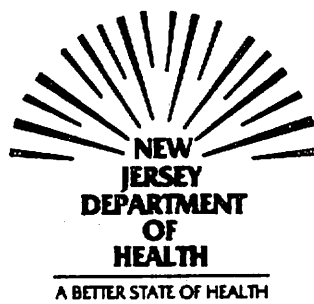


**MORTALITY EXPERIENCE OF RESIDENTS
EXPOSED TO ELEVATED INDOOR LEVELS
OF RADON FROM AN INDUSTRIAL SOURCE**



**ENVIRONMENTAL HEALTH SERVICE
DIVISION OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH
NEW JERSEY STATE DEPARTMENT OF HEALTH**

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Environmental Health Service
Division of Occupational and Environmental Health
New Jersey State Department of Health

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SUMMARY

Forty-five homes in Montclair, Glen Ridge, and West Orange, Essex County, New Jersey were documented in the winter of 1983-1984 to have indoor radon gas concentrations in excess of Federal and New Jersey guidelines. The neighborhoods of the 45 houses were originally monitored by the New Jersey Department of Environmental Protection and the U.S. Environmental Protection Agency because radium waste from a former radium processing plant had been found there.

Lung cancer, which usually is fatal, was the focus of a mortality study because it is the only disease known to be associated with radon exposure. This is a study of the mortality rates (death rates) of those who lived for at least a year in any of those homes. The time-frame for the study spanned several decades, beginning from the early 1920's and ending in 1983. Death certificates, which are public record with causes of death recorded in a standard format nationwide, were sought and analyzed. Residency histories, vital status and causes of death (if deceased) for all individuals who had ever lived in any of these 45 homes for at least one year were collected for the study. Data were collected for more than 90 percent of the persons in the study group. Standardized mortality ratios (SMRs) were calculated to compare the number of deaths observed in this study group with the number expected based on death rates of United States or New Jersey populations according to age, sex, race, time period, and causes of death.

A higher rate of death due to lung cancer was found for white males in the study group when compared to the expected death rate from lung cancer for white males in both the United States and in the New Jersey populations.

However, because of the small size of the study group, this difference is too small to rule out chance as a possible explanation. Furthermore, the inability to collect smoking histories or complete occupational histories prevents the consideration of smoking or occupation as contributors to the observed difference. Additionally, most of the lung cancer occurred among those white males who had lower indoor radon exposure than most others in the study group. Nevertheless, it is interesting to note that the degree of excess which is seen among white males is within the range predicted by the many occupational studies of lung cancer mortality among underground miners. For all other groups, no excess lung cancer was observed.

Other causes of death were also investigated, and are presented in the report. While various increases or decreases from the expected rates were observed, none of them appear to be causally related to radiation exposure.

Our study was initiated before the problem of naturally-occurring indoor radon was known to be widespread in the nation, and especially New Jersey. We now know that exposures from naturally-occurring sources are quite common and often exceed concentrations measured in most of the 45 study houses before they were remediated.

The outcome of this study does not suggest any changes in the existing health recommendations for indoor radon exposure. The current guidelines apply to both industrial and natural sources of radon. They are based on strong human data and have been used both statewide and nationwide. Indoor radon exposure from natural sources can present a serious hazard for the general population. The New Jersey Department of Health recommends that homes be tested for radon and that elevated levels in homes be reduced as low as is feasible.

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INTRODUCTION

In 1981, the New Jersey Department of Environmental Protection (NJDEP) arranged for an aerial survey of a portion of Essex County as part of a program to assess the extent of radiological contamination at industrial facilities that processed or utilized radioactive materials earlier in this century. It was believed that rubble and waste materials were discarded locally and that residences were built upon fill areas. Measurements obtained from the aerial survey revealed areas with gamma radiation levels over twice that of background. Subsequent gamma walk-throughs of the area were performed with particular attention to residential sections. Three areas were found to have radioactive material from industrial sources. Soil around and beneath the foundations of a number of residences was found to be contaminated with low levels of radium and its decay products. Of primary concern was a build-up of unacceptable levels of radon gas and radon decay products (radon progeny) inside houses built on the contaminated soil.

Radon gas, the immediate decay product of radium, can diffuse into houses from underlying soil. The decay products of radon gas are radioactive solid particles of lead, polonium and bismuth which can be inhaled. Once in the lungs, they decay further, emitting alpha radiation as well as beta and gamma radiation. The radiation released in this process contributes to an increased risk of lung cancer (NCRP, 1984; Radford, 1985; Thomas et al, 1985; National Research Council, 1988).

Initial grab sampling performed at residences located within the perimeter of the contamination problem included areas of the towns of Montclair, Glen Ridge and West Orange. Forty-five houses in these three towns were identified as having concentrations of indoor radon progeny

contamination over 0.02 working levels (WL)* with peak radon progeny concentrations up to 1.5 WL. Results of a preliminary health survey of residents in the affected areas in the winter of 1983-1984 found no excess incidence of lung cancer. Because the statistical power of this study was limited by the small number of residents in the survey (n=150), concerns about potential health hazards persisted and a more extensive study was designed. The historical cohort study described here was performed to ascertain whether the cancer mortality experience observed among residents of affected houses was different from that expected, based on the New Jersey and U.S. total and cause-specific mortality rates.

The basis for concern about health hazards of radon exposure is the vast and consistent occupational literature indicating an increased risk of lung cancer among hard-rock underground miners as a result of inhalation of the radioactive decay products of radon gas (NCRP, 1984; Radford, 1985; Thomas et al, 1985). There is little direct evidence of excess lung cancer risk in residential settings to date. A few case control studies have shown consistent results with the occupational data, but others have not; these case control studies are of limited power because they evaluated small numbers of cases or did not measure radon concentrations in homes of subjects (Edling et al, 1984; Axelson et al, 1979; Lees et al, 1987; Svensson et al, 1987).

* A working level is any combination of short-lived radon decay products which ultimately emits a specific quantity (1.3×10^5 million electron volts) of alpha radiation energy, in a liter of air.

A cohort design was selected for the current project because there was a well-defined number of homes documented to be affected with elevated radon gas concentrations. At the outset of the project, the estimated number of person-years of follow-up appeared to be large enough to provide some information on the boundaries of lung cancer risk from residential exposure, and could be used to determine whether residents of these forty-five homes experienced greater than expected rates of lung cancer mortality. Vital status and cause of death are used as surrogates for diseases which are rapidly fatal such as lung cancer. Available mortality statistics for the U.S. date back to 1925 and for New Jersey to 1955. Cancer incidence data for New Jersey, by contrast, has only been collected systematically since 1979.

METHODS

Population Definition. The study area included neighborhoods in Montclair, Glen Ridge and West Orange, New Jersey, which were found by the NJDEP in conjunction with the United States Environmental Protection Agency (USEPA) to have houses with indoor radon progeny levels above 0.02 WL. These levels were identified using carbon canister detectors for radon gas. Concentrations of radon decay products were subsequently confirmed using alpha scintillation detectors and radon progeny integrating sampling units (RPISUs). Persons eligible for the study cohort were those who lived in any of the forty-five affected houses from the dates of construction (1923 through 1962) to December 31, 1983, for one year or more. Eight-hundred and ten residents were found to be eligible (see Table 1); they were

predominantly white (86%). The immediate neighborhoods had a median household income of approximately \$20,000 (1980 U.S. Census summary). Persons entered the cohort at various times and contributed from one to fifty-five person-years of follow-up. Tables 1-15 summarize the demographic and exposure characteristics of the houses and population studied.

Data Collection Methods: Definition of Cohort at Risk. Tracing of individuals was facilitated by focusing on "family clusters" because information on other family members was usually available once one family member was traced. Additionally, once a household was identified, males were targeted for searches since they tended to be easier to trace than females (because of name changes occurring at marriage and/or divorce). City directories, which were available from the date of house construction (the earliest having been built in 1923) to the present day, provided the initial baseline data for identifying past residents of the affected homes. By searching through the directories' alphabetic listings of street names for house address, information available included: last, first and middle initial of occupant; residence status (owner; resides with householder); occupation; and place and name of employer. In some cases, information also included township or state to which residents moved; date and age of death; names of spouses for newlywed occupants; and information identifying newly widowed occupants. Detailed resident time lines were developed and reviewed. The directories were not published during particular years (e.g., during WWII); names of wives of male occupants apparently were not included in the publication until 1933; and names of occupant children were not listed until they were of employable age.

