INDOOR RADON IN NEW YORK STATE SCHOOLS

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ABSTRACT

New York State participated in a project to study radon in schools funded in part through a grant from the Environmental Protection Agency (EPA). Candidate schools were selected from areas in which existing information suggested there may be a high risk for indoor radon. These schools were invited to participate in an indoor radon survey that included short-term, confirmatory, long-term and post-mitigation measurements. Additionally, the soils under and around eighteen of the schools were measured for indoor radon potential through soil gas measurements and examined for correlation with indoor radon concentrations. Fifty-nine schools were surveyed during the project. Thirty-four of the schools were found to have one or more rooms with long-term radon levels exceeding EPA guidelines. Five of the thirty-four schools have successfully completed mitigation measures.

INTRODUCTION

Indoor radon measurements in single family houses throughout New York State have revealed many areas with geometric mean radon concentrations greater than 4 pCi/l. Consequently, the New York State Department of Health (NYS DOH) has become increasingly concerned with the radon-related health risk to school-age children in the areas with high radon potential. The purpose of this project was to measure indoor radon concentrations in school buildings in areas of the state known to have elevated levels of indoor radon. This allowed the department to obtain information regarding the extent and magnitude of the radon risk in New York State schools, learn more about how large buildings behave with regard to radon entry and distribution and provide instruction about testing procedures to school officials so that they would be able to conduct radon tests on their own in other school buildings in their area.

MATERIALS AND METHODS

For the past several years, DOH has studied the geologic factors affecting indoor radon throughout the state and, also, has accumulated a large database on indoor air radon concentrations in homes across the state [Rimawi 1989]. The geologic data and the extensive database of indoor radon screening measurements in homes [Laymon 1990] were used to select schools from areas with potential for above-average indoor radon concentrations. Figure 1 shows the EPA map of radon zones for New York State with the number of schools participating by county.

Cities, towns and villages containing schools were matched with the cities, towns and villages with the highest levels of indoor radon. Schools in areas with high levels of residential radon were then located on topographical and surficial geology maps to obtain information on geologic factors such as gravelly, permeable soils that often correlate with above average indoor radon [Kunz 1994,1995]. Schools located in areas with above-average indoor radon and/or areas with surficial geologic factors that correlate with above-average indoor radon were then considered as candidate schools. Generally, only one school per school district was selected so that schools were distributed throughout the state while still targeting high-risk areas.

During 1991 and 1992, candidate schools were selected in the chosen counties were sent a letter explaining the indoor radon testing program and asked to participate in the project. Those schools wishing to participate in the program were asked to fill out a questionnaire of general information about the school building and to return copies of floor plans. This information was used in the development of the detector deployment strategy for the selected school buildings. A total of fifty-nine schools agreed to participate in this project.

Table 1 lists the participating schools and gives the average basement screening level for the County, the Town, and the EPA Zone designation for each County. The fifty-nine schools that participated in the project were located in twenty-nine counties, of which twenty-five were classified as Zone 1 (High Risk) on the EPA map for New York State. Three of the counties had average home basement radon levels less than 4 pCi/l, twenty-one counties had average home levels of 4 to 10 pCi/l, and five counties had average home levels above 10 pCi/l.

Once a school building was selected, the school was notified and requested to designate an individual from the school as the primary contact. This individual took an active role in the program from initial screening tests to post mitigation testing. The purpose of selecting a primary contact was that this person would then become knowledgeable enough to carry out and supervise testing in other school buildings in the district.

When radon measurements were about to commence, boxes containing detectors, deployment instructions, data sheets and floor plans marked with room location were shipped to the school. Additional detectors for Quality Assurance measurements were also included in the shipment. The detector deployment instructions explained where to place the detectors, how to record information on the data sheets, how long to test and where to ship the detectors at the end of the test period.

