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

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Report describing 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. Topics include history of the problem, problem perspective, model development, model testing through study of the effects of organizational concern on worker health, and "historical" factors on organizational "concern", and searching for causes.

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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.

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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

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* 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

<u>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.</u>

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.

Chapter 4

DEVELOPING A MODEL

The development of a theoretical approach to an issue as complex as the elimination of the lung cancer epidemic among uranium miners is fraught with difficulty. Only the human ecologists seem to have undertaken theoretical explanations with regard to issues so complex. While their approach ultimately proves more stimulating than useful, it is only proper to pay them homage. In the present context, their most useful conceptual tool is the "ecosystem," along with its component categories: population, organization, environment and technology.[63] As Duncan puts it:

> These categories, population, organization, environment and technology (P,O,E,T), provide a somewhat arbitrary simplified way of identifying clusters of relationships in a preliminary description of ecosystem processes. The description is, by design, so biased as to indicate how the human elements in the ecosystem appear as foci of these processes. (64)

In terms of the conceptual scheme of the ecological complex, the problem of official delay in the reduction of excess radiation in mines becomes more understandable. Underground miners were exposed to radioactive emissions from uranium rock (E→P)[65] which were believed to impair health. In response to this situation, certain health officials appealed to business and government leaders (O→O) to control underground radiation levels (O→E). Technology to reduce radiation has been developed to handle the problem in Europe decades earlier (O→T) and was available for adoption by American mining companies (T→E) at an extra expense (O→T). However, because of the strong need for uranium for the domestic weapons program, (E→T) the unstable and transient character of the industry which made it difficult to supervise by government agencies (O→O) and the absence of immediate evidence that biological harm was occurring to underground miners as a result of their exposure to uranium ore (E→P), officials were not convinced that the situation merited regulation (O→E). Subsequently, economic and political considerations shifted. The government accumulated a uranium surplus and no longer required additional reserves (E→O). The industry became successively more stable and large scale and subject to government overview (O→O). Moreover, evidence accrued demonstrating that miners were dying of lung cancers at elevated rates (E→P). Finally, government enforcement agencies issued regulations covering radiation levels in underground mines (O→E). As a result, companies installed ventilation technologies that reduced or eliminated underground radiation altogether (O,T→E). This diminished the hazards of mining uranium and disease rates among uranium miners are expected to exhibit parallel declines (T→P).

In this framework, the resolution of the problem involved an intricate interaction of factors in the ecological complex (P,O,T→E). Environmental modification and social change were systematically interrelated. Any less elaborate scheme could hardly handle the interrelations of the variety of variables which featured in the reduction of radiation in mines to tolerable levels.

But for actual research purposes such an approach provides insufficient guidance. Therefore a more modest approach has been adopted. It draws upon and modifies some of the more established conceptual ideas utilized in research on complex organizations.

This approach treats the solution of the lung cancer epidemic among uranium miners, documented briefly in Chapter 2, supra, as a historical process. The actors in the process are, of course, organizational actors--regulatory agencies, companies and unions. Their problem-solving behavior will be examined in terms of the ways in which it was shaped by historical factors and interorganizational influence.

Analytically, the key concepts in the above statement of the approach are those underscored: historical process, historical factors and inter-organizational influence. A brief discussion of each is in order.

That the solution of social or technological problems occurs to greater or lesser extent as historical process may seem merely definitional. In this analysis, however, statement of the truism permits distinction of some conceptual significance. For the historical process by which a social problem (e.g., a lung cancer epidemic among uranium miners) is solved by organizational actors embodies two distinct stages. The first stage involves designation of the solution of the problem as an organizational goal. In the language employed in the study of complex organizations, this refers to organizational goal-formulation. An organizational goal in this sense is what Etzioni has called " . . . a desired state of affairs which the organization attempts to realize."[66] The goal-formulation stage in the present case was, of course, the stage at which the organizational actors adopted policies designed to eradicate lung cancer in the mines. The distinct second stage, once an organization has formulated a goal, is carrying out the goal; or, again borrowing from Etzioni, becoming "effective" in realizing the goal.

The importance of the distinction between the goal-formulation and the goal-realization stages is best illustrated by an example of what happens when the distinction is ignored. One body of sociological literature on problem-solving tends to do just that; it ignores the goal-formulation stage and concentrates exclusively on the realization stage.[67] It asserts that the prerequisite for the solution of any social problem is information about the problem coupled with technology to solve it in the hands of appropriate decision makers. With such a view, one might expect that once scientists knew about the cause-and-effect relationship between lung cancer and exposure to radiation, and once they conveyed such information to industry and government leaders, and once these leaders possessed the technology to reduce radiation in the mines . . . steps would have been taken at once to bring the problem under control.

Such, however, was not the case. The record shows that from the very outset medical evidence from the European experience of the early part of the twentieth century was widely available; it strongly suggested radiation in mines was harmful to workers. Technology to solve the problem was also available from the start. Moreover, information was published and available showing that the costs of providing adequate ventilation were a mere fraction of the operating expenses of mines which were unventilated.