To identify household members not included in city directories (i.e., children below employable age, wives before 1933, extended family members, boarders, and servants), the NJDOH contracted with the Montclair Health Department to utilize available local resources including school records, voting records, funeral home and cemetery records, church and club records, local vital statistics records, local tax assessor records, and telephone directories. Interviews with former and current residents, their family members and neighbors were also conducted, as necessary. In addition, New Jersey State Vital Statistics records of births and marriages were utilized.

An investigator specializing in genealogy and tracing populations served as consultant to the study. Selected newspapers and the NJDEP Radium Cleanup Report published lists of names of 96 individuals whom we had had difficulty in tracing. An intense search of both in-state and out-of-state motor vehicle records was performed.

Data Collection Methods: Vital Status. The names of the cohort members were compared with a computer-generated list of names and dates of individuals who died in the towns of Montclair, Glen Ridge and West Orange from 1957 (the first year New Jersey deaths were computerized) through 1983. New Jersey death certificates were searched manually for years preceding 1957 for all names of cohort members whose vital status was in question. Copies of death certificates were obtained and examined to ensure correct match and to ascertain underlying cause of death. Over 90% of the death certificates of cohort members who died in other states or countries were obtained. Information sources utilized for determining residence status were also used, as appropriate, to assist in vital status and death certificate

searches. Underlying causes of death were coded by a trained nosologist according to the eighth revision of the International Classification of Diseases (ICD).

Analysis of Mortality Data. The analysis of mortality outcomes was conducted using standardized mortality ratios (SMR), with the U.S. population (1925-1983) and New Jersey population (1955-1983) as the comparison groups. The mortality rates for the comparison groups were derived from data compiled by the National Center for Health Statistics. The analyses were conducted using the SMR program of Richard Monson (1986). The program compares the observed number of deaths, by specific cause of death, to the sum of the age-adjusted "expected number" of the study population. The expected number is based on the rate of death for each cause in the comparison population (U.S. population or N.J. population) according to specific age groups, race, and sex. In addition, the specific years that each person in the study group is being followed is taken into account, since mortality patterns from different causes have varied greatly over time. This complex program enables all persons to be followed for various durations so that they contribute to the study a number of "person-years" proportional to their length of follow-up. (A few disease categories can only be analyzed for certain decades, as indicated in the tables.)

Exposure Indices. Mining studies and hazard assessments of radon have shown the preeminence of cumulative inhalation of radon as a predictor of degree of risk. Cumulative dose was estimated in this study by multiplying the average concentration of radon progeny by the number of years of residency.

This surrogate exposure variable was analyzed and constructed as follows:

- 1) Average annual radon progeny concentrations inhaled during residence in the index houses were estimated by calculating the mean of all working level measurements on the first living floor of the home before any remediation measures were taken. The measurements were made by EPA at three month intervals for up to three years. The number of measurements for each house varied from one to ten. The duration of these measurements was approximately five days.
- 2) Excess cumulative exposure in WLM* from the index residence was estimated as:

$$\text{Number of residence years} \times 40 \times (\text{Average WL} - 0.005)$$

The 0.005 WL subtracted here is assumed to be the background concentration to which the U.S. population is typically exposed indoors. Data collected by NJDEP as of October 1987 indicates that the typical basement concentration of radon in Essex County homes is about 1.3 picocuries per liter, corresponding to 0.0065 WL, assuming a 50% equilibrium between radon and its decay products.

* WLM denotes "working level months," a unit adopted from mining exposures. The factor 40 WLM/WL per year is used for residences although there would be 12 WLM/WL per year in mines. Forty is substituted for twelve because it is assumed that more hours are spent at home than at work per year. If 75% of time is spent at home and 35 hours per week at work, the ratio of hours at home to hours at work is about 40/12.

- 3) For calculation of an "attributable risk coefficient," both exposure and person-years at risk were lagged by five years based on the assumption that the latency of radiogenic cancer is at least five years (Hornung, 1986; NRC, 1988). This calculation is intended to estimate the carcinogenic strength of radon in the residential setting in comparison to former human (occupational) studies, and is discussed below.

Tables 2-13 present demographic and exposure characteristics of the cohort. Tables 14 and 15 show the distribution of construction year and radon progeny concentration for the 45 residences.

RESULTS

Comparisons of Study Cohort with United States Population, 1925-1983

Compared to the U.S. population rates for 1925-1983, the study cohort did not show an overall excess of deaths of cancers or, specifically, of lung cancer. Mortality findings in subgroups are described below (See Tables 16-19.)

For white males (n = 321) the ratio of observed to expected deaths for all causes is significantly lower than expected (SMR = 0.82, 95% confidence interval (C.I.) = 0.67-0.99). Malignancies of all sites combined were about equal to expected. The hypothesized effect of radon exposure (cancer of the lung) was not significantly elevated, (SMR = 1.5, 95% C.I. = 0.71-2.72). This SMR is not statistically significant because the interval

includes one. Cancers of the rectum and skin had SMRs over 2.0 but these were based on small numbers and were not statistically significant (95% C.I.s were 0.70-10.1 and 0.57-18.3 respectively). Non-malignant respiratory diseases were significantly decreased (95% C.I. = 0.07-0.98). There were only 45 non-white males in the cohort; the one death in this group was due to arteriosclerotic heart disease.

Among white females neither the total nor the cause-specific SMRs were significantly different from expected. Total cancers, but not lung cancer, were somewhat elevated. Rectal cancer was elevated but not significantly (there were only two cases in this category). Heart disease mortality occurred somewhat more frequently than for the U.S. population. There were 62 non-white females in the cohort. The three deaths in this group were not due to respiratory cancer.

Comparison of Study Cohort with New Jersey and U.S. Populations, 1955-1983

The mortality rates from all causes and all malignancies were more elevated for the 1955-1983 New Jersey SMRs than for U.S. comparisons, especially for white females (Tables 20-23). For white males, the excess in lung cancer was somewhat more marked (SMR = 1.73), and for white females, total mortality and mortality from circulatory disease (especially ischemic heart disease) were significantly high, and deaths due to diabetes were more pronounced. Deaths due to cerebrovascular disease were in excess in both males and females. It may be noted that while the first three decades of observation (1925-1955) added a substantial number of person years and,

therefore, expected deaths, relatively few observed deaths occurred before 1955 in the study population. For comparison with the New Jersey ratios, U.S. ratios 1955-1983 were generated (Tables 24-27) and found to be generally between those using U.S. 1925-1983 and New Jersey 1955-1983 as comparisons.

Exposure Subgroups

The impact of exposure was evaluated in three ways. A preponderance of a excess cases in a higher exposure group would support hypotheses that radon decay products were a causal factor. First, to examine whether the higher exposure groups also had higher death rates, the white male and white female populations were divided into two exposure groups. A subcohort was selected with exposures greater than 10 WLM above what would be expected from background exposures. (Non-whites were not analyzed further because of small numbers.) U.S.-based SMRs for these groups are shown in Tables 28A and B. In view of the similarity of age-structures between the high-exposure subgroup and the entire cohort (Table 29), comparison of this SMRs is statistically permissible.

SMRs were also calculated for subgroups according to two other exposure indices. They are: 1) exposure intensity: those who resided in homes with radon progeny concentrations equal to or greater than 0.04 WL average on the first floor and, 2) length of residency: those who resided in the index houses for more than 10 years. These analysis did not show any greater SMRs for all causes or from any specific cancer, including lung cancer, in subgroups with higher radon exposure.

DISCUSSION

Hypothesis testing: lung cancer

Our only a priori hypothesis was that excess radon exposure causes increased mortality from lung cancer. Several factors which make such an association difficult to detect in this study include the relatively small number of subjects,* the absence of smoking data, the absence of complete occupational histories, and the relatively high frequency of lung cancer as a cause of death in the general population.

In an attempt to evaluate occupation, the brief occupational titles which were available from death certificates (26% of the cohort) and city directories (28%) were compared and found to be consistent in 81% of the instances where both of these sources were present for the same individual. When the occupational titles of the male lung cancer cases were compared with those of a sample of other males, no important difference between these titles was apparent:

Smoking information was available on only 25% of the cohort: 9% were known smokers, and 16%, nonsmokers. It should be noted that a multiplicative or submultiplicative interaction of radon and smoking has been proposed (NAS, 1988) suggesting that the majority of lung cancers in which radon is a contributing cause may occur in smokers.

