NUREG/CR-0635

# EXCESS CANCER INCIDENCE IN MESA COUNTY, COLORADO

## Final Report

M. C. Cunningham
S. W. Ferguson T. Foreman

Colorado Department of Health

Prepared for
**U. S. Nuclear Regulatory Commission**

922 020

7909070180

Available from
National Technical Information Service
Springfield, Virginia 22161

922 021

NUREG/CR-0635

# EXCESS CANCER INCIDENCE IN MESA COUNTY, COLORADO

Prepared by
M. C. Cunningham
S. W. Ferguson T. Foreman

Disease Control and Epidemiology Division
Colorado Department of Health
4210 East 11th Avenue
Denver, CO 80220

Date Published: July 1979

Prepared for
Division of Siting, Health and Safeguards Standards
Office of Standards Development
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN No. B10728

922 022

ABSTRACT

The initial phase of this investigation has determined that there is a twofold excess of leukemia incidence for all ages in Mesa County, Colorado, for the period 1970-1976. The greatest excess was observed among residents over 65 years of age who developed leukemia 2-1/2 times the expected rate. No excess incidence of lung cancer has been identified.

The second phase of the investigation has been case-control study of all adult leukemia deaths since 1960. No significant differences were found between cases and controls with respect to: years of residence in Mesa County, general health status prior to diagnosis, and radiation exposure from "tailings" buildings. Only two cases and two controls had ever lived in houses with elevated gamma radiation from uranium mill tailings used in construction. Only one case and one control had a cumulative and average annual exposure significantly higher than the other subjects. Leukemia cases had higher socioeconomic levels and more positive family histories of leukemia than controls. No association between tailings structures and leukemia excess was observed.


922 023

TABLE OF CONTENTS

## TABLE OF CONTENTS (Continued)

LIST OF TABLES





922 026

LIST OF TABLES (Continued)

## ACKNOWLEDGEMENTS

The investigators wish to acknowledge the cooperation of the medical community and the residents of Mesa County, Colorado especially:

- Geno Saccomanno, M.D. and the Mesa County Pathology Department, St. Mary's Hospital, Grand Junction

- Kenneth Lampert, M.D., Medical Director Mesa County Health Department, Grand Junction

- Members of the Medical Records Departments of St. Mary's Hospital, Grand Junction Osteopathic Hospital, Mesa Memorial Hospital and Grand Junction Veterans' Administration Hospital

- Pat Moran, M.D., Director of Continuing Education, St. Mary's Hospital, Grand Junction

- John Berg, M.D., Epidemiologist, Colorado Regional Cancer Center, Denver, Colorado

Thanks also to staff members of the Colorado Department of Health

- Bud Franz and Al Hazle, Division of Hazardous Wastes and staff of the regional office in Grand Junction

- Larry Franz and staff of the Colorado Central Cancer Registry, Denver, Colorado

- Don Davids and staff of the Division of Vital Statistics, Denver, Colorado

- and especially the secretarial staff of Disease Control and Epidemiology Division



922 028

## FOREWORD

This document represents an edited version of the final report received from the Colorado Department of Health. The revisions, which in no way alter the technical content of the report, reflect typographical and grammatical corrections, or minor changes in introductory material to improve technical clarity and accuracy.

Stephen C. Whitfield
Project Officer
Division of Siting, Health and Safeguards Standards
Office of Standards Development

## I. SUMMARY OF FINDINGS

### A. The Incidence Study: Leukemia and Lung Cancer 1970-1976

An apparent excess of leukemia and lung cancer was noted in Mesa County, Colorado, an area where uranium mill tailings were used extensively for construction purposes between 1952 and 1966. An intensive search was conducted through pathology reports at St. Mary's Hospital and through medical records at the other three hospitals in Grand Junction. Age specific incidence rates were computed for all diagnosed cases of leukemia and lung cancer. The findings are:

1. There is no total excess incidence of lung cancer apparent at this time in Mesa County, Colorado.
2. A slight but not statistically significant excess incidence of lung cancer among 35 to 49 year old males is probably explained by the presence of uranium miners in the study population.
3. There is a twofold excess incidence of leukemia in Mesa County, Colorado, for all age groups which is statistically significant at the p F .01 level.
4. This excess leukemia rate is:
    a. primarily in persons aged 65 and over where the observed rate is 2-1/2 times the expected rate
    b. primarily of the type Acute Myelogenous Leukemia (AML).
    c. equally distributed between males and females.

### B. The Case-Control Study: Leukemia Deaths 1960-1978

A case-control study was designed to examine all cases of adult leukemia between 1960 and 1978 who had lived in Mesa County at least two years prior to diagnosis, who had never worked in the uranium mining or milling industry, and who had never been treated previously with chemotherapy or radiotherapy. Two



922 030

control groups were selected from death certificate data, one group of individuals who died of radioassociated cancers and the other group of individuals who died of heart disease. Controls were matched by age within 5 years, sex, and year of death.

Data on cases and controls were gathered from interviews with surviving next of kin, medical records in hospital and physicians' offices, and from public records, (e.g., obituary notices, city directories, phone books, and tax assessors' records). Study variables included: occupational status, years of residence in Mesa County, general health status prior to diagnosis, family history of leukemia or cancer, and radiation exposure from tailings buildings (work sites and homes). The findings are:

1. There are no significant differences between the leukemia groups and the 2 control groups for the independent variables:

    a. length of residence in Mesa County
    b. general health status prior to diagnosis
    c. radiation exposure to "tailings" locations

2. There are slight but not significant differences among the study groups for the independent variables:

    a. socioeconomic level - higher in the leukemia group
    b. family history of leukemia - more positive in the leukemia group.

The inconclusive nature of these findings and the limitation of study design are discussed. The very small number of cases in this study precludes any definitive conclusions about the relationship between leukemia and low-level radiation.

Further research is recommended with an adequate sized population with known dose exposure over long time periods. Such a study would provide a more conclusive answer to the basic research question: What are the health effects of long-term exposure to very low levels of radiation such as exist in communities near uranium mill tailings or near nuclear reactors and power plants?

## II. THE PROBLEM: Health Effects of Low-Level Radiation Exposure

### A. General Background

Although much has been written about the health effects of exposure to low levels of ionizing radiation, this represents one of the newer fields of environmental epidemiologic investigation. This section reviews the current state of knowledge about these health effects, summarizes them by type of radiation, and concludes that little is known about very low levels of exposure.

#### 1. Literature review

> It has become clear that the most important late somatic effect of low doses of radiation is the occasional induction of malignant diseases, as shown by their increased incidence in the exposed populations.1

Indeed, this recently published statement is based on a large and growing body of research about the human health effects of low-level exposure to ionizing radiation. These research reports fall into four categories according to the exposure situation: 1) occupational radiation exposure; 2) atomic bomb radiation exposure; 3) therapeutic radiation exposure; and 4) diagnostic radiation exposure. This research is reviewed within these categories.

##### a. Occupational radiation exposure

The first evidence linking radiation exposure to cancer in humans was reported in 1944 by March who noted that British radiologists between 1929 and 1943 were dying of leukemia at a rate 10 times higher than other physicians.[2,3] Although experimental evidence of this link had existed since 1906,[4] it had not been documented in humans prior to this time. Comparable results were subsequently reported by Ulrich among U.S. radiologists.[5]

A more recent U.S. study by Seltzer and Sartwell has shown that, as of 1965, the highest leukemia risk was for radiologists over age 50 who



922 032

presumably used X-ray equipment in the early era of roentgenography before the exposure risks were known.[6]

In these studies, the increased leukemia risk can be attributed to repeated exposure to electromagnetic radiation from X-ray equipment in the dose range of 0.4 to 2.0 rads per week.[7]

Cancer excesses have also been identified among workers in the nuclear industries. Cancers of pancreas, bone marrow, and lung have been reported in excess in workers at the Hanford plant in Richland, Washington. Mancuso Stewart and Kneale have estimated that the radiation dose required to double the mortality from cancer of the reticulo-endothelial system including leukemia was less than 10 rem.[8] Similar cancer excesses have been reported among employees at Los Alamos Experimental Labs in New Mexico.[9]

More recently, a 5.6 fold excess of leukemia deaths have been reported among workers at the Portsmouth Naval Shipyard who repaired and maintained the reactors of nuclear submarines over the past 18 years. For all cancer types combined, the ratio of observed to expected deaths has been 1.78.[10]

Cancer excesses have also been reported among uranium miners and uranium millers in Europe and in the U.S. Uranium miners on the Colorado Plateau die of lung cancer at a rate 4 times higher than non-miners, as reported by Wagoner.[11] Saccomanno reports that miners develop lung cancer at an earlier age (median age 54 vs non-miners at median age 63-65) and have a shorter course of the disease (2 months from diagnosis to death vs 5 months for non-miners).[12] No excess leukemia, however, has ever been reported among these miners.

Studies of U.S. uranium mill workers have not shown similar excess of lung cancer, but have reported a threefold excess of hematopoietic cancers (including leukemia).[13] This excess is based on only 3 cases among the study group of 611 in which no cases were expected. Although not statistically significant because of the small numbers, this finding is suggestive of a possible relationship.



922 033

This apparent discrepancy in cancer excess among miners and millers may be explained on the basis of the different type of radiation exposure experienced by each group.

The principle radiation in uranium mines is alpha from radioactive radon daughters including isotopes of lead, bismuth, and polonium. These isotopes, found in high concentrations in the closed mines, may be inhaled on dust particles and lodge in the lung, presumably becoming the potential focus for the eventual development of cancer.[14] The very small doses of gamma radiation that are present probably do not play a major role in lung cancer etiology.

The major radiation exposure for uranium mill workers is probably gamma radiation which is emitted in low doses from the ore. Radon daughter emissions of aplha radiation are also present, but remain in low concentrations because the dust particles are easily dispersed in the more open work areas of the mill. Unfortunately, the uranium millers have not been as intensively studied as uranium miners. Therefore, the lack of concentrated alpha radiation in mills may account for the lack of lung cancer excess in millers.

b. Atomic bomb radiation exposure

The results of the myriad followup studies of the Japanese victims of World War II bombings at Nagasaki and Hiroshima have been extensively reviewed elsewhere. Briefly, 24,000 persons who were exposed to an estimated dose of 10 rads or more of gamma radiation have been followed for up to 25 years.[15,16]

An excess leukemia incidence for all ages was first identified 2 years post-exposure, peaked at about 6 years, then began to decrease. After 25 years, however, there remained a significant excess among persons who received doses of 100 rads or more.[17] This excess occurred in all leukemia types except chronic lymphocytic leukemia.

Other cancers were first noted in excess 15 years post-exposure, and only among persons with 100 rads or more of exposure.[18] These cancers



922 034

included the following types for children under age 10 at time of exposure: thyroid, brain, gastrointestinal and salivary gland cancers.[19] Excess cancers noted in adults included: respiratory, gastrointestinal,[20] lymphosarcoma,[21] thyroid (persons over 40 with greater than 200 rads exposure),[22] and breast (especially ages 10-19 with 50 rads or more exposure).[23]

These findings provide the strongest support for the linkage between large doses of radiation and excess cancer incidence. As noted, leukemia had the shortest latent period between exposure and its appearance (2 years), whereas other cancers did not appear for at least 15 years.

c. Therapeutic X-ray radiation exposure

The classic studies of cancers induced by therapeutic irradiation emanate from England where persons with ankylosing spondylitis, a form of arthritis which affects the spine, received X-ray treatments for relief of low back pain. Among the 14,000 persons followed over 25 years, there occurred a tenfold excess in leukemia deaths with a latent period of 3-5 years post-irradiation. These included 80% acute leukemias and 20% chronic leukemias, with no excess in chronic lymphocytic leukemias (CLL). Other cancers occurring in excess included pharyngeal, gastric, pancreatic, lung, lymphatic and hematopoietic (other than leukemia).[24,25]

Other studies of persons receiving X-ray therapy have revealed an increased risk of developing leukemia and other cancers: among women treated for menorrhagia (heavy bleeding),[26,27] children treated for tinea capitis (ringworm),[28] and children treated for enlarged thymus glands.[29] A more recent report has shown that thyroid cancer may occur up to 35 years following head and neck irradiation in childhood.[30]

d. Diagnostic X-ray

Studies of excess cancers in persons receiving routine diagnostic X-rays include those of children who were irradiated in utero and adults who were irradiated in adulthood.

The initial evidence of excess childhood cancer came from England when Stewart reported in 1958 that children irradiated diagnostically in utero as fetuses had almost a twofold excess risk of death from leukemia and other cancers before age 10.[31] Subsequent reports from the U.S. showed a similar excess risk of death from all cancers[37] and from leukemia[33] in children whose mothers received X-rays to the pelvis, abdomen, and chest during the pregnancy.

Two of these research groups later investigated this relationship between X-rays and cancer in adults with similar findings. Stewart reported in 1962 that adults (male and female) with acute and chronic myelogenous leukemia had a 1.8 times greater exposure to 10 or more trunk X-rays during the 5 years preceding their diagnosis than matched controls.[34] The Tri-State Leukemia Survey Group reported in 1972 a similar excess exposure in males only with myelogenous leukemias (acute and chronic).[35]

All of these studies have used "number of X-rays" as the indicator of gamma exposure rather than the actual dose received because of the difficulty of retrospectively assigning dose values to diagnostic X-rays taken in multiple locations over an extended time period.

2. Health Effects by Type of Ionizing Radiation

The health effects reviewed here have been principally related to alpha or gamma radiation and x-irradiation.

Alpha radiation can be characterized by its low tissue penetrability and high linear energy transfer (LET). In human tissue, alpha particles release large doses of energy to areas immediately adjacent to the emitter. Since these particles travel only a short distance (measured in microns), tissues located at a distance in other body organs are not involved.

A good example of this is seen in the health effect of radon daughters on human lung tissue as previously noted for uranium miners. The alpha emissions from the radioactive daughters of radon exert their effect on lung tissue adjacent to the inhaled particles. The dose-response relationship which has been observed implies that the greater the exposure dose, the greater the risk of developing the cancer.

Gamma or x-rays have a very low LET along their course of travel, but have the highest penetration ability As noted, the primary health effects of increased gamma or x-ray exposure are leukemia and other selected cancers of radiosensitive tissues including: thyroid, lymph modes, bronchus (lung), breast, and gastrointestinal (especially stomach, pancreas and large intestine). Leukemia differs from the other radioassociated cancers in its latency period and its ease of identification. Although rare by comparison, leukemia seems to be the most radioassociated of the cancers with the shortest latent period (minimum of 2 years). Other cancers have a minimum of a five-year latency period, with lung cancer generally considered with a 15- to 20-year minimum latency.[36]

In addition, because of its clinical presentation, leukemia is relatively easy to identify, especially in an exposed population, whereas lung cancer and other radioassociated tumors may often go undiagnosed for prolonged periods. Therefore, leukemia incidence rates in a population exposed to x- or gamma-rays offer a reasonable indicator of radiation exposure. The studies reviewed here clearly demonstrate the role of radiation as a potential causal agent in the development of several types of leukemia. The radiation doses in these studies are at relatively low levels. However, these radiation doses are in the range of at least 1000 times the background radiation levels of most persons in the U.S.

