Proceedings of the 2003 International Radon Symposium – Volume I
American Association of Radon Scientists and Technologists, Inc.
October 5 – 8, 2003

CLASSROOM RADON MEASUREMENTS IN THE PALOS VERDES PENINSULA UNIFIED SCHOOL DISTRICT, PALOS VERDES ESTATES, CALIFORNIA

Fukumoto, Laren; Duval, Joseph S.; and Fukumoto, Joseph M.

Lauren E. Fukumoto
Palos Verdes High School, Palos Verdes Estates, CA 90274

Joseph S. Duval
U. S. Geological Survey, Reston, VA 20192

Joseph M. Fukumoto
Rancho Palos Verdes, CA 90275

Abstract

Radon concentrations in 335 classrooms were quantified using short term, activated charcoal detectors in the seventeen schools that comprise the Palos Verdes Peninsula Unified School District. During a four month period from February 15 to June 6, 2003, 10.5% of classrooms tested exceeded the U.S. EPA action level of 4.0 pCi/L. The percentage of schools having one or more rooms exceeding 4.0 pCi/L was 52.9%, and the maximum number of classrooms exceeding the EPA action level at one site was 14, found at Silver Spur Elementary School. The highest classroom radon concentration was 48.3 pCi/L found at Palos Verdes High School.

Palos Verdes High, Montemalaga Elementary, and Silver Spur Elementary were consistently found to support elevated levels in a number of classrooms. Mitigation efforts at Palos Verdes High were successful, reducing the highest district classroom concentrations to levels representative of typical outdoor air. Initial remediation attempts at Montemalaga Elementary have not yet shown reductions, but more direct strategies will be tested. Silver Spur Elementary has just recently completed a second round of measurements to ascertain elevated levels, and mitigation efforts are forthcoming.

Introduction

Predictions of average radon concentrations at the county level have been made by national radon projects [1] in an attempt to inform residences of the radon potential in their specific areas. These predictions are based on a number of factors such as airborne surveys of soil uranium levels, local geological formations, and average building type and age. Unfortunately, high indoor radon concentrations can be very localized and difficult to predict, and low county averages may be misinterpreted to imply that *all* residences in the county exhibit low values. Californians, in particular, are largely unaware of the health implications of radon exposure due to the low overall risk rating of the state [2], and the perception that high radon levels are found only in the east coast and mid west areas of the country.

A California statewide survey of residential radon concentrations by Liu, *et al.* [3], using long term alpha track detectors (ATD) in 310 randomly selected residences, resulted in 0.8% of the homes with radon concentrations exceeding the U.S. EPA recommended action level of 4 pCi/L. A larger study by Quinton [4] involving

approximately 2300 residences sampled with short term charcoal canisters predicted 2.4% of homes to exceed 4 pCi/L. When compared with short term results from other states, California ranked 32nd out of the 34 states that participated in the study for the percentage of homes exceeding 4 pCi/L [4]. More recently, a statewide elementary school survey using ATDs found that 1.1% of the classrooms exceeded 4 pCi/L [5]; however none of the schools tested were located in the Palos Verdes area.

The objective of the present work was to quantify classroom radon concentrations in the schools of the Palos Verdes Peninsula Unified School District (PVPUSD), located approximately twenty miles south of Los Angeles, California. The majority of the peninsula is geologically similar to the coastal mountains of the Santa Barbara, California area which have been shown to support elevated indoor radon levels [6]. In addition, the small number of measurements that had been taken in Palos Verdes prior to this study showed an unusually high percentage that exceeded 4 pCi/L [7]. Since the approximately 11,000 district students spend a significant fraction of their daily lives inside the classrooms, elevated radon levels can become an important health issue for students, parents, and the community in general.

Materials and Methods

Short term (48-hour) activated charcoal (AC) radon detectors (Alpha Energy Laboratories, Carrollton, TX) were placed in twenty randomly selected classrooms in each of the seventeen schools in the PVPUSD. The measurements were conducted in accordance with the document *Indoor Radon and Radon Decay Product Measurement Device Protocols*, published by the U. S. Environmental Protection Agency [8] for closed room screening measurements. However, since all measurements were executed on weekends to avoid detector tampering and provide the most consistent classroom conditions, the stipulation of a 12-hour closed room environment prior to detector placement could not be accommodated.

Detectors were typically placed in the classrooms at 3:30 p.m. on Friday afternoon following school dismissal, and retrieved on Sunday afternoon at approximately the same time. Efforts to insure the shut down of heating, ventilation, and air conditioning (HVAC) systems over the weekend were coordinated through the district office. Teachers working over the weekend inadvertently breached the closed-room conditions in a small number of classrooms under test. It is estimated that less than 5% of the classrooms were affected in this manner.

The starting time, date, location, and any pertinent classroom information were recorded for each data run. Forty-eight hours after placement, the detectors were collected and sealed inside airtight aluminum bags. The collection time and date were carefully noted, together with any additional measurement-related observations. All detectors were then air freighted to Alpha Energy Laboratories for analysis.

The screening measurements for the seventeen schools, which included several remediation attempts, took place over the course of four months from February 15 to June 6, 2003. Each school site having more than two rooms reading above the U.S. EPA action level of 4 pCi/L was measured at least twice, in order to generate more reliable measurement statistics.

Results and Discussion

Classroom Radon Measurements

The location of the seventeen PVPUSD school sites is shown in Fig. 1, together with a table of the school abbreviations used in this study. Many of the schools are located on a geologic unit identified as the Miocene Monterey Formation (the orange shaded areas on the geologic map by Dibblee [9] in Fig. 1), which has been

associated with enriched uranium deposits relative to the world shale average [10]. The Monterey Formation also comprises the coastal mountains surrounding the Santa Barbara, California area, and through aerial radiometric measurements has been implicated in generating elevated radon concentrations in the county [6].

