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A CHAMBER EXPOSURE OF EIC'S AND AT'S TO SIMULATE THEIR USE AS DOSIMETERS FOR RADON WORKERS.

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ABSTRACT

The EPA "Radon Mitigation Standards" require all RCP contractors to monitor the exposure of their employees during installation of mitigation systems. It is also prudent to monitor anyone's exposure who might experience high exposure values. The only recognized methods for determining the exposure strength is to either make an on site radon or RDP measurement or to use the highest radon/WL concentration recorded for the workspace. The disadvantage with these methods is that they will tend to over or under predict a persons exposure because of the use of older measurements or a general area measurement may be significantly different than the exposure received in other locations within the dwelling. In addition tracking a persons time in each location is difficult and making on-site measurements is expensive. A dosimeter detector that records a persons exposure as he moves around would provide a more accurate measurement of their exposure. A practical and effective dosimeter must be durable, lightweight, portable, low cost and sensitive to rapid changes in the radon/WL levels. Passive radon detectors appear suitable except their sensitivity to changing radon levels needs to be evaluated. In this study triplicate EIC's, and AT's, from five different manufacturers were exposed repeatedly to radon for 60 minutes and then low radon air for 120 minutes in a specially designed radon chamber. Radon was provided by a Pylon source with a measured air flow through the source. Length of exposure was carefully recorded. Grab samples of the chamber concentration were taken to confirm the exposure strength. A second run was made exposing new passive detectors to 15 minutes of exposure and 120 minutes of low radon air. The results of the study show the effectiveness of passive detectors at recording short exposure times.

INTRODUCTION

Since the late 1900's with the discovery of nuclear radiation and the first over-exposure to this radiation, it has been considered prudent to determine exposures to humans during times when their exposures could become significant. For Radon mitigators and testers this is no different. Testers exposures to working level months may be taken by using the measured radon concentrations in the homes they are testing and converting to working level months using an equilibrium ratio of 0.5 . Mitigators have problems more challenging. Their exposures in working level months may be calculated by using the measured radon concentrations in the buildings they are mitigating and converting to working level months using an equilibrium ratio of 1.0.

Clearly there are difficulties in establishing confidence in the values determined by these methods for both mitigators and testers. For testers, it is inconvenient to monitor their times in the homes where the measurements are being made and furthermore because of the wild fluctuations of the radon concentrations in the homes, there is serious doubt as to using that average value in determining the actual exposure to the tester.

Using the initial Radon measurement or on site measurements is suspect for a mitigator because he is moving around the basement and the outside during the installation.

There have been some attempts at developing personal dosimeters for radon testers and mitigators. Some alpha track devices are now constructed with clips so that they may more easily be attached to the individual for personal monitoring. This then brings the following question to the surface: Do the personal dosimeters developed for the radon industry measure accurately the radon concentrations to which testers and mitigators are exposed? It is the purpose of this experiment to begin an analysis of this question.

MATERIALS AND METHODS

In this study triplicate EIC's, and triplicate AT's from five manufacturers[1] were exposed to radon for 60 minutes and then to low radon air for 120 minutes in a specifically designed radon chamber (See Figure 1). This cycle was repeated 43 times. Radon was provided by a Pylon source[2] with a measured air flow through the source. Length of exposure was carefully recorded with a timer. Grab samples of the chamber concentration were taken to confirm the exposure strength. A second run was made exposing new passive detectors to 15 minutes of exposure and 120 minutes of low radon air over 136 cycles.

