1993_38

INITIAL RESULTS FROM FOLLOW-UP OF NEW JERSEY HOMES MITIGATED FOR RADON*

Bill Brodhead, Mike Clarkin, and Terry Brennan†

ABSTRACT

This Project involved house diagnostics and four quarterly E-PERM measurements taken in three locations at 97 single-family homes in New Jersey. The house selection criteria included that the house was mitigated for radon and follow-up measurements were available. The selection of houses was not random, but chosen to include a wide variety of mitigation types, installers, house types and follow-up measurements. Houses with elevated post mitigation results were included in the selection so that mitigation failures could be located and evaluated. Measurements were made of the radon system exhaust and revealed that from 0% to 90% of the exhaust was thoron. Data from gamma measurements made at each test location was compared with average state gamma levels. All of the outdoor measurement locations had one of the quarterly measurements include an E-PERM gamma measurement. This gamma data indicated that the E-PERM gamma measurement averaged about 20% higher as compared to the original Ludlum uR/hr readings taken at the same location. A second phase of the study included follow-up work at fifteen of the original houses that had at least one quarterly measurement elevated. Additional diagnostics and system alterations were done on these houses to improve the performance of the initial mitigation. One home that was part of phase two follow-up had an unusual measurement result. The outdoor radon concentration measured hourly revealed regular spikes to greater than 10 pCi/l and was occasionally higher than the indoor radon level.

FOLLOW-UP STUDY OF NJ HOMES MITIGATED FOR RADON

One hundred homes with mitigation systems were initially chosen for the study. The selection was not random. The target was to have 50 percent of the houses with radon levels still above 4 pCi/l. Fifty percent of the houses were to have the system installed before 1/1/1989. Sixty percent were to have active soil de-pressurization systems. Ten percent were to only be sealed. The remaining 30 percent were to be other types of mitigation systems. Seventy to eighty percent of the contractors were to be NJ certified.

Each house in the study was initially visited to perform diagnostic measurements and to begin the first quarterly measurements. E-PERMs were used for all the quarterly measurements. One L-chamber E-PERM was placed in the basement and one L-chamber was placed on the first floor. A third S-chamber sealed in a tyvek envelope and placed outside about one meter off the ground on a corner of the house farthest from any radon system exhaust. The E-PERMs were mailed back after each quarter by the occupant and new E-PERMS return mailed to be placed in the same locations by the homeowners.

At the completion of all four quarters, fifteen houses were chosen that had at least one quarterly measurement that was above the 4 pCi/l level. Each of these houses had continuous radon monitors placed in the basement for one week. During the monitor placement, more thorough diagnostics were performed on each house. Additional corrective action was taken to lower the radon levels further and the continuous monitors were run for an additional week. If necessary, more work was done to further reduce the radon levels with another week of post mitigation monitoring.

---

* Work performed under NJ DEPE Div. of Science & Research, Contract #90118

† Building Research Assoc., RD #1, Box 222, East Carter Rd., Oriskany, NY 13424

QUALITY ASSURANCE

Duplicate measurements were made in at least 10 percent of all the measurements. Two exposures at EPA's Montgomery radon chamber were made of ten of each type of E-PERMS used in the study to confirm accuracy of the calibration factor used. All test locations were measured with a uR/Hr Ludlum meter. In addition, gamma measurements were made over one of the quarters at each outdoor location using E-PERM's double sealed in mylar bags. The two Pylons used for Phase 2, 15 house follow-up were also exposed at the Montgomery chamber in order to determine the proper calibration factor.

MICRO-R READINGS

Figure 4 depicts the number of houses for each succeeding higher level of uR/Hr for the three test locations. Note that the uR/Hr in the basement and outdoor locations averaged about 20% higher than the first floor, 8.0 versus 10.1 and 10.7. Rad Elec, Inc. gives a state average of 6.9 for lower elevations and 9.87 for higher elevations. It would appear that the higher elevations gamma number is much closer to the correct uR/Hr number for basement measurements in western part of the state. It would appear from the data that it would be appropriate to use a gamma level that is 20% lower for any floors that are eight or more feet above the earth.

In Figure 5 and Figure 6, the Ludlum spot gamma readings taken outdoors are compared to the E-PERM gamma readings. The gamma E-PERMs were short term electrets using L-Chambers double sealed in Mylar bags. These were left exposed with the outdoor large S-chambers and short term electrets sealed in porous tyvek bags. Note that in Figure 5 the E-PERMs consistently indicated more gamma than the Ludlum uR meter. Even if the four E-PERMs that varied greater than a factor of 1.75 times the Ludlum readings were eliminated, as illustrated in Figure 6, the E-PERM gamma measurements still averaged 18% higher than the Ludlum uR. This higher response to gamma energy may be due to the fact that the E-PERMs are affected by all gamma while the Ludlum is measuring a limited energy range of gamma.

INITIAL OBSERVATION OF THORON EXHAUST

A grab sample of the radon mitigation exhaust was taken with a scintillation cell and an AB5 Pylon at each house that had an active sub-slab or sub-membrane system. At House 14, it was noted that the initial radon counts during the exhaust sampling rose to 4500 counts per minute. Three hours later the same cell averaged only 575 counts per hour or 485 pCi/l. Using a sniff calibration factor of net counts times approximately 1.6, depending on which scintillation cell was used, the initial grab sample indicated there was 7200 pCi/l of activity in the cell if all the counts were being produced by radon. Since 485 pCi/l should only produce 303 counts per minute during the initial sampling, it must be assumed that the remaining 4200 counts were from Thoron.

THORON MEASUREMENT PROCEDURES

In order to better quantify the amount of Thoron in the mitigation exhaust, the following technique was used after house fourteen for mitigation exhaust sampling.

A .271 liter scintillation cell was read for three to ten minutes before any sampling was begun in order to obtain the average background counts per minute (BKG CPM). The Pylon was set for one minute count intervals. The mitigation exhaust was then sampled for four to six minutes. At the end of a count interval, the pump was turned off and the tubing disconnected from the Pylon before the tubing inlet was removed. The Pylon was allowed to continue counting for an additional ten to fifteen minutes. Three hours or more later, the scintillation cell was counted for twenty minutes and then flushed with clean air for ten minutes.

