were deployed in the main bathroom, a living room on the same floor, the laundry room, and basement or crawl space of each home. After four days the canisters were mailed to the contract laboratory. A second waterborne radon sample was collected during the canister deployment to verify the initial mail-out screening results. A survey was completed on building characteristics and water use for each home. Three homes participated in mitigation demonstrations to reduce radon levels. Continuous indoor radon levels were obtained at 15 min counting intervals over several days using Pylon[2] passive radon detectors (PRD) interfaced to a laptop computer.

RESULTS AND DISCUSSION

<u>Wellwater Samples</u>

Radon concentrations measured in private water supplies ranged from 30 to 91,400 pCi/L, with arithmetic (x_a) and geometric (x_g) means of 4900 and 1900 pCi/L, respectively. A previous study (Kitto et al 1996) in these areas identified wells containing 110,000 pCi/L of radon. Whereas this study targeted high-risk areas in several counties, the random Statewide sampling in a previous study (New York 1990) resulted in a substantially lower range (13-26,800 pCi/L) and mean concentrations (x_a=2300 and x_g=600 pCi/L). Radon levels above 300 pCi/L (EPA-proposed MCL) were found in 90% and 40% of the wells measured in this study and Statewide, respectively. The geometric mean of the private water supplies is double the radon levels of the measured public water supplies.

[1] Packard Instrument Co., 2200 Warrenville Rd., Downers Grove, IL 60515
[2] Pylon Electronic Development Co. Ltd., 147 Colonnade Rd., Ottawa, Canada K2E 7L9

Wells with waterborne radon concentrations exceeding 20,000 pCi/L were examined for gross alpha, gross beta, radium, and uranium activities. Gross alpha and beta levels ranged from 1-140 and 1-100 pCi/L, respectively, in the 11 water supplies, with the high gross beta resulting from potassium (^{40}K) used in a water softener. The highest concentrations for radium and uranium of 5 and 140 pCi/L, respectively, were determined in

the private water supplies of Fort Montgomery. Concentrations of the three uranium isotopes (^{234}U, ^{235}U and ^{238}U) were in proper natural abundances and ^{228}Ra was often below the detection limit (0.7 pCi/L).

Airborne Samples

Living-area radon concentrations up to 128 pCi/L were determined at the 56 participating homes, with 25% of the homes exceeding 4 pCi/L in the first-floor living area. Bathroom radon concentrations exceeded those in the adjacent living rooms in several homes but was not significant. Concentrations in basement laundry rooms were usually equivalent to other basement measurements due to a significant soil-gas contribution.

One home with basement and first-floor radon levels of 1.1 and 0.5 pCi/L, respectively, had concentrations of 2.3 pCi/L in the first-floor laundry. The waterborne levels were 11,400 pCil/L. Results from a continuous radon detector operated in the laundry room for seven days is shown in Fig. 2. Washing machine use was documented by the homeowner and coincided with observed radon peaks.

Continuous indoor radon measurements with the PRD were conducted in a home prior to a mitigation demonstration. Initial screening measurements were 108 and 129 pCi/L in the downstairs and upstairs, respectively. A strong diurnal cycle was observed in the home as windows were opened each morning at 7^{am} (Fig. 3), though living area concentrations consistently exceeded 4 pCi/L.

Correlations With Geology

We are presently correlating indoor and groundwater radon measurements with both surficial and bedrock geologies using GIS mapping. Boundary maps of the geologies were derived by digitizing existing maps. By overlying these maps with spatial coordinates from each measurement site, geologies have been identified which contain elevated waterborne radon concentrations. To date, wells containing the highest radon levels in NYS are located within bedrock containing hornblende granite and granite gneiss. However, it was observed that this association is not always transferable to an adjacent area of the State. While all groundwater supplies cannot be tested, this correlation mapping will be used as a predictive tool of groundwater radon levels.

CONCLUSIONS

Groundwater radon measurements have identified high concentrations in counties in SOUTHEASTERN New York State. Additional measurements, obtained through a mail-out offer to homes with private wells considered likely to contain elevated radon, resulted in levels to 91,400 pCi/L. Indoor radon concentrations were measured in homes with >5000 pCi/L of waterborne radon. Spatial coordinates were used to correlate concentrations with bedrock geology. Three homes with high indoor radon concentrations were mitigated to examine the contribution from the water supplies.