The experimental arrangement is shown in Fig. 1. Consider the first case where 15 passive detectors (3 from each of 5 manufacturers) are placed into the dosimeter exposure chamber and 15 passive detectors (again 3 from each of 5 manufactures) are placed into the dosimeter non-exposure chamber. A relatively large building compressor was used to supply a steady stream of low radon air into the line labeled "Constant air source". To begin the experiment, this low Radon air is passed through the Pylon source at a fixed flow rate and simultaneously through the dosimeter non-exposure chamber. For the first 60 minutes of the experiment, solenoid 'a' was set by the timer to allow the radon laden air through the exposure chamber which then passed through a flowmeter and was then exhausted to the outside air. Simultaneously solenoid 'b' permitted the non-exposure chamber air flow to be exhausted to the outside air. After the first 60 minutes of exposure, solenoids 'a', and 'b' changed settings determined by the timer so that the radon laden air was directly exhausted to the outside air, and the low radon air which passes through the non-exposure chamber to pass through the exposure chamber and then vent directly to outside air.

In this way, the exposure chamber builds up from low ambient radon values to a maximum at the beginning of the exposure and then returns to low ambient radon values at the same rate during the period it is flooded with low radon air. This process was then repeated through many cycles of high radon air then low radon air to approximate what a mitigator or tester might actually experience. This was termed "RUN 1". The number of cycles chosen for each run was such that a minimum of 200 (pCi/l)days of exposure was achieved.

The experiment was then performed allowing high radon air to enter the chamber for a period of 15 minutes followed by low radon air for 120 minutes. Again this was permitted to occur for many cycles such that significant exposures could occur. This describes "RUN 2".

It should be mentioned that a third experiment using an exposure time of 30 minutes per cycle was also performed but the monitoring of the flow rates indicated that there was inadequate control during this experiment to evaluate its results with any degree of confidence.

After each run, detectors were then removed and returned to the manufacturer for analysis except for the E-Perms which were evaluated in house. Grab samples that were taken were analyzed using a Pylon AB-5 with appropriately calibrated cells. The experimental results for both runs are given in Tables 1 and 2 below.

Six Lucas cells were used. Each was sent to the DOE environmental chamber[3] laboratory in New York and were filled under the supervision of Andy George and returned to ESU in order to calibrate each of the cells against the Pylon AB-5 monitor.

Two Dwyer flow indicators were used. Each was sent to the PA DER[4] to be calibrated under the supervision of Mr. Bob Lewis.

TABLE I. RUN 1---1 HOUR EXPOSURES, 2 HOURS NON-EXPOSURE.

	DAYS EXPOSED	GRAB SAMPLES	RSSI	ALPHA SPECTRA	LANDAUER RADTRACKS	REMS	E-PERMS
# of msmts.		4	3	3	3	3	3
AVERAGE (pCi/l)days	1.80	429.8	726.7	617.6	591.1		417.6
STANDARD DEVIATION		9.5	411.4	35.9	18.9		19.4
% DIFF.			+69	+44	+38		-2.8

Table 1: A tabulation of the results of the exposed detectors. Percent differences are taken assuming grab samples are 'correct' values. All units are (pCi/l)days except for 'DAYS EXPOSED'. REMs were not returned in time for this paper. Maximum Radon concentration in the chamber = 238.8 pCi/l. with 43 cycles completed.

TABLE 2. RUN 2---15 MINUTE EXPOSURES, 120 MINUTES NON-EXPOSURE.

	DAYS EXPOSED	GRAB SAMPLE	RSSI	ALPHA SPECTRA	LANDAUER RADTRACKS	REMS	E-PERMS
# of msmts.		3	3	3	3	3	3
AVERAGE (pCi/l)days	1.42	329.4	387.3	408.5	362.7	429.7	330.8
STANDARD DEVIATION		---	23.4	35.0	38.8	41.0	12.7
% DIFF		---	+18	+24	+10	+30	+0

Table 2. A tabulation of the results of the exposed detectors. Percent differences are taken assuming grab samples are 'correct' values. All units are (pCi/l)days except for 'DAYS EXPOSED'. Maximum Radon concentration in the chamber = 232.0 pCi/l. with 136 cycles completed.

RESULTS

Results of this experiment are given in Tables 1 and 2 above. Depiction of this data is shown in Figs. 3 and 4 below.

Every detector except the E-Perm's yielded higher values for exposure than the experimentally determined values. The percent errors for the alpha track detectors ranged from a low of 10% to a high of 69% with every error indicating an over exposured.