* Statistical power to detect a significant excess was known to be low. For example, assuming a mean excess exposure of 35 WLM, a 3% excess relative risk per WLM, and less than 0.5% incidence of lung cancer in the standard population for most of the observation period, over four thousand subjects would be required for 80% power to detect a relative risk of 2.0 with a two-sided alpha of 10%. We had 80% power to detect only a four-fold relative risk in the population being studied (Schlesselman 1974).

It was also not possible to account for several important exposure variables, since the necessary information was unavailable for all or a substantial portion of the cohort. Among such factors are variations in proportion of time spent at home by men, women, and children; changing patterns of home construction, insulation, and heating; and contributions of other radiation from outside the body or from ingestion. In addition, the surrogate exposure variable is a very rough estimate of actual radiation dose.

SMRs with U.S. 1925-1983 as comparison were also generated with a 10 year lag between first year of residence and first year at risk, in accordance with the widely held assumption of 10 year latency for induction by radiation of most cancer, but no substantial differences from the non-lagged SMRs were seen.

Hypothesis generating: Other Cancers, Causes of Death other than Cancer

In addition to testing the hypothesis of an association of lung cancer and radon exposure, the methods used for data collection, preparation, and analysis in this study also permitted comparisons of observed and expected mortality for many other causes of death and for all causes combined in the same cohort. Small numbers of individuals and multiple comparisons greatly increase the likelihood of false positive outcomes for causes other than lung cancer, so such hypothesis-generating results must always be viewed as extremely tentative and as suggestive of areas for further consideration rather than as indicators of causality.

Among white females, excess heart disease accounted for most of the excess mortality, but these observations were consistent with the variations and trends among statewide and Essex County mortality rates for heart disease between 1950 and 1970.

Rectal cancer was the only cause of death which was observed in greater numbers than expected for both males and females of the cohort. Diverse labeling and diagnostic practices for lower digestive tract cancers of the "large intestine," "colon" and "rectum" suggest combining these rubrics for further analysis (Schottenfeld and Winawer, 1982). Interestingly, four of the twelve affected people lived in the same residence at various times but were not genetically related. This house had only moderate radon progeny levels (0.03 WL). A major causal factor in these cancers is believed to be diet (Schottenfeld and Winawer, 1982), and radiation has been previously linked to colorectal cancer only when massive doses were given to the pelvic area, as radiation therapy for cancer at another site. Neither dosimetric, experimental, nor epidemiologic considerations therefore suggest a plausible causal link between substantial excess colorectal cancer and radon exposure (Sandler and Sandler, 1983; Polednak et al, 1978). Further, New Jersey as well as the southern part of New York state have among the highest rates of colorectal cancer in the U.S. (Schottenfeld and Winawer, 1982). The New Jersey Department of Health previously published cancer mortality rates for the State, its counties, and its municipalities for the year 1949-1976 (New Jersey State DOH, 1981). That compilation did not indicate that the towns of Montclair, Glen Ridge and West Orange had unusually high rates of colon or rectal cancer mortality during this period with respect to Essex County. However, Essex county ranked high during the years 1950-1969 for mortality from these sites among both white males and females. Again, a regional pattern is suggested. Nevertheless, it is notable that when male and female colorectal cancer cases were pooled for

the study population, a statistically significant excess was seen. In light of the absence of supporting theory or data and the lack of dose-related effect when exposure groups were examined separately, a causal association with radon does not appear to be indicated.

The overall SMRs found for the non-white males and females were both low. Comparison of the white and non-white segments of the cohort indicate that the latter were younger, had longer residency durations in the index houses, and were more likely to be owners of their homes (Table 30). Other parameters such as percentage of follow-up and year their home was constructed are comparable.

We may speculate that differences in mortality ratios when only outcomes in the years 1955-1983 are included may be due to a selection bias in observing a group of individuals immediately after they moved into a newly built house. We may surmise a phenomenon, analogous to the "healthy worker effect" (which operates especially strongly at the inception of employment) whereby people who have just bought a house may well represent a particularly healthy segment of the population.

Risk Estimates for Lung Cancer per Unit Dose

Although the number of lung cancers observed in the white males do not constitute a statistically significant excess, a calculation of excess risk per unit exposure of radon progeny was performed to compare the extent of excess lung cancers per WLM in this subpopulation with the findings of mining studies (NCRP, 1984; Thomas et al, 1985; Solli et al, 1986; Radford and St Clair Renard, 1984; NRC, 1988). These occupational studies, consisting of male workers of various nations, yielded "absolute" risk

coefficients of radon potency between five and fifty additional cases of lung cancer per million person years (PY) at risk for each WLM of exposure by the population of risk. They yielded relative risk coefficients of between 1% and 4% excess lung cancer per WLM.

For this cohort, the absolute risk coefficient is calculated as follows, using a five-year minimum lag between exposure and outcome. For females, since no excess in lung cancer was seen, only the 95% upper confidence limit could be calculated.

Number Excess Cases X Number Individuals Contributing to PY at Risk

Total (lagged) excess WLM x Total (lagged) PY at risk

The coefficient found in this study was 13 excess lung cancer cases per million person-years per WLM based upon U.S. rates and 23 cases per million for New Jersey (1955-1983) rates (Table 31). These coefficients are within the range of previously generated estimates.

For the U.S. comparison, the upper bound of the absolute risk coefficient in males is thus 44 cases per million persons per WLM, while for the New Jersey comparison it is 69 per million persons per WLM. The upper bounds for females are 10 and 16 excess cases per million person-years per WLM, respectively (Table 31).

The recently published report on radon of the National Academy of Sciences, "BEIR IV", supports a proportional excess risk model whereby males, who have a greater baseline risk of lung cancer than females, also accrue greater excess risks than females as a result of equivalent radon exposures.

Previous ranges of relative risk estimates for lung cancer have ranged from one to four percent per WLM: the BEIR committee estimates that figure to be about 2.5%. The 95% confidence intervals and point estimates of excess risk extrapolated from the current study are shown in Table 32. It is consistent with BEIR IV in that the upper limits of percent increase risk per WLM are approximately equal for males and females, while the "absolute" coefficients are much greater in males than in females.

The occurrence of most excess lung cancer cases in males among those with low exposure weakens any conclusions which can be drawn. While some houses were originally found to have radon gas and radon decay product concentrations greatly in excess of the federal and state guidance levels of 4 pCi/L and 0.02 WL, the cumulative exposures of most members of the cohort were not dramatically high. In many hard rock mines, and in many New Jersey homes with elevated naturally-occurring radon, the concentrations often surpassed that of the study houses by an order of magnitude. For example, less than half of the cohort accumulated more than 10 WLM (including background) during their residency in the study houses; 10 WLM is probably typical of most lifetime exposures for U.S. residents during 50 years. Further, almost 36% of the cohort resided in houses with average concentrations less than 0.02 WL, the usual level at which remediation is suggested.

The original categories of exposure created by federal and state agencies for use in decision-making on remediation priorities in Essex County do not necessarily correspond to the exposure index used in this study; the former categories ("Tiers A, B, & C") were based on the measurement of highest radon concentration at any location in the home,

while the present study uses an average of the measurements made in living areas which represent more realistic estimates of the amount of radionuclides inhaled by residents on a long-term basis.

Methodological Conclusions

The identification and follow-up of all or most of the potential subjects is an important aspect of any cohort study. Tables 1 and 33 illustrate the degree to which identification and follow-up were estimated and achieved for in this investigation.

Although the design of this study did not include a specific component to evaluate the success of the various resources used in tracing individuals, there were four resources which proved to be of the greatest utility:

1. City directories - Approximately half of the individuals found to be eligible in the cohort were identified by searching Price and Lee City Directories. The directories often served to provide follow-up clues on individuals by providing information on place of employment and town/state of relocation.
2. Local records - Most important in this category were local vital statistics records, school records, funeral home records, cemetery records and telephone directories. School records were of special importance to us since children were not listed in city directories until they were of employable age. Search of these local records assisted us in identifying an additional 10% of the study population.

3. Telephone and personal interviews - Questionnaire mailings proved to be of limited value. Telephone and personal interviews were more useful and there was excellent participant cooperation. To clarify conflicting data or to obtain complete information, it was often necessary to re-contact individuals. This also served as a useful check of data consistency. Information obtained from these conversations were validated by comparison with other available records whenever possible.