Histograms of radon concentration categories for each of the seventeen individual schools are shown in Fig. 2 - 6, with a district-wide summary of the results shown in Fig. 7. For the current screening measurements, 10.5% of the classrooms tested exceeded the EPA action level of 4.0 pCi/L. The percentage of schools having one or more rooms exceeding 4.0 pCi/L was 52.9%, and the maximum number of classrooms exceeding the EPA action level at one site was 14, found at Silver Spur Elementary (SSE). The highest classroom radon concentration was found at Palos Verdes High (PVH) and measured 48.3 pCi/L.

Three schools sites were found to produce elevated concentrations in a number of rooms, and were the focus of repeat short-term measurements in an effort to compile more reliable statistics and identify radon entry points.

Palos Verdes High School
Palos Verdes High School (PVH) was the first site where levels exceeding 9 pCi/L were discovered. A color-coded site map of PVH, which is the composite result of three separate measurement weekends, is presented in Fig. 8. The highest reading rooms were clustered in the 203 - 210 science wing (Fig. 9), where radon was found to enter from openings around through-slab plumbing and natural gas lines. Room 314 was also found to have through-slab plumbing and gas lines, but no obvious plumbing or gas service was found in Room A.

The 203 - 210 wing produced the highest reading rooms in the district due to a seldom used, unventilated crawl space below the slab foundation (Fig. 10), where radon was allowed to freely collect. Measurements from the crawl space yielded readings of 544 and 590 pCi/L, demonstrating the substantial radon source available to these rooms. Fortunately, this type of sub-slab excavation was unique to the 203 - 210 wing at PVH, and not found at any other school site in the district.

Montemalaga Elementary School
Montemalaga Elementary (ME) was a second site that produced a number of classrooms with elevated levels. A site map is shown in Fig. 11, where the higher reading rooms appear biased towards one half of the site. Eight classrooms were found to exceed 4 pCi/L, with five of the eight exceeding 9 pCi/L. Three of the five classroom wings supported elevated levels, suggesting a more widespread radon source issue than that found at the PVH site.

The first measurements were taken on a weekend with unexpectedly low atmospheric pressure accompanied by moderate rainfall. Because unusual weather can contribute to a transient rise in indoor radon levels [11], the site was measured a second time in completely different weather conditions to increase measurement statistics. Figure 12 summarizes the second round measurements that were taken on a high atmospheric pressure weekend, with no precipitation and comparable wind speed. The radon levels were clearly reduced, with five rooms exceeding 4 pCi/L, and only one exceeding 9 pCi/L.

During this second round, additional detectors were placed at suspected radon entry points in the high reading classrooms, in order to substantiate entry pathways. Figure 13 shows results of measurements made under sinks, in storage cabinets, and near non-functioning wall heaters. Because high levels were consistently measured under sinks and near one wall heater, it was presumed that these points were adjacent to the primary radon entry paths in these rooms. In a similar fashion, under-sink measurements at PVH confirmed that openings around through-slab plumbing lines were primary entry points.

Silver Spur Elementary School

The third site that displayed elevated classroom levels was Silver Spur Elementary (SSE), where in the first round of testing, fourteen rooms were found to exceed the 4 pCi/L action level, with one of these greater than 9 pCi/L (Fig. 14). No unusual weather factors were present on the first round of measurements, but a second round was executed in order to increase measurement statistics.

The second round produced similar results (Fig. 15), and more portable classrooms were tested in an attempt to complete the entire site. The result from Room 14 was not reported due to the inadvertent operation of the HVAC system solely in this room during the test period. Although individual variation in room readings occurred in the highest reading rooms, the average of these rooms differed by less than 12% (excluding room 14 values) between the two weekend samples. Furthermore, the first portable classroom to produce elevated levels (8.9 pCi/L in Room 19) was discovered at this site.

The SSE site is unusual in that virtually all of the soil surface area between classroom wings is covered with asphalt or concrete, which could lead to radon enhancement through a permanent "capping" effect, similar to the transient effects seen with heavy rains or snowfall [11].

Preliminary Mitigation Results

The 203 - 210 wing at PVH was the target of the first district remediation efforts due to the early discovery of high levels in this section. Because the openings around drainage and gas lines had been suspected as radon entry points, an initial attempt to foam seal these crevices was carried out by district personnel. The results of measurements taken after the foaming effort ("Foam") are shown in Fig. 16, where the average of post-foam levels is seen to be substantially *higher* than the pre-foam ("Before") levels, when no sealant was in place. With the exception of Rooms 207 and 208, all post-foam levels were clearly higher. This increase may have been due to the exceptionally low atmospheric pressure and precipitation of the post-foam measurement weekend, in combination with the inability to detect and seal every possible leakage route connected to the substantial radon reservoir beneath the 203 - 210 wing.

The district radon mitigation consultant (M. Llanos, Max Llanos Construction, Poway, CA) was then contacted to design and implement a more effective mitigation system. A sub-slab pumping approach was proposed that included four perforated flex hoses placed at the bottom of the crawl space and running the length of the wing, each connected to fans that drew the radon up to the roof. A large tear-resistant polymer sheet was then positioned on top of the perforated hoses and sealed along the crawl space walls. This sheet acted as a gas barrier that isolated the soil surface of the crawl space from the classrooms. With the fans running, a negative pressure is produced in the region between the sheet and soil surface, routing the radon from the soil surface to the roof for rapid dilution.

The efficacy of the sub-slab pumping strategy can been seen in Fig. 16, where the room results in the "Pumping" row show radon levels for all rooms in the wing to be effectively zero with the fans operating normally. These levels are as low as typical outdoor levels, and represent a vast improvement in the indoor air quality of these rooms. The fans must be kept on indefinitely to maintain these low levels, and periodic classroom testing is recommended in order to insure effective operation of the mitigation system.

