A SOCIOLOGICAL ANALYSIS OF THE REDUCTION OF HAZARDOUS RADIATION IN URANIUM MINES

Jessica S. Pearson, Ph.D.
University of Denver
Denver, Colorado

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Salt Lake City, Utah
April 1975

The contents of this report are reproduced herein as received from the author except for minor changes. This document was determined by NIOSH to be significant in the area of occupational safety and health and is being reproduced by NIOSH for general availability to the scientific community. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of NIOSH. Mention of company or product names is not to be considered as an endorsement by NIOSH.

HEW Publication No. (NIOSH) 75–171

TABLE OF CONTENTS

Page

ABSTRACT

Chapter

1. INTRODUCTION 1

2. HISTORY OF THE PROBLEM 3

3. A PERSPECTIVE ON THE PROBLEM 7

4. DEVELOPING A MODEL 17

5. TESTING THE MODEL I: THE EFFECTS OF ORGANIZATIONAL "CONCERN" ON WORKER HEALTH 35

6. TESTING THE MODEL II: THE EFFECTS OF "HISTORICAL" FACTORS ON ORGANIZATIONAL "CONCERN". 61

7. SEARCHING FOR CAUSES 95

8. CONCLUSIONS. 109

APPENDIXES

A. CHRONOLOGY OF EVENTS IN THE HISTORY OF THE RADIATION HEALTH HAZARD AND ITS CONTROL: 1947-1972. 119

B. FOOTNOTES. 123

FOREWORD

The health of uranium miners and their working conditions have been studied by the National Institute for Occupational Safety and Health and its predecessor organizations for about 25 years. Other government agencies (most notably the Atomic Energy Commission) and many private individuals (most notably Dr. Geno Saccomanno) have contributed substantially to these studies. They have led to the present permissible exposure standard for radon daughters in mines. These studies as related to hazard control were exhaustively reviewed by Cross et al. in "Evaluation of Methods for Setting Occupational Health Standards for Uranium Miners" in the hope that an analysis of this experience would provide guidance in the development of standards for other noxious substances. These studies devoted themselves to the environmental radiation encountered in uranium mines, to the effects of this radiation on the health of miners, and to methods of controlling the hazard. Social factors were not considered.

Ms. Pearson, with this report, has added another dimension to the studies noted above. Scientific facts and deductions have little influence by themselves on any but other scientists. Ms. Pearson in this study has explored the development of concern by industry, by legislators and by administrative units with the hazards of uranium mining. In past years, the development of this type of concern over an occupational hazard was necessary before safe standards could be achieved. With the advent of the Occupational Safety and Health Act of 1970, 29 U.S.C. 655, the development of concern by a relatively small group of individuals involved in its administration may be all that is necessary to set and enforce safe standards in industrial processes. The lengthy process of slowly developing concern by all interested parties, as detailed by Ms. Pearson, may no longer be necessary. Hopefully this new law will greatly reduce the time between recognition of a hazard by a few scientists and imposition of a safe standard. However, administrators of programs which deal with occupational and environmental standards should be aware of the importance of the social factors involved because neglect of these factors could jeopardize the effectiveness of occupational and environmental protection regulations. On the other hand, recognition of these factors will enhance the effectiveness of the program by encouraging informal cooperation.

ACKNOWLEDGMENTS

Many names do not appear on the title page whose help was indispensable to the completion of this project. Were such a list to be compiled it would be headed by Dr. Victor Archer, M.D., of the National Institute for Occupational Safety and Health, Western Area Occupational Health Laboratory, Salt Lake City, Utah. Dr. Archer provided me with a huge amount of quantitative information on radiation in the nation's uranium mines. In addition, he put me in touch with many individuals who had been involved with the problem of excess radiation in mines at an earlier point in time and critically read this manuscript prior to its publication.

My thanks also extend to Mr. Norman Blake, State Mines Inspector for Colorado. He kindly tolerated me from January 1973 to May 1973, when I became a permanent fixture in his office. His office staff, headed by Mrs. Leonard, also deserves warm thanks for permitting me and my research assistants to prowl through office files for months on end.

I am also indebted to the fifty or more individuals from mining companies, government regulatory agencies and unions who taught me about the problem of excess radiation in uranium mines. They gave generously of their time and interest and made the day to day life of the project lively and interesting.