Measurements were performed according to specific protocols recommended by EPA for school buildings [EPA 1989, 1993]. Short-term measurements were made with the electret type detectors[1] deployed for two to five days. Long-term measurements were made with alpha track detectors[2] that were generally deployed for six months to one year. Both detector types were deployed in all basement and first floor rooms. Alpha track detectors were also placed in a few upper floor rooms in the first year, and in all upper floor rooms in the second year of the project. In large rooms such as libraries, cafeterias and gymnasiums, one detector was deployed for every two thousand square feet of floor area as required by the measurement protocol.

Quality Assurance measurements were done throughout the course of this project. Duplicate detectors were sent to schools and deployed in about 10% of the rooms. Instructions on how to place the detectors were included in the detector deployment strategy informational sheet. The following QA criteria applied to duplicates:

1. If the average of the pair was less than 4 pCi/l, then the difference in readings should be less than 0.5 pCi/l; and

2. If the average of the pair was 4 pCi/l or more, the calculated covariance of the pair should be less than 15%.

In addition, blank detectors were mailed to schools and returned for analysis without being deployed.

Several groups of short-term and long-term control detectors were exposed to known radon concentrations in the Bowser-Morner Radon Chamber, the Department of Energy Environmental Measurements Laboratory Radon Chamber, or the EPA Radon Chamber. These control detectors were submitted for processing and evaluation to

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[1] The E-Perm® detectors were supplied by Rad Elec Inc., 5330J Spectrum Drive, Frederick, MD 21701

[2] The Rad-Track® detectors were supplied by Landauer Inc., 2 Science Road, Glenwood, IL 60425

the measurement laboratories and marked so that the laboratory could not distinguish them from detectors exposed at schools. Control detectors were required to be within 20% of the chamber value.

Any school that had routinely occupied rooms with measured radon levels above 100 pCi/l was to be visited to suggest preliminary measures, which could result in a temporary reduction in radon concentrations, pending the use of more permanent mitigation measures. This proved to be unnecessary as no routinely occupied room exceeded this level.

Officials at schools that had elevated radon levels were notified of the availability of diagnostic assistance through the New York State Energy Office (SEO) and of the Department of Health's offer to provide short and long-term post-mitigation measurements. A telephone survey was made of the 34 schools with long-term radon levels above 4 pCi/l to determine what actions they had taken, or planned to take, based upon the measurements.

RESULTS

The average short-term radon concentrations measured in each of the fifty-nine schools is given in Table 1.

Table 2 provides a summary breakdown for all 59 schools in terms of short-term and long-term measurements. The table shows the number of schools in which all rooms measured were less than 4 pCi/l, or which had one or more rooms with concentrations between 4 to 20 pCi/l, or greater than 20 pCi/l. Table 3 shows a similar breakdown in terms of the combined number of rooms.

Table 4 shows a breakdown for all rooms where both short-term and long-term measurements were available. The short-term data is categorized as below 4 pCi/l, between 4 and 10 pCi/l, or greater than 10 pCi/l. The corresponding long-term result is categorized as less than 4 pCi/l or equal to or greater than 4 pCi/l. In each case the percentage for the long-term category is also shown. The matched data set of Table 4 was also examined using Regression Analysis and a correlation coefficient of 0.83 was calculated.

Soil characterization measurements were made for eighteen of the fifty-nine schools. The results of these measurements are reported separately [Kunz 1994, 1995].

The telephone survey of the 34 schools with elevated radon levels found that only 17 of them had taken advantage of the SEO offer to provide diagnostic assistance in assessing their radon levels and suggesting potential mitigation measures. The other 17 schools performed some type of internal evaluation to develop their course of action. Five of the thirty-four schools have successfully completed mitigation measures (Fig. 2).

DISCUSSION

School staffs deployed and retrieved detectors. This procedure worked well, particularly if the staff were interested in detecting the radon levels in their school. Duplicates were generally deployed as instructed and blanks were returned with the exposed detectors.

As indicated in Table 2, sixteen schools had all of their rooms below 4 pCi/l for short-term results, with forty-three schools having one or more rooms in the 4 to 20 pCi/l range and twelve schools having at least one room above 20 pCi/l. Long-term results showed that twenty-five schools had all rooms below 4 pCi/l, thirty-four schools had rooms in the 4 to 20 pCi/l range, with eleven schools having one or more rooms above 20 pCi/l.