Initial efforts to reduce the levels at ME were conducted by re-programming the HVAC system to remain operational during a specified test weekend. The air mixture was adjusted to maximize the intake of outside air, in order to positively pressurize the classrooms and dilute the entering radon. A site summary is displayed in Figure 17, where it can be seen that the weather factors for the measurement period were typical, yet elevated levels persisted in a number of rooms.

If compared to the prior measurements at ME (Figs. 12 and 13, representing two weather extremes), this most recent data set qualitatively shows an overall intermediate level of radon that is consistent with the average weather factors for that weekend. The effect of the activated HVAC system is unclear since no extreme indoor levels were found. Since the HVAC system is thermostatically controlled, and temperature extremes did not occur during the measurements, the forced air system might not have operated for long enough periods to make a measurable difference in the radon levels. In addition, it was noted that forced airflow was not evident during placement and collection of the detectors, although the system could have activated intermittently during the 48 hr. sampling period. Continuous forced airflow operation with maximum outside air mixing may still be a viable remediation approach and will be tested this summer.

Remediation efforts are planned for the SSE site since elevated radon levels are widespread, and have been documented on two separate occasions. Similar continuous-operation HVAC strategies will be the first pursued at SSE, in an attempt to reduce classroom levels before more costly systems are considered. The results of these efforts will be reported as soon as the data is available.

Acknowledgements

The authors gratefully acknowledge the full cooperation and support of the Palos Verdes Peninsula Unified School District, with special thanks to Mr. Bruce Auld, Deputy Superintendent, Business Services, Ms. Lora Dodell, administrative secretary, and Mr. Joe Holdridge, groundskeeper and radon measurement assistant. Mr. Richard Blood, Radon Program, California Department of Health Services, provided all radon detectors and sound technical advice. Dr. Ron Churchill, California Geological Survey, provided expert technical direction, pertinent references, and valuable radon tutorials. Dr. Stuart Salot, CTL Environmental Services, reviewed strategy and positively contributed to key discussions. Finally, this effort would not have been possible without the contributions, support, and assistance of Marianne and Kathryn Fukumoto.

References

1. U.S. Environmental Protection Agency, "EPA Map of Radon Zones, California," at http://www.epa.gov/iaq/radon/zonemap/california.htm.
2. Columbia University Department of Statistics and Lawrence Berkeley National Laboratory Radon Project at http://www.stat.columbia.edu/radon/counties/06.html.
3. Liu, K.-S., Hayward, S. B., Girman, J. R., Moed, B. A., and Huang, F.-Y., "Survey of Residential Indoor and Outdoor Radon Concentrations in California," California Department of Health Services, CA/DOH/AIHL/SP-53 (1990).
4. Quinton, D., "California Statewide Radon Survey Screening Results," U. S. Environmental Protection Agency and California Department of Health Services, Sacramento, California (1993).
5. Zhou, J. Y., Liu, K. S., and Waldman, J., "Survey of Indoor Radon Concentrations in California Elementary Schools," California Department of Health Services, CA/DOH/EHLB/R-400 (1998).
6. Churchill, R., "Radon Mapping, Santa Barbara and Ventura Counties," California Geology Nov/Dec, p. 167-177 (1997).
7. California Department of Health Services, "Radon Data Base for California, October 2002," at http://www.consrv.ca.gov/cgs/minerals/hazardous_minerals/radon/DHS_Radon_Database.pdf.
8. U. S. Environmental Protection Agency, "Indoor Radon and Radon Decay Product Measurement Device Protocols," at http://www.epa.gov/iaq/radon/pubs/devprot1.html (1992).
9. Dibblee, T. W., Jr., *Geologic Map of the Palos Verdes Peninsula and Vicinity, 1999*, H. E. Ehrenspeck, P. L. Ehlig, W. L. Bartlett, eds., The Dibblee Geological Foundation, Santa Barbara, CA (1999).
10. Keller, M. A., and Evans, K. R., *Hazardous Trace Elements in Petroleum Source Rocks*, U. S. Geological Survey web site http://geology.wr.usgs.gov/wreg/env/content.html.

MAP TO BE DISTRIBUTED

Fig. 1. Location of school sites and school abbreviations used in this study. Many of the schools are located on the Monterey Formation (orange colored areas) as mapped by Dibblee [9].

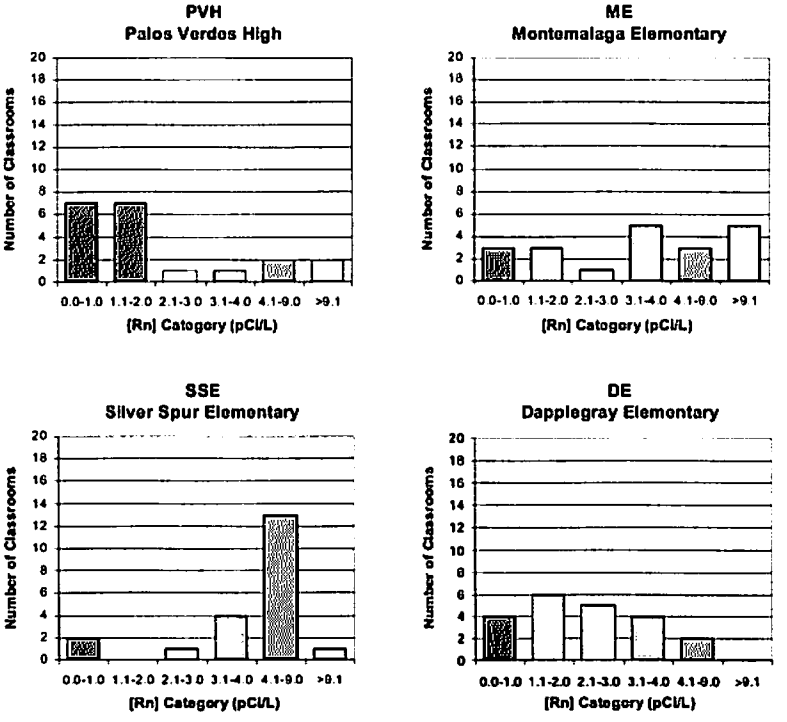

Fig. 2. Classroom radon results for Palos Verdes High, Montemalaga Elementary, Silver Spur Elementary, and Dapplegray Elementary. Data may have been taken on different weekends.