This study is based on data gathered and analyzed between September 1972 and December 1973. It was first described in my Ph.D. dissertation entitled, "The Process of Solving an Industrial Health Hazard." That manuscript was successfully presented to the faculty of the Princeton University Sociology Department in June, 1974. To the individuals who oversaw my dissertation project: Frederick H. Harbison, Professor of Industrial Relations and Economics at Princeton University; Gerald Breese and Suzanne Keller, Professors of Sociology at Princeton University; and Wilbert Moore, Professor of Sociology and Law at the University of Denver; I wish to convey deep appreciation for forthcoming help and patience. I am particularly grateful for the guidance and promptness Professor Harbison demonstrated in responding to my long distance communications; and for the attention Professor Moore generously bestowed on me despite the fact that I was not his official charge.

While in Denver I have used the University of Denver library and computer facilities. For this I am deeply indebted to Professor William H. Key, Chairman of the Sociology Department at the University of Denver.

Needless to say, I am thankful for the financial support I enjoyed throughout my graduate studies at Princeton University. I also appreciate the small grant the faculty of the Sociology Department at Princeton awarded to me during academic year 1972-1973 to facilitate the completion of this project. With it, I was able to acquire assistance in the time-consuming process of collecting and coding information for this project.

ABSTRACT

This report describes the responses of companies, unions and government enforcement agencies to the problem of excessive radiation in mines resulting in respiratory cancer in Colorado chiefly between the years 1950 and 1969. It focuses on the organizational actions which ultimately solved the hazard as well as the non-technological factors that prevented an earlier solution of the problem.

Information was assembled from mining archives on more than 500 Colorado uranium mines. This permitted a statistical analysis of the relationships between and among the scale and stability of the industry over time, the history of government enforcement activities and the changing levels of radiation in mines. Such analysis revealed that the greatest reduction in hazardous radiation in mines followed inspection and sanction activities by an enforcement agency.

From an extensive historical analysis and a series of interviews, it was also shown that the demand for uranium ore for defense purposes, the invisibility of the radiation hazard to the naked senses, and the transient and speculative nature of the early uranium mining industry prevented an earlier solution of the problem.

These results argue for policies related to health and job safety that emphasize periodic inspections which carry a threat of punishment for employers who knowingly violate standards.

Chapter 1

INTRODUCTION

This is a study of the historical and organizational dynamics by which the problem of an industrial health hazard was solved. The setting is the uranium mining industry in Colorado chiefly between the years 1950 and 1969. The particular health hazard is excessive radiation in mines which often results in pulmonary fibrosis and lung cancer. The organizations whose response is of greatest interest to this study are those which had the greatest opportunity to solve the problem: companies, unions and government enforcement agencies.

The uranium industry setting is particularly appropriate to an examination of the role of organizational and historical variables in the solution of an industrial health hazard for several reasons. First, there is documentation of the existence of a hazard in the uranium industry for many years (since 1597), even though the hazard was not specifically identified as being radiation from radon daughters until 1951. Second, the technology to solve the problem (mine ventilation) was available from the start of the industry in the United States in the 1940's, even though application of the technology to the specific hazard was not demonstrated until 1953. Third, in recent years, after considerable delay, organization action has brought the hazard under control. The uranium industry setting therefore permits identification of the organization actions that eventually reduced hazardous radiation in mines and the factors that blocked a speedy resolution of the problem.

Accordingly, the aims of the study are twofold. First, it seeks to determine whether certain specific steps taken by companies, unions and government agencies were more successful than others in reducing radiation in mines. Second, once such steps are identified, it analyzes why they were taken; or, alternatively, why they were not taken at an earlier point of time. In other words, it asks what the barriers are to eradicating an industrial health hazard for which a technical remedy is available.

In meeting these aims, the study elaborates a model of the process of solving a "social" problem. The model incorporates certain patterns in the historical development of modern industry and in the capacity of formal organizations to act. These patterns, it is contended, are of some typicality in mid-twentieth century America. Thus the model lays the groundwork for a sociological theory, or, more accurately, a perspective with import for policies aimed to remedy a variety of social and consumer ills.

In order to more fully understand the aims of this project, some detail concerning the history of the radiation health hazard and its control is necessary. The following section presents the problem in its historical context.