The radon concentration was obtained by dividing the net counts by the calibration factor (CF) with a compensation for sampling decay. The calibration factor was obtained for each scintillation cell by making previous grab samples chamber with a known value. To obtain the Thoron concentration, the BKG CPM and the average CPM obtained ten minutes after the sampling is complete are subtracted from the average of the last two minutes of sampling in the radon exhaust. These net counts are divided by the CF for Thoron which is different from the radon

CF because there is only one alpha decay from the Thoron during the initial sampling, since one of the initial Thoron decay products has a 10 hour half life.

Using the following formula for pCi/l, it can be determined that there was approximately 10,000 pCi/l of Thoron and only 485 pCi/l of radon in the exhaust of house 14.

$$\text{Th pCi/l} = \frac{\text{net Th CPM}}{\text{cell eff.} \times 2.22 \text{ DPM} \times \text{cell vol.} \times \text{DF}}$$

net Th CPM	= Gross CPM – (BKG CPM + initial CPM from radon)
cell eff.	= 70%
cell vol.	= .271 liters
2.22 DPM	= Activity of one pCi in a liter
DF (Decay Factor)	= 1 (since counts obtained during sampling)

Additional Thoron measurements were made in the basement of House 14 in order to quantify the amount of Thoron present. Thoron is difficult to measure while a radon system is running because the concentrations are typically too low. Two Thoron E-PERMs were exposed side by side with two regular E-PERMs for a week. The Thoron averaged 7.0 pCi/l and the Radon averaged 2.6 pCi/l.

RADON AND THORON CONCENTRATIONS IN MITIGATION EXHAUST

The Thoron concentration in the exhaust was measured in the remaining houses in the study after House 14. Figure 1 shows that for 76 of the houses, the Thoron averaged 401 pCi/l while the Radon averaged 305 pCi/l. Figure one also shows that the sixty two percent of the homes fell into the 10 to 200 pCi/l range of radon in the exhaust. Thirty-eight percent were greater than 200 pCi/l. Thirteen percent were greater than 500 pCi/l and five percent of the mitigation exhausts were greater than 1800 pCi/l. combine the CFM rate of Figure 2 with the radon concentration you obtain the pCi/sec contribution to the atmosphere that is being contributed by the radon exhaust as shown in Figure 3.

HOUSE 52 BASEMENT vs OUTDOOR MEASUREMENTS

House 52 had initial radon readings that were over 2000 pCi/l in the basement, which is one of the highest measurements in the state. The quarterly average radon levels in three of the quarters were still above 4 pCi/l with the radon system operating. Note that the radon levels outdoors were higher during warmer months than the colder months.

	Basement	1st Floor	Outdoor
1/10 to 4/10/92	3.07	2.59	1.08
4/10 to 7/14/92	5.00	4.20	1.97
7/14 to 10/12/92	4.76	3.59	1.46
10/12 to 1/12/93	4.76	4.12	0.48
average =	4.39	3.62	1.25

The year long average difference between the basement and the outdoors is about 3.1 pCi/l. During the first week of follow-up measurements, from 5/27 to 6/2/93, before any changes were made to the radon system, the basement averaged 5.6 pCi/l and the outdoor averaged 3.2 pCi/l. See Figure 7. This is only a 2.0 pCi/l difference between the basement and the outdoor. Note that the outdoor levels matched the rise and fall of the indoor basement levels with about a 2 pCi/l bias.

In order to determine if the two Pylons were biased to each other, the second run, Figure 8, was run with both units sampling the same outdoor air. As can be seen from the graph, the two corresponded so closely to each other it is difficult to tell them apart. This significantly improves the confidence that the comparison between the indoor and outdoor levels is a valid measurement. As can be seen from the graph, the outdoor levels consistently rose above 6 pCi/l during the early morning hours with spikes as high as 13 pCi/l.

House 52 is a two story house with a block foundation, unfinished basement under the whole house and an attached garage. The basement had a sump pit with no pump and a perimeter canal. The remediation system consists of a T2 Turbo Kanalflakt fan mounted in the garage attic with the exhaust out the rear roof. The sub-slab system consists of two suction holes on opposite sides of the basement and one suction hole through the garage slab. The french drain was sealed with closed cell backer rod with urethane flow-able caulk laid on top of the backer rod. The sump was sealed with a piece of pressure treated plywood. The house has city water. The radon exhaust was over 4500 pCi/l, which is the highest radon exhaust concentration measured in the study.

Diagnostic measurements found a strong vacuum under the basement slab, 0.184", and the garage slab, 0.085". Even the block walls had vacuum readings from 0.003" to 0.012". It was unclear what additional remedial work would significantly lower the indoor radon levels since a large portion of the indoor levels were obviously coming from the outdoor radon. An additional F150 fan was added in line with the original radon T2 fan to see if any changes could be seen. Surprisingly the basement levels fell from 5.6 pCi/l to 4.1 pCi/l while the outdoor average climbed slightly. In Figure 9 it can be seen that the outdoor and basement radon levels tracked almost perfectly during the first four days. Even during the last three days the indoor and outdoor levels tracked closer than before the second fan was added. It appears that the second fan did improve the system performance.