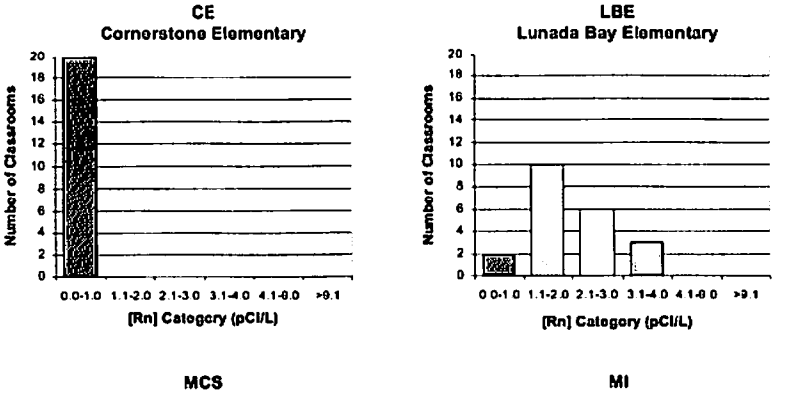

Fig. 3. Classroom radon results for Cornerstone Elementary, Lunada Bay Elementary, Malaga Cove School, and Miraleste Intermediate. Data may have been taken on different weekends.

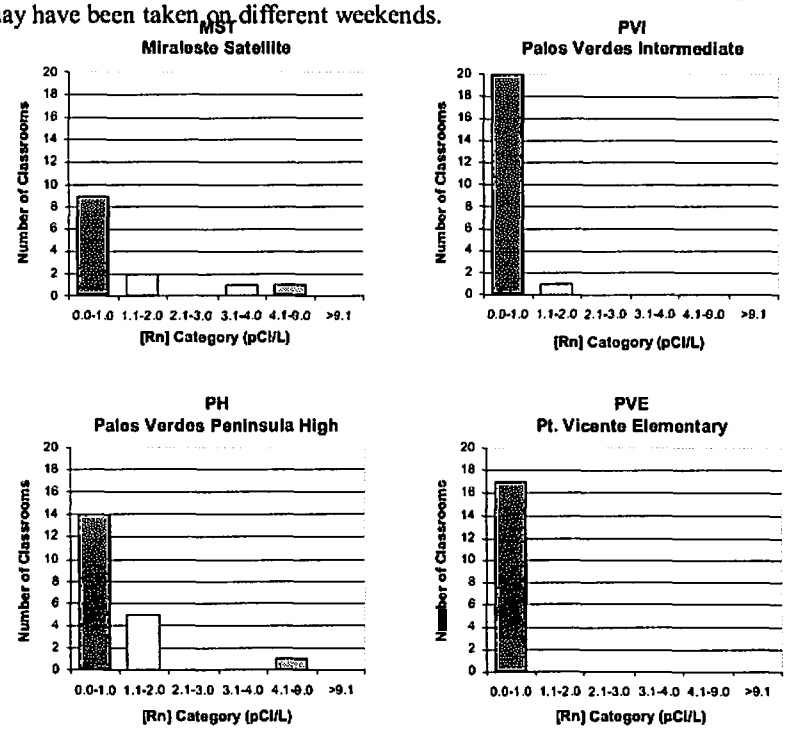

Fig. 4. Classroom radon results for Miraleste Satellite, Palos Verdes Intermediate, Palos Verdes Peninsula High, and Pt. Vicente Elementary. Data may have been taken on different weekends.

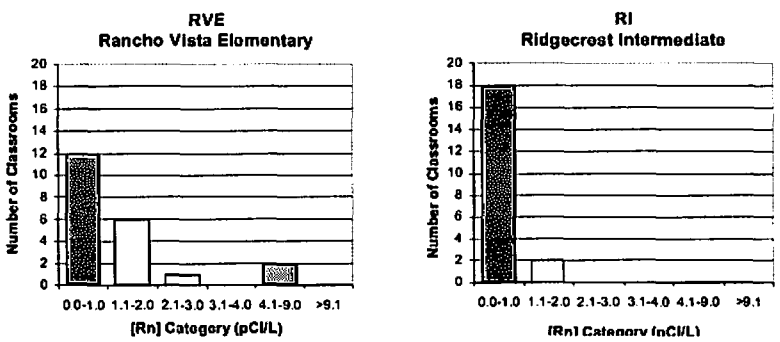

Fig. 5. Classroom radon results for Racho Vista Elementary, Ridgecrest Intermediate, Soleado Elementary, and Vista Grande Elementary. Data may have been taken on different weekends.

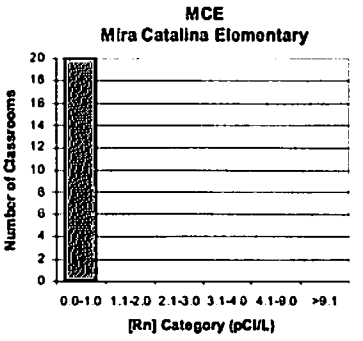

Fig. 6. Classroom radon results for Mira Catalina Elementary.