Chapter 2

HISTORY OF THE PROBLEM*

The hazards of mining uranium arise from the radioactive nature of the mineral. Like all other radioactive elements, uranium decays to form a series of decay products which in turn decay to form a series of radioisotopes. The decay products are radon gas and its radon daughters, respectively. Bodily harm occurs from the inhalation of radon gas and radon daughter products which attach themselves to dust particles in the air, and thus enter the tracheo-bronchial tree. Once inhaled, radon and radon daughter particles irradiate sensitive lung tissues. The lung cancer effects associated with mining uranium are due to the irradiation of cells by radioactive particles deposited in the body.[1]

Today, the uranium mining population in the United States is experiencing what has been termed a "lung cancer epidemic."[2] Currently more than 200[3] of the estimated 6000[4] persons who have mined uranium in Colorado at some time in their lives, have died of lung cancer. Actuarial studies project that a total of 1150 cases of lung cancer will have appeared among this population by 1985.[5] In addition to this toll of human life, the cost of compensating the afflicted miners and their families through the year 1985 will be about $21.6 million.[5]

The tragedy assumes more striking proportions, however, when it is noted that it was predicted in advance by health officials in the United States. Moreover, methods of controlling the hazard were available at the start of the domestic mining industry.

Empirical evidence dating to the sixteenth century notes the incidence of excessive lung disease among miners extracting uranium-bearing ores.[6] The association between lung cancer and mining uranium, however, was first established in the early twentieth century. Miners in central Europe who handled pitchblende and other uranium-bearing ores were found to suffer elevated risks of lung cancer. These studies showed that 50%-75% of the deaths among the uranium mining population between 1921 and 1926 and 1929 and 1930 were due to lung cancer. Published in American journals, these studies succeeded in arousing concern among American health officials about human exposure to uranium.[7]

In addition to information about the hazard, technical information on its remedy was also available in the literature. Ventilation techniques are the most effective ways to protect workers against overexposure to radioactive particles in mine environments. Since radiation builds up

---

* See Appendix A for "Chronology of Events in the History of the Radiation Health Hazard and its Control: 1947-1972."

the longer radon and its daughter products are permitted to remain in the underground atmosphere, successful control of the hazard depends on their rapid dilution and removal. This is accomplished by continually circulating the air in mines so that the underground atmosphere is replenished with fresh air and contaminated air is directed away from the area occupied by workers.[8] Although recent research and development has refined the equipment used in ventilating mines, adequate protective techniques were available at the start of the domestic uranium mining industry in 1947. Indeed, journals show that ventilation techniques had been devised for the successful control of airborne radioactivity in Czechoslovakian mines in the early 1930s.

Shortly after the United States declared its intention to stimulate the domestic production of uranium in 1946,[10] the problem of excess radiation was reviewed. The first study of the radiation environment in American uranium mines was done in 1947 by the Atomic Energy Commission and the Colorado Department of Health.[11] Results showed that airborne radioactivity in domestic mines was comparable to and in some cases higher than levels measured in the fatal mines of Europe. Although differences in work procedure and the length of the working day in the European and American mining experience were cited to emphasize the incomparability of the two cases,[12] the situation aroused concern among members of the health community. Officials of the Colorado Department of Health met with government and business leaders to urge that preventive ventilation measures be adopted in the nation's uranium mines in 1949.[13] Their warnings, however, were not heeded and in 1950 the United States Public Health Service began a study of the uranium mining health situation.[14]

Between the years 1950 and 1960, additional attempts were made by medical researchers and health agency officials to convince mine operators and government authorities of the need for preventive control measures in uranium mines. Industry representatives and government enforcement agents were advised of the European mining experience;[15] of the findings of the Public Health Service regarding environmental quality of the American mines; and of the techniques for mine radiation measurement and control that had been found effective in European mines.[16] Study by the French on financial aspects of effecting adequate ventilation techniques in uranium mines in 1958 put the cost at an additional 1% of the operating expenses of unventilated mines, and more recent American findings have not substantially altered this conclusion.[18] However, because there is a time lag between individual radiation exposure and the appearance of lung cancer effects, it was impossible to demonstrate that biological injury was occurring to miners.[19] In the absence of proof of this nature, state mine inspectors with enforcement authority[20] were unconvinced that they should require environmental control measures to regulate radiation levels in uranium mines.[21]

The Public Health Service first demonstrated a statistically significant excess of deaths among men with three or more years of

uranium mining experience relative to the non-uranium mining population in 1959. At a conference of governors of uranium producing states,[22] convened by the Secretary of the Department of Health, Education and Welfare in 1960,[23] the Public Health Service reported that lung cancer was occurring at five times the expected rate among the experienced uranium mining population. As a result of these findings, control programs were initiated in most of the states.[24]

Although the quality of mine environments improved with the initiation of statewide control programs following 1961,[25] enforcement was found to vary from state to state, and generally recognized quality goals were not met.[26] In view of this situation, the Secretary of Labor, Willard Wirtz, invoked the powers of the Walsh-Healy Public Contracts Act in 1967[27] to promulgate a regulation covering the enforcement of a uniform radiation standard in uranium mines.[28] The regulation called for immediate enforcement of a widely advocated radiation standard[29] and the gradual transition to one three times more stringent.[30]