Table 3 (short-term results) shows that about 77% of the rooms were less than 4 pCi/l, while 22% were between 4 and 20 pCi/l, and about 1% of the rooms were above 20 pCi/l. The long-term data shows that about 84.5% of rooms were below 4 pCi/l, with 14.5% between 4 and 20 pCi/l, and about 0.7% above 20 pCi/l.

Table 4 presents a subset of the data from Table 3 in which both short and long-term detector results were available in each room. Not all rooms had both short-term and long-term measurements due to loss of some detectors or failure to deploy detectors in every room. Short-term results are divided into three radon ranges, below 4 pCi/l, from 4 to 10 pCi/l, and greater than 10 pCi/l. The corresponding long-term result is shown as below 4 pCi/l or greater than or equal to 4 pCi/l. This provides a sense of how well short-term screening results predict long-term results for a particular room.

When short-term results are below 4 pCi/l, the long-term result is also below 4 pCi/l about 99% of the time. At the other end of the scale, if short-term results were above 10 pCi/l, then the long-term result was above 4 pCi/l about 95% of the time. In the middle range of 4 to 10 pCi/l, results are almost evenly split in terms of long-term data with 54% of rooms below 4 pCi/l and 46% of rooms at or above 4 pCi/l. This table suggests the need to carefully evaluate rooms where short-term results are in the 4 to 10 pCi/l range. It also shows that when short-term results are below 4 pCi/l there is only a small chance that the long-term result will be above 4 pCi/l, and conversely, when the short-term result is above 10 pCi/l there is only a small chance that the long-term result is less than 4 pCi/l.

Figure 3 shows a plot of the data for rooms with both short and long-term measurement results. The relationship between short and long-term measurements was calculated by Regression Analysis to be: $Y=0.65X + 0.3$, where Y is the long-term measurement value and X is the short-term value. The regression analysis suggests that, on the average, the long-term measured value was equal to 65% of the short-term value. Figure 3 suggests that such a relationship cannot be used to estimate the long-term radon concentration for any individual room from a short-term measurement due to the wide distribution of points around the regression line.

While no definite conclusion can be drawn about the radon levels in rooms with missing long-term measurements, if the short-term results are available for these rooms, and are below 4 pCi/l, it is unlikely that such rooms would have long-term radon levels above 4 pCi/l, based on the results shown in Table 4. For rooms with short-term results at or above 4 pCi/l, additional measurements should be made to determine if remedial actions should be taken to reduce radon levels in the school.

All QA categories except duplicates were above the 90% requirement. The short-term duplicates failed to meet QA requirements in the second year of measurements. As a result, it was decided to use charcoal canisters for short-term measurements in the later years of the School Measurement Program. Difficulties with QA results for short-term measurements using electrets may suggest that the units were sensitive to handling. The units were shipped to the schools where school staff deployed them, retrieved them, and then shipped them back to DOH for analysis. Handling and shipping processes may have led to excessive discharge of some electrets, leading to problems with duplicates. When DOH staff deployed and retrieved electret detectors directly, there were fewer QA problems. The long-term alpha track detectors met the QA requirements.

As indicated in Figure 2, a total of 27 schools attempted to reduce elevated radon levels by adjustment of their heating and ventilation systems (HVAC). Most schools had made modifications to these systems over the years in order to reduce energy costs. The SEO diagnostic visits showed that in many cases the systems were not working properly, and that the amount of fresh air was considerably below that normally recommended for large buildings. It was thus suggested that HVAC systems be properly adjusted prior to any mitigation work. This was also recommended in the information packet DOH mailed to all schools with elevated radon levels.

Only two schools were completely successful in reducing radon levels by adjustment of their HVAC systems. Fourteen other schools are continuing their work in this area. Eleven of the schools which were unable to reduce radon levels below 4 pCi/l in all areas have installed, or are considering sub-slab mitigation systems. Three of these schools reported complete success with their sub-slab mitigation systems, but two other schools were unable to reduce all rooms to less than 4 pCi/l.

