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RESULTS OF THE NATIONWIDE SCREENING FOR RADON IN DOE BUILDINGS[1]

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ABSTRACT

The U.S. Department of Energy (DOE) conducted a nationwide screening of its buildings during the 1989-90 winter season in response to the Indoor Radon Abatement Act of 1988. Three-month radon measurements using alpha-track radon monitors were made in approximately 3,100 DOE buildings distributed among 74 administrative units, the goal of which was to identify occupied buildings at DOE sites with elevated radon concentrations. Radon-in-water samples were also obtained from approximately 120 non-public water sources distributed among 22 DOE sites.

The screening measurements identified 86 of 3,100 buildings with winter season radon concentrations exceeding 4 picocuries per liter ($pCi \cdot L^{-1}$). The geometric mean of the entire set of alpha-track measurements was 0.63 $pCi \cdot L^{-1}$, the arithmetic mean was 0.91 $pCi \cdot L^{-1}$, the geometric standard deviation was 1.89, and the highest reported measurement was 148.5 $pCi \cdot L^{-1}$. Results of the measurements in DOE buildings were considerably lower than those reported by Nero and others for U.S. residences (1). This difference may be due to the comparison of winter measurements versus Nero's annual average measurements or may be the result of higher ventilation rates in commercial buildings and other factors related to construction techniques, building use, or geographic distribution of DOE sites.

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INTRODUCTION

The U.S. Department of Energy (DOE) Indoor Radon Study was conducted in response to Public Law 100-551, the Indoor Radon Abatement Act, enacted by Congress on October 28, 1988. This law required each Federal department or agency to conduct a study to determine the extent of radon contamination in its buildings and to report the results to Congress by October 1, 1990.

Management responsibility for the DOE Indoor Radon Study was assigned to the DOE Office of Management and Administration (DOE-MA)[2]. DOE-MA selected the DOE Grand Junction Projects Office (GJPO) and its contractor, UNC Geotech[3], to implement the study. Work scope and milestones for the study were set by DOE-MA.

The DOE Indoor Radon Study was designed and implemented to conform with the recommended protocols and guidance of the U.S. Environmental Protection Agency (EPA) (2) for alpha-track screening measurements in buildings with heating, ventilating, and air conditioning (HVAC) systems operating in a normal manner.

The goal of the radon survey was identification of occupied buildings with elevated radon concentrations at DOE sites, and identification of DOE sites at which elevated radon concentrations might be suspected. Because limited resources and a limited number of monitors were available for this study, the choice was made to sample a large number of buildings at a low density of monitors instead of intensively sampling a few buildings.

METHOD

The Radtrak™ alpha-track radon monitor[4] was selected for the DOE Indoor Radon Study. Of the 6,000 monitors purchased for the study, approximately 5,700 monitors (including 500 monitors used for duplicate measurements) were deployed in the field at DOE sites and the remaining 300 monitors were used as exposed and unexposed controls. Radon measurements were performed during the winter season from mid-November 1989 to mid-February 1990. These 3-month measurements were performed under assumed normal building operating conditions.

Given a fixed number of monitors and a fixed number of DOE sites and buildings, the challenge was to determine the allocation of monitors that minimized the probability of false-negatives; i.e., an incorrect conclusion that all buildings at a given DOE site were below a 4-picocuries-per-liter ($pCi\ L^{-1}$) action level if in fact some were above 4 $pCi\ L^{-1}$. The primary

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[2]Later renamed the Office of Administration and Human Resource Management (DOE-AD) as a result of reorganization.

[3]UNC Geotech was acquired by Chem-Nuclear Environmental Services, Inc. in 1990 and was renamed Chem-Nuclear Geotech, Inc.

[4]Tech Ops Landauer, 3 Science Road, Glenwood, Illinois, 60425.