Although evidence had steadily mounted to document the lung cancer effects of radiation in mines, the action of the Secretary of Labor met with opposition from mining companies, the Atomic Energy Commission, the Joint Committee on Atomic Energy and the Bureau of Mines. The baseline standard advocated by Wirtz did not go into effect until July 1, 1971, a full four years after its initial promulgation. Ten months prior to the proposed enforcement date the Joint Committee on Atomic Energy held hearings at which it unsuccessfully challenged the feasibility of the new standard,[31] and three weeks before its enforcement date a six month postponment was granted by President Nixon for the purposes of further study.[32] Two days after the new standard became law, a proposal to permit variances to the law was published in the Federal Register, and at hearings held six months later in January 1972, the Bureau of Mines ruled to permit the issuance of variances.[33] Finally, an attempt was made to thwart the enactment of the lower radiation standard by challenging the validity of the Public Health Service data which had been used to bolster the new standard.[34]

Despite these delays, however, most of the nation's uranium mines today are free of radiation concentrations believed capable of causing bodily harm. It is widely acknowledged that a critical factor in the reduction of radiation in mines was the controversial promulgation by Secretary of Labor Wirtz in 1967. This action, however, came a full twenty years after the Atomic Energy Commission had first sampled mines in an industry which it had created and found them at exposure levels comparable to those of the ill-fated mines in central Europe. The action also came eighteen years after the first recorded discussions among officials in government agencies of possible radiation hazards in uranium mines.[35] Moreover, nationwide control lagged seven years behind statistical documentation by the Public Health Service that uranium miners suffered elevated mortality from lung cancer, far above what would be expected on the basis of regional age specific rates of

the non-uranium mining, male population. Finally, when control came, it came as a result of the regulatory initiatives of the Secretary of the Department of Labor--an agency only tangentially involved with the mining of uranium--and not as a result of the actions of those federal agencies more routinely concerned.

This is the historical context in which the factors shaping organizational response to the health hazard confronting uranium miners will be examined.

Chapter 3

A PERSPECTIVE ON THE PROBLEM

To explain the health and safety picture in uranium mining between 1950 and 1969, a theory must handle the following: Why was the industry begun and supported by the government when pre-existing European evidence indicated that it presented a worker health hazard? Why was it a full twenty years until a federal standard was imposed on mine radiation by an agency only tangentially concerned with the situation? In the interim, what steps, if any, were taken by organizations to improve mine health conditions? And what was the nature of evidence or advocacy actions necessary to promote mine radiation control?

Work agreements between miners and employers lacked explicit reference to health and safety issues. Nevertheless, it is assumed that it was not the formal goal of companies, unions or government agencies to imperil the health of employees. The lung cancer epidemic among uranium miners today, however, is evidence that such imperilment occurred.

There appear to be four factors which initiated a chain of events which ultimately led to death and disease. Each served to divert attention from the prevention and early correction of the health hazard to miners.

The following section describes these factors.

I. CONDITIONS OF NATIONAL CRISIS: THE NEED FOR URANIUM

> The deleterious consequences of excess mine radiation to a handful of miners were shadowed by the more dramatic spectre of severely endangered national security. Opposition to any aspect of the weapons program during the 1940's and 1950's, of which the uranium industry was a part, also invoked the stigma of disloyalty and subversion.

During most of its history, the United States uranium mining industry has been shaped by national security interests. Indeed, it is only since the recent proliferation of atomic reactors that uranium has been used for non-military purposes on a wide scale.

The domestic uranium mining industry first began at the turn of the century when the ore was mined for use as a ceramic coloring

agent. By the mid-1920's, however, the industry had withered away and most uranium supplies emanated from foreign sources. Although some domestic mining was renewed during the 1930's for vanadium (a uranium by-product), uranium mining for government uses did not begin until the late 1940's in response to the wartime requirements of the United States weapons program. The detection and mapping of uranium deposits in the Colorado Plateau were high defense priorities. Such operations were heavily veiled with secrecy. For example, it was not until the mid-1950's that uranium production figures were declassified and published in public mining directories.