Classroom Radon Concentrations – PVPUSD Totals

Closed Room, Short-Term Activated Charcoal Detector Results
February – May 2003

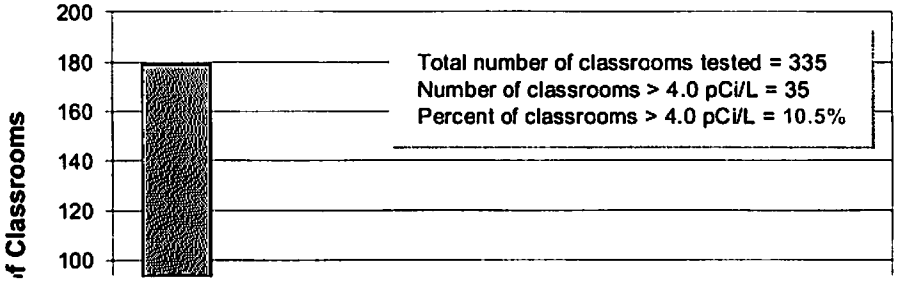

Fig. 7. PVPUSD summary of classroom radon measurements conducted during the period of 2/15 - 6/6/03. Approximately twenty classrooms per school site were tested.

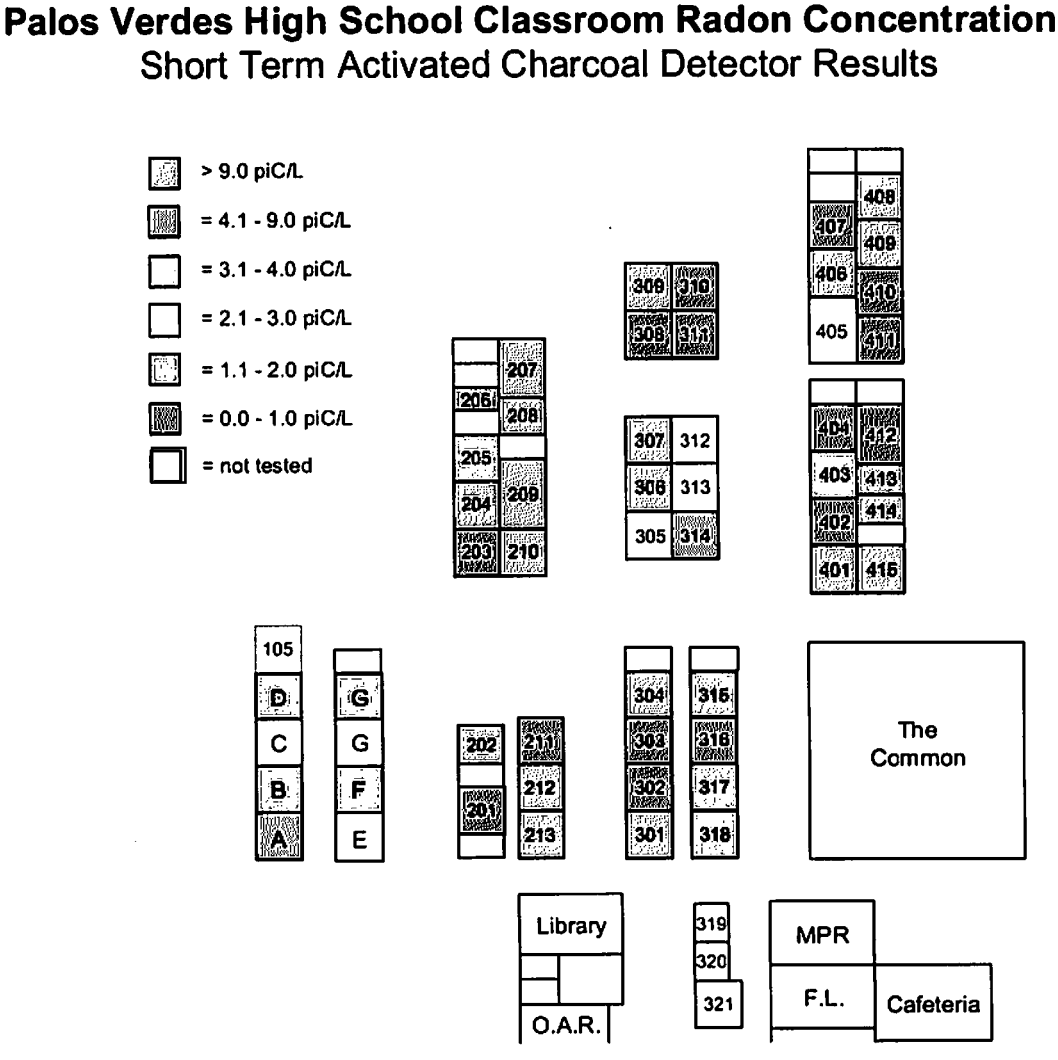

Figure 8. Palos Verdes High School short term radon detector results for the 2/15-2/17, 2/21-2/23, and 3/28-3/30/03 periods. When more than one reading was taken for a classroom, the average of the readings is displayed.