As well summarized by Jablon,

> "No data are available or are ever likely to be regarding the effect of very small doses, since the required population sizes are enormous for assessing the leukemogenic potential for man of, say, 1000 millirad."37

B. <u>Cancer Excess in a Uranium Mill County</u>

An extensive presentation of the situation in Mesa County, Colorado, and the use of uranium mill tailings from the operating mill in Grand Junction, Colorado, i· found in the published U.S. Congressional Hearings on the subject in 1971.[38] ^ ief summary will provide a general perspective to the problem n estigated under this contract (see Appendix 2).

1. The Mill and Its Tailings

The Climax Uranium Company, under contract from the AEC (Atomic Energy Commission), constructed a uranium mill in Grand Junction, Colorado, which was in operation between 1952 and 1970. The mill which produced uranium and vanadium, yielded large deposits of a sand-like end product called "tailings." This end product accumulated in a large pile near the mill. Its final size is estimated at 55 acres. Although it contained minute traces of uranium which emitted low levels of radioactivity, the tailings no longer had any commercial value. During the period 1952 to 1966, the Climax Uranium Company allowed the public free access to this pile and encouraged the removal of tailings for private purposes. Its use included sub-base for highways, culverts, patios, sidewalks, driveways and floor slabs, sand replacement in concrete mixes, a loose filler for flower gardens and sandboxes, and landfill under basement floors and against basement walls. Of the 300,000 tons estimated to have been removed, about 17% (50,000 tons) was presumably used in commercial and residential construction.[39] This free public access and use of tailings was terminated in August 1966 under order of the Colorado State Health Department.

A remedial action program began in 1970 with an extensive survey of structures in Mesa County to determine the presence of tailings as indicated by elevated gamma radiation. Since no records had been kept of the use of tailings in building construction, this gamma screening survey attempted to identify all "tailings buildings." Owners of structures with elevated gamma readings could apply for corrective action to a Remedial Action Program, managed by the Colorado State Health Department. Tailings would then be removed from these structures and replaced with nonradioactive fill material. The expense was covered by funds from Federal and State sources.

The program, which continues through 1980, has identified about 600 structures with elevated gamma radiation in the range designated as "Corrective

Action Recommended" (.100 mR per hour or more above background). These include commercial buildings (about 1/3) as well as schools and private homes (about 2/3). To date, over half of these locations have been reconstructed.

2. The Apparent Cancer Excess

There has been a long-lasting concern about the potential health-effects on the persons in Grand Junction from chronic exposure to low-level radiation from the mill tailings. There has, as yet, been no conclusive documentation of an existing or potential health hazard.

Mortality data from the Colorado Department of Health, 1965-1968, were presented at the Congressional Hearings in 1971 to suggest that a problem might exist.[40] Slight but not significant differences were reported for Mesa County statistics compared to the State in the following areas:

1. 50% higher death rate due to congenital anomalies (Mesa County 8.2 cases/1000 births vs. Colorado 5.2 cases/1000 births)

2. almost twofold increases in cleft lip and palate (Mesa County 2.2 cases/1000 births vs. Colorado 1.2 cases/1000 births)

3. higher death rate due to cancer (Mesa County 127 cases/100,000 vs. Colorado 103 cases/100,000) after excluding lung cancers (influenced by uranium miners)

4. lower birth rate (Mesa County 14.5/1000 vs. Colorado 17.9/1000)

Although suggestive, these data are inconclusive since: they are based on a very small time period (4 years); the numbers of cases are very small; and cancer death rates were not age-adjusted.

A study of newborns at St. Mary's Hospital, Grand Junction, was conducted between January 1972 and May 1973 by Lubs.[41] From cord blood samples of newborns, chromosome abnormality rates were compared in "high" and "low" exposure groups determined by the residential and work exposure of the parents at the time of conception. An analysis of a sample of 229 of the 1000 newborns studied revealed no significant differences in chromosome abnormality rates or in congenital anomalies. Of the six children identified with chromosome abnormalities, the mother of only one case had an elevated exposure to gamma radiation from a "tailings" structure. Presumably because of the very small numbers involved, the study was not continued.

In 1977, the Colorado Health Department compared lung cancer and acute leukemia incidence in Mesa County with 3 other rural counties for the period 1970-1975. Based on information from the Colorado Central Registry, an apparent excess incidence rate for both types of cancer was identified.[42] Although preliminary, this finding suggested the need for further investigation.



922 040

## III. THE RESEARCH OBJECTIVES

### A. The Objectives

The specific objectives of this study are:

1. To determine whether there is a significant excess incidence of leukemia and/or lung cancer in Mesa County, Colorado.

2. To determine whether persons who had leukemia in Mesa County had excess radiation exposure from uranium mill tailings used for construction purposes.

### B. The Epidemiologic Approach

#### 1. Incidence Study

In order to verify the apparent excess incidence of leukemia and lung cancer, an in-depth study was conducted to document all cases of these cancer types diagnosed between 1970-1976 through comprehensive casefinding activities at Mesa County hospitals and physicians' offices. Age-adjusted rates were then computed and compared with expected rates based on the State of Colorado as a standard population.

#### 2. The Case-Control Study

To investigate the leukemia excess, all deaths from leukemia between 1960 and 1978 were identified and matched with paired controls. Residential, occupational, family and medical history were reconstructed through interviews with next of kin and review of medical and public records. Results were compared for leukemia cases and controls to determine whether there were significant differences among any of the study variables, including radiation exposure from the uranium mill tailings.

## IV. THE INCIDENCE STUDY: Leukemia and Lung Cancer 1970-1976

### A. Objective

To determine whether there has been a significant excess incidence of leukemia and lung cancer in Mesa County, Colorado, for the period 1970 to 1976.

### B. Methods

#### 1. Cancer Types

We attempted to identify all persons diagnosed with lung cancer and leukemia between 1970 and 1976 who had Mesa County addresses at the time of diagnosis. Table 1 lists the specific diagnostic types with their respective codes from ICDA-8.[43] As noted, the "lung" group includes malignant tumors of trachea, bronchus and lung, pleura and mediastinum. The "leukemia" group refers to acute lymphatic (ALL), acute myeloid (AML), and chronic myeloid and chronic monocytic (CML). For simplicity and by convention, the chronic myeloid and chronic monocytic are combined and designated CML. In addition, cases diagnosed as "subacute" were considered as "acute." Chronic lymphocytic leukemia (CLL) is excluded from the study because this type has never been identified in excess in any groups with radiation exposure. Unlike the other leukemia types which are generally fatal, persons with CLL follow a prolonged course of waxing and waning with elevated white blood counts, but often die of unrelated causes.

#### 2. Casefinding

All cases listed with the Colorado Central Cancer Registry with the appropriate diagnosis made between 1-1-70 and 12-31-76 served as the basic core of the study group. Additional cases were identified from hospital records in Grand Junction.

All pathology reports in the Pathology Department of St. Mary's Hospital were reviewed. Useful reports included those of sputum cytology, lung biopsy, bone marrow and peripheral blood smears. Cases not entered in the Cancer Registry were followed through records at one of the area hospitals which refer diagnostic studies to the department at St. Mary's. These include: Grand Junction Osteopathic Hospital, Grand Junction Veterans' Hospital, and Mesa Memorial Hospital. In addition, a review of all Mesa County coroner cases identified one additional lung cancer case which had been previously undiagnosed. Diagnoses, residence addresses, and dates of birth for each person were verified from hospital charts or from physicians' office records.

As noted in Table 2, the Central Cancer Registry had identified 81.9% of the lung cases and 85.4% of the leukemia cases. The cases identified from pathology record review were all from the other area hospitals. St. Mary's is the only Mesa County hospital which has been participating in the Central Cancer Registry. In addition, its registry has been based in the medical records department and has picked up cases identified by discharge diagnosis on the hospital charts. Therefore, persons referred from other hospitals to the St. Mary's Pathology Department for diagnostic work but never actually hospitalized at St. Mary's would be missing from the registry. This was the situation for the additional 28 lung cases and the additional 6 leukemia cases noted in Table 2.

3. Rate Determinations

Age-specific incidence rates for lung cancer and leukemia were calculated for Mesa County using population estimates from the State Division of Planning for 1973, the midpoint of the study period. Fortunately, a special census was conducted in 1977 in selected energy impact areas of western Colorado, including Mesa County. This confirmed that the estimates for 1973 were valid as noted by the trends in percent distribution between 1970 and 1977 highlighted in Table 3. The deviations for age groups "less than 5" and "65 and over" are very slight and would contribute to underestimating the rates for those age groups. If a small bias were introduced, it would be in favor of the null hypothesis that there is no excess cancer incidence.

These age-specific rates were then compared to expected rates based on data for the State of Colorado from the Third National Cancer Survey, 1969-1971.[44]

Fortunately, the entire State was included in that incidence study which used casefinding techniques similar to those employed in this study. The use of the State as a standard reference population is preferred to using data for the entire U.S., as is usually done in comparisons of this type.

The Standard Morbidity Ratio (SMR), a comparison of observed cases (or rates) to expected cases (or rates), was calculated for both cancer types by age groups. Significance tests were applied to appropriate portions of the analysis using the table developed by Bailor for significance factors for the ratio of an observed value to its expectation.[45]

C. Results and Discussion

1. Lung Cancer

During the study period, 160 cases of lung cancer were observed, whereas 143 were expected, as noted in Table 4. The SMR for all ages of 1.12 is not significant. The table does, however, show small differences for age groups 35-49 yrs. (SMR 1.6) and 50-64 yrs. (SMR 1.27). Although neither are significant at the 0.05 level, the excess observed for the 35-49 year age group would be significant at this level had it included one additional observed case.

Table 5 depicts the percent distribution of the lung cancers in Mesa County by cell type. They are distributed in proportions similar to cell types in the U.S. lung cancer population. In Mesa County, squamous cell carcinoma is the the most prevalent cell type (55%), adenocarcinoma the next (26%), and small/oat cell carcinoma the third most prevalent (18%). This table also shows the lung cancer cell types observed in uranium miners. Small/oat cell is most prevalent (64%), squamous cell is next (25%), followed by adeno (7%).[46]

Table 6 was prepared to determine whether the slight excess of lung cancer cases in the younger age groups might be explained on the basis of uranium miners, many of whom retire in Mesa County or move to Mesa County for treatment following diagnosis of their lung cancer. As previously noted, miners develop lung cancer at earlier ages than non-miners.

As seen in Table 6, five of the 14 cases in the 35-49 year age group have small/oat cell carcinoma, a higher proportion (1/3) than might be expected in a non-miner's population (1/5). In addition, 4 of these 5 cases are males. These findings may be explained on the basis of uranium miners present in this study population. Indeed, review of death certificates reveals that 10 of the 160 cases in this study had "mining" entered as their primary life occupation. This probably represents underreporting since retired miners who work at a subsequent occupation may have "retired" entered on the death certificate. Therefore, we conclude that this slight excess in the 35-49 year age group is probably due to the presence of uranium miners in this population.

2. Leukemia

Age-specific leukemia rates are shown in Table 7. For all age groups, there is twofold excess of observed cases with an SMR of 2.05 which is significant at the 99% level (p F 0.01). Although the number of cases is small within each age group, this excess is found primarily in persons 65 years and over, where the incidence is 2-1/2 times expected (SMR 2.53). There is no significant excess noted in children and young adults.

Table 8 illustrates the distribution of these cases by type of leukemia. As is well known, ALL is primarily found in children and young adults, whereas AML and CML are found primarily in older adults. The large group of cases (14) are persons 65 years and over with AML. Indeed, almost half the cases in the study group (20 out of 41) are in persons 50 years and over with AML.

This distribution is compared with that for the State of Colorado in Table 9. AML cases in persons aged 65 and over comprise 34% of all cases in Mesa County, but only 18% of all cases in Colorado.

This finding is consistent with other research which suggests that the body's defense systems weaken with aging and become less competent to fight foreign invaders, whether microorganisms or "aberrant" host cells.

A shift towards increased cases of acute leukemias (ALL and AML) has been reported in A-bomb victims, while studies of X-ray associated leukemias show an increase of both AML and CML. The observed increase in AML in Mesa County is consistent with these findings if radiation exposure is considered as a possible causal agent in this western Colorado county.

There is nothing unusual about the sex distribution within this group of leukemia cases as illustrated in Table 10. Because of the small numbers involved, the sex ratio (males:females) of the cases in Mesa County (0.95) is not significantly different from that predicted by Statewide statistics (1.23). Within the "65 and over" age group, no difference is observed. These findings are not significantly different from national data which show a slight predominance of males to females for leukemia.

D. Summary

In summary, this phase of the study shows that:

1. There is no total excess incidence of lung cancer apparent at this time in Mesa County, Colorado.

2. A slight but not statistically significant excess incidence of lung cancer among 35 to 49 year old males is probably explained by the presense of uranium miners in the study population.

3. There is a twofold excess incidence of leukemia in Mesa County, Colorado, for all age groups which is statistically significant at the $p < 0.01$ level.

4. This excess leukemia rate is:

    a. primarily in persons aged 65 and over where the observed rate is 2-1/2 times the expected rate
    b. primarily of the the type Acute Myelogenous Leukemia (AML)
    c. equally distributed between males and females.



922 046

This leukemia excess may be a random variation from the average since age-adjusted rates are not available county by county throughout Colorado, it is not possible to compare Mesa County's twofold excess with other counties. Therefore, it is not possible to report that this county has the highest leukemia rate in the State, only that its rate is twice the expected rate.

The finding that the leukemia excess is among the elderly who are most susceptible to any foreign agent, and that the cell type is that often seen in excess in populations exposed to radiation, raise serious questions in a geographical area where radioactive uranium mill tailings have been used extensively for construction purposes.

Because of this potential linkage between a known leukemogenic agent and an observed leukemia excess, further investigation was needed. The second phase of the study (a case-control approach) is explained in the following section.

## V. THE CASE-CONTROL STUDY: Leukemia Deaths 1960-1978

### A. Objective

To determine whether persons who died of leukemia in Mesa County, Colorado, were at any increased risk because of exposure to uranium mill tailings used for construction purposes.

### B. Methods

#### 1. The Research Design

The retrospective case-control study design was felt to be most appropriate to this investigation of leukemia excess in Mesa County, Colorado. The case group included all adults who died of leukemia (ALL, AML or CML) between 1960 and 1978 who had lived in Mesa County at least 2 years prior to their diagnosis. Additional entry criteria included: no occupational history of uranium or hard rock mining or milling, and no history of radiotherapy or chemotherapy prior to the time of diagnosis.[47]

Two control groups were created from persons who died of other causes. Control Group 1 was composed of persons who died of Grade "A" cancers, i.e., cancers of tissue known to be associated with ionizing radiation as a potential cancer-causing agent. Control Group 2 was comprised of persons who died of cardiovascular causes (heart disease) or accidental deaths for cases where there were no heart disease matches. Controls were matched pairwise with cases by age (within 5 years), sex, and year of death.

Data were collected through interviews with surviving relatives and through review of medical records and public records. The advantages of this research design are threefold. First, it provides two matched controls per case rather than a single control. Second, since grade "A" cancers may be linked to radiation, this control group also serves as a second study group to



922 048

compare with the heart disease group where radiation would not have any causal role. Third, leukemia is much more radioassociated than the other grade "A" cancers. Subsequently, leukemia would show the greatest effect if radiation were a causal agent in this study group. The cancer control group may, therefore, show an intermediate effect between the leukemia and heart disease groups.