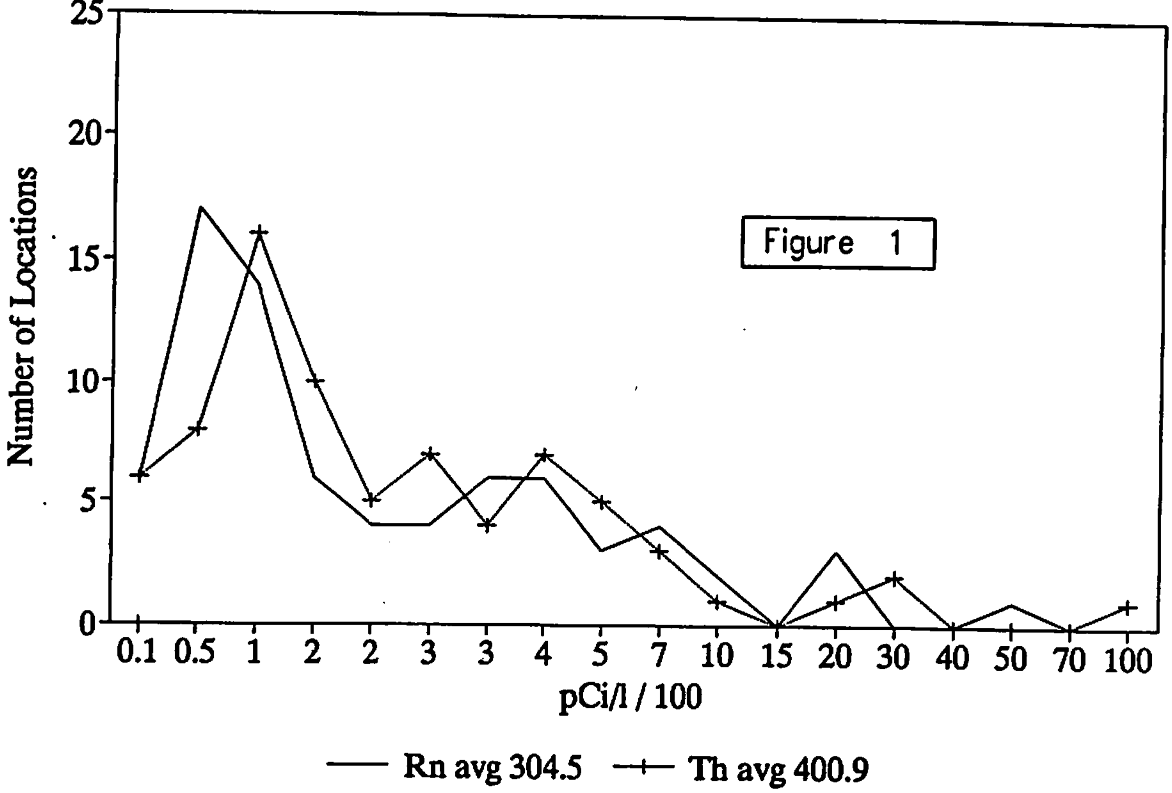
In Figure 10, the daily outside and basement averages are compared. Note that the outdoor averages on 6/17, 6/19 and 6/23 are higher than the basement averages. Although the basement average during 6/17 was above the 4 pCi/l guideline, it had not only reached but surpassed the "Congressional Mandate" to have the indoor levels as low as the outdoor levels!

Figure 11 shows the averages each hour for all the outdoor measurements at House 52. It clearly shows that the radon levels outdoors begin to rise in the late afternoon around 5 PM. They continue to rise and then start to fall in the early morning around 5 or 6 AM. This corresponds very closely with typical wind movement. Almost every night the wind dies down with the sunset and begins to pick up again with the first rays of the sun. Occasionally the wind will continue blowing into the night. This may explain the nights when the radon levels did not climb to their usual peak. The difference between the quarterly E-PERM outdoor measurements between warmer and colder months might also be explained by the wind speed. During the winter, the wind usually blows harder, which corresponds with the lower outdoor measurements.

OUTDOOR CONCLUSIONS

Outdoor measurements can be significant contributor or at least determine the lower limit of radon reduction. Although House 52 is unusual, it does show that outdoor levels can play a part in indoor measurements. In making continuous outdoor radon measurements in other houses in the study the same diurnal curve could be seen. In the other houses it was more likely to see outdoor radon levels peaking at 1 to 2 pCi/l in the middle of the night.