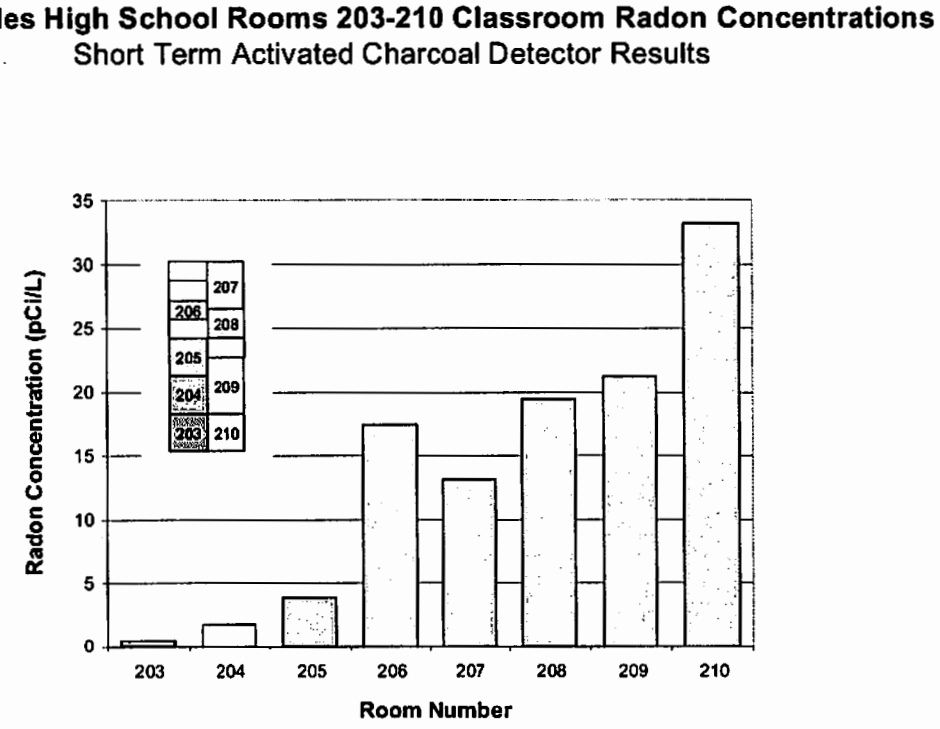

Figure 9. Palos Verdes High School rooms 203-210 short term radon detector results for the 2/21-2/23/03 period. Atmospheric pressure = 29.85 in. Hg, precipitation = 0.00 in., avg. wind speed = 6.2 mph.

Palos Verdes High School, Palos Verdes Estates, California

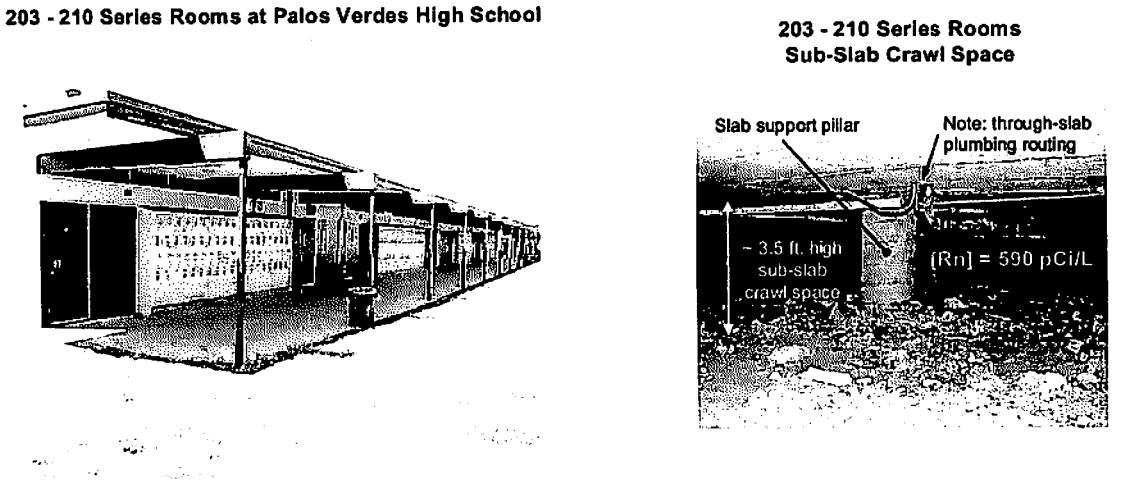

Fig. 10. Palos Verdes High School room 203 - 210 wing and sub-slab crawl space. Note through-slab plumbing and gas lines.

Montemalaga Elementary School Classroom Radon Concentrations
Short Term Activated Charcoal Detector Results 3/14 – 3/16/03

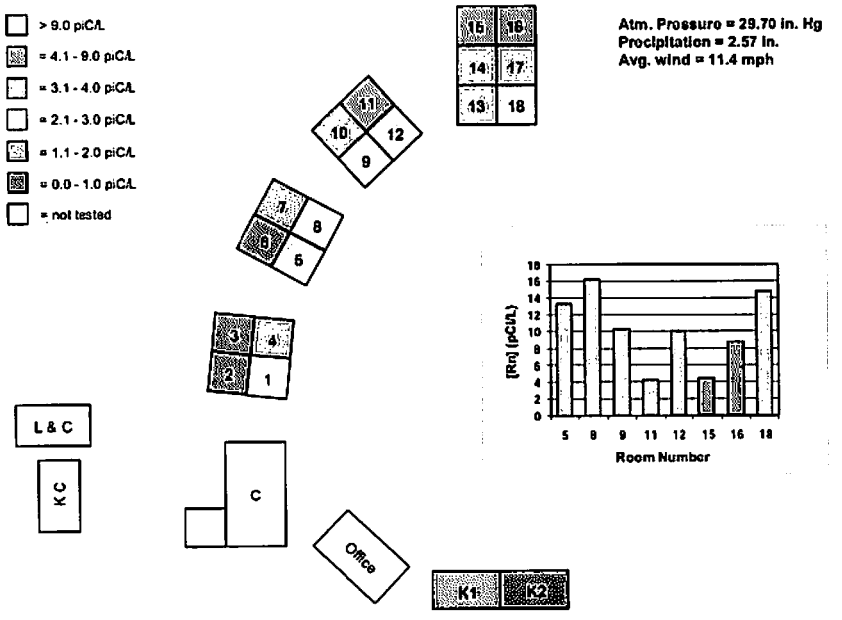

Figure 11. Montemalaga Elementary School short term radon detector results for the 3/14 – 3/16/03 period.