2. Casefinding

Of the 41 leukemia cases identified in Part I of this study, only 31 fit the study criteria. The 10 deletions included:

6 children
1 adult with residence < 2 yrs.
1 uranium miner
1 adult with chemotherapy for multiple myeloma who converted to leukemia secondary to the therapy[49]
1 adult still alive
10

In order to increase the size of the case study group, we returned to the Pathology Department of St. Mary's Hospital in Grand Junction. Pathology reports for the additional years 1960 through 1978 were reviewed to identify further cases. The Colorado Central Cancer Registry again served as a reference base for the expanded case group. Unfortunately, the Registry was created in 1969 and had incomplete data entered for the earlier years. Cases were again corroborated by review of medical charts at all area hospitals. Death certificate printouts were reviewed in the Division of Vital Statistics, Colorado Department of Health to identify further cases.

As seen in Table 11 of the 26 new cases that were identified, only 15 fit the study criteria. The 11 deletions included:

8 adults with residence < 2 yrs.
1 uranium miner
2 still living

This left a total group of 44 leukemia cases which fit the study criteria.

3. Control Group Selection

The specific causes of death used for these control groups are shown in Tables 12 and 13. Table 12 lists the types of cancers in Control Group 1: the grade "A" malignant neoplasms. This list of neoplasms of radiosensitive tissue includes cancers of the pharynx, the gastrointestinal system (excluding esophagus), the respiratory system (primarily lung), the reticuloendothelial system (excluding leukemia), and the breast. The distribution of these cancer types for this group of matched controls is shown in Table 14. This distribution is similar to the distribution of these cancer types among the general population.

The specific causes of death which comprise Control Group 2 are listed in Table 13. Of the 35 matched controls in this group, 32 (92%) are deaths from cardiovascular causes. The 3 controls with accidental deaths are matches for the youngest leukemia cases, ages 28, 32 and 33. Heart disease is very rare in this age group. Causes of death in these categories have never been shown to have any relationship with ionizing radiation. A computer run was completed through all Death Certificate tapes from the Health Department's Division of Vital Statistics for the years 1960-1977. This printout identified deaths from all causes in Mesa County which matched each leukemia case by year of death, by sex and by age within 5 years.

This pool of matched deaths for each case was manually scanned to select the 2 controls by the appropriate cause of death and the age at death closest to the case. A second potential control in each category (cancer and heart disease) was selected as the next nearest match in the event that the first control did not meet the study criteria or was untrackable. Matches for leukemia deaths in 1978 were identified manually because they had not yet been entered on tape.

4. Case and Control Tracking

After identification of cases and controls, death certificates were pulled from the Division of Vital Statistics. These provided the name and address of the "informant" (usually the surviving spouse or the next of kin), the name of the responsible physician, and the name and address of the funeral home. Hospital records and physicians' office records were reviewed to provide further leads about relatives. When necessary, funeral home records were reviewed to identify relatives who made final funeral arrangements or relatives and close friends who served as pallbearers.

In difficult cases where leads from these sources failed to locate surviving relatives, obituary notices on microfilm were reviewed at the local newspaper office in Grand Junction. These usually listed all surviving relatives at the time of death, and often provided new leads for tracking.

5. The Research Variables

The multiple independent variables examined in the three study groups are summarized in Table 14.

a. Socioeconomic Level

The primary occupation of each study subject was scored according to the occupational index developed by Hollingshead and used in social science research as an indicator of socioeconomic level.[48] Minor modifications ensured that the index was applicable to the work experience in Colorado (refer to Appendix 3). For persons with two major occupations, we used the one which accounted for the largest portion of the person's working life.

b. Length of Mesa County Residence

The total length of residence in Mesa County prior to the time of diagnosis of leukemia or cancer was examined for each subject. Time of diagnosis is extremely variable for persons with heart disease and is not applicable to accidental deaths. Therefore, to insure comparability, the time of diagnosis for each leukemia subject was used for the matched person in Control Group 2.

c. General Health Status

In order to make an assessment of each subject's general health status prior to the time of diagnosis, a General Health Assessment Index was developed (see Appendix 4). It is based on information from each person's medical history regarding number of chronic problems and number of major surgeries up to the time six months prior to diagnosis. This was done to remove the possibility of counting the actual course of symptoms which may ultimately have led to the diagnosis of the leukemia or cancer. Again, the time of diagnosis for each leukemia case was applied to the matched subject in the heart Control Group 2.

d. Family History of Leukemia and Cancer

Information was solicited about the numbers of relatives (1st, 2nd and 3rd degree) of the study subject who were known to have had leukemia or any of the other types of cancer.

e. Radiation Exposure and Dosimetry

A detailed history of residential and work addresses was reconstructed for each of the study subjects. This included the number of years at each location and a determination of whether work was part-time or full-time at each work site.

Specific addresses were then checked in the records of the Remedial Action Program which include gamma radiation screening data for over 26,000 structures in Mesa County. All of these sites had been assigned a letter classification based on the dose of radiation present in the structure. This letter assessment ranged from "A" ('corrective action' recommended to remove tailings) to "F" (no tailings). (See Appendix 5b for details.)

Because length of exposure to an "A" location may vary greatly, a cumulative gamma exposure was calculated for each subject for the time period between 1950 and the time of diagnosis. For time spent at a location for which no gamma dose was available, the background dose for the area was used in the calculation. For those years that a person lived elsewhere in the United States, the background radiation dose in that area was taken from the appropriate Environmental Protection Agency manual.[49]

922 052

For comparative purposes, an average annual gamma exposure was calculated for each person. This calculation most accurately reflects the radiation exposure experienced by each individual at work as well as at home. (Refer to Exposure Work Sheet in Appendix 5c.)

These measures are admittedly crude and imprecise indicators of radiation exposure in this community setting. In the absence of a more sophisticated methodology for direct dose determinations at the low levels under study, this indirect method of calculating dose must suffice.

6. Data Collection

The primary source of data was from structured interviews with surviving relatives of the deceased subject. A questionnaire was developed based on instruments used elsewhere in similar research (see Appendix 6). A pretest of the questionnaire with relatives of 10 leukemia victims in Denver County led to modifications in content and internal flow of the instrument.

Each informant identified through successful tracking received a letter introducing the study and requesting his/her cooperation (see Appendix 7). The introductory letter was followed by a phone call to arrange a personal or a telephone interview. All personal interviews were conducted by authors M.C. or T.F. who also completed all phone interviews with the leukemia group informants. Additional phone interviewers were trained to help complete the data collection from the informants in the control groups.

An attempt was made to reconstruct residential and work histories from public records for those subjects who had no relatives or for who relatives could not be located. This reconstruction was based on information gathered for review of obituary notices, city directories, old phone books, and tax assessors' records. Hospital charts were sometimes helpful, especially those with thorough Discharge Summaries. Physicians' office records were rarely useful for this type of information.



922 053

Table 15 illustrates our experience in locating informants, obtaining interviews, and completing data collection. The completion rates for the study groups were: 100% (44 of 44) for the leukemia groups, 87% (34 of 39) for the cancer control group, and 81% (35 of 43) for the heart disease control group. Of the 44 completed leukemia cases, informants were interviewed for 37 (84%). Of the completions in the control groups, informants were interviewed for 32 of 35 (94%) of the cancer controls and 34 of 35 (97%) for the heart disease controls.

The refusal rates were 7% for leukemias, 0% for cancer controls, and 3% for heart controls, respectively. Reasons given for refusal to cooperate in the study included: an aversion to recalling the events that led to the death of a spouse 18 years earlier, a distrust and dislike of the entire medical professsion by one family because of the perceived medical mismanagement of a parent during her terminal illness, and an unwillingness to cooperate in any study that was "trying to prove that the mill tailings were harmful."

7. Data Processing and Analysis

Responses were coded according to the coding schedule found in the Appendix 8. Radiation exposure calculations were entered directly on code sheets. These coded responses and values filled one data card per subject. An analysis program, based on the Statistical Package for the Social Sciences (SPSS), provided frequency distributions, means and medians for each research variable. A multivariate analysis for matched pairs was available if a more detailed data analysis were indicated.

8. Reliability and Bias

The reliability of information obtained from interviews with relatives has been shown to be variable depending on the degree of closeness of the relative to the subject, the nature of the cause of death, and the time period between the event and the interview. The data most critical to this study related to specific home and work addresses and the number of years spent at each. Distant recall lends itself to simple errors and confusion about specific street addresses.

Interviewers developed a simple score for informant reliability based on a subjective assessment of certainty of recall, fuzziness with addresses and dates, confusion about work history, and the degree to which informants had prepared written notes of dates and addresses from personal records. Of the leukemia informants, 68% were rated as "excellent," whereas 47% of cancer control informants and 40% of heart disease informants received this rating.

With respect to the degree of closeness of informant to subject, 98% of case informants were first degree relatives (spouse, parent, son or daughter, brother or sister), whereas 68% of cancer control informants and 83% of heart control informants were first degree relatives. The mean durations of acquaintance of the informants with the subjects were 41 years, 38 years and 44 years for the leukemia group, cancer control group, and heart control group respectively.

A 20% sample of cases was selected for verification of residence addresses through review of city directories and old phone books. Informants rated as "excellent" averaged one or fewer errors in recall of dates and addresses in the cases' residential history. These errors were regarding locations where the case spent the least amount of time. An inverse correlation was noted between informant rating and frequency of errors; i.e., the lower the rating, the more the errors documented. Therefore, all case histories with less than an "excellent" rating were verified through city directory checks. Because of the even greater concern with informant reliability among the controls, residential histories of all controls were verified in the same way.

Because of the nature of the study design and the intense activity in casefinding and control selection, it was not possible to maintain a fully blind situation for the investigators with respect to interviewing. However, control selection was completed from computer printouts showing only death certificate numbers, thus removing any bias in the selection process.

In addition, the investigators checked the radiation records which identified the "tailings" locations only after completion of the data collection for all cases and controls. The documented residential histories verified from public records did not lend themselves to interpretation or bias in assigning radiation levels taken directly from computer printouts from the Gamma Screening Program. Therefore, within the limitations of the study design, attempts were made to remove any bias towards or away from the null hypothesis that there were no significant differences between cases and controls.

C. Results and Discussion

The results are presented and discussed for each of the research variables.

1. Socioeconomic Level

Table 16 shows the percent distribution of cases and controls according to the level of each subject's primary occupation. Category 2, "Lesser Professional," accounts for 35% of the leukemia cases, whereas only 17% of cancer controls and 24% of heart disease controls appear in the category.

Category 2 includes managers of large businesses, farm owners or managers, government officials, owners of medium sized businesses, contractors, and "lesser professionals" such as nurses, pharmacists, teachers and social workers (see Appendix for full scale).

This finding is consistent with several other studies which report higher leukemia rates among higher socioeconomic levels.[50,51,52] No definitive causal linkage has ever been demonstrated to explain this observation.

Although there is a slightly higher distribution of homemakers in the leukemia group, the general distribution among all other categories is similar for cases and controls.

2. Years of Residence in Mesa County

Table 17 shows the total years of residence in Mesa County prior to the diagnosis of leukemia for all cases and controls. As noted, only 4 leukemia cases lived in Mesa County less than 10 years. The overall distribution is similar among all groups with the mean duration of 28.9 years, 22.2 years and

922 056

30.0 years respectively for the leukemia group, the cancer control group and the heart disease control group.

This finding suggests that there is probably no simple factor directly related to length of county residence which differentially influences persons who have died of leukemia since 1960.

3. General Health Assessment

The percent distribution of study subjects by general health assessment is revealed in Table 18. The general distribution among categories is similar for leukemia cases and both control groups. By this crude index, 23% of the leukemia group appears in the "excellent" category compared with 48% of cancer controls and 29% of heart disease controls. The general health status of leukemia cases is about the same as that of controls.

4. Family History of Leukemia and Cancer

Fifteen percent of the relatives of leukemia cases reported a positive family history of leukemia for at least one other family member. This compares with 0% for cancer control families and 3% for heart control families, as seen in Table 19. A positive family history of other cancers is also noted to be higher for the leukemia group (60%) than for either the cancer control group (41%) or the heart control group (47%).

The more positive family history of leukemia reported by leukemia group informants may be due to a greater interest among leukemia families in identifying other relatives with this rare disease. It is also consistent with other research which has demonstrated a slightly increased chance of developing leukemia in families having a previous history of this form of cancer.

The slightly larger percent of leukemia informants reported family histories of other cancers. However, this is probably not significant because of the small numbers involved.

922 057

5. Radiation Exposure

Three indicators of radiation exposure are presented: residence exposure to "tailings" houses, cumulative gamma radiation exposure overtime, and average annual gamma radiation exposure over time. As seen in Table 20, only 2 leukemia cases, 1 cancer control and 1 heart control ever lived in a "tailings" house, designated by the classification "A". These sites had gamma levels at least 10 times the background radiation level in the area, and are recommended for remedial action to remove the tailings from the structure.

Of these 4 persons who lived in "tailings" houses, only 2 (one leukemia case and one heart disease control) resided in them long enough to develop a cumulative exposure level which was substantially higher than background levels, as seen in Table 21. Although both persons (both men over 65) spent 19 years each in a "tailings" home, the leukemia case also worked 9 of those years in a "tailings" work site. That accounts for his total exposure of 5722 mR compared to 4315 mR for the cancer control.

The 2 other persons (both women over 65) lived in a "tailings" residence for 3 years and 1 year for the leukemia case and the cancer control respectively. They both had apartments in the same single story complex which was constructed as a limited income residential center for senior citizens. That complex, which was constructed on a concrete slab floor poured over tailings fill, has the highest gamma radiation readings of all the "tailings" locations identified in this study.

A more useful indicator of radiation exposure is seen in Table 22 which shows the average annual exposure doses for the study groups. Again, the 2 men with long-term residence in "tailings" houses fall into the >180 mR/year category. The average annual exposure for the leukemia case was 301 mR/year while that for the heart control was 227 mR/year. It is of interest to point out that this heart disease subject is, in fact, the exact matched control for this leukemia case. Indeed, these matched subjects are the only persons with average annual radiation exposures significantly higher than the upper range of background levels for Mesa County (218 mR/year).

Some perspective on gamma radiation dosage is useful in better understanding the dose ranges presented here. Table 23 lists levels of exposure in millirem or millirad (mR) in various situations in order of increasing dosage. As noted, average background radiation in Mesa County is .014 mR/hr or about 122 mR/yr. Denver County background is somewhat higher, .019 mR/hr or about 165 mR/yr.[52] Both cosmic and terrestial sources are computed in these background levels, the cosmic factor being the larger source. Since elevation above sea level determines the size of the cosmic dose, areas of high elevation have higher background doses. Therefore, Denver County at 5200 feet has a higher background radiation level than Mesa County at 4200 feet above sea level.

One attempt to correlate levels of background radiation in the U.S. with varying cancer mortality rates showed no significant relationship.[53] Another more intensive examination of this relationship is currently underway at the National Cancer Institute.[54] Most of the exposure levels presented in this study of Mesa County fall in the background range as noted. The highest levels in this study, the two persons in tailings houses ("A" locations), have average annual exposures of 227 mR and 301 mR, two to three times higher than average background in Mesa County. As noted, these are due to full-time residence and work at "tailings" locations.