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Fig. 1. County-averaged radon concentrations (pCi/L) measured in community well-water supplies in New York State (NYSDOH 1990).

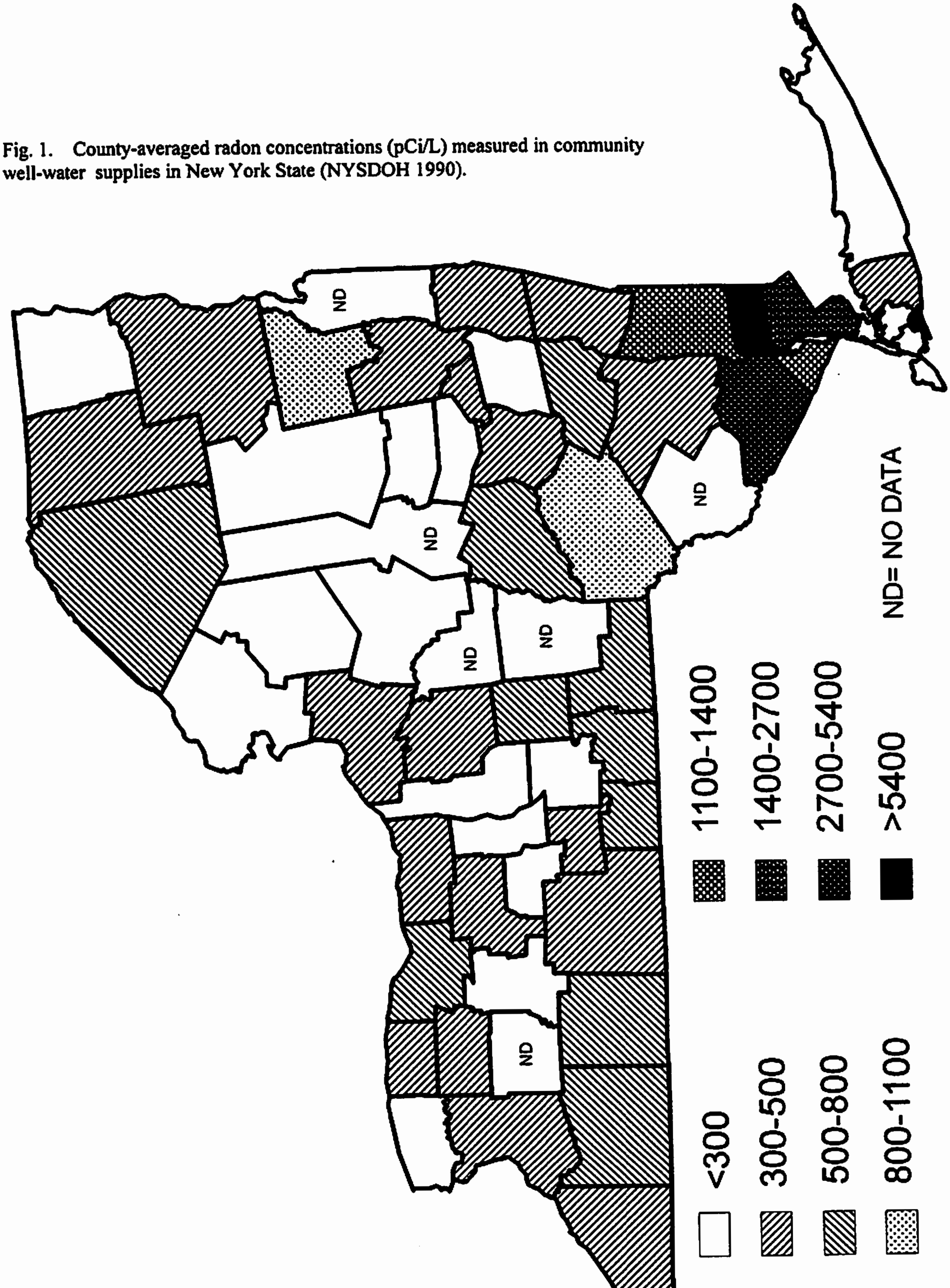

Fig. 2. Results of continuous indoor radon measurements in laundry room of a home with little soil gas contribution and 11,400 pCi/L of waterborne radon.