Four schools are still considering their options for reducing radon levels, while two schools have designated their rooms with elevated radon levels as storage rooms with limited access and use. Only one school had decided to take no action with respect to their measurement results.

As reported elsewhere, soil characterization data suggests that highly permeable soils correlate to above average indoor radon concentrations and that radon risk maps based on indoor residential measurements and surficial geology can be used to target areas of potentially elevated radon levels in schools [Kunz 1994, 1995].

CONCLUSIONS

Schools in high radon risk areas are likely to have rooms that require mitigation. More than half of the schools had at least one room with radon levels that exceed the EPA guideline for remedial action. Measured schools tended to have lower average radon levels than homes in the same areas. Results show that approximately 15% of all the rooms tested had long-term radon levels greater than or equal to 4 pCi/l.

The measurements made in this project are not sufficient to provide information on radon entry routes into school buildings. Measurements suggest that many buildings have multiple radon entry points. Thus, measurements should be made in each room in which the radon level needs to be known.

Detector distribution by mail has been effective. Informational materials provided to school officials seemed to provide the appropriate amount of instruction. Although many schools have not conducted testing on their own, school staff participation in deployment and retrieval of detectors, record keeping, quality assurance, and interpreting results provided them with the fundamentals of conducting radon measurements and will help them in the future when they will conduct such measurements. Most of the schools where rooms were identified as having radon concentrations exceeding the EPA action level have taken some actions to reduce the radon levels.

Based on the results of this project, the following recommendations are made:

1) Long-term (alpha track) testing is the most reliable method for measuring long-term average radon levels in schools, and should be used in deciding the need for mitigation.

2) Short-term detectors are useful in identifying areas within a school with elevated radon levels, but may not accurately estimate the long-term average radon level, particularly when short-term results are in the 4 to 10 pCi/l range.

3) Efforts should be made to reduce detector loss when deploying long-term detectors. This may include placing detectors in hidden places (e.g., under the teacher's desk), or involving the students in the measurement project, to reduce the chances of accidental removal or tampering. This is much less of a problem with short-term detectors due to their limited deployment time.

4) Quality control tests should be done throughout the period of measurements. Analysis and evaluation of these tests should be made on an ongoing basis to investigate deviations from quality control goals and to take timely corrective action.