It is difficult to arrive at an explanation of this result since the initial assumption was that the dosimeters would under estimate the total exposure. One explanation, currently under investigation, is that the detectors might de-absorb radon from their materials during the fresh air component of the experiment. This could help to explain the higher values found by all the detectors except the Alpha Spectrum detectors which are simply 2 inch metal cans. The total experimental error, taken as a maximum of ±11% in RUN 1 and ±7% in RUN 2 is inadequate to explain away the majority of high values reported.

DISCUSSION

There were two critical parameters to evaluate during the course of each run: the flow rate through the Pylon source, since that determined the air flow stream concentration and the total time of exposure. The total time of exposure was determined by a recording timer which ran only when the solenoid 'a' was in a position that permitted the radon laden air to pass through the exposure chamber. Evaluation of the accuracy of this timer indicates an error of less than 1% in the measurement of the total time. The more difficult parameter, the flow rate was taken as the flow rate as indicated by the flow meter and adjusted to its calibrated value. This meter was read numerous times during each run and was found to fluctuate between values of 1.7 and 2.2 during run 1, and 1.9 and 2.1 during run 2. Each time the flow meter was read, the flow adjusters were reset so that the flowmeter read to 2.0 l/min, the intended value. This indicates an error of approximately ±7% in run 1 and ±3% in run 2 due to this parameter alone.

Another concern is the 'ramp up time' and the ramp down time experienced by the radon chamber. Consider run #2 where the radon chamber is filled with radon gas for 15 minutes and then flooded with fresh air for two hours. The chamber does not immediately achieve the concentration of 232 pCi/l as indicated by the flow rate throughout the radon source as soon as the flow of air is transferred to pass through the radon source. It is expected that the radon concentration in the chamber will begin at ambient values and then rise to its maximum value as shown in Fig. 2. (This figure is a plot of the raw counts taken every 5 minutes by a second Pylon monitor used to perform continuous flow through measurements during run 2 and is presented here only to depict the ramp up time and ramp down times.)

When the airstream is switched from the radon source to the ambient air source, the concentration in the chamber will also not drop immediately to ambient values but is expected to drop as shown in Fig 2. above.

Analysis of this data shows that average ramp up time and down time slopes differ by not more than 3.0%. (One must be careful in performing this analysis to choose a sufficient number of cycles to make the comparison.) Further grab samples were taken during ramp up times and ramp down times and indicate that ramp up time to 90% of the maximum value and ramp down time to 10% of the maximum value is approximately 8 minutes in the chamber used

Therefore one may calculate the total exposure by multiplying the time during which exposure occurs by the maximum concentration during that time. Of course one must then multiply by the number of cycles; or conversely one may take the average maximum value of radon concentration during all the cycles and multiply that by the total exposure time which is well known to within ±1%. The exposure that occurs during the ramp down time exactly (within ±3%) compensates for the overestimation of exposure during ramp up time using this method. It should be noted at this point that the Pylon flow through source used during this experiment always had air flowing through it at 2.0 l/min. allowing the radon concentration leaving it to be constant.

Therefore the experimentally determined exposures were calculated as the product of the average value of the grab samples taken during the run with the radon concentration at its maximum value and the total time of exposure. The total experimental error then during run 1 is taken as ±11% while during run 2, ±7%.

Since the results caught the authors by surprise, it was expected that none of the detectors would reach the experimental exposures, the chamber was brought back on line after manufacturers results were in. The flow through the chamber at all locations was checked under the same conditions of the experiment and were found to be in agreement within 5%. Further grab samples were taken to verify the values used in the calculation of the experimental exposure. These grab samples were found to be 232 pCi/l. Further this concentration varies from the grab samples taken during run 1 by 3%. The concentration for run 1 was taken as the average value of the grab samples taken during that run, 238.8 pCi/l, and the concentration for run 2 was taken as 232 pCi/l. since it was decided that too few grab samples were taken during run 2 to base a value on them.