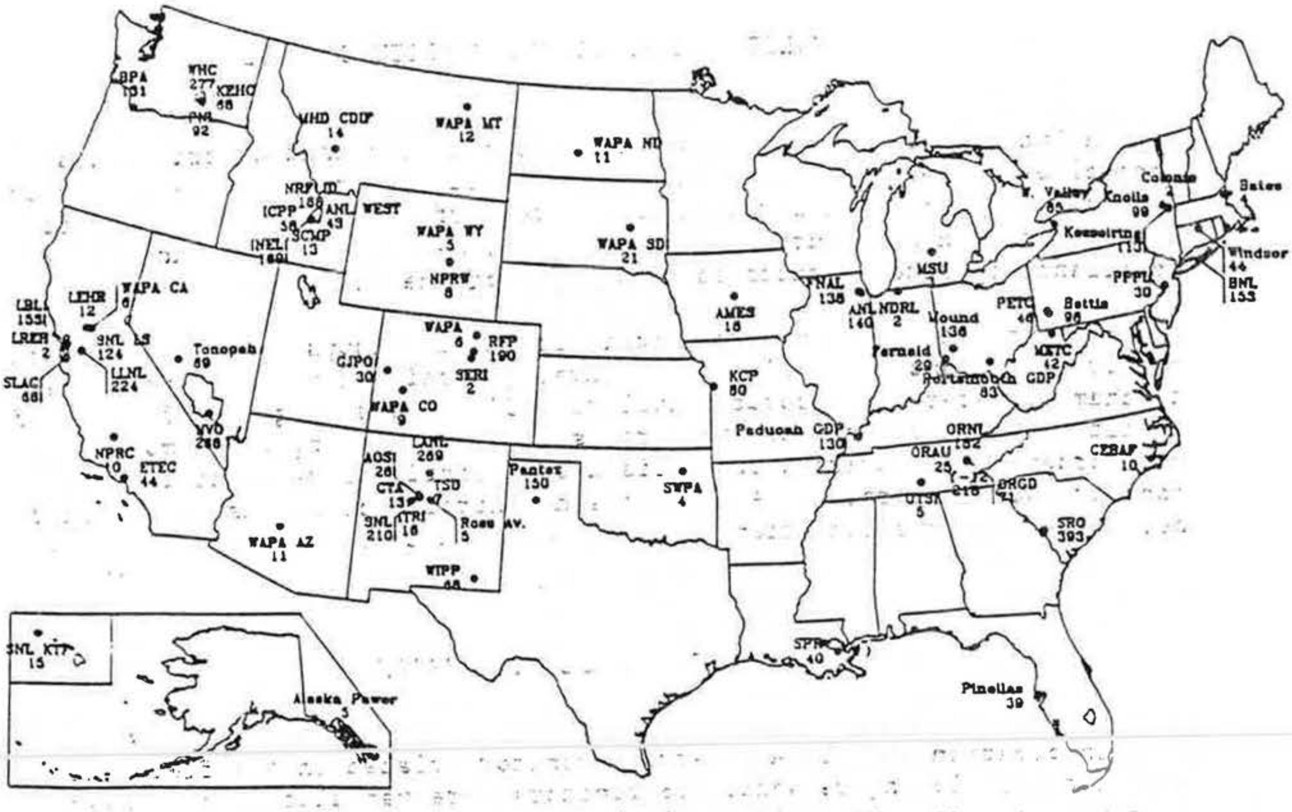
assumption made in determining this allocation was that the distribution of radon concentrations among DOE buildings was on the average similar to that published by Nero et al. (1), even though the Nero distribution was based on residences with typically lower building ventilation rates than those in commercial buildings. Using this distribution as a guide, and also assuming that a single radon monitor could be placed in a location in a building where the radon concentration was maximized, an algorithm was created for allocating the 5,700 field monitors among 74 administrative units that contained a total of 10,000 buildings. The number of radon monitors allocated to each DOE site is shown in Figure 1, as is the geographic distribution of those sites.

Allocation of monitors to specific buildings at a DOE site was left to the discretion of the site Point of Contact for the study. In most cases, these site contacts were personnel trained in health physics, many of whom had knowledge and experience in performing radon monitoring. Site contacts were advised to sample as many occupied buildings as possible with the number of monitors provided to them, while giving higher priority to buildings with greater potential radon concentrations and more occupants. Guidance was also provided for placing monitors within a building to sample areas representative of the highest radon levels likely to be found in the occupiable portions of the building, such as in basements, interior rooms on the lowest occupied level of the buildings, rooms isolated from a central HVAC system, and rooms at or near structural joints (adjacent slabs or building additions). Monitors were ultimately placed in approximately 3,100 DOE buildings.

The geographic distribution of the radon monitors across the country was by no means random. Due to the concentration of DOE facilities in certain regions, a preponderance of monitors were located in South Carolina, Tennessee, New Mexico, Idaho, Washington, and the San Francisco, California, area.

Water samples were obtained from non-public water supplies identified by the site Points of Contact. Approximately 120 water sources distributed among 22 sites were sampled in duplicate. Water samples were collected in 4-ounce glass bottles with Teflon™-lined caps following the guidance of the EPA's recommended test procedures for radon in drinking water (3). The samples were analyzed at the GJPO for radon concentration by a liquid scintillation counting technique.