After the war, an intense campaign was launched to stimulate domestic production of uranium. The procurement program called for in the Atomic Energy Act of 1946 provided for a system of price supports and bonuses. The Atomic Energy Commission agreed to buy all domestic uranium ore at a guaranteed minimum price. The program also extended general cash inducements to new producers. To defray initial production costs, the government bonus system offered up to $35,000 on the first 10,000 pounds of uranium oxide that an operator produced.[36]

The campaign to stimulate a domestic uranium capability was motivated by military considerations. It reflected America's concern with its pre-eminence in the sphere of atomic weaponry. In 1946, for example, a book appeared receiving wide attention which portrayed the spectre of "intercontinental atomic tipped rockets fired from within the aggressor's own country and reacing their destination within an hour's time."[37] According to the author, who subsequently served as executive director of the Joint Atomic Energy Committee, the danger of such attack demanded the amassing of a "whole war's supply of weapons on hand in advance of any fighting."[37] The fundamental issue confronting the nation was "whether or not the nation (would) survive."[37] The era of the Iron Curtain, weapons spy rings, domestic communists and loyalty screening programs had begun.

The decade of the 1950's began with similar preoccupations.[38] The Russian demonstration of its atomic capabilities in the summer of 1949 added new impetus to the crash program to develop the H-bomb. The year 1950 also saw the beginning of fighting in Korea and the McCarthy accusation that 250 communists lurked in the State Department. Subsequent years witnessed the initiation of Project Vista, a study of adapting atomic weapons to conventional warfare; the Lincoln Summer Study of United States air defense which recommended among other things an investment of several billion dollars in early warning radar systems; the detonation of the first hydrogen bomb; and the Eisenhower security program to rid the public payrolls of subversives. In 1954 Robert Oppenheimer's security clearance was revoked and a trial was held. Among the major evidence used against him was his opposition to the H-bomb weapons program.

The crisis-ridden atmosphere of the late 1940's and 1950's affected response to the hazard that miners faced. The prospect of menaced national security and its concomitant emphasis on extracting sufficient

amounts of uranium ore constrained actions which would have enhanced mine safety. In the words of one individual interviewed in this study, "They wanted that ore pretty badly and not much else mattered."[39] Preoccupation with domestic communism inhibited the expression of opposition to the expanded uranium and military weapons program. According to the recollections of another interviewee, "If you said anything in those days criticizing the program, you were a communist."[40]

The bugaboo of imperiled national security continued to feature in the controversy surrounding the hazard well into the 1960's. Even after the Atomic Energy Commission admitted a uranium surplus and announced its intention to release its uranium stockpiles to the commercial market, certain officials continued to suggest that radiation regulations in uranium mines would threaten national security. For example, in 1967 cross-examination of Secretary of Labor Willard Wirtz in Joint Committee on Atomic Energy Hearings concerning his promulgation of standards to restrict radiation, Chairman Pastore had the following to say:

> Was any consideration given as to whether or not this overcautious action...would close down these (uranium mining) operations, much to the chagrin of the Defense Department and the Atomic Energy Commission who are responsible for the national security of the Nation? (41)

Thus, tremendous military demands for uranium supplies occurred in a time when the nation was engulfed by a security crisis related to those demands. Official pre-occupation with the crisis and with obtaining adequate supplies of uranium diverted attention from the health of the uranium miners. It was only after the crisis and demand for uranium had subsided that worker health considerations came to the fore.

II. CONDITIONS ARISING FROM THE VISIBILITY OF THE HAZARD: THE ELUSIVENESS OF MINE RADIATION

> A health hazard such as lung cancer induced by mine radiation, which is impossible to detect with the naked senses, whose symptoms in human beings are slow to manifest themselves, and which is difficult to diagnose, will meet with widespread public disbelief. This skepticism is only overcome with the undeniable documentation of bodily harm that is close to home.

Shortly after the uranium mining industry had been launched in this country in the late 1940's, health officials met to discuss possible radiation hazards in the mines. Their concern was aroused by published accounts of excessive lung cancer deaths among European uranium miners during the first part of the twentieth century. Medical studies of the causes of death among this population attributed 50%-75% of uranium miner fatalities to lung cancers.[42]

The results of early environmental studies of American mines served to underscore the concern of health officials. Measurements of airborne radioactivity in domestic uranium mines resembled and in cases exceeded levels reported in the dangerous European mines. Armed with the data on human exposure available in the literature and evaluations of environmental conditions in the domestic industry, health officials met representatives of the industry and government to advocate measures of preventive control. They did not succeed.