A further concern is what effect the flow of radon air over the detectors might have. The volume of the chamber is determined to be 7.079 l, and with a flow rate through the source of 2 l/min., the speed of the air over the detectors is determined to be .85 ft/min. The chamber length is 3 feet and therefore in some average sense when the radon laden air begins entering the chamber, it takes 3.54 minutes to reach the far end, 3 feet downstream. It was decided that this would have little to no impact on the detector sensitivities.

Background of each Lucas cell while attached to the Pylon monitor was determined for each cell prior to its use and included in the appropriate calculations along with their individual calibration factors. Background radon concentrations in the constant air source (low radon air) was evaluated and taken to be 1.5 pCi/l.

Another concern is the order of the detectors in the chamber. Does it make a difference in the values reported by the manufacturers? This was reviewed and no trends were discovered. Being first, second or third appears to make no difference in the value reported. In some cases the detector which was first of its kind was higher than the second or third and in other cases it was less. Placement within the chamber offers no preferential results.

A consideration was also given to the orientation of each detector in the chamber. The design of each detector is different from one detector manufacturer to another and some clearly have a preferential portion for absorbing radon, or allowing radon to enter the detector chamber. These were oriented intentionally the same way in all cases. It may be that a different orientation in the chamber would yield different results.

CONCLUSIONS

Every detector except the E-Perm's yielded higher values for exposure than the experimentally determined values. It is difficult to arrive at an explanation of this result which is unexpected. (Landauer Radtraks do come quite close to being within experimental error during run 2.) One explanation, currently under investigation, is that the detectors might deabsorb radon from their materials during the fresh air component of the experiment. This could help to explain the higher values found by all the detectors except the Alpha Spectrum detectors which are simply 2 inch metal canisters. The total experimental error, taken as a maximum of ±11% for run 1 and ±7% for run 2 is inadequate to explain away the majority of high values reported.

It appears therefore based upon these experiments that the detectors used, except for E-Perms could be used as personal monitors recognizing that they produce values which are a maximum exposure for personnel. This positive bias would add a measure of safety for personnel. E-Perm's could be used as personal monitors and their values may be taken as accurate to within 3% of actual exposures.

The authors wish to thank Mr. Andy George of the DOE/EML lab in New York and Mr. Bob Lewis of the PA DER without whose help the level of accuracy could not have been verified.

REFERENCES

1. RSSI refers to RSSI 6312 West Oakton Street, Morton Grove, IL 60053-2723 (708-965-1999)
LANDAUER RADTRACKS refer to LANDAUER, Inc, Glenwood, IL 60425 (708-755- 7911
REMS refers to Radon Environmental Monitoring, Inc., 3334 Commercial Avenue, Northbrook, IL 60062 (708-205-0110)
ALPHA SPECTRA refers to ALPHA SPECTRA, Inc. Radon Analysis Laboratory, 715 Arrowest Court Grand Junction, CO 81505 (970-243-4477)
E-PERMS refers to Rad Elec., Inc. 5330 J Spectrum Dr., Frederick, MD 21701 (301-694-0011)

2. Pylon Radon source, Model 1025, SN A-145, 14.470 Bq/min.

3. Andy George, DOE/EML, New York.

4. Mr. Bob Lewis, Dept. of Environmental Resources, PO BOX 8649, 400 Market St.
13th. floor Harrisburg, PA 17105 (717-23-RADON.)