The discrepancy between what might be expected on the basis of the literature and what actually occurred lies in the failure to distinguish between the goal-formulation and goal realization stages of the problem-solving process. In the latter stage, goal-realization, the presence or absence of relevant technical information and technology is obviously critical. But in the first stage, that of goal-formulation, such information and technology may be altogether irrelevant. Records show that in the late 1940's and the 1950's a climate of indifference to the known biological consequences of mining uranium prevailed. In this climate, research findings attributing lung cancer to exposure to radiation met with official disbelief. The disbelief was not occasioned entirely by the quality of the research findings, because later equivalent findings were used to establish the official regulations which ultimately brought the uranium hazard under control.

The real difference lay in the level of concern of officials in organizations at different points of time. When concern was low, the cause-and-effect relationship between radiation and cancer was regarded with skepticism. Once concern was aroused, the relationship was taken seriously. This tendency is aptly expressed by one interviewee in response to questions on the technology needed to control radiation in mines:

> The technology has always been around. We've always had fans. The interest, however, only came about in the mid-1960's and this caused the big change. (68)

In the analysis of the goal-formulation stage, then, the question seems to become one of identifying factors other than information or technology which generated interest, or as it will be referred to later, "organizational concern."

When the solution of the lung cancer epidemic in the mines is conceptualized as a two-stage historical process, it becomes important to examine the nature of the constraints to which each stage was subject. In the approach adopted here, these constraints are categorized as historical factors and interorganizational influence.

The concept of historical factors as used here comes very close to what has perhaps more commonly been designated as the "organizational environment."[69] It flags the obvious but important idea that organizational problem-solving does not occur in a vacuum--neither in its goal-formulation nor its goal-realization stages. A variety of influences to and often beyond the control of the organizational actors (in addition to the influence of other organizations) affects their behavior throughout the problems-solving process. Such external factors include forces which are, broadly speaking: economic,[70] technological,[71] political,[72] and legal, among others. In the course of the study, specific manifestations of so-called historical factors will be examined in detail; in the conclusion an attempt will be made to show some of them represent generic forces at work in any historical process of organizational problem-solving.

The concept of interorganizational influence emphasizes that organizations acting as to a common problem act upon each other as well as upon the particular problem sought to be solved. Organizations influence each other's behavior. Just what such influences may be in a given case, let alone how they operate, is exceedingly difficult to specify. The study of formal organizations seems not to have gotten much beyond the stage of recognizing, in theory, that such interorganizational influence is important.[73] In point is Evan's notion of the "organizational set,"[74] but the utility of such a notion is uncertain in a research context such as that involved here where there may be no single "focal" organization in the field of organizational action. Norton Long has verbalized a similar idea in his phrase, "ecology of games,"[75] although he leaves the concept pretty much as he finds it on its connotative feet. Studies such as David Roger's of the New York City Department of Education[76] have purported to take up Long's notion without significantly refining or advancing it. Only Philip Selznick's study of the T.V.A. comes close to fitting the examination of interorganizational influence into a larger theoretical framework. In so doing it elaborates one type of interorganizational influence, co-optation, and shows how it operated to alter the character of the T.V.A. and its attendant policies.[77]

It will be possible in this study to specify in some detail the process by which organizational actors affect each other's formulation of goals and, at a later stage, each other's realization of those goals. In the context of organizational problem-solving, it may also be possible to state some generalizations about the process.

Having outlined a perspective designed to conceptualize the process of solving the problem of excess radiation in mines, we now turn to the actual research scheme employed.

THE STUDY DESIGN

In light of the approach adopted, initial objectives were twofold: first, to identify the actions or events that managed to arouse the concern of officials in organizations with the power to do something about the hazard (goal-formulation stage); and second, to identify the various ways in which official organizational concern, once aroused, was translated into action to reduce the hazard (goal-realization).

These objectives were met in the course of detailed historical research. The activities of organizations involved with the problem were studied over a twenty year period, though often earlier records had to be consulted. Since there are no full-scale published accounts of the hazard and its control, the research involved building a story almost exclusively from primary documents. Archives of public agencies provided relevant statistical information and legislative histories. Interviews and phone conversations were held with persons who had been involved with the problem at some time during their lives. Public directories and written accounts of other health hazards supplied useful material.

From this investigation, it appeared that at least four historical factors affected the ebb and flow of official concern about the radiation hazard. They are: (1) national needs for uranium ore; (2) the visibility of the hazard itself; (3) the stability and scale of the uranium mining industry; and (4) the vagaries in the formulation, at upper levels, of an official policy to meet the hazard.

Three types of organizations had a direct relationship to the hazard and to each other (interorganizational influence) in their daily business. Each had a unique way of responding. The companies which mined uranium responded differently from the unions which organized or attempted to organize miners, and government agencies which supervised the industry responded in yet a different way.