No previous research has been identified which has examined the health effects of radiation of these very low levels. The lowest dose ranges studied previously have been those of multiple diagnostic X-rays. Values of two of the most common X-rays are listed in Table 23.

A single view chest film delivers 10 mR in .02 seconds with a total gonadal dose estimated at 2 mR. Gonadal doses from abdominal films are 250 mR for males and 280 mR for females.

The lowest exposure levels shown to produce an excess of cancers in adults have been from the cumulative radiation of 10 or more abdominal X-rays over a 5-year period. That would roughly translate to a gonadal dose of at least 2500 mR (2.5 Rad). A 5-year period of "tailings" radiation exposure for the 2 highest exposure study subjects would yield 1250-1500 mR (1.5 Rad) of total body exposure. For comparative purposes, the gonadal dose would be somewhat less than that. As noted, only one of these persons developed leukemia, the other died of heart disease.

Estimated exposure levels of atomic bomb victims who subsequently developed leukemia are also listed on Table 23 to complete this perspective comparison on gamma exposure levels. As noted, it required an estimated 100,000 mR (or 100 Rads) to induce leukemia in this population. Although imprecise, these data from atomic bomb studies have been used to develop the current occupational standards for radiation exposure.

Comparison between the current study and these previous reports is difficult. As mentioned, all of the earlier research focused on absolute exposure levels at least 1000 times greater than the highest levels observed in Mesa County subjects. More critical, however, is the difference in duration of exposure. The diagnostic X-ray research has dealt with single or multiple exposures at one or several points at a duration of only milliseconds for each exposure. The study subjects in Mesa County have constant long-term exposure to the low levels of radiation emitted from tailings structures. It is reasonable to assume that these different durations of exposure make comparison difficult, if not impossible.

Because only two study subjects had radiation exposure at levels 2-3 times above the background level, it is not possible to say anything conclusive about the leukemogenic effects of long-term exposure to these very low levels. Since 43 of the 44 leukemia subjects did not have "residential exposure" to tailings structures, it appears that such residential exposure is unrelated to the observed leukemia excess in Mesa County.

D. Summary

The major findings of this case-control study of adult leukemia deaths between 1960 and 1978 are:

922 060

1. There are no significant differences between the leukemia group and the 2 control groups for the independent variables:

   a. lenght of residence in Mesa County
   b. general health status prior to diagnosis
   c. (residential) exposure to "tailings" locations.

2. There are slight but not significant differences among the study groups for the independent variables:

   a. socioeconomic level - higher in the leukemia group
   b. family history of leukemia - more positive in the leukemia group.

## VI. THE CONCLUSIONS

The objectives of this study have been:

1. to verify an apparent excess of lung cancer and leukemia in Mesa County.

2. to determine whether persons with leukemia had excess radiation exposure from "tailings" structures.

### A. Excess Leukemia Unexplained

The first portion of this study showed no excess incidence of lung cancer, but a verified twofold excess of leukemia in Mesa County during the study period. The second part of the study showed no significant differences between leukemia cases and matched controls for most of the study variables including radiation exposure. No explanation is found for the observed leukemia excess. This excess cannot be explained on the basis of excess radiation exposure from uranium mill tailings used for construction purposes.

### B. Need for Further Research

These findings are inconclusive with respect to the basic research question about the adverse health effects of exposure to low level radiation. Because of the limitations of the case-control study design and the very small numbers of subjects found to have any excess radiation exposure, these negative findings neither prove nor disprove the "safety" of constant, long-term exposure to the low levels of radiation such as exist in "tailings" buildings in Mesa County, Colorado.

Likewise, these findings provide no new insight in the continual process of review and revision of "safe" radiation standards for occupational exposure

922 062

in nuclear industries or for public exposure in communities surrounding or near nuclear power plants or other nuclear industries. Further research must be conducted in occupational and non-occupational settings with adequate sized populations. Direct or indirect measures of radiation exposure must be available, combined with reasonably accurate records of duration of exposure, either at the work site or at home. One example of this type of study population would be within the occupational groups in nuclear industries which are regulated by the U.S. Nuclear Regulatory Commission.

A non-occupational example would be in Mesa County, Colorado, where a "tailings" cohort could be identified from existing records. The population at risk since 1952 from known exposure levels in remedial action locations is estimated to be about 2,500 persons. A "non-tailings" cohort could be selected as a control group. Both cohorts could be traced historically over the time period following their exposure to determine whether there are any differences in their experiences with illness and death.

An alternative potential study would be to identify a cohort of children born since 1952 in Mesa County who were conceived and lived in "tailings" structures. A similar cohort of "non-tailings" children could be traced to document any differences in their illnesses or malignant diseases.

Since radiation exposure doses could be estimated for these cohorts in either study design, dose-response relationships could be calculated from the data on morbidity and mortality patterns. The results of studies such as these might provide more conclusive answers to the basic question: Are there any adverse health effects from long-term exposure to very low levels of ionizing radiation?

## REFERENCES


1. United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation 1977 Report. United Nations, N.Y. 1977.

2. March, H.C., "Leukemia in Radiologists," Radiology 43:275-278, 1944.

3. March, H.C., "Leukemia in Radiologists in a 20-Yr. Period"

4. Ziegler, K., Experimentelle und Klinesche Untersuchunger uker die Histogenese der Myeloischen Leukamie. Gustav Fisher, Jena, 1906.

5. Ulrich, H., "The Incidence of Leukemia in Radiologists" N.E.J.M. 234:45-56, 1946.

6. Seltzer, R. and Sartwell, P.E., "The Influence of Occupational Exposure to Radiation on the Mortality of American Radiologists and Other Medical Specialists. Am. J. Epidemiol. 81:2-22, 1965.

7. Warren, S., "Longevity and Causes of Death from Irradiation in Physicians." JAMA 162:464-468, 1956.

8. Mancuso, T.F., Stewart, A. and Kneale, G., "Radiation Exposure of Hanford Workers Dying of Cancer and Other Causes," Health Physics 33:369, 1977.

9. Voelz, G.L. et al., "Studies on Persons Exposed to Plutonium." Unpublished paper presented at the International Symposium on the Late Biological Effects of Ionizing Radiation, Vienna, Austria, March 1978. From the Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

10. Najarian, T. and Colton, T., "Mortality From Leukemia and Cancer in Shipyard Nuclear Workers," Lancet 8072:1018-20, 1978.

11. Wagoner, J.K., Archer, V.E. et al., "Radiation as the Cause of Lung Cancer Among Uranium Miners." N. Engl. J. Med. 273:181-188, 1965.

12. Saccomanno, G. et al., "Histologic Types of Lung Cancer Among Uranium Miners." Cancer 27:515-523, 1971.

13. Archer, V., Gillam, J. and Wagoner, J., "Respiratory Disease Mortality Among Uranium Miners," Ann. N.Y. Acad. Sci. 271:280-293, 1976.

14. Wagoner, J.K., Archer, V.E., et al., "Cancer Mortality Patterns Among U.S. Uranium Miners and Millers, 1950 through 1962." J. Natl. Cancer Inst. 32:787-801, 1964.


922 064

REFERENCES (Continued)


15. Jablon, S., "Environmental Factors and Radiation," Chapter 10 in Fraumeni, J.F. (Ed.) Persons At High Risk of Cancer, N.Y., Academic Press, Inc., 1975.

16. UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation. Ionizing Radiation: Levels and Effects, Vol. II, United Nations, N.Y., 1972.

17. Moriyama, I.M. and Kato. M., "JNIH-ABCC Life Span Study Report 7: Mortality Experience of A-Bomb Survivors 1970-1972, 1950-1972." Atomic Bomb Casualty Commission Technical Report 15-73, Hiroshima, Japen, 1973.

18. Jablon, S. and Kato, H., "Studies of the Mortality of A-Bomb Survivors. 5 Radiation Dose and Mortality, 1950-70," Radiat. Res. 50:649-698, 1972.

19. Jablon, S., et al., "Cancer in Japanese Exposed as Children to Atomic Bombs." Lancet 1:927-932, 1971.

20. Jablon, S. and Kato, H., "Studies of the Mortality of A-Bomb Survivors. Part 5-Radiation Dose and Mortality, 1950-70," Radiat. Res. 50:649-698, 1972.

21. Nishiyama, H., et al., "The Incidence of Malignant Lymphoma and Multiple Myeloma in Hiroshima and Nagasaki Atomic Bomb Survivors, 1945-1965," Cancer 32:1301-1309, 1973.

22. Wood, J.W., et al., "Thyroid Carcinoma In Atomic Bomb Survivors, Hiroshima and Nagasaki," Am. J. Epidemiol. 39:4-14, 1969.

23. Wanebo, C.K. et al., "Breast Cancer After Exposure to the Atomic Bombing of Hiroshima and Nagasaki." N. Engl. J. Med. 279:667-671, 1968.

24. Court Brown, W.M. and Doll, R., "Leukemia and Aplastic Anemia in Patients Irradiated for Ankylosing Spondylitis," Her Majesty's Stat. Off., London, 1957.

25. Court Brown, W.M. and Doll, R., "Mortality from Cancer and Other Causes After Radiotherapy for Ankylosing Spondylitis," Br. Med. J. 2:1327-1332, 1965.

26. Alderson, M.R. and Jackson, S.M., "Long-Term Follow-up of Patients with Menorrhagia Treated by Irradiation," Br. J. Radiol. 44:295-298, 1971.

27. Doll, R. and Smith, P.G., "The Long-Term Effects of X-irradiation in Patients Treated for Metropathia Hemorrhagica," Br. J. Radiol. 4:362-368, 1967.

28. Albert, E.R. and Omran, A.R., "Follow-up Study of Patients Treated by X-ray Epilation for Tinea Capitis," Arch. Environ. Health 17:899-950, 1968.

REFERENCES (Continued)

29. Hempelmann, L.H., et al., "Neoplasms in Persons Treated with X-rays in Infancy for Thymic Enlargement," J. Natl. Cancer Inst. 38:317-341, 1967.

30. Favus, M.J., et al., "Thyroid Cancer Occurring as a Late Consequence of Head-and-Neck Irradiation," N.E.J.M. 294:1019-1025, 1976.

31. Stewart, A., Webb, J. and Hewitt, D., "A Survey of Childhood Malignancies," Br. Med. J. 1:1495-1508, 1958.

32. MacMahon, B., "Prenatal X-ray Exposure and Childhood Cancers," J. Natl. Cancer Inst. 28:1173-1191, 1962.

33. Graham, S., et al., "Preconception, Intrauterine and Postnatal Irradiation as Related to Leukemia," Natl. Cancer Inst. Monogr. 19:347-371, 1966.

34. Stewart, A., Pennybacker, W. and Barber, R., "Adult Leukemias and Diagnostic X-rays," Brit. Med. J. 5309:882-890, 1962.

35. Gibson, R., et al., "Irradiation in the Epidemiology of Leukemia Among Adults," J. Natl. Cancer Inst. 48; No. 2:301-311, 1972.

36. International Commission on Radiological Protection (ICRP), Publication 14: Radiosensitivity and Spatial Distribution of Dose, London, Pergamon Press, 1969.

37. Jablon, S., "Environmental Factors, Radiation," Chapter 10 in Fraumeni, J.F. (Ed.) Persons At High Risk of Cancer, N.Y., Academic Press. Inc., 1975.

38. "Use of Uranium Mill Tailings for Construction Purposes," U.S. Congressional Hearings, Subcommittee on Raw Materials, Joint Committee on Atomic Energy, Washington: Government Printing Office, Publ. No. 70-5540, 1971.

39. Ibid, Testimony of Anthony Mastrovich, AMAX Uranium Corp., pp. 142-155.

40. Ibid, Statement by Henry Kempe, M.D., University of Colorado Medical Center and Robert Ross, M.D., Pediatrician in Grand Junction, pp. 281-283.

41. Lubs, Herbert and Lubs, Marie-Louise, "Study of Newborns in Grand Junction, Colorado," Unpublished Report, Department of Pediatrics, University of Colorado Medical Center, Denver, 1973.

42. Ferguson, Stanley H., Memorandum of February 24, 1978, Division of Disease Control and Epidemiology, Colorado Department of Health.

43. International Classification of Diseases, Adapted-Eighth Revision, U.S. Department of HEW, National Center for Health Statistics, Public Health Service Publ. No. 1693, Washington: Government Printing Office, 1967.

922 066

REFERENCES (Continued)

44. Third National Cancer Survey: Incidence Data, National Cancer Institute Monograph 41, DHEW Publication No. (NIH) 75-787, 1975.

45. Bailar, J.C., "Significance Factors for the Ratio of a Poisson Variable to its Expectation," Biometrics $20^3$:639-643, 1964.

46. Saccomanno, G., "Histologic Types of Cancer Among Uranium Miners," Cancer 27:515-523, 1971.

47. Kyle, R.C. et al., "Multiple Myeloma and Acute Leukemia Associated with Alkytating Agents," ARCH Intern Med., Vol. 135, January 1975.

48. Hollingshead, A.B., "A Two-Factor Index of Social Position," as described in Bonjean, C.M., Hill, R.J. and McLeMore, S.D., Sociological Measurement: An Inventory of Scales and Indices, Chandler Publishing Co., 1967, New York, New York.

49. U.S. Environmental Protection Agency, Office of Radiation Programs, Surveillance and Inspection Division, Washington, D.C., No. EP 6.10/2:72-1.

50. Sacks, M.S. and Seeman, I., "A Statistical Study of Mortality from Leukemia," Blood 2:1-14, 1947.

51. Hewitt, D., 1955 British J. Preventive Soc. Med. 9:81-88.

52. World Health Organization: "Mortality from Hodgkin's Disease and From Leukemia and Aleukemia." Epidemiology and Vital Stats. Rep. 8:81-90, 1955.

53. Frigerio, N.A. and Stowe, R.S., "Carcinogenic and Genetic Hazard from Background Radiation," in Biological and Environmental Effects of Low-Level Radiation, Vol. 2, pages 385-391 (Argonne National Laboratory, Ill., U.S.A.) 1976.

54. Mason, Thomas, Environmental Epidemiology Branch, National Cancer Institute, Bethesda, Md., Personal Communication, August 1978.

APPENDIX 1

TABLE 1

TYPES OF CANCER INCLUDED IN THE CANCER INCIDENCE STUDY OF
MESA COUNTY, COLORADO
1970-1976

| General Category | Specific Type | ICDA-8 Code # |
|---|---|---|
| LUNG | Trachea | 162.0 |
| | Bronchus and Lung | 162.1 |
| | Pleura | 163.0 |
| | Mediastinum | 163.1 |
| LEUKEMIA | Lymphatic, Acute (ALL) | 204.0 |
| | Myeloid, Acute* (AML) | 205.0 |
| | Chronic (CML) | 205.1 |
| | Monocytic, Acute* (AML) | 206.0 |
| | Chronic (CML) | 206.1 |

*Includes those types diagnosed as "subacute."