Instructional materials were provided to each site for training and general information. A set of Implementing Instructions gave step-by-step instructions for selecting buildings for inclusion in the survey and for the placement of the alpha-track radon monitors. Water sampling instructions were provided to those sites requiring radon-in-water measurements. Copies of the DOE Indoor Radon Study Fact Sheet were distributed to each site. These fact sheets contained information about the study and described radon health risks and sources of radon. Additionally, a placard was placed with each monitor that identified the site contact person and the study project manager.



Legend

Acronym	Site Name
AMES	Ames Laboratory
ANL	Argonne National Laboratory – East
ANL WEST	Argonne National Laboratory – West
AOS	Albuquerque Office Site
Alaska Power	Alaska Power Administration
BNL	Brookhaven National Laboratory
BPA	Bonneville Power Administration
Bates	Bates Accelerator Facility
Bettis	Bettis Atomic Energy Laboratory
CEBAF	Continuous Electron Beam Accelerator Facility
CTA	Albuquerque Office Site, Central Training Academy
Colonie	Colonie Interim Storage Site (Formerly Utilized Sites Remedial Action Project)
ETEC	Energy Technology Engineering Center
FNAL	Fermi National Accelerator Laboratory
Fernald	Fernald Feed Materials Production Center
GJPO	Grand Junction Projects Office
ICPP	Idaho National Engineering Laboratory – Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory – EG&G
ITRI	Inhalation Toxicology Research Institute
KCP	Kansas City Plant
KEHC	Kaiser Engineers Hanford Company
Kesselring	Knolls Atomic Energy Laboratory – Kesselring
Knolls	Knolls Atomic Energy Laboratory – Knolls
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LEHR	Laboratory for Energy-Related Health Research
LLNL	Lawrence Livermore National Laboratory
LREH	Laboratory for Radiobiology and Environmental Health
METC	Morgantown Energy Technology Center
MHD CDIF	MHD Component Development Integration Facility
MSU	MSU Plant Research Laboratory
Mound	Mound Facility
NPRW	Naval Petroleum Reserves (Wyoming, Colorado, and Utah)
NDRL	Notre Dame Radiation Laboratory
NPRC	Naval Petroleum Reserves (California)
NRF IO	Idaho Naval Reactor Facility
NVO	Nevada Operations Office

Acronym	Site Name
ORAU	Oak Ridge Associated Universities
ORGD	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
PETC	Pittsburgh Energy Technology Center
PNL	Pacific Northwest Laboratory
PPPL	Princeton Plasma Physics Laboratory
Paducah GDP	Paducah Gaseous Diffusion Plant
Pantex	Pantex Plant
Pinellas	Pinellas Plant
Portsmouth GDP	Portsmouth Gaseous Diffusion Plant
RFP	Rocky Flats Plant
Ross Av.	Albuquerque Office Site – Ross Aviation
SCMP	Idaho National Engineering Laboratory – Specific Manufacturing Capabilities Project
SERI	Solar Energy Research Institute
SLAC	Stanford Linear Accelerator Center/ Stanford Synchrotron Radiation Laboratory
SNL	Sandia National Laboratories (Albuquerque Site)
SNL KTF	Sandia National Laboratories (Kauai Site)
SNL LS	Sandia National Laboratories (Livermore Site)
SPR	Strategic Petroleum Reserves
SRO	Savannah River Operations Office
SWPA	Southwestern Power Administration
TSD	Albuquerque Office Site, Transportation Safety Division
Tonopah	Sandia National Laboratories (Tonopah Site)
UTSI	University of Tennessee Space Institute
W. Valley	West Valley
WAPA	Western Area Power Administration
WAPA AZ	Western Area Power Administration – Phoenix
WAPA CA	Western Area Power Administration – Sacramento
WAPA CO	Western Area Power Administration – Montrose
WAPA MT	Western Area Power Administration – Fort Peck
WAPA ND	Western Area Power Administration – Bismarck
WAPA SD	Western Area Power Administration – Huron
WAPA WY	Western Area Power Administration – Loveland
WHC	Westinghouse Hanford Company
WIPP	Waste Isolation Pilot Plant
Windsor	Knolls Atomic Energy Laboratory – Windsor
Y-12	Y-12 Plant

Figure 1. Participating DOE Sites and Distribution of Monitors

QUALITY ASSURANCE AND QUALITY CONTROL

A Quality Assurance Program Plan was prepared that described quality-control exposures for alpha-track radon monitors and radon-in-water sample analyses. A number of surveillances were performed to verify laboratory compliance with procedures for handling alpha-track monitors and to verify compliance by site contacts for placement of the monitors.