Distribution of RN/TH Exhaust
76 NJ Mitigation Systems



Distribution of CFM Exhaust
87 NJ Mitigation Systems

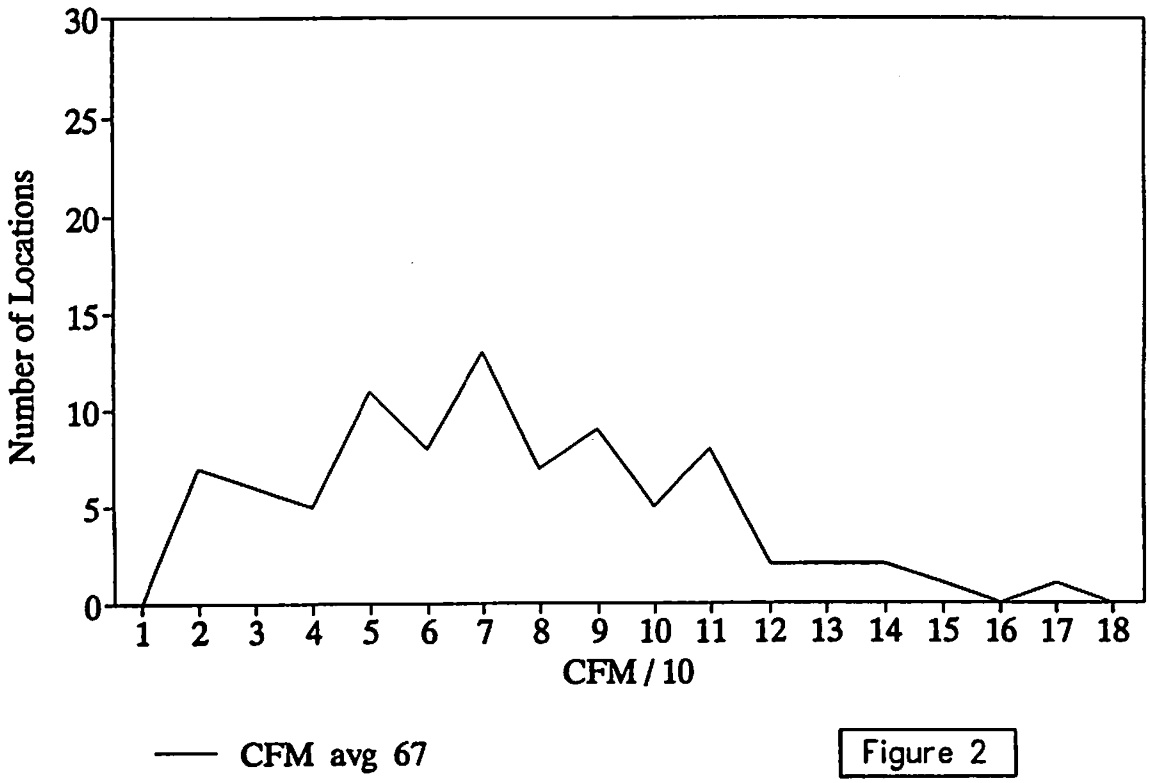