Consultant with expertise in genealogy - A private consultant who specialized in genealogy was successful in tracing 72% (69/96) individuals who were otherwise designated as lost to follow-up, thereby increasing the percent of follow-up from less than 85% to over 90%. We strongly recommend that personnel with expertise in genealogy be involved from the start in any similar study.

CONCLUSIONS

In summary, despite limitations, the results of this cohort investigation, particularly the attributable and relative risk estimates, are not inconsistent with previous epidemiologic studies of radon exposure with regard to lung cancer excesses. This study is pertinent to radon exposure from both naturally occurring and industrial sources. No change in the state and federal guidelines and actions regarding preventing human exposures to radon appears to be indicated.

Table 1

FOLLOW-UP OF COHORT

Number in cohort	810 (100%)
Number without analyzable data	58 (7%)
Number analyzable by SMR program	752 (93%)
Vital Status unknown as of 1983	8 (1%)
Number with complete follow-up	744 (92%)

COHORT DESCRIPTION

TABLE 2

SEX

	Number	Percent
MALE	366	48.7
FEMALE	386	51.3
TOTAL	752	100.0

TABLE 3

RACE

	Number	Percent
WHITE	645	85.8
BLACK	106	14.1
OTHER	1	.1
TOTAL	752	100.0

TABLE 4

TOWN OF RESIDENCE

	Number	Percent
GLEN RIDGE	216	28.7
MONTCLAIR	464	61.7
WEST ORANGE	72	9.6
TOTAL	752	100.0

TABLE 5

YEAR HOME WAS CONSTRUCTED

	Number	Percent
1923-1929	573	76.2
1930-1939	104	13.8
1940-1949	22	2.9
1950-1959	37	4.9
1960-1980	16	2.1
TOTAL	752	100.0

Mean = 1930

Median = 1927

COHORT DESCRIPTION

TABLE 6

YEAR OF BIRTH

	Number	Percent	Cum Percent
1857 - 1872	10	1.3	1.3
1873 - 1892	55	7.3	8.6
1893 - 1912	180	23.9	32.6
1913 - 1932	225	29.9	62.5
1933 - 1952	179	23.8	86.3
1953 - 1972	83	11.0	97.3
1973 - 1982	20	2.7	100.0
	-----	-----	
TOTAL	752	100.0	
Mean - 1925			Median - 1925

TABLE 7

VITAL STATUS AS OF Dec. 31, 1983

	Number	Percent
LIVE	537	71.4
DEAD, CERTIFICATE RECEIVED	204	27.1
DEAD, CERTIFICATE UNAVAILABLE	3	.4
STATUS UNKNOWN	8	1.1
	-----	-----
TOTAL	752	100.0

TABLE 8A

RESIDENCY: YEAR COMMENCED

	Number	Percent
1923 - 1939	264	35.0
1940 - 1959	280	37.0
1960 - 1983	208	28.0
	-----	-----
TOTAL	752	100.0

COHORT DESCRIPTION

TABLE 8B

RESIDENCY: LENGTH

Years	Number	Percent	Cum Percent
1 - 9	458	60.9	60.9
10 - 19	146	19.4	80.3
20 - 29	112	14.9	95.2
30 or greater	36	4.8	100.0
	-----	-----	
TOTAL	752	100.0	

Mean = 10.4 yrs. Median = 6.0 yrs.

TABLE 9

OWNER OR TENANT

	Number	Percent
OWNER	481	64.0
TENANT	214	28.5
UNKNOWN	57	7.6
	-----	-----
TOTAL	752	100.0

TABLE 10

PERSON YEARS OF FOLLOW-UP

	Number	Percent
0 - 9	137	18.2
10 - 19	146	19.4
20 - 29	155	20.6
30 - 39	159	21.1
40 or greater	155	20.6
	-----	-----
TOTAL	752	100.0

Mean = 25.2 yrs. Median = 26.0 yrs.

COHORT DESCRIPTION

TABLE 11

RADON PROGENY CONCENTRATION
AVERAGE FIRST FLOOR MEASUREMENTS

Working Levels	Number	Percent
Less than 0.02	271	36.0
0.02 - 0.09	288	38.3
0.1 - 0.47	193	25.7
	-----	-----
TOTAL	752	100.0
Mean	= 0.078 WL	Median = 0.03 WL

TABLE 12

SMOKING DATA AVAILABLE

	Number	Percent
SMOKER	54	7.2
EX-SMOKER	13	1.7
NONSMOKER	123	16.4
NO INFO AVAIL	562	74.7
	-----	-----
TOTAL	752	100.0

TABLE 13

CUMULATIVE RADON EXPOSURE:
WORKING LEVEL MONTHS FROM ESSEX COUNTY RESIDENCE

Cumulative WLM	Number	Percent	Cum Percent
Less than 10	378	50.3	50.3
10 - 19	100	13.3	63.6
20 - 39	91	12.1	75.7
40 - 59	49	6.5	82.2
60 - 99	53	7.0	89.2
100 - 199	53	7.0	96.3
200 - 299	20	2.7	98.9
300 - 999	8	1.1	100.0
	-----	-----	
TOTAL	752	100.0	
Mean	= 38.3 WLM	Median	= 9.6 WLM

TABLE 14

STUDY HOMES:
YEAR OF CONSTRUCTION

	Number	Percent
1923 - 1929	24	53.3
1930 - 1939	9	20.0
1940 - 1949	3	6.7
1950 and later	9	20.0
	-----	-----
TOTAL	45	100.0

TABLE 15

STUDY HOMES:
RADON PROGENY CONCENTRATION
AVERAGE FIRST FLOOR MEASUREMENTS

Working Level	Number	Percent
Less than 0.02	14	31.1
0.02 - 0.09	18	40.0
0.1 - 0.47	13	28.9
	-----	-----
TOTAL	45	100.0

TABLE 16

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
WHITE MALES - N = 321
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1925-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	111	135.50	0.82	0.67	* 0.99
MALIGNANT NEOPLASMS	24	24.25	0.99	0.63	1.47
CANCER OF BUCCAL CAVITY AND PHARYNX	0	0.74	0.00	0.00	4.99
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	8	7.51	1.07	0.46	2.10
-CANCER OF ESOPHAGUS	1	0.56	1.79	0.02	9.94
-CANCER OF STOMACH	0	1.65	0.00	0.00	2.23
-CANCER OF LARGE INTESTINE	3	2.37	1.27	0.25	3.71
-CANCER OF RECTUM	3	0.87	3.46	0.70	10.12
-CANCER OF LIVER	0	0.59	0.00	0.00	6.19
-CANCER OF PANCREAS	0	1.30	0.00	0.00	2.81
CANCER OF RESPIRATORY SYSTEM	10	7.20	1.39	0.67	2.56
-CANCER OF LARYNX	0	0.35	0.00	0.00	10.49
-CANCER OF LUNG	10	6.77	1.48	0.71	2.72
CANCER OF BONE	0	0.14	0.00	0.00	25.81
CANCER OF SKIN	2	0.39	5.07	0.57	18.32
CANCER OF PROSTATE	2	2.21	0.91	0.10	3.27
CANCER OF BLADDER	1	0.87	1.14	0.01	6.36
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.58	0.00	0.00	6.30
CANCER OF THYROID	0	0.04	0.00	0.00	81.68
LYMPHOPOIETIC CANCER	0	2.26	0.00	0.00	1.62
INFECTIOUS AND PARASITIC DISEASES	0	3.16	0.00	0.00	1.16
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	1	1.99	0.50	0.01	2.79
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	0	0.44	0.00	0.00	8.42
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	1	1.29	0.78	0.01	4.32
OTHER DISEASES OF CIRCULATORY SYSTEM	70	70.81	0.99	0.77	1.25
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	48	45.03	1.07	0.79	1.41
VASCULAR LESIONS OF CNS	10	10.83	0.92	0.44	1.70
OTHER RESPIRATORY DISEASES	3	8.93	0.34	0.07	** 0.98
OTHER DISEASES OF DIGESTIVE SYSTEM	4	6.06	0.66	0.18	1.69
OTHER DISEASES OF GENITO-URINARY SYSTEM	1	2.75	0.36	0.00	2.03
OTHER DISEASES OF THE BONES AND ORGANS OF MOVEMENT	0	0.21	0.00	0.00	17.22
EXTERNAL CAUSES OF DEATH	3	11.79	0.25	0.05	0.74