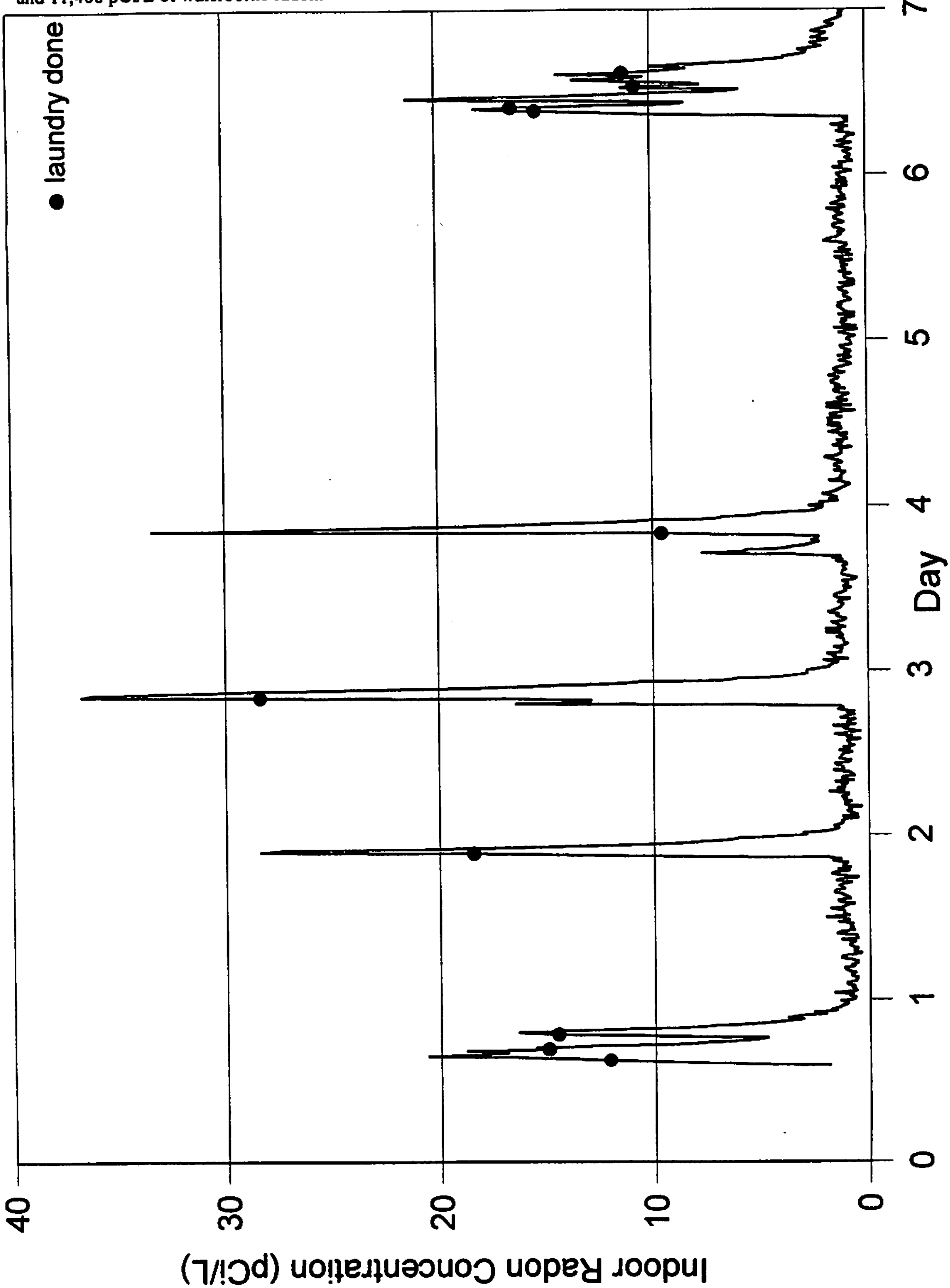

Fig. 3. Results of continous indoor radon levels in a home prior to mitigation. Vertical grids indicate 7[am] each day. Measurements were <u>not</u> made under closed-house conditions.