Figure 2

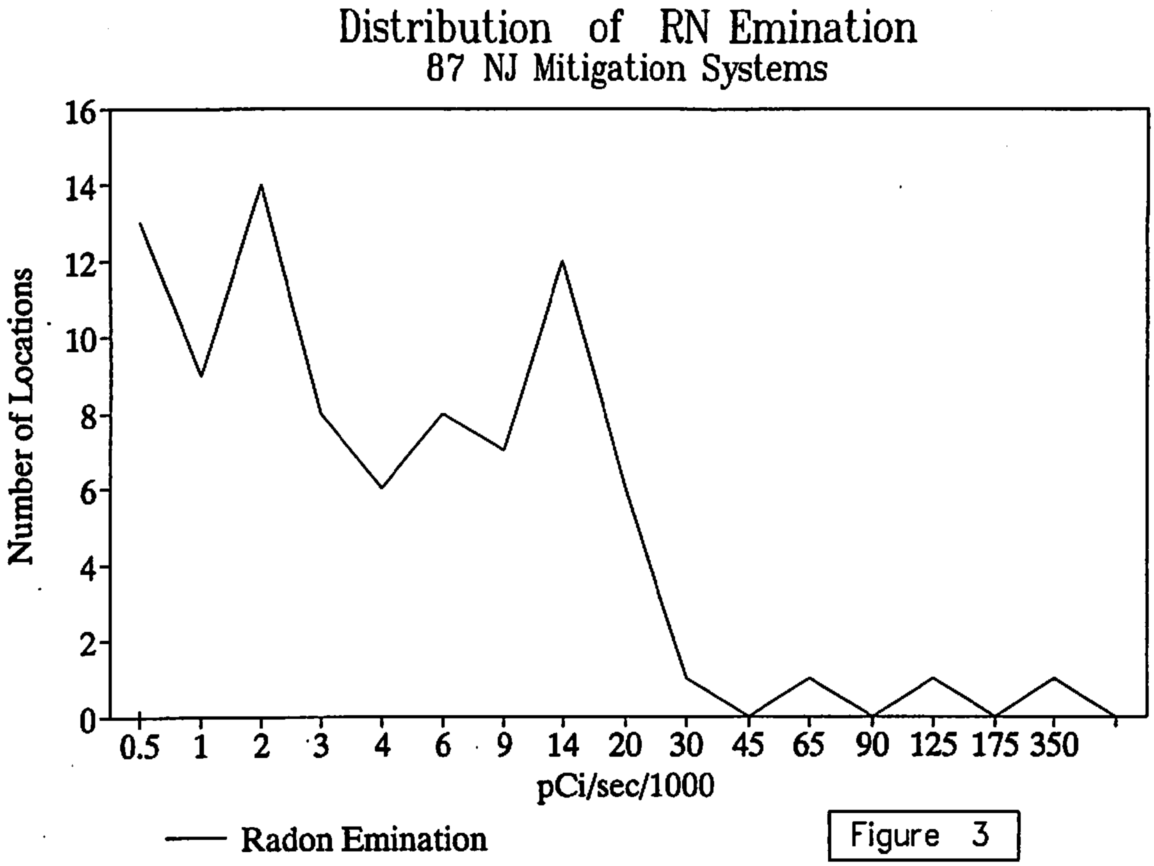


Figure 3

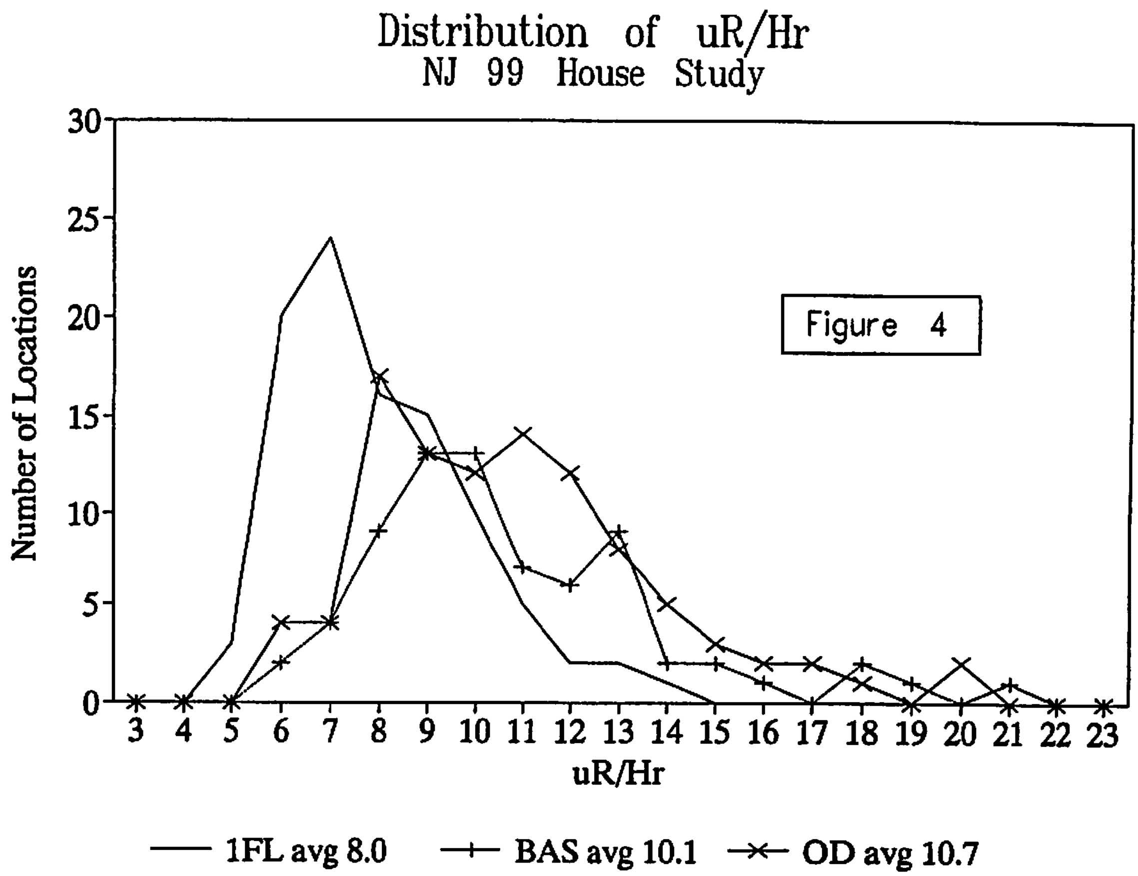
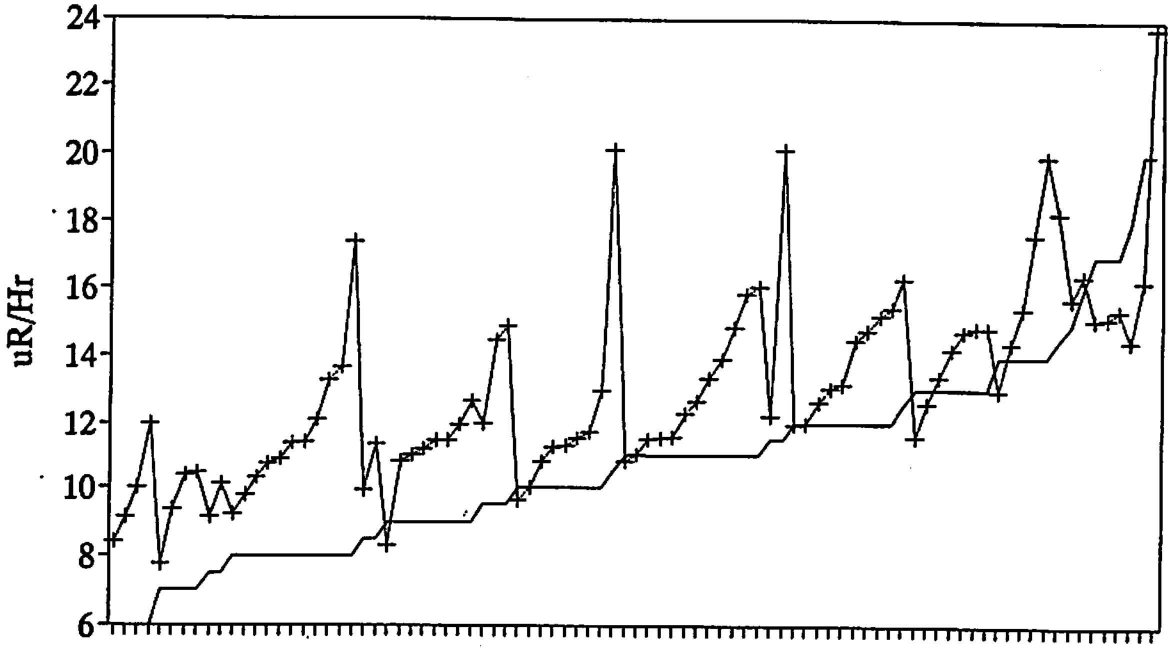