* 95% CONFIDENCE LIMIT DOES NOT INCLUDE 1.00, POISSON $X^2 = 4.43$ 1 d.f. p = 0.04

** 95% CONFIDENCE LIMIT DOES NOT INCLUDE 1.00, POISSON $X^2 = 3.30$ 1 d.f. p = 0.07

TABLE 17

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
WHITE FEMALES - N = 324
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1925-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	92	84.75	1.09	0.88	1.33
MALIGNANT NEOPLASMS	21	18.46	1.14	0.70	1.74
CANCER OF BUCCAL CAVITY AND PHARYNX	1	0.23	4.38	0.06	24.37
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	5	5.45	0.92	0.30	2.14
-CANCER OF ESOPHAGUS	0	0.15	0.00	0.00	24.00
-CANCER OF STOMACH	0	0.88	0.00	0.00	4.15
-CANCER OF LARGE INTESTINE	3	2.23	1.35	0.27	3.93
-CANCER OF RECTUM	2	0.57	3.50	0.39	12.65
-CANCER OF LIVER	0	0.61	0.00	0.00	5.98
-CANCER OF PANCREAS	0	0.84	0.00	0.00	4.35
CANCER OF RESPIRATORY SYSTEM	1	1.66	0.60	0.01	3.35
-CANCER OF LARYNX	0	0.04	0.00	0.00	85.78
-CANCER OF LUNG	1	1.58	0.63	0.01	3.52
CANCER OF BONE	0	0.10	0.00	0.00	38.15
CANCER OF SKIN	0	0.24	0.00	0.00	15.47
CANCER OF BREAST	2	3.72	0.54	0.06	1.94
CANCER OF CERVIX UTERI	1	0.71	1.41	0.02	7.87
CANCER OF CORPUS UTERI	2	0.62	3.20	0.36	11.56
CANCER OF BLADDER	1	0.29	3.49	0.05	19.41
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.40	0.00	0.00	9.27
CANCER OF THYROID	0	0.07	0.00	0.00	53.54
LYMPHOPOIETIC CANCER	2	1.51	1.32	0.15	4.78
INFECTIVE AND PARASITIC DISEASE	0	1.82	0.00	0.00	2.01
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	4	2.17	1.85	0.50	4.73
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	1	0.37	2.68	0.04	14.93
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	1	0.94	1.06	0.01	5.91
OTHER DISEASES OF CIRCULATORY SYSTEM	51	43.23	1.18	0.88	1.55
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	29	21.83	1.33	0.89	1.91
VASCULAR LESIONS OF CNS	11	9.75	1.13	0.56	2.02
OTHER RESPIRATORY DISEASES	2	4.04	0.50	0.06	1.79
OTHER DISEASES OF DIGESTIVE SYSTEM	1	3.61	0.28	0.00	1.54
OTHER DISEASES OF GENITO-URINARY SYSTEM	0	2.10	0.00	0.00	1.75
OTHER DISEASES OF THE BONES AND ORGANS OF MOVEMENT	1	0.27	3.65	0.05	20.29
EXTERNAL CAUSES OF DEATH	5	4.14	1.21	0.39	2.82

TABLE 18

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
NONWHITE MALES - N = 45
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1925-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	1	7.09	0.14	0.00	* 0.78
MALIGNANT NEOPLASMS	0	1.38	0.00	0.00	2.66
CANCER OF BUCCAL CAVITY AND PHARYNX	0	0.06	0.00	0.00	61.34
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	0	0.40	0.00	0.00	9.16
-CANCER OF ESOPHAGUS	0	0.09	0.00	0.00	40.75
-CANCER OF STOMACH	0	0.08	0.00	0.00	43.40
-CANCER OF LARGE INTESTINE	0	0.09	0.00	0.00	42.26
-CANCER OF RECTUM	0	0.03	0.00	0.00	145.92
-CANCER OF LIVER	0	0.04	0.00	0.00	100.58
-CANCER OF PANCREAS	0	0.07	0.00	0.00	52.19
CANCER OF RESPIRATORY SYSTEM	0	0.50	0.00	0.00	7.38
-CANCER OF LARYNX	0	0.03	0.00	0.00	138.42
-CANCER OF LUNG	0	0.47	0.00	0.00	7.87
CANCER OF BONE	0	0.01	0.00	0.00	678.81
CANCER OF SKIN	0	0.01	0.00	0.00	521.63
CANCER OF PROSTATE	0	0.13	0.00	0.00	28.83
CANCER OF BLADDER	0	0.02	0.00	0.00	169.5
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.02	0.00	0.00	191.45
CANCER OF THYROID	0	0.00	0.00	0.00	2120.50
LYMPHOPOIETIC CANCER	0	0.10	0.00	0.00	37.30
INFECTIVE AND PARASITIC DISEASE	0	0.13	0.00	0.00	28.75
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	0	0.15	0.00	0.00	24.72
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	0	0.02	0.00	0.00	151.98
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	0	0.08	0.00	0.00	47.48
OTHER DISEASES OF CIRCULATORY SYSTEM	1	2.79	0.36	0.00	1.99
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	1	1.46	0.68	0.01	3.81
VASCULAR LESIONS OF CNS	0	0.54	0.00	0.00	6.77
OTHER RESPIRATORY DISEASES	0	0.40	0.00	0.00	9.17
OTHER DISEASES OF DIGESTIVE SYSTEM	0	0.40	0.00	0.00	9.25
OTHER DISEASES OF GENITO-URINARY SYSTEM	0	0.15	0.00	0.00	25.15
OTHER DISEASES OF THE BONES AND ORGANS OF MOVEMENT	0	0.01	0.00	0.00	312.96
EXTERNAL CAUSES OF DEATH	0	1.15	0.00	0.00	3.20

2

* 95% CONFIDENCE LIMIT DOES NOT INCLUDE 1.00, POISSON $X^2 = 4.41$ 1 d.f. $p = 0.04$

TABLE 19

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
NONWHITE FEMALES - N = 62
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1925-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	3	5.86	0.51	0.10	1.49
MALIGNANT NEOPLASMS	1	1.15	0.87	0.01	4.83
CANCER OF BUCCAL CAVITY AND PHARYNX	0	0.02	0.00	0.00	184.83
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	0	0.30	0.00	0.00	12.12
-CANCER OF ESOPHAGUS	0	0.03	0.00	0.00	117.92
-CANCER OF STOMACH	0	0.05	0.00	0.00	70.70
-CANCER OF LARGE INTESTINE	0	0.10	0.00	0.00	35.35
-CANCER OF RECTUM	0	0.02	0.00	0.00	151.80
-CANCER OF LIVER	0	0.02	0.00	0.00	147.46
-CANCER OF PANCREAS	0	0.06	0.00	0.00	64.09
CANCER OF RESPIRATORY SYSTEM	0	0.14	0.00	0.00	26.82
-CANCER OF LARYNX	0	0.01	0.00	0.00	631.72
-CANCER OF LUNG	0	0.13	0.00	0.00	28.96
CANCER OF BONE	0	0.01	0.00	0.00	706.52
CANCER OF SKIN	0	0.01	0.00	0.00	598.13
CANCER OF BREAST	0	0.21	0.00	0.00	17.13
CANCER OF CERVIX UTERI	1	0.11	9.04	0.12	50.29
CANCER OF CORPUS UTERI	0	0.05	0.00	0.00	70.35
CANCER OF BLADDER	0	0.02	0.00	0.00	207.60
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.02	0.00	0.00	232.01
CANCER OF THYROID	0	0.00	0.00	0.00	938.28
LYMPHOPOIETIC CANCER	0	0.09	0.00	0.00	43.00
INFECTIVE AND PARASITIC DISEASE	0	0.11	0.00	0.00	33.12
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	0	0.26	0.00	0.00	14.33
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	0	0.03	0.00	0.00	118.36
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	0	0.07	0.00	0.00	55.67
OTHER DISEASES OF CIRCULATORY SYSTEM	1	2.63	0.38	0.00	2.12
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	1	1.11	0.90	0.01	5.03
VASCULAR LESIONS OF CNS	0	0.67	0.00	0.00	5.49
OTHER RESPIRATORY DISEASES	1	0.26	3.87	0.05	21.56
OTHER DISEASES OF DIGESTIVE SYSTEM	0	0.30	0.00	0.00	12.26
OTHER DISEASES OF GENITO-URINARY SYSTEM	0	0.17	0.00	0.00	21.21
OTHER DISEASES OF THE BONES AND ORGANS OF MOVEMENT	0	0.03	0.00	0.00	131.37
EXTERNAL CAUSES OF DEATH	0	0.43	0.00	0.00	8.46