Exposure of 252 alpha-track monitors in six groups in the GJPO radon calibration chambers resulted in an average ratio of vendor-reported exposure to chamber reference exposure equal to 0.89. The average coefficient of variation for these six control groups, each consisting of 42 monitors, was 9.4 percent. The average coefficient of variation for 470 field duplicate monitors was 13 percent. All unexposed controls, or blanks, reported results below the vendor's detection limit of 30 $pCi \cdot d \cdot L^{-1}$.

RESULTS AND DISCUSSION

Information for 107 alpha-track monitors placed in the field was lost for one of the following reasons: 16 monitors were vandalized or damaged, 76 monitors were physically misplaced and not returned by site contacts, and 15 monitors were incorrectly labeled by the vendor or the placement data sheets contained incorrect information that invalidated the data. Another 124 monitors were not placed by site contacts for a variety of reasons. Data were, therefore, successfully returned from 5,469 of the 5,700 monitors initially distributed.

Figure 2 shows the frequency distribution of the alpha-track radon measurement results, and Figure 3 is a histogram of the natural log of the measurement results. The geometric mean (GM) and geometric standard deviation (GSD) of these 3-month winter measurement data are 0.63 $pCi \cdot L^{-1}$ and 1.89 $pCi \cdot L^{-1}$, respectively, and the arithmetic mean (AM) is 0.91 $pCi \cdot L^{-1}$. In a compilation of annual average radon measurements made in U.S. homes, Nero et al. (1) calculated a GM of 0.96, a GSD of 2.84, and an AM of 1.66 $pCi \cdot L^{-1}$.

Eighty-six of the 3,100 measured buildings, or 2.8 percent, were found to exceed a 4 $pCi \cdot L^{-1}$ action level. The detection limit reported by the alpha-track vendor was 30 $pCi \cdot d \cdot L^{-1}$, which corresponds to a concentration of 0.3 $pCi \cdot L^{-1}$ for the 90-day exposure period recorded by the majority of monitors in this study. This means that monitors exposed to radon levels ranging from 0 to 0.3 $pCi \cdot L^{-1}$ all reported a value of 0.3 $pCi \cdot L^{-1}$. More than 14 percent of the DOE building measurements were below 0.3 $pCi \cdot L^{-1}$.

The DOE buildings measured in this study exhibited lower radon levels than the levels measured in U.S. homes by Nero. If the distribution of year-long average radon concentrations in DOE buildings was similar to Nero's distribution of annual average measurements, the 3-month winter screening measurements should show higher levels than measured by Nero. The

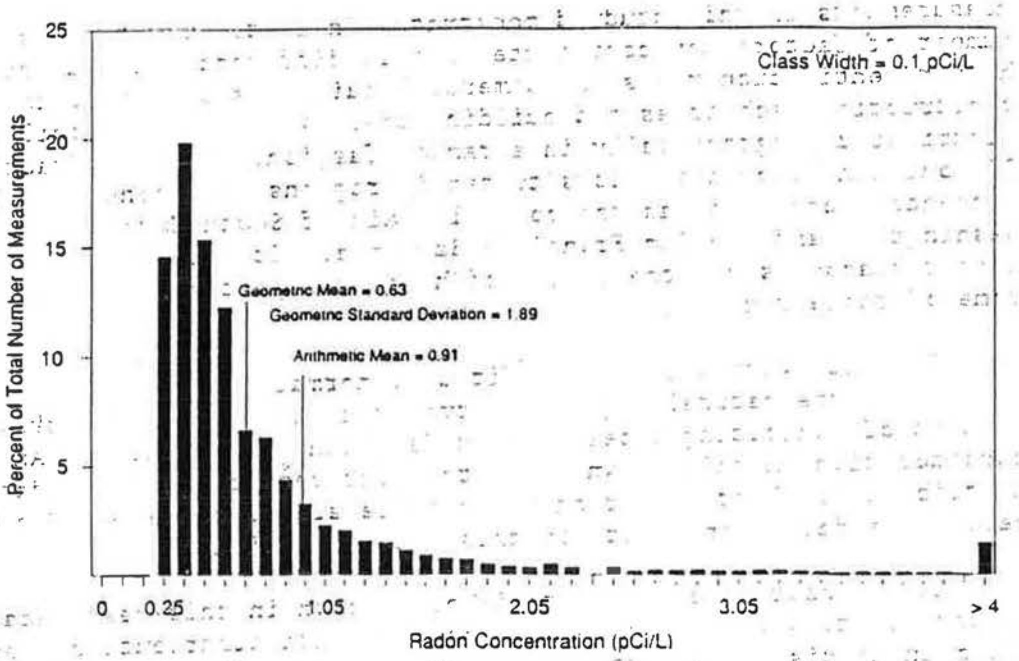


Figure 2. Histogram of the measurement results from the DOE Indoor Radon Study plotted as a percentage of the total number of measurements. The class width shown is 0.1 pCi/L, which represents the actual resolution available from the data. The arthmetic mean and geometric mean are given in pCi/L.