Despite documentation of a hazard in the mines, the hazard was too subtle for most people to believe. The dangers associated with mining uranium are due to its radioactive nature. Uranium, like all other radioactive elements, decays to form a series of decay products which in turn decay to form radioisotopes. The decay products are respectively, radon and its radon daughters. Bodily harm occurs from the inhalation of irradiated radon particles. Suspended in air the particles attach themselves to dust fragments and enter the tracheobronchial tree. Once inhaled, they emit alpha rays which irradiate the sensitive lung tissue.[43]

The invisible, scentless, and intangible quality of radiation contributed to the reactions of disbelief the advocates of radiation control encountered. For example, at government hearings in 1969, a representative of the small uranium mining operators made the following ironic comment:

> Although I do not have a degree in mining engineering nor geology, I have been mining uranium for many years, but until just a few years ago I had never heard of radon, and I had never met any of her "daughters." However, in the past few years her daughters have cost me a lot of money without returning to me any pleasure. (44)

Another interviewee has recalled that "there was a lot worse to be concerned about in the mines. There were too many dangers all around you that you could see and smell and taste."[45]

The lag between individual radiation exposure and the appearance of lung cancer effects also contributed to the visibility problem. It was impossible to demonstrate that biological injury was occurring to miners until the irradiated population began to suffer lung cancer deaths. As the Commissioner of the Atomic Energy Commission, Ramey, testified before 1967 governmental hearings on miner health and safety:

> Unfortunately, because of the long latent period between commencement of exposure and the appearance of the disease, the epidemiological significance of the problem was not fully recognized until the late fifties and the better control practices of the sixties will not be demonstrated by the lower incidence of lung cancer for some time. (46)

Mine radiation was also difficult to monitor. Studies of air samples in mines showed that levels of radiation within the same mine and even within specific locations, fluctuated widely over a short period of time. This made it difficult to pinpoint the locus of a radiation hazard, and raised questions about the reliability of measurements of mine radiation. For example, the following exchange occurred during the Joint Committee on Atomic Energy Hearings in 1967:

> Representative Hosmer: I wish to ask one more question. Is that (the recorded mine radiation level) indicative of the condition of the mine thirty days later?
> Dr. Hibbard: No, Sir.
> Representative Hosmer: Two days later?
> Dr. Hibbard: No, Sir. The mine could change.
> Representative Hosmer: One day later?
> Dr. Hibbard: The mine could change in a day. (47)

The upshot of all this was that warnings of a health hazard to uranium miners went unheeded. Government and industry officials alike vetoed suggestions to initiate preventive measures to ventilate in the mines, and the dangers of exposure to mine radiation were minimized. For example, it was suggested that the European and American mining industries were so imcomparable that the fatal mining experiences of the former could not be generalized to the latter.

Others belittled the adverse consequences of mine radiation per se and blamed the lung cancers occurring to miners on excessive smoking, drinking and low living. One interviewee, for example, described the uranium mining population of the early fifties as "drunks and tramps."[48]

Still others contended that the body was able to recover from certain levels of "radiation insult."[49] As one eminent physicist testified before government hearings on the hazard:

> All living organisms possess a capability of repairing themselves after modest injury. A scratched hand heals, a sunburned back recovers, a broken finger knits. When penetrating radiation traverses a living cell, it does produce an initial ionization of the atoms which is in linear proportion to the intensity and duration of the radiation. But there the linear relationship terminates. Compensatory repair and recovery processes within the living cell, the tissue, the organ and the whole organism intervene. (50)

Public and official acknowledgement of the radon hazard and the subsequent initiation of control efforts followed the statistical documentation of excesses of lung cancers among the domestic uranium mining labor force. It is reported that a former director of mining in Colorado dismissed the European data on lung cancer as insufficient

evidence to warrant control measures and instructed health investigators to produce some "American bodies."[51] The Public Health Service accomplished this in 1960, whereupon control measures were begun. In short,

> It required ten years and the accumulation of a number of deaths to convince the authorities that real hazards existed in the uranium mines. (52)

Similar types of proof were needed to convince miners themselves as well as official agencies. Miners and inspectors alike overwhelmingly cited the death of friends and relatives as the reason for their belief in the dangers of mine radiation. In the words of one respondent:

> I remember in particular the first death that was proved to be due to uranium mining radiation--the small cell type--it was a feller named Johnson and lots of the miners knew him and heard about him. That made a difference. (53)

Thus, even in the face of a documented health hazard, companies, official agencies and miners alike remained unconvinced of the need for preventive measures to control mine radiation. Their skepticism was reinforced by the low visibility of the hazard: its imperceptibility to the naked senses; its elusiveness to monitoring devices; and its delay in manifesting biological damage. It was only after the unquestionable demonstration of bodily harm to miners and the dissemination of such information in the popular press that reactions of disbelief began to be dispelled. On a personal level, this required the demonstration of injury to friends and family. For government agencies, it necessitated the statistical documentation of injury to the domestic working force.