TABLE 20

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
WHITE MALES - N = 299
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR NJ 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
All Causes of Death	92	79.88	1.15	0.93	1.41
Malignant Neoplasms	23	18.54	1.24	0.79	1.86
Cancer of Buccal Cavity & Pharynx	0	0.51	0.00	0.00	7.14
Cancer of Digestive Organs & Peritoneum	7	5.63	1.24	0.50	2.56
-Cancer of Esophagus	1	0.43	2.30	0.03	12.81
-Cancer of Stomach	0	1.00	0.00	0.00	3.65
-Cancer of Large Intestine	3	2.09	1.44	0.29	4.20
-Cancer of Rectum	2	0.68	2.93	0.33	10.56
Cancer of Biliary Passages & Liver	0	0.30	0.00	0.00	12.12
Cancer of Pancreas	0	0.98	0.00	0.00	3.74
Cancer of Respiratory System	10	6.13	1.63	0.78	3.00
-Cancer of Larynx	0	0.27	0.00	0.00	13.61
-Cancer of Bronchus, Trachea, Lung	10	5.77	1.73	0.83	3.19
Cancer of Bone	0	0.08	0.00	0.00	48.74
Malignant Melanoma of Skin	2	0.21	9.46	1.06	34.14
Cancer of Prostate (Males only)	2	1.60	1.25	0.14	4.50
Cancer of Bladder	1	0.74	1.35	0.02	7.51
Cancer of Central Nervous System	0	0.40	0.00	0.00	9.23
Cancer of Thyroid Gland & Other Endocrine Glands	0	0.05	0.00	0.00	66.74
Cancer of All Lymphatic & Haematopoietic Tissue	0	1.55	0.00	0.00	2.36
All Heart Disease	45	36.70	1.23	0.89	1.64
Ischemic Heart Disease	41	34.80	1.18	0.85	1.60
Cerebrovascular Disease	9	5.46	1.65	0.75	3.13
Non-malignant Respiratory Disease	3	4.78	0.63	0.13	1.83
All External Causes of Death	3	3.93	0.76	0.15	2.23

TABLE 21

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
WHITE FEMALES - N = 300
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR NJ 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
All Causes of Death	72	46.92	1.53	1.20	* 1.93
Malignant Neoplasms	18	12.50	1.44	0.85	2.28
Cancer of Buccal Cavity & Pharynx	1	0.16	6.17	0.08	34.35
Cancer of Digestive Organs & Peritoneum	5	3.64	1.37	0.44	3.20
-Cancer of Esophagus	0	0.12	0.00	0.00	31.60
-Cancer of Stomach	0	0.48	0.00	0.00	7.57
-Cancer of Large Intestine	3	1.64	1.83	0.37	5.35
-Cancer of Rectum	2	0.39	5.09	0.57	18.38
Cancer of Biliary Passages & Liver	0	0.28	0.00	0.00	13.04
Cancer of Pancreas	0	0.63	0.00	0.00	5.87
Cancer of Respiratory System	1	1.53	0.65	0.01	3.63
-Cancer of Larynx	0	0.04	0.00	0.00	89.88
-Cancer of Bronchus, Trachea, Lung	1	1.46	0.69	0.01	3.82
Cancer of Bone	0	0.04	0.00	0.00	87.00
Malignant Melanoma of Skin	0	0.13	0.00	0.00	28.84
Cancer of Breast	2	2.75	0.73	0.08	2.63
Cancer of Cervix Uteri (Females only)	0	0.35	0.00	0.00	10.46
All Uterine Cancers (Females only)	2	0.80	2.51	0.28	9.05
Cancer of Bladder	1	0.19	5.35	0.07	29.78
Cancer of Central Nervous System	0	0.28	0.00	0.00	12.95
Cancer of Thyroid Gland & Other Endocrine Glands	0	0.06	0.00	0.00	58.42
Cancer of All Lymphatic & Haematopoietic Tissue	2	1.00	2.00	0.22	7.23
All Heart Disease	29	19.30	1.50	1.01	** 2.16
Ischemic Heart Disease	25	17.24	1.45	0.94	2.14
Cerebrovascular Disease	9	4.49	2.00	0.91	3.80
Non-malignant Respiratory Disease	1	1.93	0.52	0.01	2.88
All External Causes of Death	4	1.60	2.50	0.67	6.39

* 95% CONFIDENCE LIMIT DOES NOT INCLUDE 1.00, POISSON $X^2 = 12.88$ 1 d.f. p = 0.003

** 95% CONFIDENCE LIMIT DOES NOT INCLUDE 1.00, POISSON $X^2 = 4.39$ 1 d.f. p = 0.04

TABLE 22

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
NONWHITE MALES - N = 45
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR NJ 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
All Causes of Death	1	4.92	0.20	0.00	1.13
Malignant Neoplasms	0	1.09	0.00	0.00	3.37
Cancer of Buccal Cavity & Pharynx	0	0.06	0.00	0.00	62.97
Cancer of Digestive Organs & Peritoneum	0	0.31	0.00	0.00	12.01
-Cancer of Esophagus	0	0.09	0.00	0.00	41.85
-Cancer of Stomach	0	0.05	0.00	0.00	66.88
-Cancer of Large Intestine	0	0.07	0.00	0.00	53.73
-Cancer of Rectum	0	0.02	0.00	0.00	243.09
Cancer of Biliary Passages & Liver	0	0.03	0.00	0.00	139.29
Cancer of Pancreas	0	0.05	0.00	0.00	71.58
Cancer of Respiratory System	0	0.43	0.00	0.00	8.51
-Cancer of Larynx	0	0.03	0.00	0.00	145.84
-Cancer of Bronchus, Trachea, Lung	0	0.40	0.00	0.00	9.13
Cancer of Bone	0	0.00	0.00	0.00	1045.83
Malignant Melanoma of Skin	0	0.00	0.00	0.00	1020.89
Cancer of Prostate (Males only)	0	0.08	0.00	0.00	47.03
Cancer of Bladder	0	0.02	0.00	0.00	201.95
Cancer of Central Nervous System	0	0.02	0.00	0.00	224.79
Cancer of Thyroid Gland & Other Endocrine Glands	0	0.00	0.00	0.00	1323.36
Cancer of All Lymphatic & Haematopoietic Tissue	0	0.07	0.00	0.00	54.18
All Heart Disease	1	1.48	0.67	0.01	3.75
Ischemic Heart Disease	1	1.22	0.82	0.01	4.55
Cerebrovascular Disease	0	0.28	0.00	0.00	13.12
Non-malignant Respiratory Disease	0	0.28	0.00	0.00	13.07
All External Causes of Death	0	0.69	0.00	0.00	5.32

TABLE 23

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
NONWHITE FEMALES - N = 62
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR NJ 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
All Causes of Death	3	3.48	0.86	0.17	2.52
Malignant Neoplasms	1	0.80	1.25	0.02	6.96
Cancer of Buccal Cavity & Pharynx	0	0.02	0.00	0.00	191.78
Cancer of Digestive Organs & Peritoneum	0	0.20	0.00	0.00	18.52
-Cancer of Esophagus	0	0.03	0.00	0.00	133.55
-Cancer of Stomach	0	0.03	0.00	0.00	129.76
-Cancer of Large Intestine	0	0.07	0.00	0.00	49.58
-Cancer of Rectum	0	0.02	0.00	0.00	216.42
Cancer of Biliary Passages & Liver	0	0.01	0.00	0.00	334.45
Cancer of Pancreas	0	0.04	0.00	0.00	101.87
Cancer of Respiratory System	0	0.11	0.00	0.00	32.87
-Cancer of Larynx	0	0.00	0.00	0.00	768.54
-Cancer of Bronchus, Trachea, Lung	0	0.10	0.00	0.00	35.08
Cancer of Bone	0	0.00	0.00	0.00	951.59
Malignant Melanoma of Skin	0	0.00	0.00	0.00	2671.97
Cancer of Breast	0	0.17	0.00	0.00	21.65
Cancer of Cervix Uteri (Females only)	1	0.07	14.67	0.19	81.62
All Uterine Cancers (Females only)	1	0.10	10.25	0.13	57.05
Cancer of Bladder	0	0.01	0.00	0.00	361.10
Cancer of Central Nervous System	0	0.01	0.00	0.00	340.67
Cancer of Thyroid Gland & Other Endocrine Glands	0	0.00	0.00	0.00	943.58
Cancer of All Lymphatic & Haematopoietic Tissue	0	0.06	0.00	0.00	65.27
All Heart Disease	1	1.00	1.00	0.01	5.58
Ischemic Heart Disease	1	0.79	1.26	0.02	7.03
Cerebrovascular Disease	0	0.30	0.00	0.00	12.14
Non-malignant Respiratory Disease	1	0.16	6.42	0.08	35.74
All External Causes of Death	0	0.26	0.00	0.00	13.85