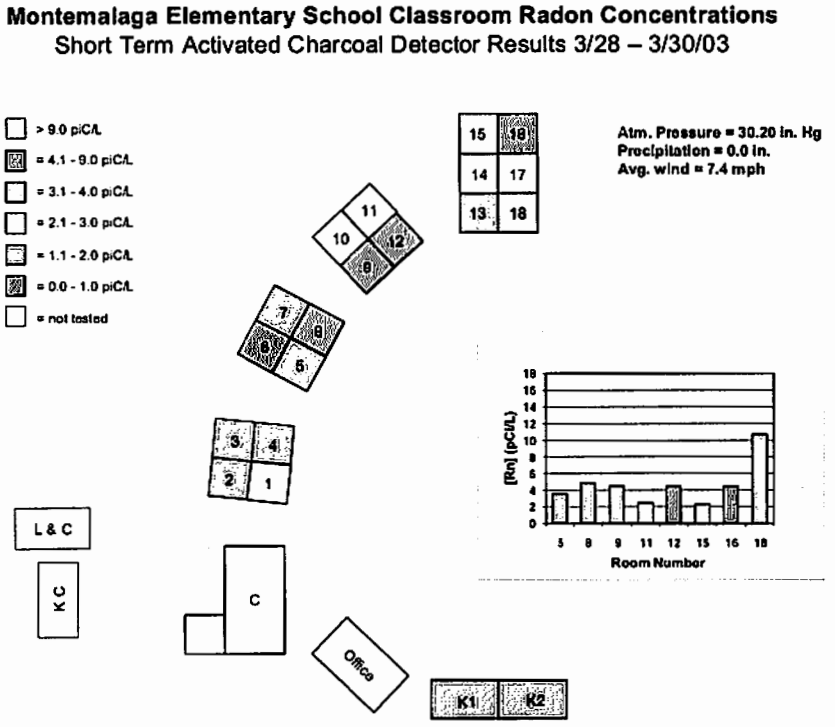

Figure 12. Montemalaga Elementary School short term radon detector results for the 3/28 – 3/30/03 period.

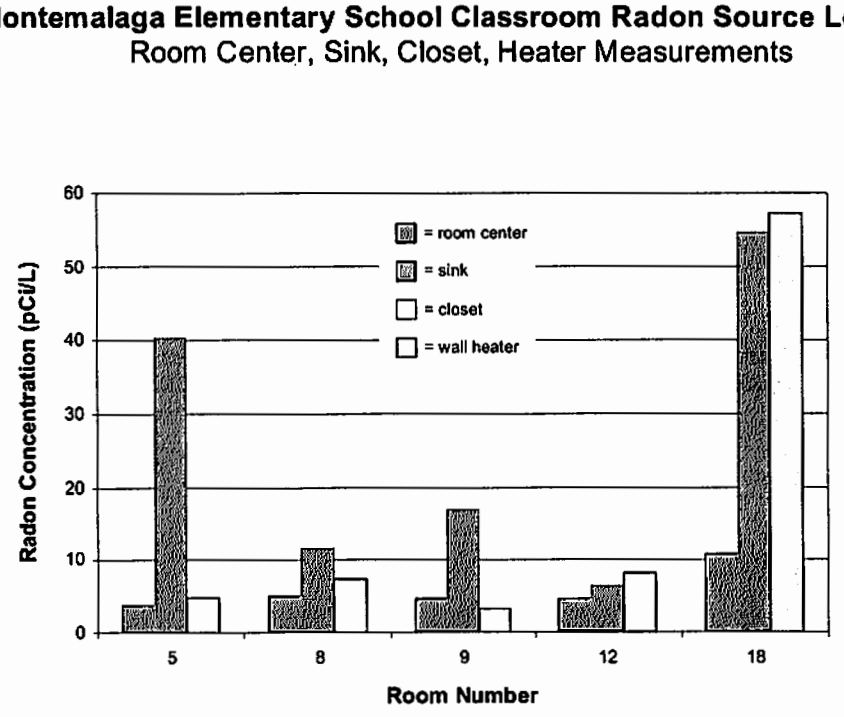

Figure 13. Montemalaga Elementary School radon source location measurements for the 3/28 – 3/30/03 period. For the five highest reading rooms, detectors were placed under the sinks, in closets, and near wall heaters when present. Sink radon concentrations always surpassed the room center values, in some cases by factors of 5-10. Radon concentrations next to the wall heater in room 18 surpassed those of the sink, and clearly contributed to the relatively high room center value.

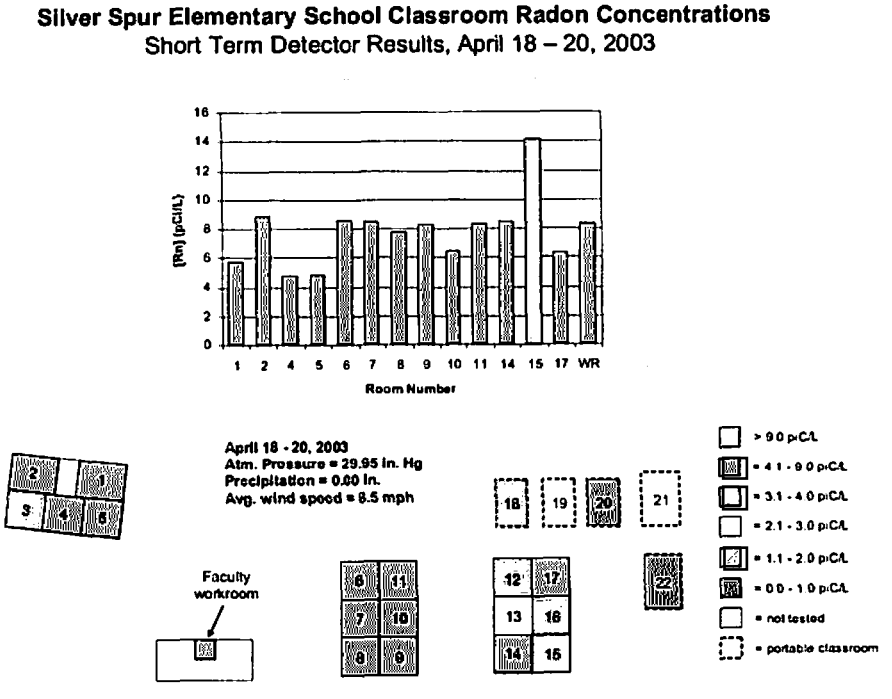

Figure 14. Silver Spur Elementary School closed room, short term radon detector results for the 4/18 – 4/20/03 period. Atmospheric pressure for the test period averaged 29.95 in. Hg.