922 068

## TABLE 2

### CASEFINDING RESULTS BY SOURCE AND BY TYPE OF CANCER
### MESA COUNTY, COLORADO
### 1970-1976

| Source | Lung Cancer No. | Lung Cancer (%) | Leukemia* No. | Leukemia* (%) |
|---|---|---|---|---|
| Central Cancer Registry | 131 | (81.9) | 35 | (85.4) |
| Pathology Records | 28 | (17.5) | 6 | (14.6) |
| Autopsy Records (Coroner Cases only) | 1 | (0.6) | 0 | - |
| TOTALS | 160 | (100.0) | 45 | (100.0) |

*Excludes chronic lymphatic leukemia and unspecified types.

TABLE 3

POPULATION CHANGES IN MESA COUNTY, COLORADO
1970-1977

| Age Group | 1970[1] No. | 1970[1] (%) | 1973[2] No. | 1973[2] (%) | 1977[3] No. | 1977[3] (%) |
|---|---|---|---|---|---|---|
| Less than 5 | 3,754 | (6.9) | 3,394 | (5.9) | 4,870 | (7.2) |
| 5-19 | 16,852 | (31.0) | 16,338 | (28.4) | 17,586 | (26.1) |
| 20-34 | 9,253 | (17.0) | 12,101 | (21.1) | 16,850 | (25.0) |
| 35-49 | 9,329 | (17.1) | 9,343 | (16.3) | 10,636 | (15.8) |
| 50-64 | 8,685 | (16.0) | 9,110 | (15.9) | 9,761 | (14.5) |
| 65 and Over | 6,501 | (12.0) | 7,157 | (12.4) | 7,685 | (11.4) |
| TOTAL | 54,374 | (100.0) | 57,443 | (100.0) | 67,388 | (100.0) |

SOURCES:

1. U.S. Census, April 1970, U.S. Department of Commerce, Bureau of the Census.
2. Colorado Population Estimates by County 1970-1980, State of Colorado Department of Local Affairs, Division of Planning, June 15, 1973.
3. Special Census, March 1977, U.S. Department of Commerce, Bureau of the Census.

TABLE 4

AGE-SPECIFIC LUNG CANCER INCIDENCE RATES PER 100,000
IN MESA COUNTY, COLORADO
1970-1976

| | EXPECTED* | | OBSERVED+ | | |
|---|---|---|---|---|---|
| Age at Diagnosis | Period Cases | Ann. Rates | Period Cases | Ann. Rates | SMR** |
| Less than 5 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| 5-19 | 0.06 | 0.05 | 0 | 0.00 | 0.00 |
| 20-34 | 0.51 | 0.61 | 0 | 0.00 | 0.00 |
| 35-49 | 9.40 | 14.37 | 15 | 22.94 | 1.60 |
| 50-64 | 55.81 | 87.52 | 71 | 112.91 | 1.27 |
| 65 and Over | 77.33 | 154.34 | 74 | 147.71 | 0.96 |
| TOTAL | 143.11 | 35.6 | 160 | 42.3 | 1.12 |

SOURCE: * Expected Rates based on Third National Cancer Survey, State of Colorado, 1969-1971.

+ Observed rates based on Casefinding Results, Colorado Department of Health, Disease Control and Epidemiology Division

** STANDARD MORBIDITY RATIO (SMR) = $\frac{\text{Observed Cases}}{\text{Expected Cases}}$



922 071

TABLE 5

PERCENT DISTRIBUTION OF LUNG CANCERS BY CELL TYPE IN SELECTED POPULATIONS

| Cell Type | U.S.* | Mesa County | Uranium Miners** |
|---|---|---|---|
| Squamous cell | 49 | 55 | 25 |
| Adeno | 28 | 26 | 7 |
| Small/Oat cell | 20 | 18 | 64 |
| Miscellaneous | 3 | 1 | 4 |

SOURCE: * Third National Cancer Survey, 1969-1971, white males and females.

** Saccomanno, G., "Histologic Types of Lung Cancer Among Uranium Miners," Cancer 27[1]:515-523, 1971.

TABLE 6

DISTRIBUTION OF LUNG CANCER IN MESA COUNTY
BY CELL TYPE AND BY AGE AND SEX

| Cell Type* | AGE GROUPS 35-49 M | F | 50-64 M | F | 65+ M | F | TOTAL M | F | SEX RATIO |
|---|---|---|---|---|---|---|---|---|---|
| Squamous cell (6.8) | 7 | 1 | 25 | 5 | 22 | 3 | 54 | 9 | 6.0 |
| Adeno (2.2) | 1 | - | 6 | 10 | 9 | 4 | 16 | 14 | 1.1 |
| Small/Oat cell (3.7) | 4 | 1 | 8 | - | 5 | 3 | 17 | 4 | 4.3 |
| Miscellaneous * | - | - | 1 | - | - | - | 1 | - | - |
| TOTAL (3.8) | 12 | 2 | 40 | 15 | 36 | 10 | 88 | 27 | 3.3 |

*Male:Female Sex Ratio noted in brackets.

SOURCE: Third National Cancer Survey, Whites, All States combined, 1969-1971.



922 073

TABLE 7

AGE-SPECIFIC LEUKEMIA INCIDENCE RATES PER 100,000
IN MESA COUNTY, COLORADO
1970-1976

| | EXPECTED* | | OBSERVED+ | | |
|---|---|---|---|---|---|
| Age at Diagnosis | Period Cases | Ann. Rates | Period Cases | Ann. Rates | SMR** |
| Less than 5 | 1.27 | 5.37 | 2 | 8.42 | 1.57 |
| 5-19 | 3.16 | 2.76 | 6 | 5.25 | 1.90 |
| 20-34 | 1.71 | 2.02 | 3 | 3.54 | 1.75 |
| 35-49 | 2.06 | 3.15 | 2 | 3.06 | 0.97 |
| 50-64 | 4.00 | 6.28 | 8 | 12.55 | 2.00 |
| 65 and Over | 7.91 | 15.79 | 20 | 39.92 | 2.53++ |
| TOTAL | 20.11 | | 41 | | 2.05++ |

SOURCE: * Expected Rates based on Third National Cancer Survey, State of Colorado, 1969-1971.

\+ Observed Rates Based on Casefinding Results, Colorado Department of Health, Disease Control and Epidemiology Division

** STANDARD MORBIDITY RATIO (SMR) = $\frac{\text{Observed Cases}}{\text{Expected Cases}}$

++ Significant at p = .01

TABLE 8

DISTRIBUTION OF LEUKEMIA CASES BY AGE AND BY TYPE*
MESA COUNTY, COLORADO
1970-1976

| Age in Years at Diagnosis | ALL | AML | CML | TOTAL |
|---|---|---|---|---|
| Less than 5 | 2 | 0 | 0 | 2 |
| 5-19 | 6 | 0 | 0 | 6 |
| 20-34 | 1 | 2 | 0 | 3 |
| 35-49 | 1 | 0 | 1 | 2 |
| 50-64 | 0 | 6 | 2 | 8 |
| 65 and Over | 1 | 14 | 5 | 20 |
| TOTALS | 11 | 22 | 8 | 41 |

*ALL = Acute Lymphocytic Leukemia

AML = Acute Myeloid or Monocytic Leukemia

CML = Chronic Myeloid Leukemia

TABLE 9

COMPARATIVE DISTRIBUTION OF LEUKEMIA CASES BY AGE AND BY TYPE
MESA COUNTY, 1970-1976, AND THE STATE OF COLORADO

| | Age in Years at Diagnosis | ALL No. | ALL (%)* | AML No. | AML (%)* | CML No. | CML (%)* | TOTAL No. | TOTAL (%)* |
|---|---|---|---|---|---|---|---|---|---|
| MESA COUNTY+ | Less than 50 | 10 | (24) | 2 | ( 5) | 1 | ( 2) | 13 | (32) |
| | 50-64 | 0 | ( 0) | 6 | (15) | 2 | ( 5) | 8 | (20) |
| | 65 and Over | 1 | ( 2) | 14 | (34) | 5 | (12) | 20 | (49) |
| | TOTAL | 11 | (27) | 22 | (54) | 8 | (20) | 41 | |
| COLORADO* | Less than 50 | 60 | (20) | 69 | (23) | 23 | ( 8) | 152 | (52) |
| | 50-64 | 7 | ( 2) | 23 | ( 8) | 23 | ( 8) | 53 | (18) |
| | 65 and Over | 6 | ( 2) | 53 | (18) | 30 | (10) | 89 | (30) |
| | TOTAL | 73 | (25) | 145 | (49) | 76 | (26) | 294 | |

SOURCES: + Colorado Department of Health, Disease Control and Epidemiology Division Research

* Third National Cancer Survey, State of Colorado, 1969-1971.

*Shown as a percent of the total for all types and all ages. Totals may not equal 100 because of rounding.

922 076

## TABLE 10

## SEX RATIOS OF LEUKEMIA CASES IN MESA COUNTY, COLORADO 1970-1976

| Male/Female Ratio | Colorado* | Mesa County+ |
|---|---|---|
| All Ages | 156/138 = 1.13 | 20/21 = 0.95 |
| Ages 65 and Over | 46/43 = 1.07 | 10/10 = 1.00 |

SOURCES: * Third National Cancer Survey, State of Colorado, 1969-1971.
+ Colorado Department of Health, Disease Control and Epidemiology Division Research.

TABLE [illegible]

LEUKEMIA CASE REMOVALS BY SOURCE OF CASEFINDING
AND BY REASON FOR REMOVAL

| | From Incidence Study Group (1970-1976) | | Added Study Group (1960-69,1977-78) | | Totals | |
|---|---|---|---|---|---|---|
| ALL CASES IDENTIFIED | | | | | | |
| Children (< 18 yrs) | 7 | | 8 | | 15 | |
| Adults | 34 | | 26 | | 60 | |
| TOTAL | 41 | | 34 | | 75 | |
| POTENTIAL ADULT CASES FOR STUDY | | 34 | | 26 | | 60 |
| CASE REMOVAL (UNMET CRITERIA) | | | | | | |
| Less than 2 yrs Residence | 2 | | 8 | | 10 | |
| History of Mining | 1 | | 1 | | 2 | |
| History of Chemotherapy | 1 | | - | | 1 | |
| Still Living | 1 | | 2 | | 3 | |
| SUBTOTAL | 5 | | 11 | | 16 | |
| | | -5 | | -11 | | -16 |
| TOTAL ELIGIBLE FOR STUDY | | 29 | | 15 | | 44 |



922 078

TABLE 12

CANCER: CONTROL GROUP 1
GRADE "A" MALIGNANT NEOPLASMS*

| Causes of Death | ICDA-8 Code | No. Controls |
| --- | --- | --- |
| Pharynx | 146-149 | - |
| Gastro-Intestinal (Excluding esophagus) | 151-159 | 19 |
| Respiratory | 160-163 | 12 |
| Reticulo Endothelial System (Lymphosarcoma, Hodgkins, Lymphoid Tissue, Multiple Myeloma excluding Leukemia) | 200-203 | 2 |
| Breast | 174 | 1 |
| TOTAL | | 34 |

*SOURCE: International Commission on Radiological Protection (ICRP), Radiosensitivity and Spatial Distribution of Dose (Publication No. 14), London: Pergamon Press, 1969.

## TABLE 13

### HEART DISEASE: CONTROL GROUP 2

| Causes of Death | ICDA-8 Code | No. Controls | |
|---|---|---|---|
| Cardiovascular | | 32 | |
| . Hypertensive Disease | 400-404 | | 1 |
| . Ischemic Heart Disease | 401-414 | | 25 |
| . Symptomatic Heart Disease | 427 | | 6 |
| External Cause of Injury | 800-845 | 3 | |
| . Accidents | 880-949 | | 3 |
| TOTAL | | | 35 |

922 080

TABLE 14

INDEPENDENT VARIABLES AND INDICATORS

| | | | |
|---|---|---|---|
| 1. | Socioeconomic Status | - | Occupational Index |
| 2. | Mesa County Residence | - | Years Prior to Diagnosis |
| 3. | General Health Status | - | General Health Assessment Index |
| 4. | Family History | - | # Cases Leukemia and Cancer Among Relatives |
| 5. | Radiation Exposure | - | Residence Site Classification |
| | | - | Cumulative Gamma Exposure 1950 to Diagnosis |
| | | - | Average Annual Gamma Exposure |

TABLE 15

DATE COLLECTION EXPERIENCE

| | Cases No. | Cases (%) | Cancer Control 1 No. | Cancer Control 1 (%) | Heart Control 2 No. | Heart Control 2 (%) |
|---|---|---|---|---|---|---|
| Original Subjects in Study Group | 44 | (100) | 39 | (100) | 43 | (100) |
| Unable to complete* | 0 | ( - ) | -5 | ( 13) | -8 | ( 19) |
| Completed | 44 | (100) | 34 | ( 87) | 35 | ( 81) |
| Interviews | 37 | ( 84) | 32 | ( 94) | 34 | ( 97) |
| Refusals | 3 | ( 7) | 0 | ( - ) | 1 | ( 3) |
| Other reasons** | 4 | ( 9) | 2 | ( 6) | 0 | ( - ) |
| TOTAL | 44 | | 34 | | 35 | |

*Unable to track and unable to reconstruct occupational and residential history.

**Unable to track (no living relatives or informant, unable to locate or no response from relative or informant) but able to reconstruct history from public records.

## TABLE 16

PERCENT DISTRIBUTION OF CASES AND CONTROLS BY OCCUPATIONAL STATUS*

| Category | | Cases (N=44) | Cancer Control 1 (N=35) | Heart Control 2 (N=34) |
|---|---|---|---|---|
| 1. | Major professional | 0 | 3 | 6 |
| 2. | Lesser professional | 34 | 17 | 24 |
| 3. | Minor professional | 2 | 9 | 12 |
| 4. | Clerical | 0 | 9 | 15 |
| 5. | Skilled | 23 | 26 | 18 |
| 6. | Semi-skilled | 9 | 3 | 6 |
| 7. | Unskilled | 11 | 14 | 12 |
| 8. | Homemaker | 21 | 17 | 12 |

*Totals may not equal 100 because of rounding.

TABLE 17

YEARS OF RESIDENCE IN MESA COUNTY PRIOR TO DIAGNOSIS

| Duration in Years | Cases | Cancer Control 1 | Heart Control 2 |
|---|---|---|---|
| 2 - 9 | 4 | 6 | 5 |
| 10 - 19 | 15 | 11 | 5 |
| 20 - 29 | 9 | 10 | 9 |
| 30 - 39 | 2 | 1 | 8 |
| 40 - 49 | 6 | 4 | 2 |
| 50 - 59 | 4 | 1 | 3 |
| 60+ | 4 | 1 | 3 |
| TOTAL | 44 | 34 | 35 |
| Mean for Group | 28.9 Yrs. | 22.2 Yrs. | 30.0 Yrs. |

TABLE 18

PERCENT DISTRIBUTION BY GENERAL HEALTH ASSESSMENT
PRIOR TO DIAGNOSIS*

| Index Category | Case No. | Case (%) | Cancer Control 1 No. | Cancer Control 1 (%) | Heart Control 2 No. | Heart Control 2 (%) |
|---|---|---|---|---|---|---|
| 1 = Excellent | 9 | (23) | 16 | (48) | 10 | (29) |
| 2 = Very Good | 9 | (23) | 7 | (21) | 3 | ( 9) |
| 3 = Good | 11 | (28) | 4 | (12) | 11 | (31) |
| 4 = Fair | 8 | (21) | 6 | (18) | 11 | (31) |
| 5 = Poor | 2 | ( 5) | 0 | ( -) | 0 | ( -) |
| TOTALS | 39 | | 33 | | 35 | |

*Percent Totals may not equal 100 because of rounding.
Includes only subjects with informant interview or with medical history reconstructed from hospital records and physicians' office records.