TABLE 24

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
WHITE MALES - N = 299
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	92	108.90	0.84	0.68	1.04
MALIGNANT NEOPLASMS	23	20.87	1.10	0.70	1.65
CANCER OF BUCCAL CAVITY AND PHARYNX	0	0.60	0.00	0.00	6.16
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	7	6.07	1.15	0.46	2.38
-CANCER OF ESOPHAGUS	1	0.47	2.12	0.03	11.81
-CANCER OF STOMACH	0	1.14	0.00	0.00	3.23
-CANCER OF LARGE INTESTINE	3	2.05	1.47	0.29	4.29
-CANCER OF RECTUM	2	0.68	2.95	0.33	10.64
-CANCER OF LIVER	0	0.45	0.00	0.00	8.21
-CANCER OF PANCREAS	0	1.14	0.00	0.00	3.21
CANCER OF RESPIRATORY SYSTEM	10	6.59	1.52	0.73	2.79
-CANCER OF LARYNX	0	0.29	0.00	0.00	12.66
-CANCER OF LUNG	10	6.23	1.61	0.77	2.95
CANCER OF BONE	0	0.09	0.00	0.00	38.90
CANCER OF SKIN	2	0.34	5.96	0.67	21.51
CANCER OF PROSTATE	2	2.03	0.99	0.11	3.56
CANCER OF BLADDER	1	0.76	1.32	0.02	7.9
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.47	0.00	0.00	7.81
CANCER OF THYROID	0	0.04	0.00	0.00	90.94
LYMPHOPOIETIC CANCER	0	1.97	0.00	0.00	1.87
INFECTIVE AND PARASITIC DISEASE	0	1.01	0.00	0.00	3.63
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	0	1.86	0.00	0.00	1.97
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	0	0.26	0.00	0.00	14.05
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	0	0.83	0.00	0.00	4.40
OTHER DISEASES OF CIRCULATORY SYSTEM	57	60.49	0.94	0.71	1.22
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	41	40.30	1.02	0.73	1.38
VASCULAR LESIONS OF CNS	9	9.29	0.97	0.44	1.84
OTHER RESPIRATORY DISEASES	3	7.44	0.40	0.08	1.18
OTHER DISEASES OF DIGESTIVE SYSTEM	3	4.37	0.69	0.14	2.01
OTHER DISEASES OF GENITO-URINARY SYSTEM	1	1.62	0.62	0.01	3.44
OTHER DISEASES OF THE BONES AND ORGANS OF MOVEMENT	0	0.17	0.00	0.00	21.01
EXTERNAL CAUSES OF DEATH	3	7.73	0.39	0.08	1.13

TABLE 25

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
WHITE FEMALES - N = 300
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	72	65.76	1.09	0.86	1.38
MALIGNANT NEOPLASMS	18	14.66	1.23	0.73	1.94
CANCER OF BUCCAL CAVITY AND PHARYNX	1	0.19	5.18	0.07	28.80
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	5	4.23	1.18	0.38	2.76
-CANCER OF ESOPHAGUS	0	0.13	0.00	0.00	28.16
-CANCER OF STOMACH	0	0.57	0.00	0.00	6.45
-CANCER OF LARGE INTESTINE	3	1.83	1.64	0.33	4.80
-CANCER OF RECTUM	2	0.42	4.76	0.53	17.19
-CANCER OF LIVER	0	0.42	0.00	0.00	8.78
-CANCER OF PANCREAS	0	0.74	0.00	0.00	4.96
CANCER OF RESPIRATORY SYSTEM	1	1.53	0.65	0.01	3.63
-CANCER OF LARYNX	0	0.04	0.00	0.00	100.18
-CANCER OF LUNG	1	1.46	0.68	0.01	3.80
CANCER OF BONE	0	0.06	0.00	0.00	62.37
CANCER OF SKIN	0	0.20	0.00	0.00	18.71
CANCER OF BREAST	2	2.96	0.68	0.08	2.44
CANCER OF CERVIX UTERI	0	0.60	0.00	0.00	6.16
CANCER OF CORPUS UTERI	2	0.54	3.67	0.41	13.26
CANCER OF BLADDER	1	0.23	4.31	0.06	23.99
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.33	0.00	0.00	11.24
CANCER OF THYROID	0	0.06	0.00	0.00	59.29
LYMPHOPOIETIC CANCER	2	1.32	1.52	0.17	5.49
INFECTIVE AND PARASITIC DISEASE	0	0.52	0.00	0.00	7.09
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	4	2.00	2.00	0.54	5.13
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	0	0.22	0.00	0.00	17.05
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	0	0.60	0.00	0.00	6.09
OTHER DISEASES OF CIRCULATORY SYSTEM	41	36.31	1.13	0.81	1.53
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	25	20.17	1.24	0.80	1.83
VASCULAR LESIONS OF CNS	9	8.04	1.12	0.51	2.13
OTHER RESPIRATORY DISEASES	1	3.12	0.32	0.00	1.78
OTHER DISEASES OF DIGESTIVE SYSTEM	0	2.50	0.00	0.00	1.47
OTHER DISEASES OF GENITO-URINARY SYSTEM	0	0.98	0.00	0.00	3.72
OTHER DISEASES OF THE BONES AND ORGANS OF MOVEMENT	1	0.25	4.08	0.05	22.67
EXTERNAL CAUSES OF DEATH	4	2.93	1.36	0.37	3.49

TABLE 26

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
NONWHITE MALES - N = 45
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	1	7.09	0.14	0.00	0.78
MALIGNANT NEOPLASMS	0	1.38	0.00	0.00	2.66
CANCER OF BUCCAL CAVITY AND PHARYNX	0	0.06	0.00	0.00	61.34
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	0	0.40	0.00	0.00	9.16
-CANCER OF ESOPHAGUS	0	0.09	0.00	0.00	40.75
-CANCER OF STOMACH	0	0.08	0.00	0.00	43.40
-CANCER OF LARGE INTESTINE	0	0.09	0.00	0.00	42.26
-CANCER OF RECTUM	0	0.03	0.00	0.00	145.92
-CANCER OF LIVER	0	0.04	0.00	0.00	100.58
CANCER OF PANCREAS	0	0.07	0.00	0.00	52.19
CANCER OF RESPIRATORY SYSTEM	0	0.50	0.00	0.00	7.38
-CANCER OF LARYNX	0	0.03	0.00	0.00	138.42
-CANCER OF LUNG	0	0.47	0.00	0.00	7.87
CANCER OF BONE	0	0.01	0.00	0.00	678.81
CANCER OF SKIN	0	0.01	0.00	0.00	521.63
CANCER OF PROSTATE	0	0.13	0.00	0.00	28.83
CANCER OF BLADDER	0	0.02	0.00	0.00	169.09
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.02	0.00	0.00	191.45
CANCER OF THYROID	0	0.00	0.00	0.00	2120.50
LYMPHOPOIETIC CANCER	0	0.10	0.00	0.00	37.30
INFECTIVE AND PARASITIC DISEASE	0	0.13	0.00	0.00	28.75
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	0	0.15	0.00	0.00	24.72
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	0	0.02	0.00	0.00	151.98
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	0	0.08	0.00	0.00	47.48
OTHER DISEASES OF CIRCULATORY SYSTEM	1	2.79	0.36	0.00	1.99
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	1	1.46	0.68	0.01	3.81
VASCULAR LESIONS OF CNS	0	0.54	0.00	0.00	6.77
OTHER RESPIRATORY DISEASES	0	0.40	0.00	0.00	9.17
OTHER DISEASES OF DIGESTIVE SYSTEM	0	0.40	0.00	0.00	9.25
OTHER DISEASES OF GENITO-URINARY SYSTEM	0	0.15	0.00	0.00	25.15
OTHER DISEASES OF THE BONES AND ORGANS OF MOVEMENT	0	0.01	0.00	0.00	312.96
EXTERNAL CAUSES OF DEATH	0	1.15	0.00	0.00	3.20