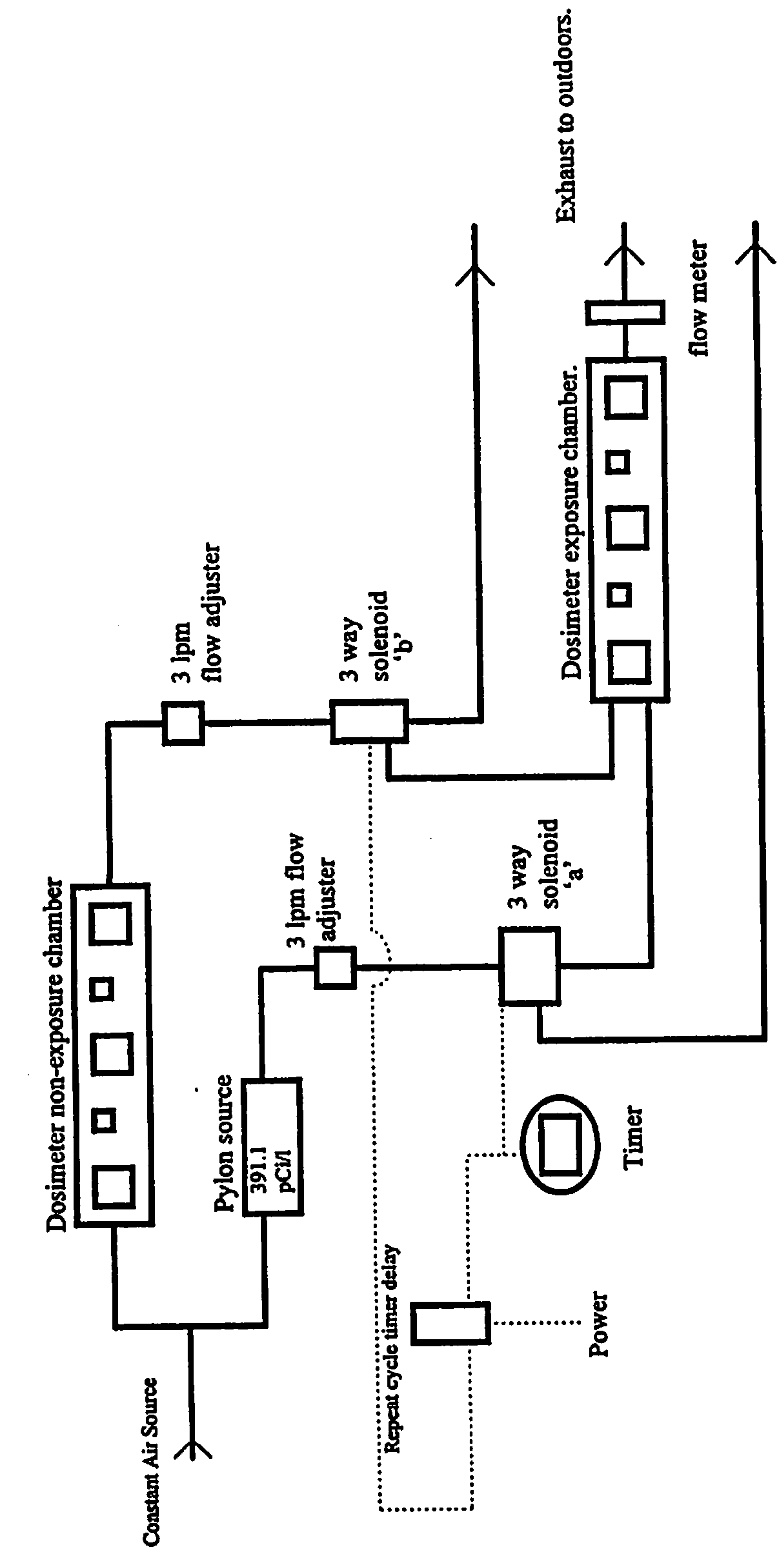

Fig. 1 Experimental Setup.