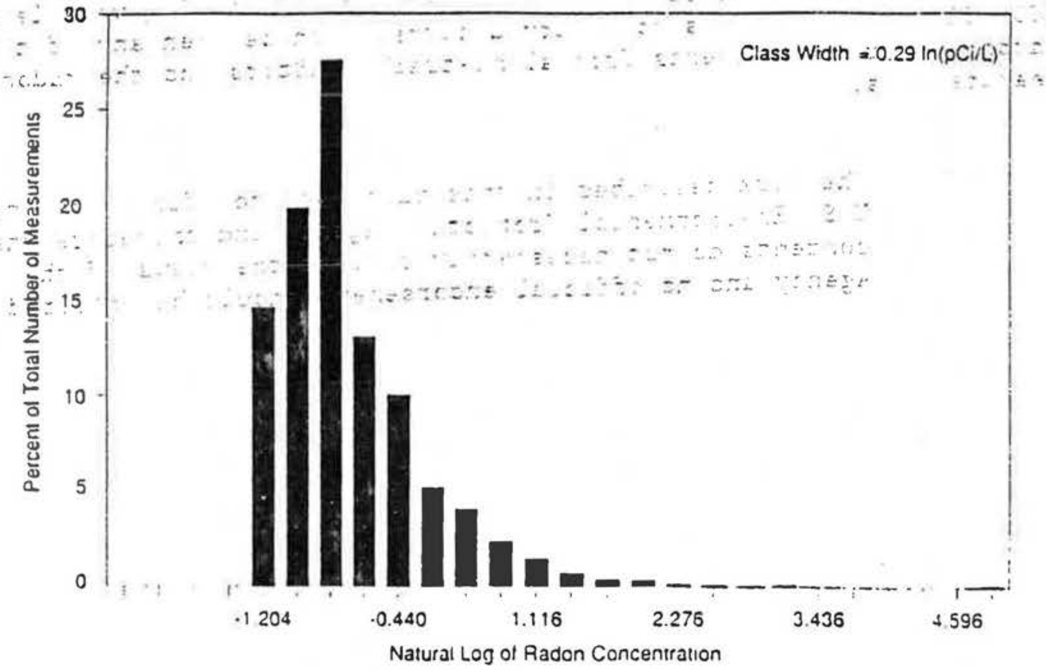


Figure 3. Histogram of the natural log of the measurement results from from the DOE Indoor Radon Study plotted as a percentage of the total number of measurements. The class width shown is 0.29 natural log of the radon concentration in pCi/L. This distribution shows a marked positive skewness.

measurements in this study demonstrate, in fact, just the opposite trend. A number of factors may contribute to this difference, including the typically higher ventilation rates in commercial buildings and other factors related to construction techniques and building use. Also, the DOE buildings were not distributed geographically in a random fashion. A large fraction of the DOE building population is situated in regions with generally low radon concentrations, such as the coastal plain of South Carolina, eastern Washington, and the San Francisco Bay area. It also may be possible that the winter season is not the season of highest expected radon concentration for some of these regions.

The data were expected to fit a lognormal distribution, but as Figure 3 indicates, the natural log-transformed data are apparently skewed to the right instead of exhibiting a bell-shaped Gaussian distribution. An important consideration in this skewness is the left censoring of the data in the distribution. Left censoring means there are no concentration values reported below some detection limit, in this case 0.3 $pCi \cdot L^{-1}$.

Left censoring of the data is of concern in this case because the censor point, 0.3 $pCi \cdot L^{-1}$, intersects the data distribution close enough to the mean to distort the observed distribution. The observed skewing of the distribution to the right may be the result of this left censoring. Left censoring of the data also shifts the observed mean of the data to a higher value.

Duplicate water samples were taken from 120 water-supply locations at 22 sites. The highest radon-in-water measurement was 1,460 $pCi \cdot L^{-1}$. Approximately two-thirds of the measurements, 82 of 120, were less than 200 $pCi \cdot L^{-1}$. There was no observed correlation between any of the elevated radon-in-air measurements from alpha-track monitors and the radon-in-water measurements.

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