III. CONDITIONS ARISING FROM INTRA-INDUSTRY STRUCTURE: SCALE AND STABILITY

> The early uranium mining industry was unstable, extremely transient and highly speculative. It was both ill-equipped to remedy the mine radiation hazard and resistant to encroachments by the government on its entrepreneurial freedoms. The uranium mining industry gradually became more stable, less speculative and more established. The mature industry was financially able to reduce the worker hazard. It also held more enlightened views on the role of the government in private enterprises.

During the study period, the uranium mining industry consisted of mines that were government owned and operated, mines owned and operated by large companies and mines owned and operated by small companies, partnerships, families and individuals. In early years, however, small owners and operators composed the largest segment of the industry. The Atomic Energy Commission purchase program and cash bonus system were inviting to the small entrepreneur, and in 1950 this type of owner accounted for a majority of the mining operations in Colorado. Mines of this type, however, were unstable, ephemeral, and frequently only economically marginal.[54]

In subsequent years, the era of the individual uranium prospector came to a close. The changing profile of the industry was due to several factors. The ore purchasing and cash bonus programs were terminated in 1961 for some operators and in 1966 for many others. The promotional efforts by the government to stimulate a domestic uranium capability eventually led to overproduction and uranium stockpiling. As the open-market value of the ore declined, speculative, smaller production units folded. Delays in the widespread adoption of atomic reactors as energy sources further depressed the sluggish uranium market. Survival favored the large scale, stable mining organizations, and by 1970 multi-national, multi-million dollar conglomerates held nearly 80% of the Colorado mineral land producing uranium ore.[55]

Accompanying this economic and structural transformation were changes in the industry's relations with government agencies. What the mature industry of the mid and late 1960's acknowledged as the legitimate role of government in mining operations, including health and safety matters, was vehemently denied by the young industry. A 1953 policy statement issued by the Colorado Mining Association, for example, included the following:

> We oppose changes in mining laws which have been just for eighty years. We shall have none of this socialistic theory that government knows best and that metals in the ground can be removed only under government regulation and control. We believe in private ownership and we insist upon the rights of the metal miner to locate, operate and own his mine. We want no armchair specialists dictating how we shall mine. (56)

Although Colorado Mining Association policy statements of the late 1960's reflect concern about the duplication of policing and mine inspection activities by federal agencies, the principle of government involvement is not challenged.

Thus, tremendous instability characterized the speculative uranium mining industry of the 1940's and 1950's. Transient, loosely rationalized and economically marginal production units were relatively inattentive to health and safety issues and hostile to the efforts of government agencies concerning these matters. It was only after the industry became a stable, solvent and large-scale one that such factors as the health of workers received consideration.

IV. CONDITIONS ARISING FROM GOVERNMENT POLICY FORMATION: THE LAG IN OFFICIAL CONCERN

> The vacuum of federal level agencies willing to assume responsibility for formulating uranium mining health policy, adversely affected the control process. In the wake of federal abdication, local caretaking agencies inherited the mine radiation problem. Many agencies lacked the technical expertise, personnel and legislative and political authority necessary to remedy mine conditions.

Throughout its history, the uranium mining industry has maintained close relations with federal agencies. The industry arose as a result of government efforts to create a domestic uranium capability and for nearly two decades the Atomic Energy Commission leased mineral lands for prospecting, guaranteed minimum prices for uranium ore and offered cash bonuses for new producers. Uranium was forbidden on the open-market until the late 1960's and the government purchase of uranium only ceased in December 1970. Another federal agency with which the industry has maintained close contact is the Federal Bureau of Mines. It has provided technical support, equipment, research facilities, advice and data. The Department of Health, Education and Welfare also entered the picture through the activities of the Public Health Service. The latter agency has conducted continuing epidemiological studies of the health hazards associated with mining uranium.

Despite the intensity of federal involvement, legal responsibility to regulate worker health in the mines has gone largely unclaimed. Although the Atomic Energy Act grants the Atomic Energy Commission exclusive control over the whole field of atomic energy, including uranium, a semantic ambiguity in the Act restricting A.E.C. authority to regulate the mineral after "removal from its place of deposit in nature" was interpreted by the Atomic Energy Commission lawyers to exclude the regulation of uranium mining. As Atomic Energy Commission Commissioner Ramey testified at government hearings on health and safety in the uranium industry:

> The commission . . . does not have authority legally to regulate the mines. This authority was not in the original McMahon Act and it was not put into the 1954 amendments. (57)

Until recently, the Federal Bureau of Mines also played a very limited role in uranium mining. Prior to the passage of the 1966 Metal Mine Safety Act, the Federal Bureau of Mines served as a purely advisory body in the non-coal mining industry. Even after the passage of the 1966 Act, which extended Department of Interior authority to the inspection of uranium mines and the formulation of mine radiation standards, another four years elapsed before the beginning of federal inspection activity. Thus, the involvement of the Bureau of Mines in uranium safety did not begin until 1970.