TABLE 27

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS
NONWHITE FEMALES - N = 62
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1955-1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	3	5.81	0.52	0.10	1.51
MALIGNANT NEOPLASMS	1	1.15	0.87	0.01	4.86
CANCER OF BUCCAL CAVITY AND PHARYNX	0	0.02	0.00	0.00	185.54
CANCER OF DIGESTIVE ORGANS AND PERITONEUM	0	0.30	0.00	0.00	12.23
-CANCER OF ESOPHAGUS	0	0.03	0.00	0.00	118.34
-CANCER OF STOMACH	0	0.05	0.00	0.00	71.87
-CANCER OF LARGE INTESTINE	0	0.10	0.00	0.00	35.59
-CANCER OF RECTUM	0	0.02	0.00	0.00	153.73
-CANCER OF LIVER	0	0.02	0.00	0.00	149.61
-CANCER OF PANCREAS	0	0.06	0.00	0.00	64.43
CANCER OF RESPIRATORY SYSTEM	0	0.14	0.00	0.00	26.87
-CANCER OF LARYNX	0	0.01	0.00	0.00	633.53
-ALL CANCER OF LUNG	0	0.13	0.00	0.00	29.01
CANCER OF BONE	0	0.01	0.00	0.00	715.58
CANCER OF SKIN	0	0.01	0.00	0.00	602.74
CANCER OF BREAST	0	0.21	0.00	0.00	17.22
CANCER OF CERVIX UTERI	1	0.11	9.13	0.12	50.80
CANCER OF CORPUS UTERI	0	0.05	0.00	0.00	71.74
CANCER OF BLADDER	0	0.02	0.00	0.00	209.61
CANCER OF CENTRAL NERVOUS SYSTEM	0	0.02	0.00	0.00	232.50
CANCER OF THYROID	0	0.00	0.00	0.00	949.96
LYMPHOPOIETIC CANCER	0	0.08	0.00	0.00	43.18
INFECTIVE AND PARASITIC DISEASE	0	0.11	0.00	0.00	33.73
ALLERGIC, ENDOCRINE, METABOLIC, NUTRITIONAL DISEASES	0	0.25	0.00	0.00	14.43
OTHER DISEASES OF BLOOD AND BLOOD-FORMING ORGANS	0	0.03	0.00	0.00	118.87
OTHER DISEASES OF NERVOUS SYSTEM AND SENSE ORGANS	0	0.07	0.00	0.00	55.98
OTHER DISEASES OF CIRCULATORY SYSTEM	1	2.60	0.39	0.01	2.14
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD	1	1.10	0.91	0.01	5.06
VASCULAR LESIONS OF CNS	0	0.66	0.00	0.00	5.57
OTHER RESPIRATORY DISEASES	1	0.26	3.91	0.05	21.74
OTHER DISEASES OF DIGESTIVE SYSTEM	0	0.30	0.00	0.00	12.32
OTHER DISEASES OF GENITO-URINARY SYSTEM	0	0.17	0.00	0.00	21.50
DISEASES OF THE BONES AND ORGANS OF MOVEMENT	0	0.00	0.00	131.95	
EXTERNAL CAUSES OF DEATH	0	0.43	0.00	0.00	8.49

TABLE 28A

SELECTED CAUSES OF DEATH
OBSERVED AND EXPECTED NUMBERS AND RATIOS

WHITE MALES - N = 135

EXCESS WORKING LEVEL MONTHS GREATER THAN OR EQUAL TO 10 WLM
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1925 - 1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	43	62.42	0.69	0.50	0.93
ALL MALIGNANT NEOPLASMS	8	11.26	0.71	0.31	1.40
CANCER OF LARGE INTESTINE	2	1.10	1.81	0.20	6.54
CANCER OF RECTUM	1	0.40	2.49	0.03	13.84
CANCER OF LUNG	3	3.15	0.95	0.19	2.78
ALL DISEASES OF CIRCULATORY SYSTEM	27	32.29	0.84	0.55	1.22
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD*	20	20.46	0.98	0.60	1.51
ALL VASCULAR LESIONS OF CNS**	3	4.88	0.62	0.12	1.80

TABLE 28B

WHITE FEMALES - N = 138

EXCESS WORKING LEVEL MONTHS GREATER THAN OR EQUAL TO 10 WLM
EXPECTED NUMBERS BASED ON MORTALITY RATES FOR US 1925 - 1983

	OBSERVED	EXPECTED	OBS/EXP	95% CONFIDENCE INTERVAL	
				LL	UL
ALL CAUSES OF DEATH	38	42.99	0.88	0.63	1.21
ALL MALIGNANT NEOPLASMS	8	8.65	0.92	0.40	1.82
CANCER OF LARGE INTESTINE	1	1.08	0.93	0.01	5.16
CANCER OF RECTUM	1	0.28	3.56	0.05	19.79
CANCER OF LUNG	0	0.70	0.00	0.00	5.26
ALL DISEASES OF CIRCULATORY SYSTEM	22	22.62	0.97	0.61	1.47
ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CHD*	12	11.07	1.08	0.56	1.89
ALL VASCULAR LESIONS OF CNS**	5	5.19	0.96	0.31	2.25

* CHD = Coronary Heart Disease

** CNS = Central Nervous System

Table 29

Age Structure of "Highly Exposed" Subpopulation
 Compared to Entire Cohort

<u>Age as of end of follow-up</u>	Cumulative Percent	
	<u>> 10 WLM</u>	<u>Entire Cohort</u>
Less than 10	1.8	3.2
10-19	4.0	5.6
20-29	12.8	14.5
30-39	25.3	29.9
40-49	39.9	40.7
50-59	53.1	59.4
60-69	71.8	77.7
70-79	89.0	91.0
80 or greater	100.0	100.0

Table 30

Comparison of White and Non-White Residents

	<u>White</u>	<u>Nonwhite</u>
% Male	50	47
Median age at end of follow-up	57.0 yrs	37.5 yrs
Median length of residency	6.0 yrs	8.0 yrs
Percent renters	32.5%	7.8%
Percent lost to follow-up	1.6%	4.7%

TABLE 31

ADDITIVE ATTRIBUTABLE RISK COEFFICIENT
FOR LUNG CANCERS INDUCED BY RADON EXPOSURE
(Lagged 5 Years)

OBSERVATION PERIOD AND COMPARISON GROUP	NUMBER OF PERSONS CONTRIBUTING PERSON-YEARS	PERSON-YEARS FOLLOWED	EXCESS MLM	EXCESS CASES OBSERVED	UPPER BOUND OF OBS/EXP	EXCESS CASES PER MILLION PER MLM	
						Best estimate	Upper Bound
<u>WHITE MALES</u>							
U.S. 1925 - 1983	304	8,741	9,143	3.35	2.76	13	44
N.J. 1955 - 1983	286	5,981	8,792	.....	12.7	23	69
<u>WHITE FEMALES</u>							
U.S. 1925 - 1983	301	8,927	11,073	.....	3.59	..	10
N.J. 1955 - 1983	286	6,210	10,828	.....	3.87	..	16

TABLE 32

RELATIVE RISK COEFFICIENT ESTIMATES:

PERCENT EXCESS LUNG CANCER PER WLM (LAGGED)

COMPARISON GROUP	AVERAGE EXCESS WLM (LAGGED)	OBS EXP	-1	PERCENT EXCESS/WLM		
				Best Estimate	95% Upper Limit	Best Estimate 95% Upper Limit
<u>WHITE MALES</u>						
U.S. 1925 - 1983	30	0.50	1.76	1.7	5.9	
N.J. 1955 - 1983	31	0.75	2.22	2.4	7.2	
<u>WHITE FEMALES</u>						
U.S. 1925 - 1983	37	.....	2.59	....	7.0	
N.J. 1955 - 1983	37	.....	2.87	....	7.8	

TABLE 33

ESTIMATION OF COMPLETENESS OF ASCERTAINMENT

Number of houses	45	
House-years (Sum of years of existence from construct to 1983)	2,144	
Estimate person years occupancy, assuming average 4 persons/household	8,576	
Actual number of person years in cohort	7,783	91% of above estimate

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