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Table 1
Radon Summary Data

COUNTY	SCHOOL	Average Radon Values pCi/l (a) SCHOOL	TOWN	COUNTY	ZONE
ALBANY	VOORHEESVILLE	5.1	15.4	4.0	1
ALLEGANY	ANDOVER CENTRAL	1.4	12.1	11.3	1
BROOME	CHARLOTTE KENYON	4.5	4.7	5.7	1
	F. P. DONNELLY	13.0	14.5	5.7	1
CHEMUNG	COHEN ELEM.	2.2	11.1	13.0	1
CHENANGO	EARLVILLE ELEM.	2.9	9.0	9.3	1
	GREENE ELEM.	4.4	11.7	9.3	1
	NEW BERLIN JR/SR	6.9	8.3	9.3	1
	S. NEW BERLIN CENTRA	1.0	2.1	9.3	1
	SHERBURNE ELEM.	8.5	17.4	9.3	1
COLUMBIA	GERMANTOWN CENTR	1.4	4.4	7.1	1
	MARTIN GLYNN	2.3	9.1	7.5	1
	MARTIN VAN BUREN	0.9	5.7	7.1	1
CORTLAND	RANDALL ELEM.	5.6	15.1	14.8	1
DELAWARE	FRANKLIN-DELAWARE	1.9	12.1	7.4	1
DUTCHESS	DOVER ELEM.	3.6	9.3	6.6	1
	HAVILAND JR HS	1.4	6.4	6.7	1
	RED HOOK HIGH	2.2	6.1	6.6	1
GENESEE	ALEXANDER ELEM.	0.2	4.9	6.9	1
	BYRON-BERGEN ELEM.	1.7	12.8	6.9	1
LEWIS	PORT LEYDEN ELEM.	1.1	8.8	4.4	2
LIVINGSTON	CALEDONIA-MUMFORD	1.6	26.0	8.0	1
	CALEDONIA-MUMFORD	3.7	18.3	8.0	1
MADISON	GREEN STREET SCHOO	0.8	4.3	5.7	1
MONROE	MONICA LEARY ELEM.	0.6	3.0	3.4	1
ONONDAGA	ENDERS RD ELEM.	1.5	17.1	8.3	1
	MEACHEM ELEM.	2.3	6.5	8.3	1
	WELLWOOD MIDDLE	1.4	11.5	8.3	1
ONTARIO	CLIFTON SPRINGS ELE	2.6	6.9	5.8	1
	DESAL.LES HS	0.9	3.0	5.8	2
	NAPLES ELEM.	1.5	14.6	5.8	1
OTSEGO	EDMESTON CENTRAL	1.6	17.2	8.2	1
RENSSELAER	BELL TOP ELEM.	3.3	6.2	6.8	1
	GREEN MEADOW	3.4	9.0	6.8	1
SCHOHARIE	MIDDLEBURGH JR/SR	1.0	8.9	5.4	1
	RICHMONDVILLE CENT	1.0	3.8	5.4	1
SENECA	SOUTH SENECA ELEM.	0.7	2.7	2.6	1
STEUBEN	CAMPBELL-SAVONA EL	3.4	18.0	11.9	1
	CANISTEO ELEM.	4.3	9.7	11.9	1
	DANA LYON ELEM.	6.5	16.4	11.9	1
	HAVERLING JR/SR HS	1.8	16.4	11.9	1
	VALLEY ELEM.	21.1	25.9	11.9	1
	WAYLAND CENTRAL	3.8	25.2	11.9	2
TIOGA	CANDOR ELEM.	8.7	17.3	9.2	1
	CANDOR JR/SR	5.6	20.6	9.2	1
	NATHAN T HALL	6.2	14.9	9.2	1
	NEWARK VALLEY HS	6.6	16.4	9.2	1
	NICHOLS ELEM.	3.3	16.2	9.2	1
TOMPKINS	CAROLINE ELEM.	1.6	4.5	4.6	1
	DARWIN SMITH ELEM.	1.0	4.5	4.6	1
	NEWFIELD ELEM.	0.6	5.4	4.6	1
	TRUMANSBURG ELEM.	1.6	3.7	4.6	1
ULSTER	MARLBORO MIDDLE	3.1	5.4	4.5	1
WASHINGTON	ARGYLE CENTRAL	1.2	8.0	4.8	1
	GREENWICH HS	1.4	6.7	4.8	1
WAYNE	PALMYRA ELEM.	1.4	12.0	4.3	2
WESTCHESTE	NY SCHOOL FOR THE D	0.7	2.1	2.8	3
WYOMING	WYOMING CENTRAL	5.8	12.7	10.1	1
YATES	DUNDEE CENTRAL	3.4	11.9	6.3	1

(a) Short-term data based on DOH measurements

Table 2
School Data by Radon Level

MEASUREMENT	SCHOOLS ALL<4	4 TO 20	>20
SHORT-TERM	16	43	12
LONG-TERM	25	34	11

Table 3
Room Data By Radon Level

MEASUREMENT	ROOMS <4	4 TO 20	>20
SHORT-TERM	2173	623	28
PERCENT	76.95	22.06	0.99
LONG-TERM	2424	415	20
PERCENT	84.78	14.52	0.70

Table 4
Short-Term vs Long-Term Data

SHORT TERM pCi/l	LONG-TERM pCi/l -> <4	>=4
<4	1655	22
PERCENT	98.69	1.31
4 TO 10	193	163
PERCENT	54.21	45.79
>10	7	122
PERCENT	5.43	94.57