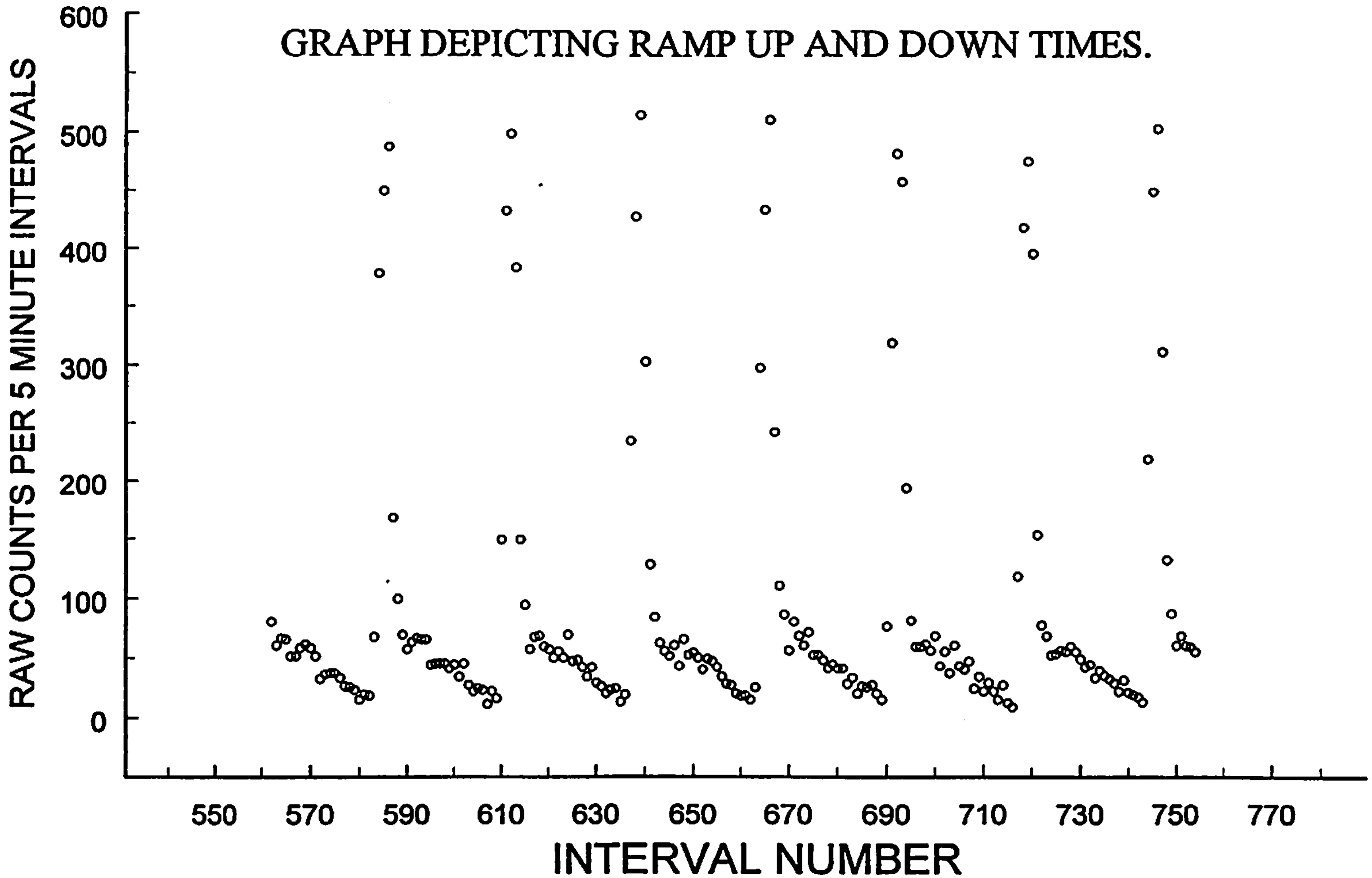

Fig. 2. A graph of the raw counts taken during run 2. Counting was done on a Pylon AB-5 for 5 minute periods. This data is not useful in determining radon concentrations in the chambers since these 5 minute cycles are not correlated to the on/off cycle times of the experiment. It is useful in the calculation of ramp up times and ramp down times.