922 085

TABLE 19

PERCENT DISTRIBUTION BY FAMILY HISTORY OF LEUKEMIA AND OTHER CANCERS

| Family History: | Cases (N=44) % | Cases (N=44) Cum* | Cancer Control 1 (N=35) % | Cancer Control 1 (N=35) Cum* | Heart Control 2 (N=34) % | Heart Control 2 (N=34) Cum* |
|---|---|---|---|---|---|---|
| Leukemia: | | | | | | |
| 1 Relative | 15 | 15 | 0 | 0 | 3 | 3 |
| None | 85 | 100 | 100 | 100 | 97 | 100 |
| Other Cancers: | | | | | | |
| 1 Relative | 34 | 34 | 28 | 28 | 32 | 32 |
| 2 or More Relatives | 29 | 63 | 13 | 41 | 15 | 47 |
| None | 37 | 100 | 59 | 100 | 53 | 100 |
| Either Leukemia or Cancer: | | | | | | |
| Yes | 38 | 38 | 23 | 23 | 25 | 25 |
| No | 62 | 100 | 77 | 100 | 75 | 100 |

*Cumulative Percentage.

922 086

TABLE 20

HIGHEST RESIDENTIAL EXPOSURE BY SITE CLASSIFICATION

| Site Classification | | Cases No. | (%) | Cancer Control 1 No. | (%) | Heart Control 2 No. | (%) |
|---|---|---|---|---|---|---|---|
| A | "Action" | 2 | ( 5) | 1 | ( 3) | 1 | ( 3) |
| B | "No Concern" | 1 | ( 2) | 4 | (12) | 0 | ( 0) |
| C | "Tailings Near" | 8 | (18) | 2 | ( 6) | 7 | (20) |
| E | "Tailings Away" | 4 | ( 9) | 7 | (21) | 6 | (17) |
| F | "No Tailings" | 26 | (59) | 15 | (44) | 14 | (40) |
| NA | (Not Available) | 3 | ( 7) | 5 | (15) | 7 | (20) |
| | | 44 | | 34 | | 35 | |

TABLE 21

CUMULATIVE GAMMA EXPOSURE FROM 1950 TO DIAGNOSIS

| Gamma in mR | Cases No. | Cases (%) | Cancer Control 1 No. | Cancer Control 1 (%) | Heart Control 2 No. | Heart Control 2 (%) |
|---|---|---|---|---|---|---|
| Less than 2000 | 9 | (20) | 11 | (32) | 13 | (37) |
| 2000 to 2999 | 30 | (68) | 21 | (62) | 18 | (51) |
| 3000 to 3999 | 4 | ( 9) | 2 | ( 6) | 3 | ( 9) |
| 4000 to 4999 | 0 | ( 0) | 0 | ( 0) | 1 | ( 3) |
| 5000 and Over | 1 | ( 2) | 0 | ( 0) | 0 | ( 0) |
| | 44 | | 34 | | 35 | |
| Mean for Group | 2451 mR | | 2161 mR | | 2235 mR | |

922 088

<u>TABLE 22</u>

DISTRIBUTION OF AVERAGE ANNUAL EXPOSURE
(1950 TO DIAGNOSIS)

| Gamma in mR/Yr | Case | Cancer Control 1 | Heart Control 2 |
|---|---|---|---|
| <100 | 2 | 9 | 7 |
| 100-149 | 39 | 23 | 27 |
| 150-179 | 2 | 2 | 0 |
| >180 | 1 | 0 | 1 |
| TOTAL | 44 | 34 | 35 |
| Mean | 122 mR/yr. | 137 mR/yr. | 1[illegible] mR/yr. |

NOTE: Mesa County Background - average 122 mR/yr.
- range 70-218 mR/yr.



922 089

CITY-COUNTY STATE MAP
SIZE 8½ X 11

COLORADO

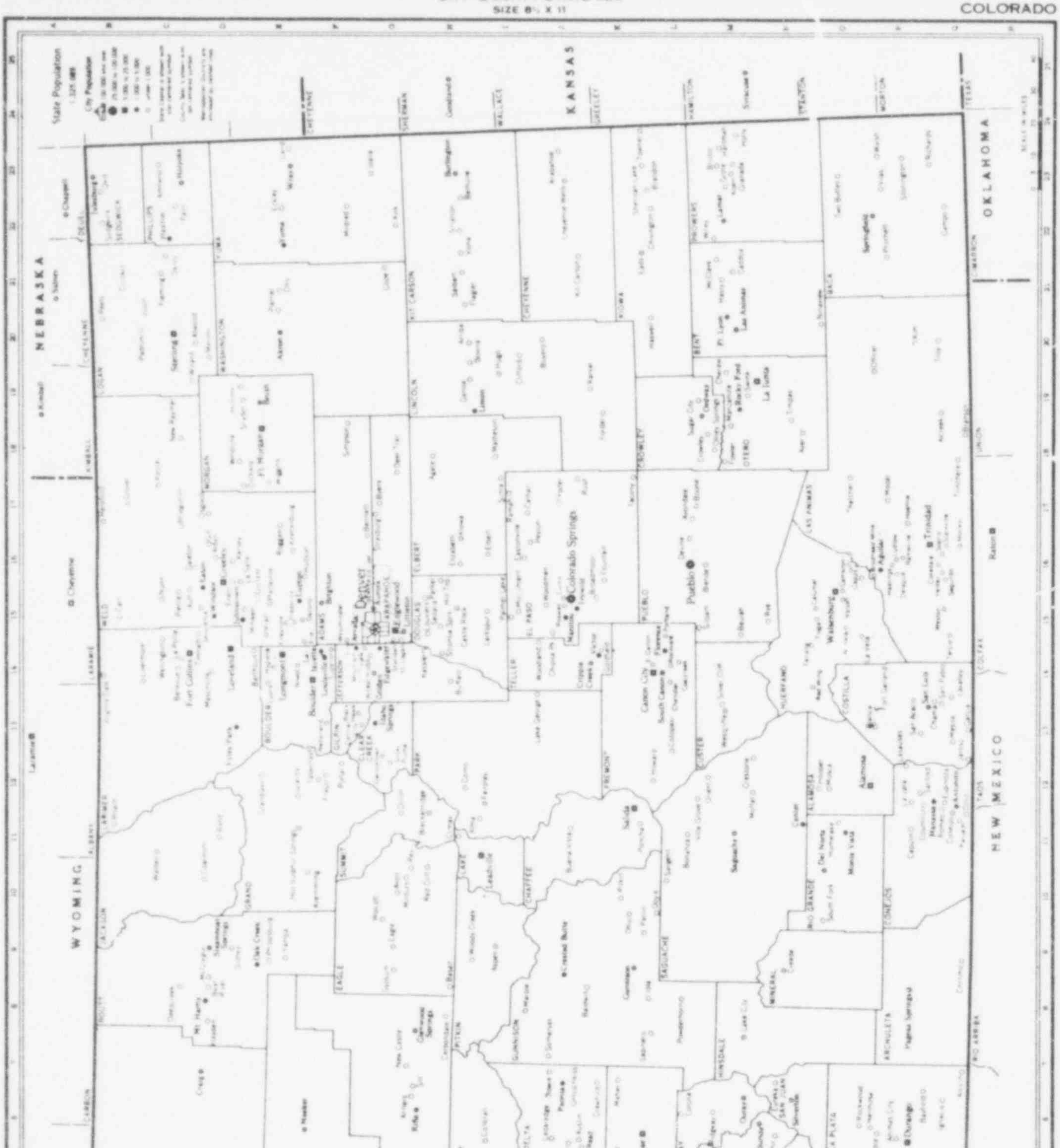


TABLE 23

GAMMA EXPOSURE PERSPECTIVE

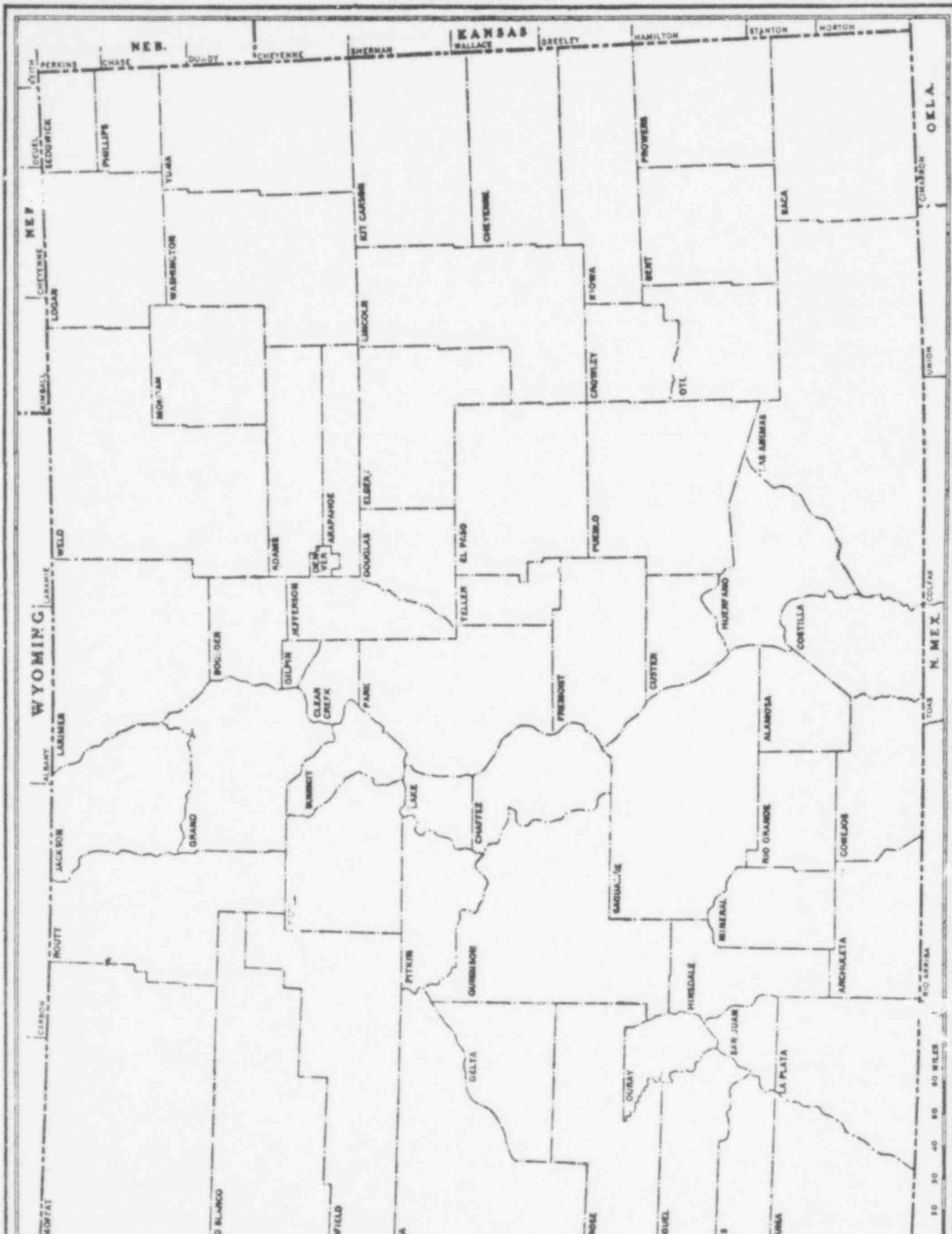
| | | |
|---|---|---|
| Current Study: | | |
| Mesa County Background | .014 mR/hr | (122 mR/yr)* |
| Denver County Background | .019 mR/hr | (165 mR/yr)* |
| Previous Research: | | |
| Diagnostic Chest X-ray | 10.000 mR/.02 sec. | |
| | 2.000 mR/** | |
| Abdomen Supine | 250.000 mR - male** | |
| | 280.000 mR - female** | |
| A-Bomb Leukemia Victims | 100,000.000 mR (or 100 Rads)* | |

* = Whole Body Dose

** - Gonadal Dose



922 090


NEB.
KANSAS
OKLA.
N. MEX.
UTAH
WYOMING
PERKINS
CHASE
DUNDY
CHEYENNE
SHERMAN
WALLACE
GREELEY
HAMILTON
STANTON
MORTON
DEUEL
SEDGWICK
PHILLIPS
YUMA
KIT CARSON
CHEYENNE
PROWERS
BACA
CIMARRON
LOGAN
WASHINGTON
LINCOLN
KIOWA
BENT
CROWLEY
OTERO
UNION
MORGAN
KIMBALL
ELBERT
ARAPAHOE
LAS ANIMAS
WELD
ADAMS
DENVER
DOUGLAS
EL PASO
PUEBLO
LARAMIE
JEFFERSON
TELLER
HUERFANO
COSTILLA
COLFAX
BOULDER
GILPIN
CLEAR CREEK
PARK
FREMONT
CUSTER
LARIMER
ALAMOSA
TAOS
ALBANY
SUMMIT
LAKE
CHAFFEE
GRAND
JACKSON
RIO GRANDE
CONEJOS
SAGUACHE
MINERAL
ROUTT
PITKIN
GUNNISON
ARCHULETA
HINSDALE
RIO ARRIBA
CARBON
DELTA
SAN JUAN
OURAY
LA PLATA
SWEETWATER
MOFFAT
RIO BLANCO
GARFIELD
MESA
MONTROSE
SAN MIGUEL
DOLORES
MONTEZUMA
UINTAH
GRAND
SAN JUAN
0 5 10 20 30 40 50 60 MILES

MADE IN U.S.A.

# SOCIOECONOMIC STATUS

## OCCUPATIONAL INDEX*

LEVEL 1: MAJOR PROFESSIONALS, OWNERS AND HIGHER EXECUTIVES OF LARGE BUSINESSES

LEVEL 2: LESSER PROFESSIONALS, OWNER AND MANAGERS OF MEDIUM-SIZED BUSINESS

LEVEL 3: MINOR PROFESSIONALS, ADMINISTRATIVE PERSONNEL, OWNERS OF SMALL BUSINESSES

LEVEL 4: CLERICAL AND SALES WORKERS, TECHNICIANS, OWNERS OF VERY SMALL BUSINESSES

LEVEL 5: SKILLED MANUAL EMPLOYEES

LEVEL 6: SEMISKILLED EMPLOYEES, MACHINE OPERATORS

LEVEL 7: UNSKILLED EMPLOYEES

LEVEL 8: HOMEMAKERS

SOURCE: *"A. B. Hollingshead's Two-Factor Index of Social Position," as described in Bonjean, D.M., Hill, R.J. and Mc Lemore, S.D. Sociological Measurement: An Inventory of Scales and Indices, Chandler Publishing Co., 1967.