Fig. 1

NEW YORK - EPA Map of Radon Zones

SHOWING NUMBER OF SCHOOLS PARTICIPATING BY COUNTY

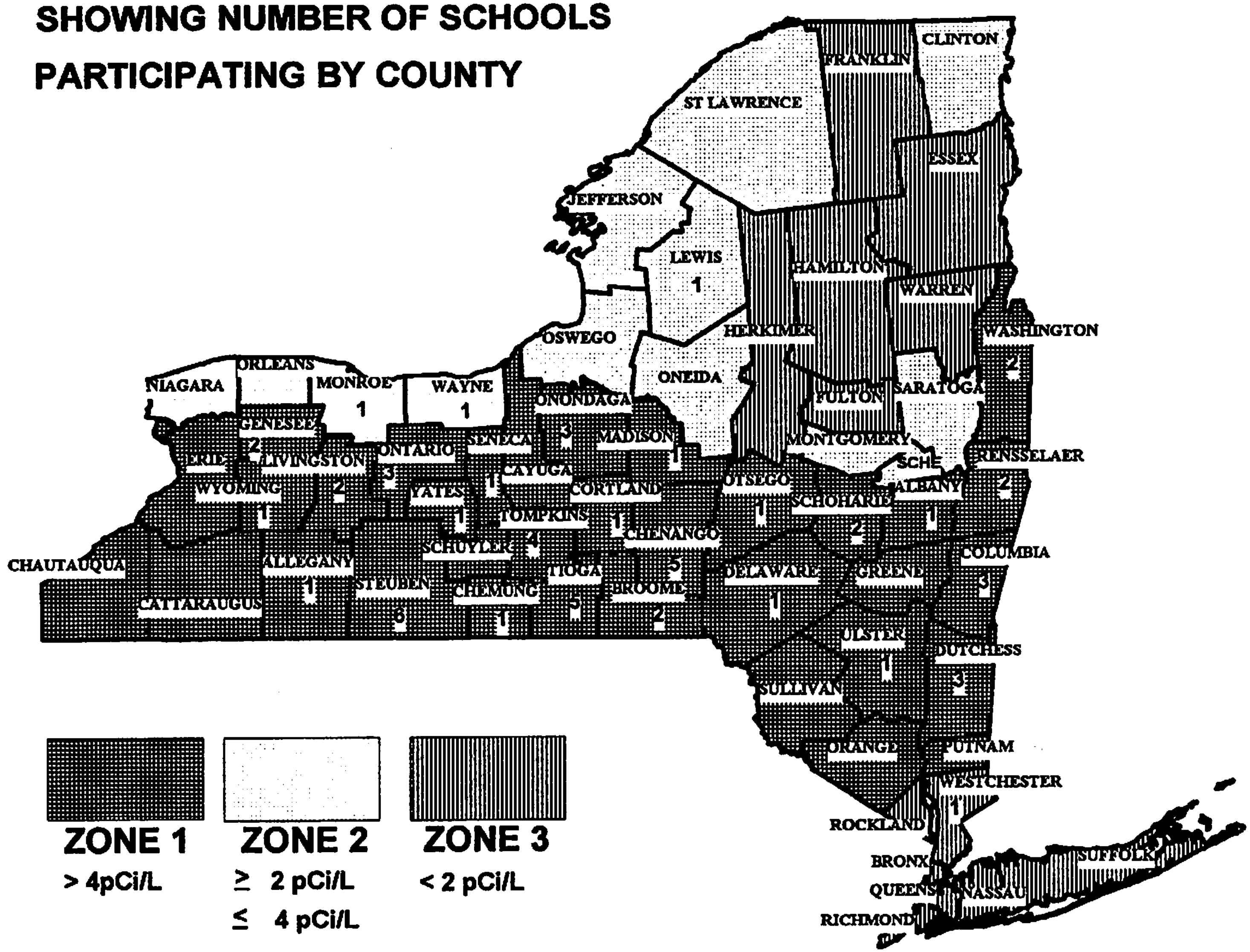