The federal agency most deeply involved with the biological effects of mine radiation, the Department of Health, Education and Welfare through the activities of the Public Health Service, also lacked the authority to establish standards or supervise mine conditions. Public Health Service researchers were permitted to study mine conditions only with the consent of mine owners and their role in policy formation was purely advisory.

It was the Department of Labor that was responsible for the first restrictive regulation covering mine radiation. The association of the Labor Department with the health situation confronting miners derived from the provisions of the Walsh-Healey Public Contracts Act. This law confers on the Secretary of Labor authority to monitor the working conditions of employees engaged in work that is contracted by a Federal agency.

If there is a violation of the contractor's commitment to employee safety, the contract is subject to cancellation and the contractor barred from further Government contracts for three years. Since the vast majority of uranium was used by mills which had contracts with the Atomic Energy Commission, the Public Contracts Act was applicable to the uranium situation.

The provisions of the Walsh-Healey Act, however, were first exercised in 1967 when Secretary of Labor Willard Wirtz promulgated restrictive standards on mine radiation. The reasons cited for the lack of Labor Department action prior to 1967 are vague. According to testimony presented by Wirtz:

> The general and prevailing view was that other agencies, Federal and State, could more appropriately exercise here both the standard setting and the inspection functions. There is no excuse, however, for the acceptance by the Secretary of Labor of that view or for the resulting fact that the Public Contracts Act has not been enforced in any case involving the mining of uranium. (58)

Thus, the federal agencies involved with uranium mining provided little policy guidance concerning the issue of worker exposure to mine radiation. On the contrary, government involvement consisted of

> Literally hundreds of efforts, studies, meetings, conferences, and telephone calls--each of them leading only to another--most of them containing sufficient reason for not doing anything then--but adding up over a period of years to totally unjustifiable "lack of needed consummative action." (59)

The dearth of federal agency policy on health meant that the burden of initiating and enacting regulations passed to various state agencies in the uranium producing states. State response was highly variable. Mining associations exercised considerable clout in state government; efforts to restrict the uranium boom met with strong opposition. The former director of occupational and radiological health for the state of Colorado has noted that "Many people at that time accused the state health officers of inventing the whole problem. They tried to get people to believe that what we were really interested in was to expand our department and our power."[60] In the absence of clearcut mandates from federal agencies, local caretakers relied on their own criteria to assess the importance of the problem.

State response to the demonstration of statistically significant excesses of lung cancer in 1960 among uranium miners was also highly variable. Only Colorado and New Mexico expanded their state mining inspection staffs. In Utah and Wyoming, on the other hand, no staff expansions were effected and in Arizona, state inspection agents were not even given the necessary authority to regulate mine radiation.

Other state-wide variations occurred in the compensation allocated

to uranium miners who contracted lung cancer and the quality goals achieved in various state programs to monitor radiation. For example, a survey of the uranium mining states in 1967 showed that while Colorado state inspectors closed a mine when radiation readings exceeded 3.0, New Mexico inspectors only levied sanctions when levels exceeded 5.0 and Wyoming when levels exceeded 10.0.[61]

The inconsistent performance of the state agencies has been attributed to their limited resources, their ties to mining personnel and their contradictory interests in promoting and regulating the state mining industry. It also ensued from the lack of official guidance regarding health issues from federal level agencies. Many claimed that the federal government had never explained the special dangers of uranium mining to the local agencies. In the words of an attorney for the State Workmen's Compensation Insurance Fund of Colorado:

> Nobody told us that we had radiation in the mines--and nobody told us that we didn't; the Atomic Energy Commission just led us down the primrose path. (62)

Federal agency involvement in the regulation and supervision of mine radiation was seriously lacking. The absence of official policies covering the health and safety of uranium miners until 1967, adversely affected the control process. In the wake of federal abdication, local caretaking agencies were confronted by a problem for which they frequently lacked technical expertise, personnel, statutory responsibility and an official mandate.

The four factors described appear to have initiated a chain of events which ultimately led to an excess of lung cancers among uranium miners. Each diverted attention away from the hazard of excessive radiation in mines. As a result, the efforts of some health officers to reduce radiation in the early days of the industry came to naught.

The next section presents a hypothesis of how these events led to the lung cancer epidemic. It also presents the design of a study to test the hypothesis.