## HOLLINGSHEAD'S OCCUPATIONAL STATUS SCALE

I. *Higher Executives of Large Concerns, Proprietors, and Major Professionals*

A. *Higher Executives* (Value of corporation $500,000 and above as rated by Dun and Bradstreet)

Bank
- Presidents
- Vice-Presidents
- Assistant Vice-Presidents

Business
- Vice-Presidents
- Assistant Vice-Presidents
- Executive Secretaries
- Research Directors
- Treasurers

Business
- Directors
- Presidents

B. *Proprietors* (Value over $100,000 by Dun and Bradstreet)

- Brokers
- Contractors
- Dairy Owners
- Farmers
- Lumber Dealers

C. *Major Professionals*

- Accountants (CPA)
- Actuaries
- Agronomists
- Architects
- Artists, portrait
- Astronomers
- Athletes (professional)*
- Attorneys*
- Auditors
- Bacteriologists
- Biologists*
- Chaplains*
- Chemical Engineers
- Chemists
- Clergymen (professionally trained)
- Dentists
- Economists
- Engineers (college graduates)
- Environmentalists*
- Foresters
- Geologists
- Judges (Superior Court)
- Lawyers
- Metallurgists
- Military: Commissioned Officers, Major and above
- Ministers*
- Officials of the Executive Branch of Government, Federal, State, Local, e.g., Mayor, City Manager, City Planning Director, Internal Revenue Director
- Physicians
- Physicists, Research
- Principals*
- Professors*
- Psychologists, practicing
- Symphony Conductors
- Teachers, university, college
- Veterinarians (veterinary surgeons)

*Asterisk next to an entry identifies an addition to the classification, based on coding of occupations not listed in original.

II. *Business Managers, Proprietors of Medium-Sized Businesses, and Lesser Professionals*

A. *Business Managers in Large Concerns* (Value $500,000)

- Advertising directors
- Branch managers
- Brokerage salesmen
- Directors of purchasing
- District managers
- Executive assistants
- Export managers, international concerns
- Farm managers
- Government officials, minor, e.g., Internal Revenue agents
- Manufacturer's representatives
- Office managers
- Personnel managers
- Police chief, Sheriff
- Postmaster
- Production managers
- Sales engineers
- Sales managers, national concerns
- Store managers

B. *Proprietors of Medium Businesses* (Value $35,000-$100,000)

- Advertising
- Clothing store
- Contractors
- Express company
- Farm owners
- Fruits, wholesale
- Furniture business
- Jewelers
- Poultry business
- Real estate brokers
- Rug business
- Store
- Theater

C. *Lesser Professionals*

- Accountants (not CPA)
- Artists (unspecified)*
- Authors (unspecified)*
- Chiropractors
- Computer Programmers*
- Contractors (unspecified)*
- Correction Officers
- Director of Community House
- Engineers (not college graduates)
- Finance writers
- Health educators
- Interpreters*
- Labor relations consultants
- Military: Commissioned Officers, Lieutenant, Captain
- Musicians (symphony orchestra, unspecified)*
- Nurses, R.N.
- Opticians
- Optometrists, D.O.
- Pharmacists
- Pilots*
- Poets*
- Public Health Officers (MPH)
- Research assistants, university (full-time)
- Social workers
- Teacher (High School, etc.)

### III. *Administrative Personnel, Owners of Small Businesses, and Minor Professionals*

#### A. *Administrative Personnel*

Advertising agents
Chief clerks
Credit managers
Managers, departments
Managers, general*
Passenger agents, railroad
Private secretaries
Purchasing agents
Sales representatives
Section heads, federal, state and local government offices
Section heads, large businesses and industries
Service managers
Shop managers
Store managers (chain)
Traffic managers
Managers, general*

#### B. *Small Business Owners* ($6,000-$35,000)

Art gallery
Auto accessories
Awnings
Bakery
Beauty shop
Boatyard
Brokerage, insurance
Car dealers
Cattle dealers
Cigarette machines
Cleaning shops
Clothing
Coal businesses
Contracting businesses
Convalescent homes
Decorating
Dog supplies
Dry goods
Engraving businesses
Feed
Finance companies, local
Fire extinguishers
Five and dime
Florists
Food equipment
Food products
Foundry
Funeral directors
Furniture
Garages
Gas stations
Glassware
Grocery, general
Hotel proprietors
Jewelry
Machinery brokers
Manufacturing
Monuments
Music
Package stores (liquor)
Paint contracting
Poultry
Real estate
Records and radios
Restaurants
Roofing contractors
Shoe
Signs
Taverns
Taxi companies
Tire shops
Trucking
Trucks and tractors
Upholstery
Wholesale outlets
Window shades

922 096

C. *Semiprofessionals*

- Actors and showmen
- Animal raisers*
- Animal trainers*
- Appraisers (estimators)
- Army, Master Sergeant
- Artists, commercial
- Authors (commercial)*
- Clergymen (not professionally trained)
- Concern managers
- Deputy Sheriffs
- Dispatchers, railroad
- Forest rangers*
- Insurance agents*
- Interior decorators
- Interpreters, courts
- Laboratory assistants
- Landscape planners
- Medical technicians*
- Morticians
- Navy, Chief Petty Officer
- Nurse, L.P.N.*
- Occupational therapists*
- Oral hygienists
- Physiotherapists
- Photographer*
- Physical therapists*
- Probation*
- Publicity and public relations
- Radio, TV announcers
- Real estate agents*
- Reporters, court
- Reporters, newspapers
- Surveyors
- Teachers, piano, driving, etc.*
- Title searchers
- Tool designers
- Travel agents
- Yard masters, railroad

D. *Farmers*

- Farm owners ($20,000-$35,000)

IV. *Clerical and Sales Workers, Technicians and Owners of Little Businesses (Value under $6,000)*

A. *Clerical and Sales Workers*

- Apartment Manager*
- Bank clerks and tellers
- Bill collectors
- Bookkeepers
- Business machine operators, offices
- Claims examiners
- Clerical or stenographic
- Conductors, railroad
- Factory storekeepers
- Factory supervisors
- Post Office clerks
- Route managers
- Sales clerks
- Secretaries*
- Sergeants and Petty Officers, military services
- Shipping clerks
- Stewardesses*
- Supervisors, utilities, factories
- Supervisors, toll stations
- Supervisors, general*
- Wardens*

B. *Technicians*

Dental technicians
Draftsmen
Driving teachers
Expediter, factory
Experimental tester
FBI*
Instructors, telephone company, factory
Inspectors, weights, sanitary, railroad, factory
Investigators
Keypunchers*
Laboratory technicians
Locomotive engineers
Models*
Nurse, Practical*
Operators, PBX
Orderly*
Private Detectives*
Proofreaders
Safety supervisors
Supervisors of maintenance
Surveyors*
Taxi Dispatchers*
Technical assistants
Telephone company supervisors
Timekeepers
Tower operators, railroad
Truck dispatchers
Window trimmers (stores)
X-ray technicians*

C. *Owners of Little Businesses ($3,000-$6,000)*

Flower shop
Grocery
Newsstand
Tailor shop

D. *Farmers*

Owners (Value $10,000-$20,000)

V. *Skilled Manual Employees*

Auto body repairers
Bakers
Barbers
Blacksmiths
Bookbinders
Boilermakers
Brakemen, railroad
Brewers
Bulldozer operators
Butchers
Cabinet makers
Cable splicers
Carpenters
Casters (founders)
Cement finishers
Cheese makers
Chefs
Compositors
Construction workers (unspecified) H.S. Graduate*
Day Care workers*
Diemakers
Diesel engineer repair and maintenance (trained)
Diesel shovel operators
Dog Groomers*
Electricians
Engravers
Exterminators
Firemen, city
Firemen, railroad
Fitters, gas, steam
Florists*
Foremen, construction, dairy
Foremen, general*
Gardeners, landscape (trained)
Gauge makers
Glass blowers
Glaziers
Gunsmiths
Hair stylists

V. *Skilled Manual Employees* (continued)

Heat treaters
Horticulturists
Linemen, utility
Linoleum layers (trained)
Linotype operators
Lithographers
Locksmiths
Loom fixers
Machinists (trained)
Maintenance foremen
Masons
Masseurs
Mechanics (trained)
Millwrights
Moulders (trained)
Painters
Paper hangers
Patrolmen, railroad
Pattern and model makers
Piano tuners
Plumbers
Policemen, city
Postmen
Printers
Radio, television maintenance
Repairmen, home appliances
Rope splicers
Sheetmetal workers (trained)
Shipsmiths
Shoe repairmen (trained)
Stationary engineers (licensed)
Stewards, club
Switchmen, railroad
Tailors (trained)
Telephone repairmen*
Teletype operators
Tool makers
Track supervisors, railroad
Tractor-Trailer trans
Typographers
Upholsterers (trained)
Watchmakers
Weavers
Welders
Yard supervisors, railroad

VI. *Machine Operators and Semiskilled Employees*

Aides, hospital
Apprentices, electricians, printers
  steam fitters, toolmakers
Assembly line workers
Bartenders
Bingo tenders
Bridge tenders
Cashiers*
Checkers
Coin machine fillers
Cooks, short order
Deliverymen
Dressmakers, machine
Drivers, bus, taxi, truck, etc.*
Elevator operators
Enlisted men, military services
Filers, sanders, buffers
Foundry workers
Garage and gas station attendants
Greenhouse workers
Guards, doorkeepers, watchmen
Hairdressers
Housekeepers (live in or in charge)
Logging*
Meat cutters and packers
Meter readers
Operators, factory machines
Oilers, railroad
Pressers, clothing
Pump operators
Receivers and checkers
Roofers
Set-up men, factories
Shapers
Signalmen, railroad
Solderers, factory
Sprayers, paint
Steelworkers (unskilled)
Stranders, wire machines
Strippers, rubber factory
Testers
Timers
Tire moulders
Trainmen, railroad
Tree cutters*
Typeminer*
Waiters-waitresses ("better" places)
Warehousemen*
Weighers
Welders, spot
Winders, machine
Wine bottlers
Wiredrawers, machine
Wood workers, machine
Wrappers, stores and factories



922 099

*Farmers*

Smaller tenants who own equipment

VII. *Unskilled Employees*

Amusement park workers (bowling alleys, poolrooms)
Ash removers
Attendants, parking lots
Baby sitters*
Cafeteria workers
Car cleaners, railroad
Carriers, coal
Countermen
Dairy workers
Deck hands
Domestics
Farm helpers
Fishermen (clam diggers)
Freight handlers
Garbage collectors
Grave diggers
Hod carriers
Hog killers
Hospital workers, (unspecified)
Hostlers, railroad
Janitors (sweepers)
Laborers (construction)
Laborers (unspecified)
Laundry workers
Longshcremen*
Maid, motel*
Messengers
Platform men, railroad
Peddlers
Porters
Relief, public, private
Road workers*
Roofer's helpers
Shirt folders
Shoe shiners
Sorters, rag and salvage
Stage hands
Stevedores
Stock handlers
Street cleaners
Struckmen, railroad
Unemployed (no occupation)
Unskilled-factory workers
Waitresses ("Hash Houses")
Washers, cars
Window cleaners
Woodchoppers

*Farmers*

Share croppers

*Other Codings*

91 Uncodable, no visible means of support
92 Student
93 Housewife
94 Retired
95 Unemployed
96 Farmer--no other information
97 Handicapped or disabled
00 Uncodable
--"works at the mill"
--unclear as to actual job or unreadable

MEDICAL HISTORY PRIOR TO DIAGNOSIS

GENERAL HEALTH ASSESSMENT INDEX

| | |
|---|---|
| 1 = EXCELLENT: | NEGATIVE HISTORY OR MINIMUM HISTORY OF MINOR INJURIES |
| 2 = VERY GOOD: | NO CHRONIC PROBLEMS. ONE MAJOR SURGERY |
| 3 = GOOD: | 1-2 CHRONIC PROBLEMS. 0-1 MAJOR SURGERIES |
| 4 = FAIR: | 3-5 CHRONIC PROBLEMS. 0-3 MAJOR SURGERIES |
| 5 = POOR: | 6+ CHRONIC PROBLEMS. 4+ MAJOR SURGERIES |

APPENDIX 5

922 102

# PROCEDURE FOR GAMMA SCREENING SURVEYS AND DATA PROCESSING

The objective of the gamma screening survey is to determine whether or not uranium mill tailings deposits are present on individual properties, and to acquire sufficient data on which to base a valid evaluation of the gamma radiation levels present.

Uranium mill tailings contain concentrated amounts of radium and its daughter products. Since these are what we are looking for, our instruments are calibrated with radium. Our gamma radiation survey instruments will then indicate normal background levels in Mesa County that range from a meter reading of 8 to as high as 35. However, the average background values are in the 8 to 15 meter reading range, with most falling in the 11 to 13 meter reading range. Thus, a meter reading of 20 or higher should be considered significantly above the average to justify further investigation. In some instances meter readings of 17 to 20 could also be indicators of buried or nearby deposits.

It should be kept in mind that there are other radiation producing materials besides tailings that you will be likely to find. Objects such as luminous dial compasses, clocks and aircraft instruments, petrified wood, dinosaur bones, and some ore samples will emit levels of gamma radiation to produce a meter reading of 20 or higher. However, by moving these objects, one can usually determine whether the radiation is coming from the object or a tailings deposit underneath or adjacent to it. Such objects act as point sources, in that the gamma field is usually very intense close to the object but drops off very rapidly as you move your detector away.

## PROCEDURE

A survey team is composed of two people, and the standard procedure for screening surveys is as follows:

(1) Obtain permission to do the screen from the occupant. Permission must be obtained from an adult who must be present at the time of the survey. You will be provided with a photo ID card for identification. Show it each time you attempt to initiate a survey.

a. In the event no one is home, check the appropriate boxes on the Gamma Screening Form and then leave one of the forms that request that the occupant contact our office to arrange for a radiation survey.

b. In the event the occupant refuses, do not be argumentative. Fill in the refusal form and have occupant or owner sign; if the occupant is not the owner, obtain the name, address and phone number of the owner.

Check the appropriate boxes on the gamma radiation survey form.

(2) When permission is granted, survey both outside and inside the structure. This can be accomplished by one person doing the inside and one person doing the outside. Do not report your findings to the occupant until you are both through and have filled out your report form. All rooms including basements and garages should be checked inside, and all sidewalks, patios, carports, flower beds, concrete slabs, planters and lawns should be checked outside. The scintillometer should be held just off the surface of the ground as you move along at a slow walk. Particular attention should be paid to all basement window wells and several points about one-half to one foot from the foundation all around each structure to detect if tailings were utilized as backfill material.

(3) The values to record on the Gamma Screening Form are as follows:

a. HIG - High inside gamma reading and the location of the HIG.

b. HOG - High outside gamma reading.

c. LOG - Low outside average gamma reading.