Fig. 2

Results of School Survey

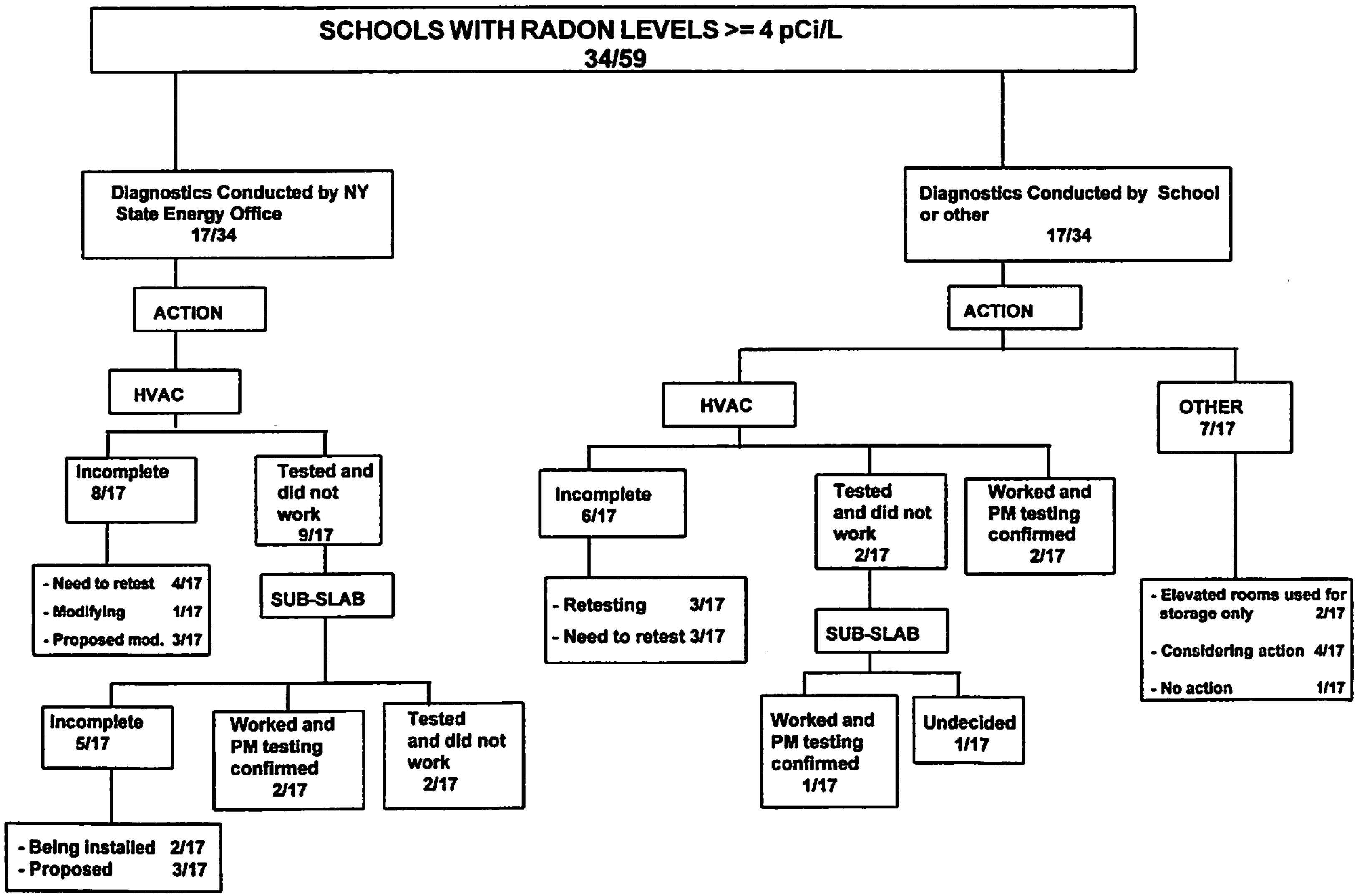
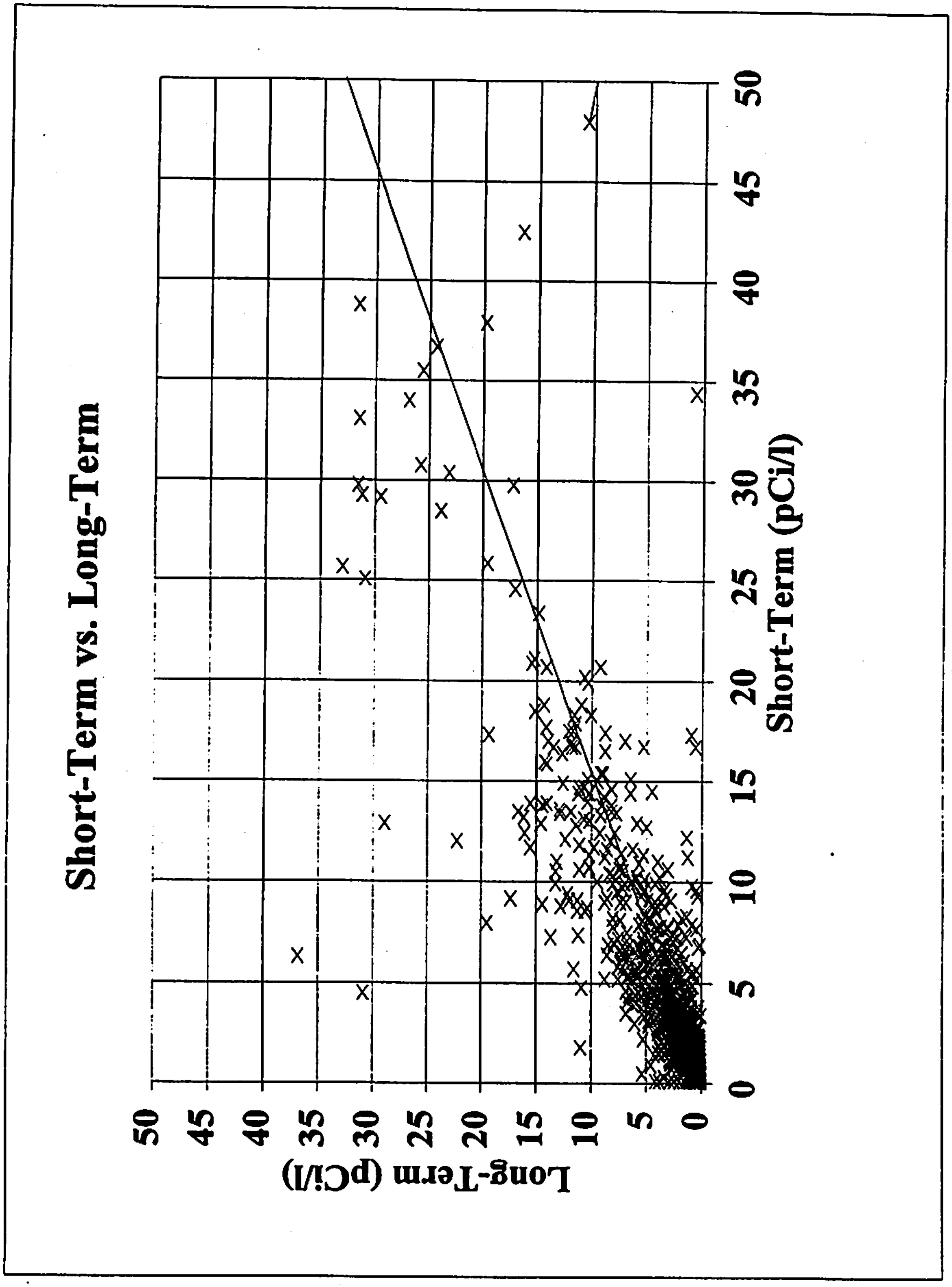


Fig. 3



Short-Term vs. Long-Term
Short-Term (pCi/l)
0 5 10 15 20 25 30 35 40 45 50
Long-Term (pCi/l)
0 5 10 15 20 25 30 35 40 45 50