Figure 4

Outdoor Ludlum vs E-PERM uR/Hr
88 NJ Houses

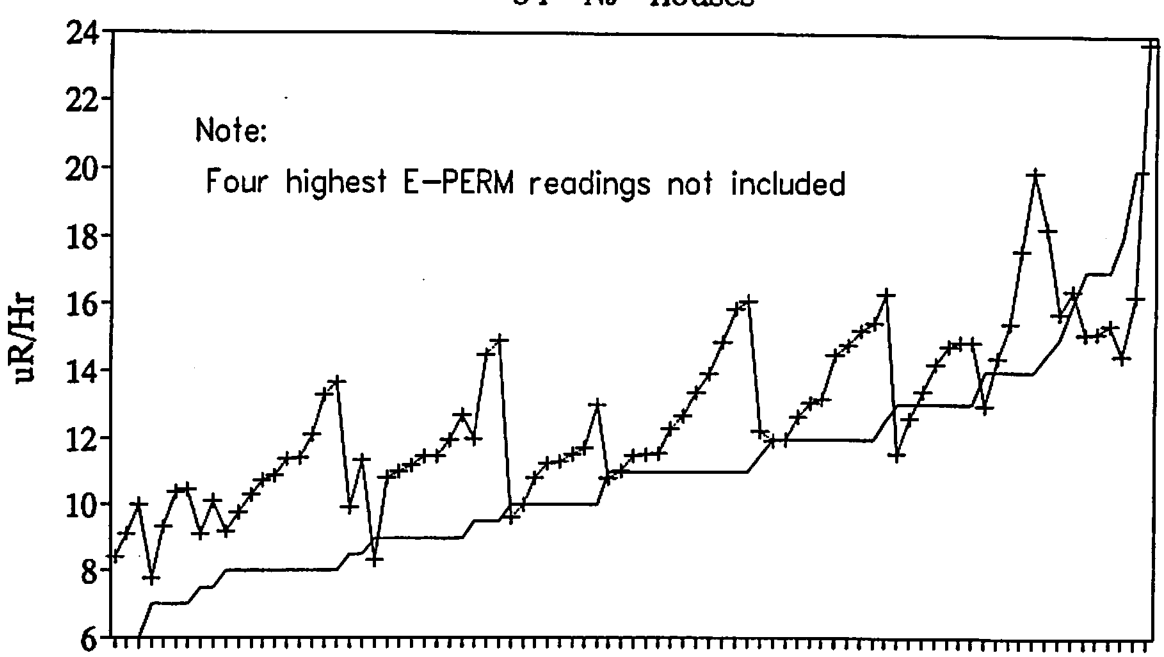


Sorted by Increasing Ludlum uR/Hr

Figure 5

—— Ludlum avg 10.8 —+— E-PERM avg 13.0

Outdoor Ludlum vs E-PERM uR/Hr
84 NJ Houses



Sorted by Increasing Ludlum uR/Hr