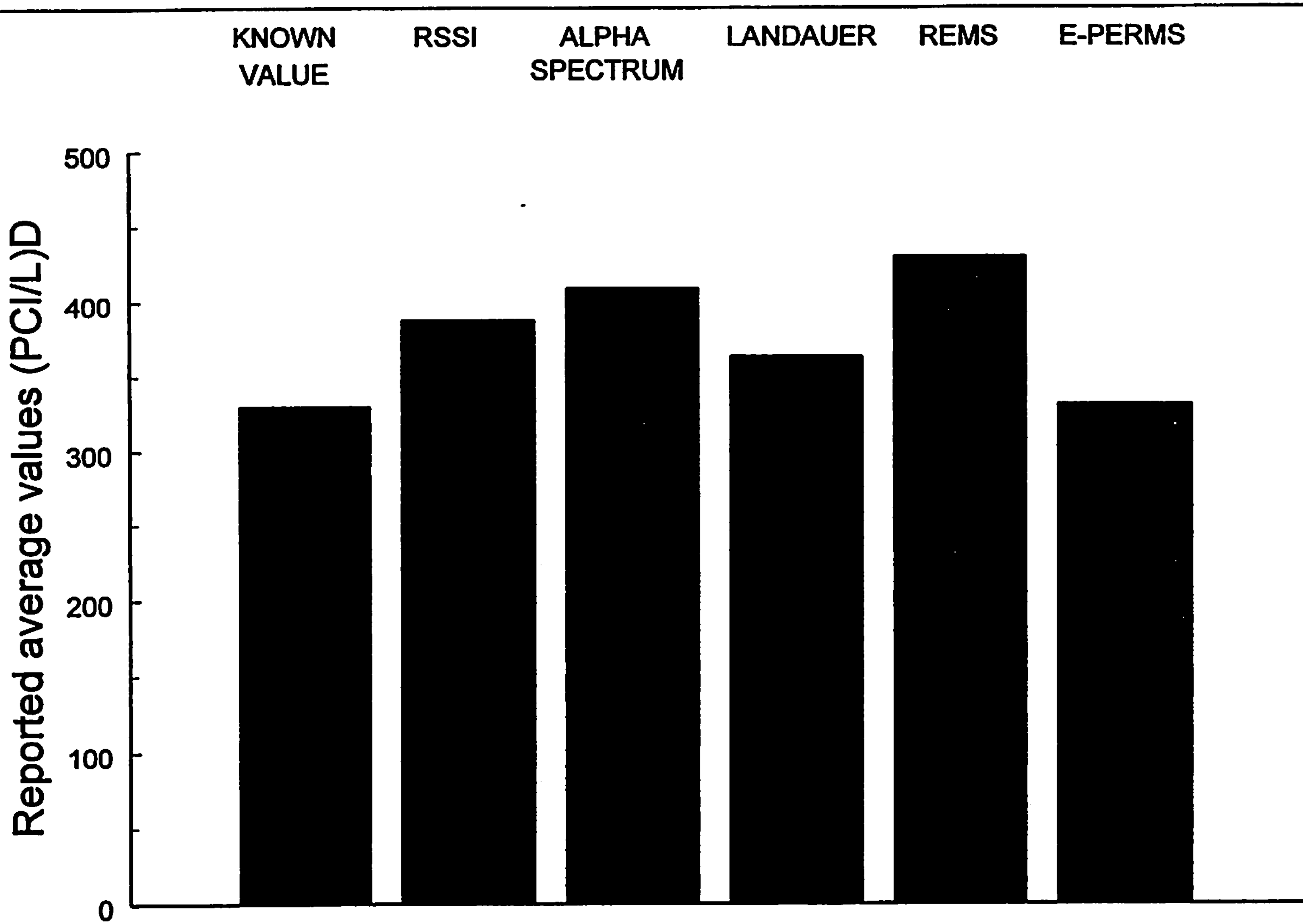

Fig. 3. Graphical depiction of results as reported from manufacturers.
15 minute exposure times followed by 120 minute fresh air periods.
Number of cycles = 136, total exposure = 329.4 pCi-d/l