(4) The screening form also has a block for tailings use. The number entered will be determined by whether there is no usage (0 = none), or if the location is an UNDER or AWAY location.

a. Any reading of 20 or greater inside or withi 10 feet of the habitable structure is an UNDER location and is indicated by a (1). This means that tailings are under or up against the structure. An AWAY location is indicated by a (2). This means that tailings were located more than 10 feet from the structure. If tailings are found under and away from the structure, a (3) is entered on the form.

b. All UNDER or "U" locations require that a gamma map or sketch be made for the structure. A sketch is sufficient if there are only two or three elevated readings inside the structure. Greater involvement requires a map. All floors, basement, first, second, etc. of an UNDER location must be mapped. The location number, address, occupant's name, owner's name, date, surveyor's name, and instrument number must appear on the gamma map. Readings inside should be taken so that each reading represents about 25 sq. ft. of the house area. Readings taken outside should represent about 100 sq. ft. of area. Readings are made at the surface and at waist height and entered on the map with the waist level over the surface level reading. Enough readings must be plotted on the map or sketch to outline the shape of any tailings deposits. Background readings should surround readings indicating tailings, to show the contaminated area boundaries. Any readings which are not a waist reading or surface reading should be noted (e.g., 50 - 6ft. up wall). All notations on the map should be placed so that the sheet does not need to be turned in order to read all notations. Gamma maps are coded (1) in box 80, Card A, of the screening form, and sketches are coded (7) in box 80 of Card A.

c. A floor plan map of an UNDER location structure should be prepared. Team members should work together, with one member making the readings and the second member entering the readings on his floor plan sketch.

d. Tailings deposits found to be away from structures by at least ten feet or on vacant lots should be noted in the free punch comment. An example would be "T ROSE BUSHES + CARPORT," or "T ALL BACKYARD." All "away" locations must have a sketch or gamma map which clearly indicates location on the property of the tailings deposits.

e. The Indoor Radon Study - Gamma Screening Form should be filled out as completely as possible for each location, and the form is to be signed in the lower right hand corner of the form by both surveyors immediately after survey.

(5) If requested, you may explain to the occupant the indicated location of tailings deposits. However, please refer any questions regarding policy or health effects to Mr. Franz.

(6) Assure the occupant that a letter will be sent to the owner of the property, indicating the findings of the survey.

# SITE ASSESSMENT CLASSIFICATION

A = TAILINGS UNDER OR AGAINST. NAG GREATER THAN .100 mR/Hr. ABOVE BACKGROUND*. "ACTION RECOMMENDED."

B = TAILINGS UNDER OR AGAINST. NAG .050 to .100 mR/Hr. ABOVE BACKGROUND*. "NO UNDUE CONCERN."

C = TAILINGS NOT UNDER, BUT WITHIN 10 FEET.

E = TAILINGS BEYOND 10 FEET.

F = NO TAILINGS.

* Background average outside: .014 mR/Hr. or 122 mR/yr.
(inside = .011 mR/Hr. or 96 mR/Yr.)
(Denver outside = 165 mR/Yr.)

# EXPOSURE WORK SHEET
(1950 to Dx.)

I.D.# ____________________

Date Dx ____________________

Name ____________________

| Location Code | Site Type R/C | Screen Assess. | LOG | HIG* x .56 + .006 = E | or for A + B Sites: NAG + .011 = GAG | xHrs./Yr.** = E Yr. | | x Yrs = $E_{mR\text{-}yrs.}$ | | W.L. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

*Use HIG if = LOG +/- 4 or if multiple readings
otherwise use LOG in computation

**Hrs./yr = R = 50 wks x 168 hrs./wk. = 8736 hrs/yr
O = 47 wks x 40 hrs./wk. = 1880 hrs/yr
R-O = 6856 hrs/yr

Screen Assess.
Hi R [ ]
Hi O [ ]

Hi GAG [ ]

Aver. Ann.G [ ]

Tot. Yrs. [ ] [ ]

Hi W.L. [ ]

APPENDIX 6

# MESA COUNTY LEUKEMIA QUESTIONNAIRE

- Name of Case ______________________ Birth Date ________
- Address (most recent) ______________________ Sex ________
- Cause of Death ______________________ Age ____ Date of Death ________
- Informant Name ______________ Relationship ________ Years acquainted with case ________
- Address ______________ Phone ________ Years and Date Married (if Spouse) ________

- TURN TO PAGE 2 -

---

INTERVIEW CLOSURE

- Thank you for your time. Do you have any comments or questions?

______________________

______________________

______________________

______________________

- Would you like a copy of the final report? ___No ___Yes

Sent to what address? ______________________

______________________

---

TO BE COMPLETED FOLLOWING END OF INTERVIEW

Interviewer ______________________

Date and time of interview ______________________

Thumbnail sketch of informant, general overview of interview process, comments:

______________________

______________________

______________________

______________________

______________________

______________________

______________________

______________________

______________________

A. OCCUPATIONAL HISTORY

1. What type of work did he/she usually do? ______________________________

| Employer and Address | Type of Work/ Position Held | Approx Years (Dates) | Full or Pt. Time | Exposure: Rad/Chem/ Fumes | Notes |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| Military Hx Branch: | Station: | | | | |

2. Did he/she ever work with any of the following:

solvents (benzene) ___
dry cleaning ________
dyes ________
shoe mfg.
chemicals ________

explosives ________
rubber cement ________
rubber tire mfg./re-treading ________
radium ________

distilling ________
painting ________
X-ray machines ________
pesticides/fertilizers ________



922 110

B. RESIDENTIAL HISTORY

Where did he/she live (specific addresses) during his/her life beginning with the most recent address?

| Address (H= House, A= Apt) | From/To | Building Material* | Remodeling Project Type | Remodeling Project Year | Tailings Used on Property Date | Tailings Used on Property Location |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

* Material Code
C = Concrete block
F = Wood frame
B = Brick
SF = Stucco frame
SB = Stucco Brick/Block
0 = Other



922 111

C. MEDICAL HISTORY

1. The death certificate lists leukemia as one of the medical problems at the time of death. When did you first learn that he/she had leukemia? ________

   Physician ______________________________Hospital ______________________________

2. Prior to the leukemia, did he/she ever have any major health problems?

   ___Yes ___No

| Problem | Date Onset | Medication How Long | Physician |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

3. Was he/she ever hospitalized prior to the time that you learned about his/her leukemia? ___Yes ___No (Probe!)

| Problem | Year | Hospital | Treatment | Physician |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

4. Prior to the leukemia, did he/she ever receive x-ray treatment for any health problem? (e.g., heavy female bleeding, large neck gland in childhood, acne, back problems, dental problems, bronchitis) ___Yes ___No ___Don't Know

| Problem | Type of Treatment | Part of Body | Location | Physician | Year |
|---|---|---|---|---|---|
| | | | | | |

5. Prior to the leukemia, did he/she ever have any treatments with radium, cobalt, iodine, phosphorous or radioisotopes? ___Yes ___No ___Don't Know

| Problem | Type of Treatment | Part of Body | Location | Physician | Year |
|---|---|---|---|---|---|
| | | | | | |

C. SOCIAL HISTORY

1. Did he/she ever smoke during his/her lifetime: ___Yes ___No ___Don't Know

If yes, what form? ___cigarettes ___ pipes ___ cigars

If cigarettes:

| No. Packs/day | x No. Years | Ever Stop? |
|---|---|---|
| | | |
| | | |
| | | |

2. What were his/her hobbies or special interests outside of work? (e.g. gardening, furniture refinishing, model airplanes, painting, etc.)

_______________________________________________

3. Did he/she ever wear a watch with a dial that could be seen in the dark?

___Yes ___No If yes, how long (which years)? ____________________

How frequently? ___daily _____day and night ____less frequently

E. FAMILY HISTORY

1. From which countries did his/her ancestors come? ______________________

______________________________________________________________

2. What type of work did his/her parents do?

   Mother ____________________________ Father ____________________________

3. What were the hobbies or special interests of his/her parents?

______________________________________________________________

______________________________________________________________

4. What is or was the health of his/her relatives? If dead, what cause and age at death?

   Mother ______________________________________________________

   Father ______________________________________________________

   Brothers ____________________________________________________

   Sisters _____________________________________________________

   Sons ________________________________________________________

   Daughters ___________________________________________________

5. Did any members of his/her family have any of the following problems? (who? when? where?)

   Leukemia __________ Mental Retardation __________

   Anemia/blood problems __________ Cancer __________

   Childbirth problems/birth defects __________ Other __________

______________________________________________________________

6. Did his/her mother have any x-rays or other radiation exposures or complications during or before pregnancy? ___Yes ___No ___Don't Know

| Problem | Part of Body | Year |
|---|---|---|
| | | |

7. What other close family members or friends might have more information about his/her early life history? ______________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

- RETURN TO PAGE 1 -

## Letter of Introduction

The Colorado Department of Health is conducting an investigation of leukemia cases in Mesa County, Colorado. We are trying to learn more about the relationships between leukemia and various occupations, other illness, and the environment in which people live.

According to our review of hospital records and physicians' office records, you have been identified as a close relative of _________. Because of your familiarity with this persons' life and work history your cooperation is critical to the success of this investigation.

I am requesting your permission for a personal interview during which I would like to ask you a few questions about the medical and work history of your relative. I will be phoning you in the next week for your response to my request and, hopefully, to set up a time for an interview. If a personal interview is not possible, I hope that I may question you by phone.

Thank you in advance for your kind cooperation.

Sincerely yours,

Merle C. Cunningham, M.D.
Clinical Investigator

Tracey Foreman
Research Associate, M.P.A.

## CODING SCHEDULE

| Variable Number | Variable Name | Variable Code |
|---|---|---|
| 1 | Mesa County Leukemia Study | |
| 2 | Identification Number | 001-044=Cases; 201-244=Cancer Controls; 101-144=Heart Controls |
| 3 | Sex | |
| 4 | Birth Date | |
| 5 | Age at Diagnosis | |
| 6 | Date of Diagnosis | |
| 7 | Age at Death | |
| 8 | Date of Death | |
| 9 | Gap Between Diagnosis and Death (Years) | |
| 10 | Cause of Death - Eighth Revision International Classification of Diseases, Adapted | |
| 11 | Informant Relationship | 1=Spouse<br>2=Son<br>3=Daughter<br>4=Parent<br>5=Sister<br>6=Brother<br>7=Other Relative<br>8=Friend<br>9=None |
| 12 | Years Acquainted with Case | |
| 13 | Gap Between Interview and Death | |
| 14 | Interview Rating | 1=Excellent<br>2=Good<br>3=Fair<br>4= Poor<br>9=No Interview |
| 15 | Primary Occupation | Hollingshead Occupational Index (See Table 7) |
| 16 | Secondary Occupation | Hollingshead Occupational Index (See Table 7) |
| 17 | Crude Occupational Exposure | 1=No Occupational Exposure<br>2=Chemical Exposure Possible<br>3=Radiation Exposure Possible<br>4=Chemical Exposure Definite<br>5=Radiation Exposure Definite<br>6=Chemical Exposure Definite, Radiation Exposure Possible<br>7=Chemical Exposure Possible, Radiation Exposure Possible<br>8=Radiation Exposure Definite, Chemical Exposure Definite<br>9=Radiation Exposure Possible, Chemical Exposure Definite |
| 18 | Total Years Residence in Mesa County | |
| 19 | Years Residence since 1950 | |
| 20 | Cumulative Gamma Expsoure since 1950 | |
| 21 | Average Annual Gamma | |
| 22 | High Gross Average Gamma | |
| 23 | Screening Assessment- Residence | 1=A<br>2=B<br>3=C<br>4=D<br>5=E<br>6=F<br>7=I<br>9=Unknown<br>(See Table 15) |
| 24 | Screening Assessment-Occupation | (same codes as 23) |



922 116

# CODING SCHEDULE



| Variable Number | Variable Name | Variable Code | |
|---|---|---|---|
| 25 | Working Level (Radon Daughters) | | |
| 26 | Health Status Assessment | 1=Excellent<br>2=Very Good<br>3=Good | 4=Fair<br>5=Poor |
| 27 | Drug Exposure | 1=None<br>2=Minimal, Intermittent<br>3=Minimal, Chronic | 4=Moderate, Chronic<br>5=Chronic, Heavy |
| 28 | Cancer History | If Present Code ICDA-8 | |
| 29 | Radiotherapy History | 1=None<br>2=Possible<br>3=Definite | |
| 30 | Smoking History | Pack Years | |
| 31 | Radium Dial Watch History | 1=None<br>2=Possible 1920's<br>3=Possible 1930's<br>4=Possible 1940's<br>5=Possible 1950's or later | 6=Definite 1920's<br>7=Definite 1930's<br>8=Definite 1940's<br>9=Definite 1950's or later |
| 32 | Ethnic Origin | 1=Spanish Surnamed<br>2=White, European (non-Mediterranean)<br>3=White, European (Mediterranean)<br>4=Black<br>5=Asian<br>9=Unknown | |
| 33 | Family History of Leukemia | Number of Family Members | Presumed or Known |
| 34 | Family History of Cancer | Number of Family Members | Presumed or Known |
| 35 | Congenital Defects in Family | Number of Family Members | Presumed or Known |
| 36 | Family History of Mental Retardation | Number of Family Members | Presumed or Known |
| 37 | Maternal Radiation Exposure | 1=Absent<br>2=Possible | 3=Definite<br>4=Unknown |



7922 117

NRC FORM 335 (7-77)

U.S. NUCLEAR REGULATORY COMMISSION

**BIBLIOGRAPHIC DATA SHEET**

| | |
|---|---|
| 1. REPORT NUMBER *(Assigned by DDC)* | NUREG/CR-0635 |
| 2. *(Leave blank)* | |
| 3. RECIPIENT'S ACCESSION NO. | |
| 4. TITLE AND SUBTITLE *(Add Volume No., if appropriate)* | Excess Cancer Incidence in Mesa County, Colorado |
| 5. DATE REPORT COMPLETED | MONTH: November; YEAR: 1978 |
| DATE REPORT ISSUED | MONTH: July; YEAR: 1979 |
| 6. *(Leave blank)* | |
| 7. AUTHOR(S) | M.C. Cunningham, M.D.<br>Stanley W. Ferguson<br>Tracey Foreman |
| 8. *(Leave blank)* | |
| 9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)* | Disease Control and Epidemiology Division<br>Colorado Dept. of Health<br>4210 East 11th Avenue<br>Denver, CO 80220 |
| 10. PROJECT/TASK/WORK UNIT NO. | |
| 11. CONTRACT NO. | NRC FIN No. B10728 |
| 12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)* | Office of Standards Development<br>U. S. Nuclear Regulatory Commission<br>Washington, D. C 20555 |
| 13. TYPE OF REPORT | |
| PERIOD COVERED *(Inclusive dates)* | |
| 14. *(Leave blank)* | |
| 15. SUPPLEMENTARY NOTES | |

16. ABSTRACT *(200 words or less)*

The initial phase of the investigation determined there is a twofold excess of leukemia incidence for all ages in Mesa County, Colorado, for the period 1979-1976 with the greatest excess appearing among residents over 65 years of age who developed leukemia 2-1/2 times the expected rate. No excess incidence of lung cancer has been identified.

The second phase of the investigation has been case-control study of all adult leukemia deaths since 1960.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

17b. IDENTIFIERS/OPEN-ENDED TERMS

| | |
|---|---|
| 18. AVAILABILITY STATEMENT | Unlimited |
| 19. SECURITY CLASS *(This report)* | Unclassified |
| 20. SECURITY CLASS *(This page)* | Unclassified |
| 21. NO. OF PAGES | |
| 22. PRICE | $ |

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. NUCLEAR REGULATORY
COMMISSION

U.S. MAIL