Figure 6

—— Ludlum avg 10.9 —+— E-PERM avg 12.8

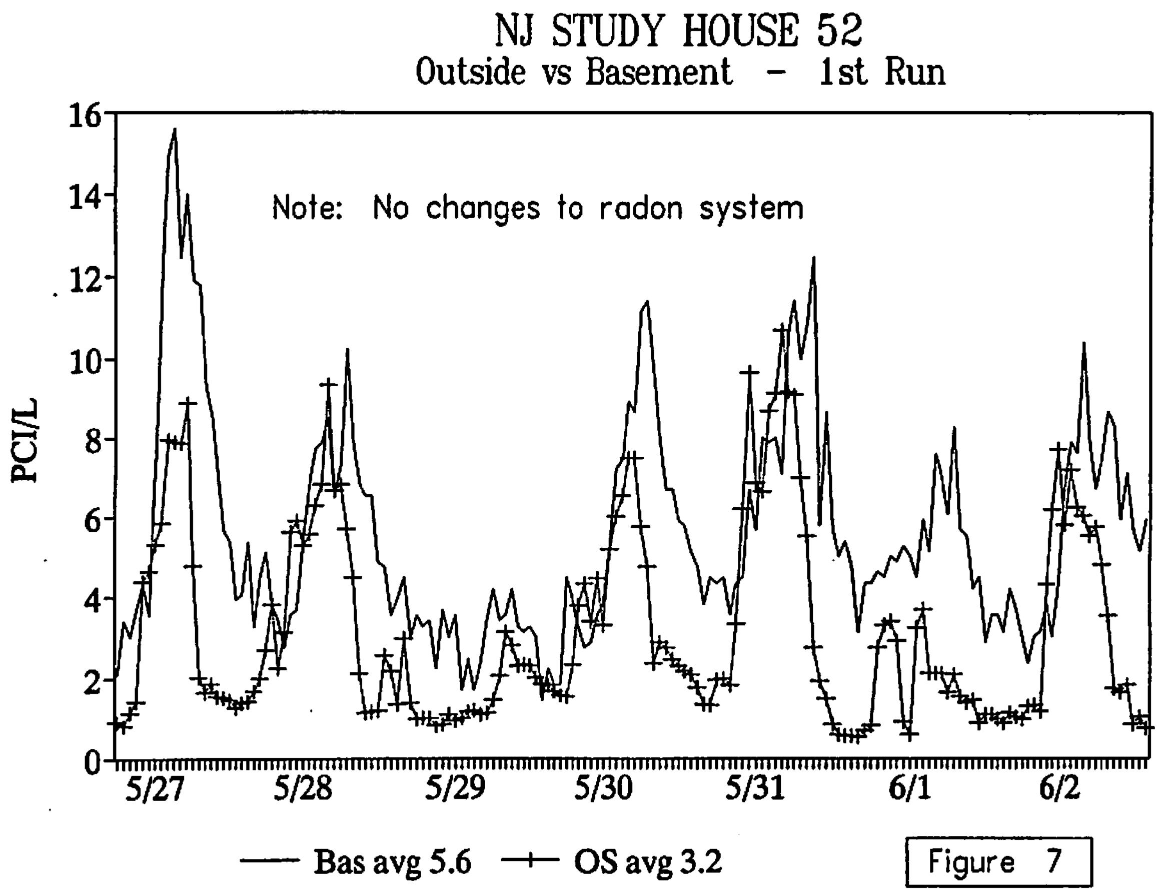


Figure 7

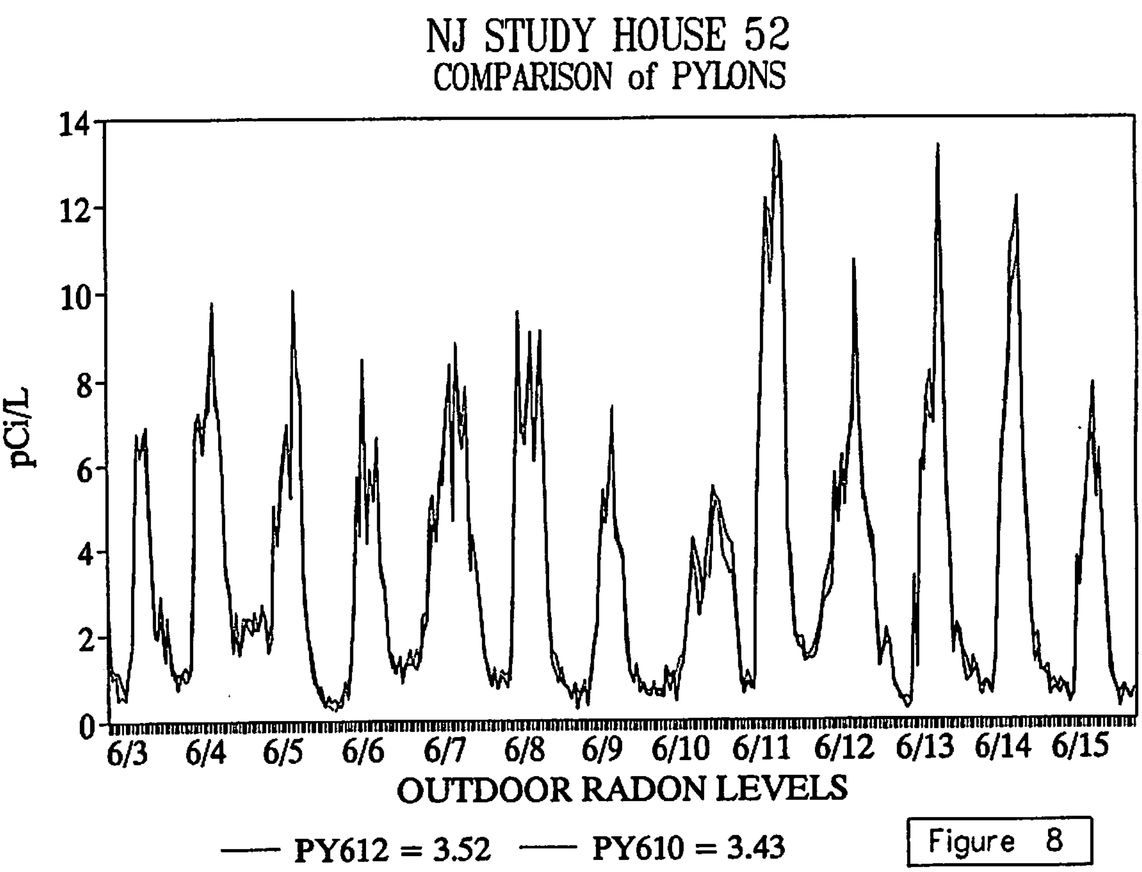


Figure 8

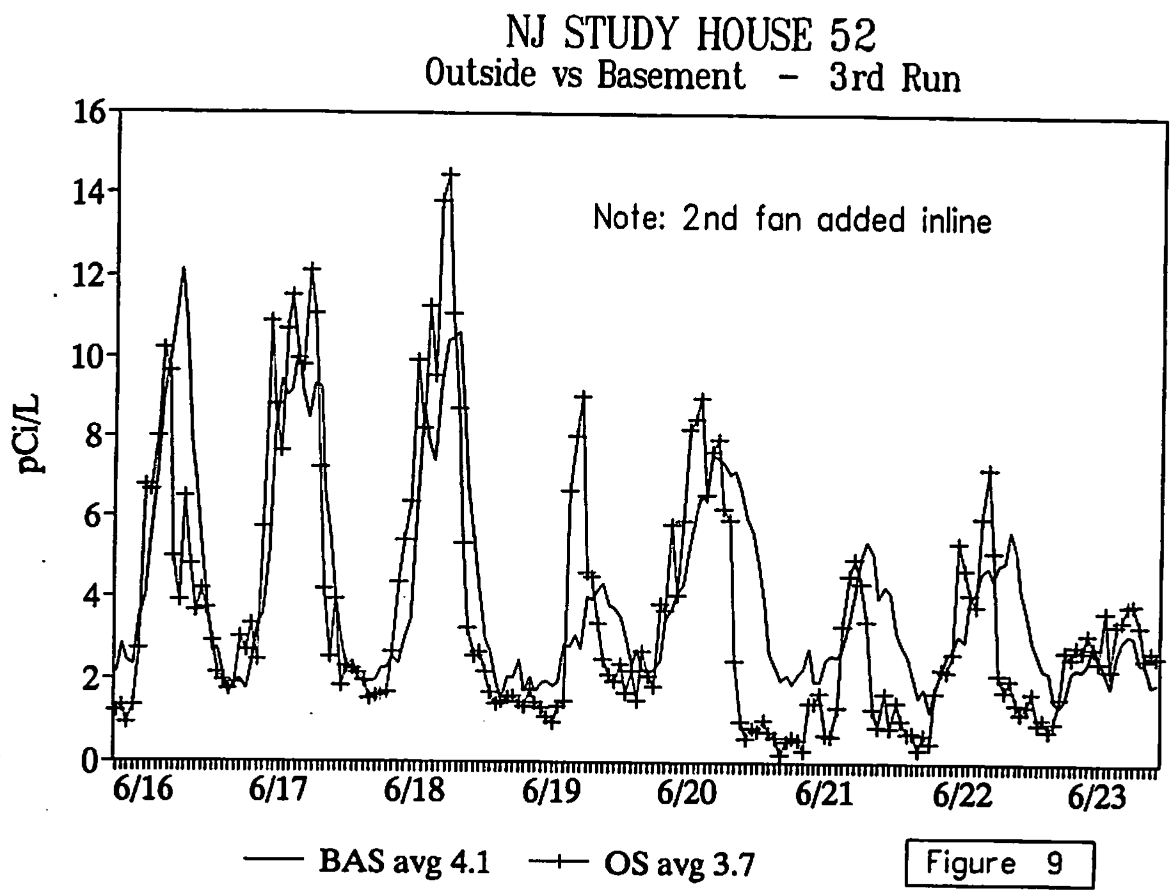


Figure 9

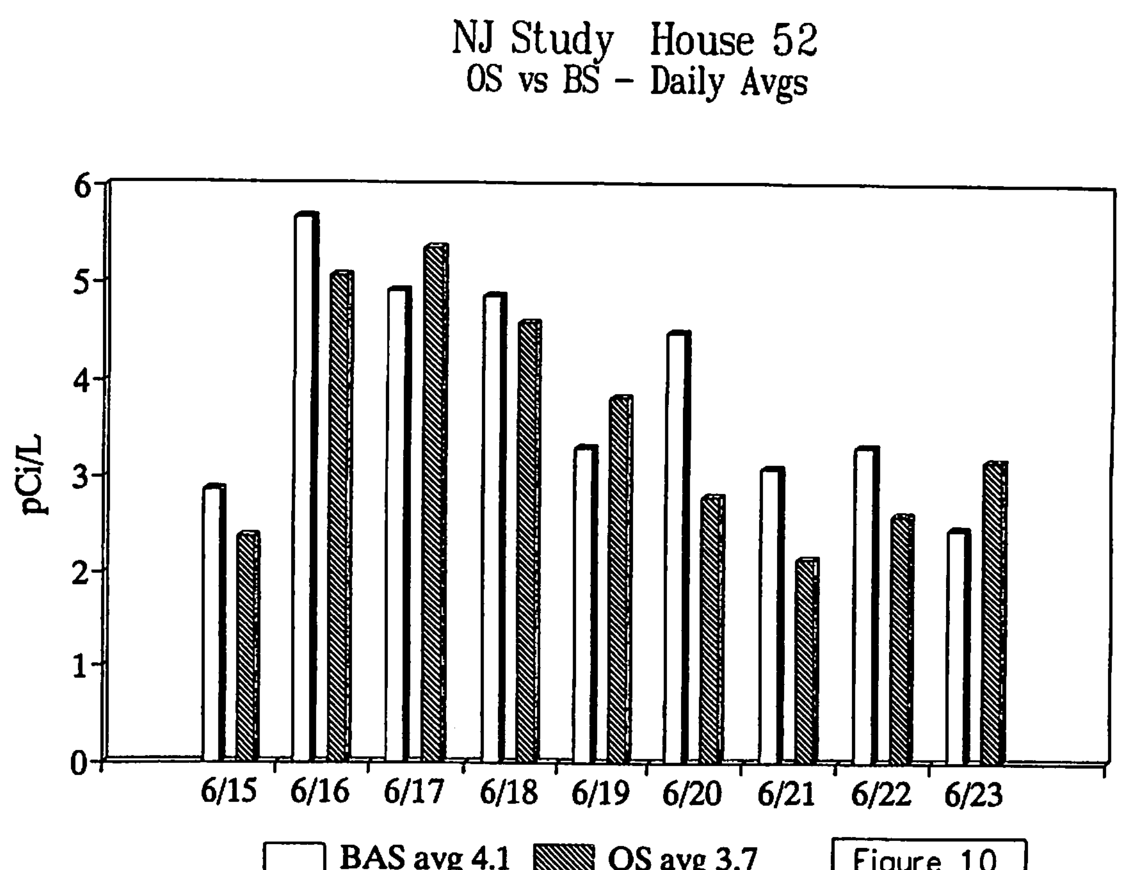