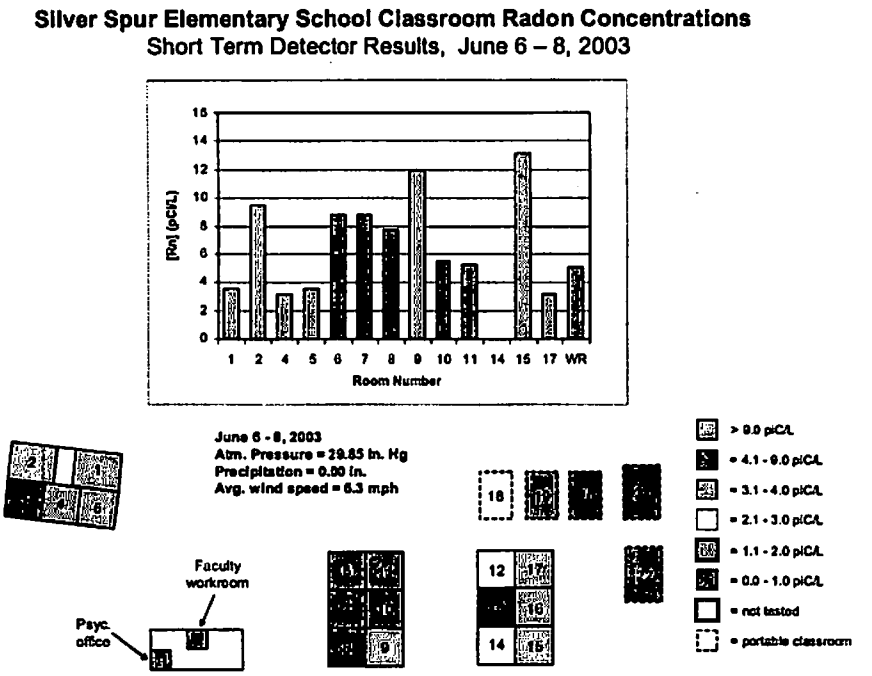

Figure 15. Silver Spur Elementary School closed room, short term radon detector results for the 6/6 – 6/8/03 period. Atmospheric pressure for the test period averaged 29.85 in. Hg.

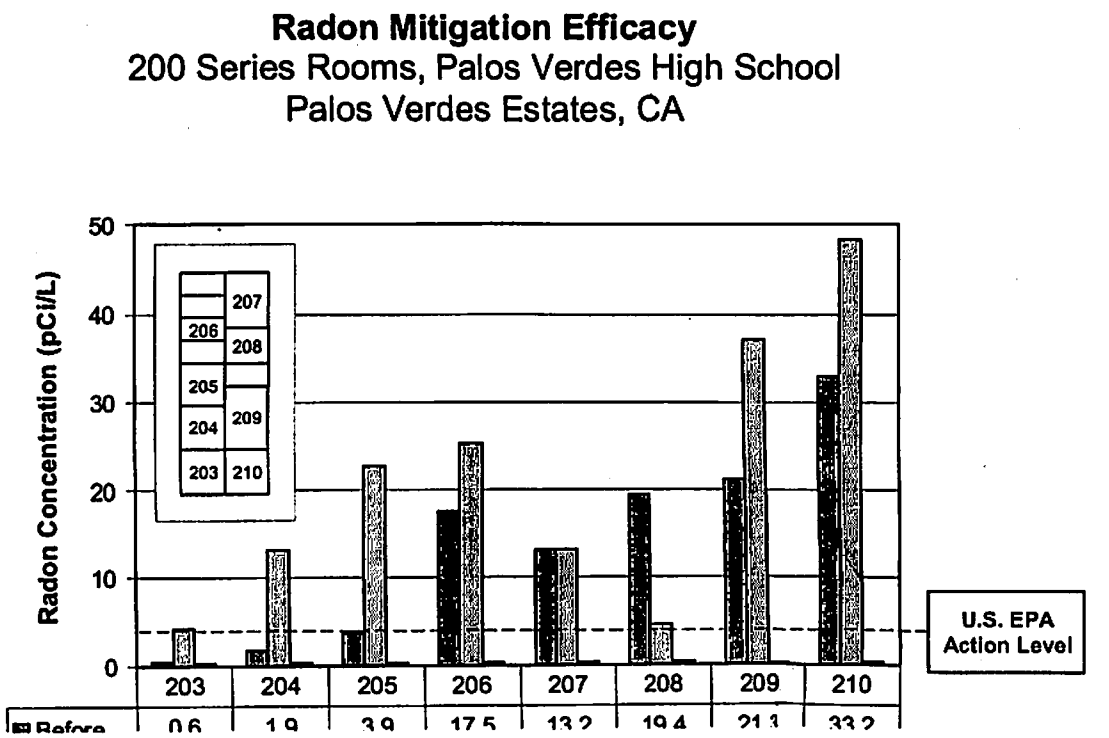

Figure 16. Results of two mitigation attempts at Palos Verdes High School. Red bars represent radon levels recorded on 2/21 - 2/23/03, prior to any mitigation actions (atmospheric pressure = 29.85 in. Hg, precipitation = 0.00 in., avg. wind speed = 6.2 mph). Pink bars represent radon levels measured on 3/14 - 3/16/03 following district foam sealing efforts (atmospheric pressure = 29.70 in. Hg, precipitation = 2.57 in., avg. wind speed = 11.4 mph). Blue bars represent levels measured following implementation of sub-slab pumping system (atmospheric pressure = 29.94 in. Hg, precipitation = 0.00 in., avg. wind speed = 7.8 mph).