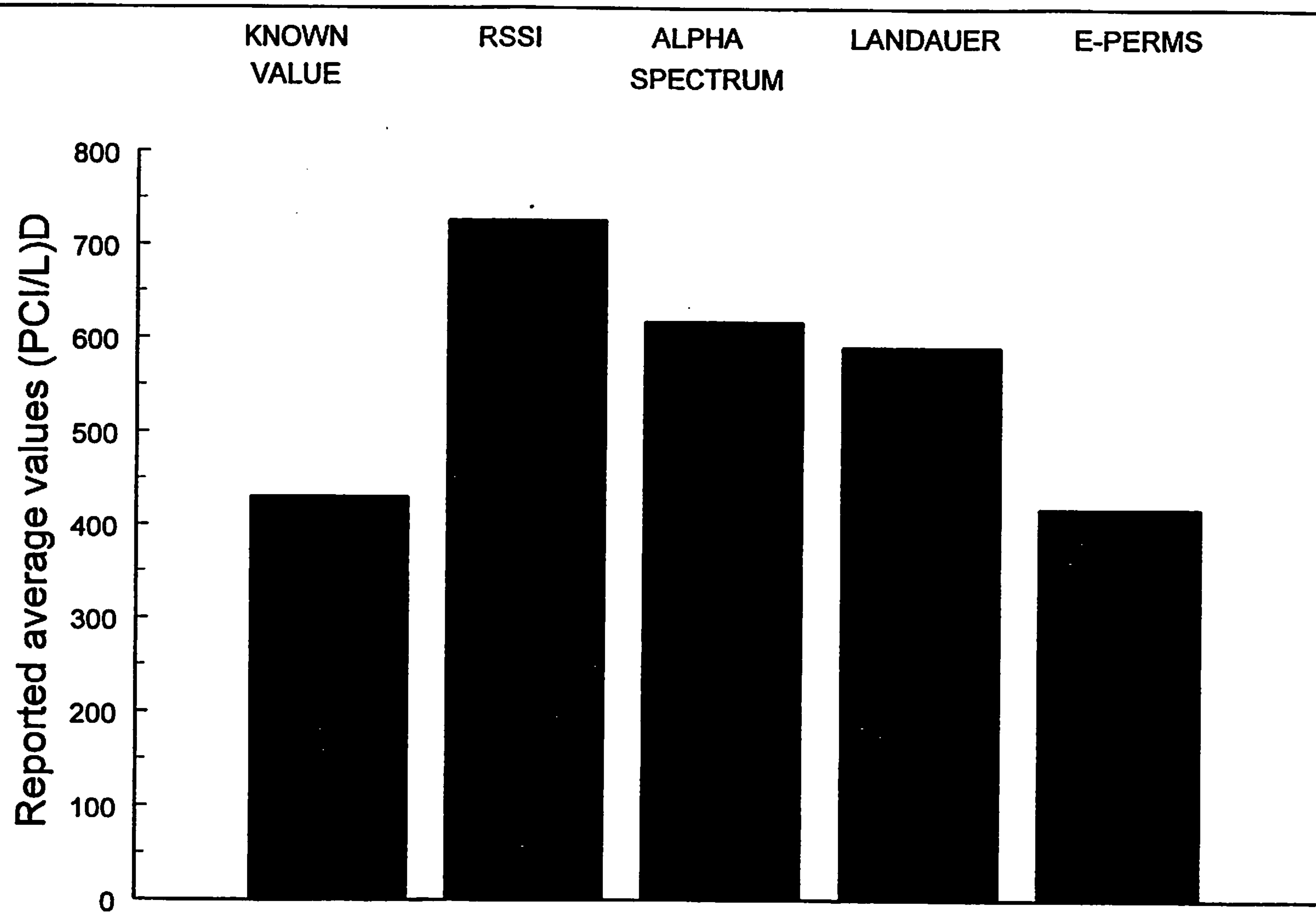

Fig. 4. Graphical depiction of results as reported from manufacturers.
60 minute exposure times followed by 120 minute fresh air periods.
Number of cycles = 43, total exposure = 429.8 pCi-d/l