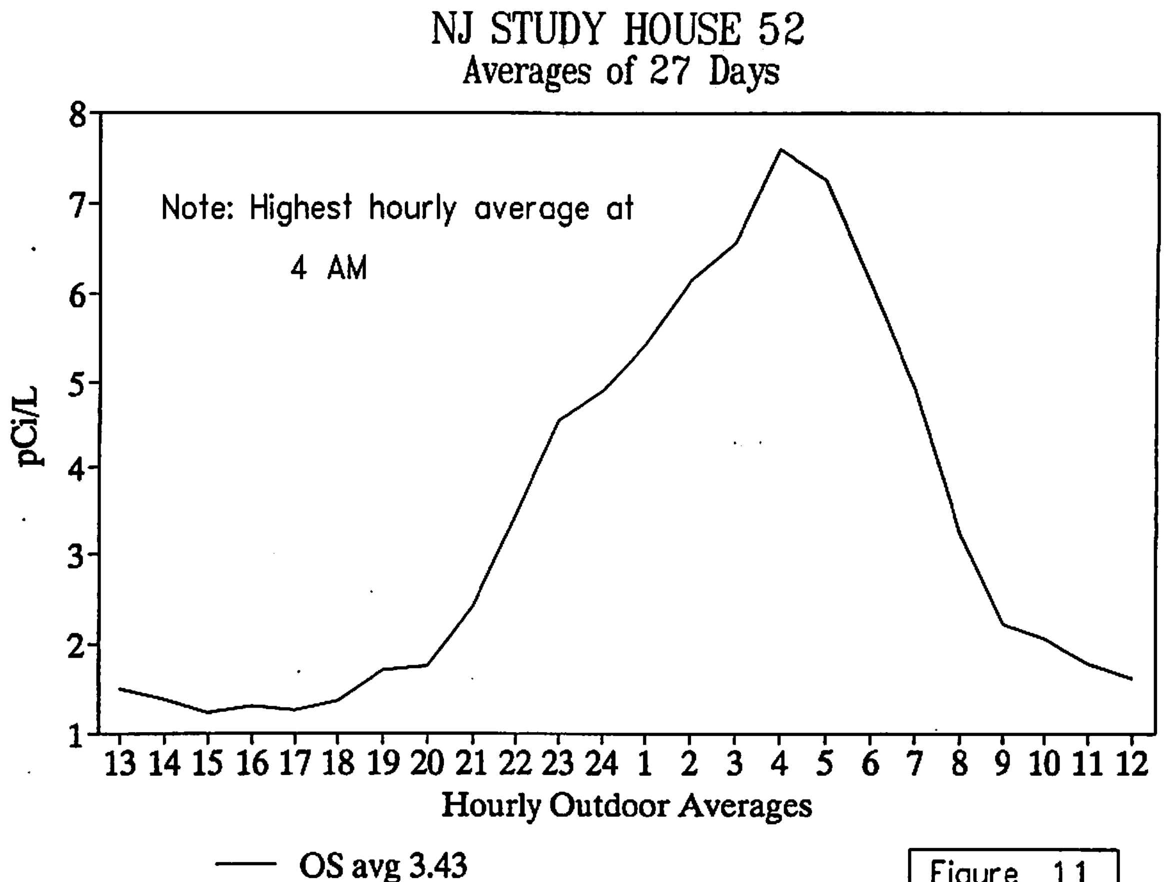


Figure 10



NJ STUDY HOUSE 52
Averages of 27 Days
Note: Highest hourly average at
4 AM
pCi/L
1
2
3
4
5
6
7
8
13 14 15 16 17 18 19 20 21 22 23 24 1 2 3 4 5 6 7 8 9 10 11 12
Hourly Outdoor Averages
OS avg 3.43

Figure 11