It is possible to depict a chain of events leading to the health situation confronting uranium miners today. This chain, in the nature of an extended hypothesis, runs as follows:

1. Several "historical" factors, including the national security crisis; the speculative and unstable nature of the early uranium industry; the absence of official policy to control radiation in mines; and the invisible nature of the radiation hazard;

2. Led to the neglect of miner health by the organizations most routinely concerned with industrial activities: mining companies, unions and government enforcement agencies;

3. Which led to the very slow amelioration of hazardous radiation conditions;

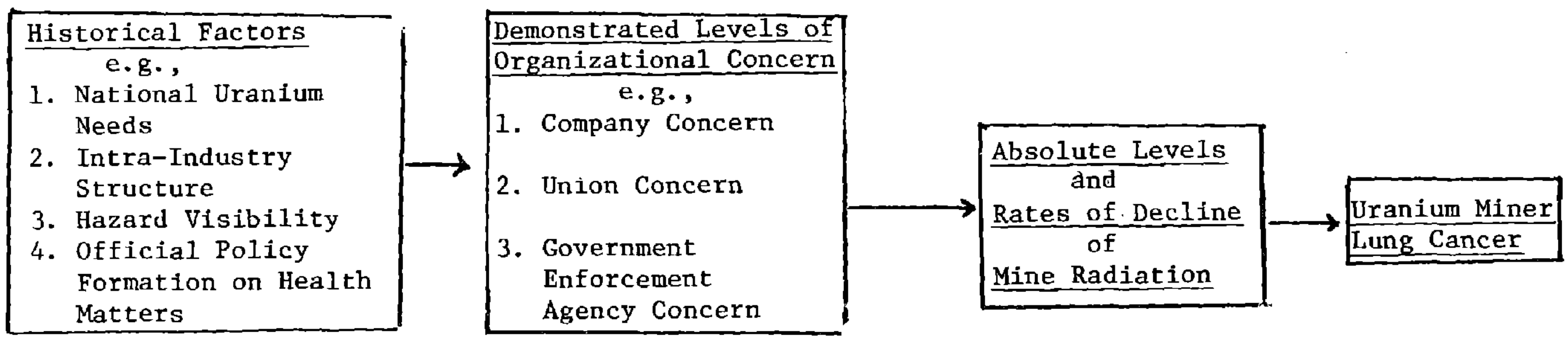
4. Which ultimately led to death and disease.

This hypothesis is portrayed graphically in Figure 1.

Given the hypothesis suggested by the historical survey, it was necessary to define variables which depicted its elements: the "historical" factors, the level of organizational "concern," and the health hazard itself. Once defined, the variables had to be measured. The process of defining and measuring the variables follows shortly.

Figure 1

Proposed Model of the Historical Process
By Which A Health Hazard
To Uranium Miners
Was Solved



Data Collection

Here it is pointed out that the underlying data which elucidated and sometimes gave quantitative standing to the variables came from many different sources. Public directories supplied most figures on mineral production, sales and exploration. Insurance records were studied for evidence of claims by miners of injury due to radiation. A content analysis of statutes, congressional records, legislative histories and the federal register helped to ascertain the level of attention devoted to the problem by federal and state level agencies over time. Annual policy statements issued by an industry lobby, the Colorado Mining Association, gave evidence of industry concern.

A thorough examination was made of the mining records of several public agencies.[78] These agencies included the Colorado Bureau of Mines, the Public Health Service and the Atomic Energy Commission, Western Operations Division. From a complete enumeration of the 923 uranium mines in Colorado operating between the years 1950 and 1969, a group of 540 mines was selected for study.[79] (See Table 1 for an illustration of the exclusion of mines from the project sample). These mine operated for a minimum of one year to a maximum of twenty years between 1950 and 1969. Information was collected for each mine for each year it operated. This resulted in the consideration of 3,623 cases or 3,623 mine-operation years. (See Table 2)

For each mine, for each year it operated, information was assembled as to: owner; operator; years of active operation; changes in ownership and operation continuity; number of underground miners employed during each year of operation; approximate level of productivity; union affiliation, if any; number of health and safety sanctions with respect to mine radiation. Among other things, this material permitted analysis of the scale and stability of the industry over time, the history of government enforcement activities, the degree of unionization the industry experiences, and the changing levels of radiation in mines.

In order to describe the process of controlling a worker health hazard from the standpoint of some of the individuals involved, a series of in-depth and open-ended interviews was conducted with representatives of the company, union and government agency sectors of the uranium mining industry. A total of 59 exploratory and in-depth interviews was held with respondents representing companies mining uranium, unions which organized uranium mill workers or miners, federal and state level inspectors for the Bureau of Mines and representatives of the Atomic Energy Commission, as well as medical researchers, health officials and insurance commissioners involved with the problem. (See Table 3) Respondents were encouraged to: describe their occupational and family background; answer specific questions related to the health hazard to miners; express opinions on the causes, magnitude and sources of reduction in radiation in mines and talk generally on the locus of responsibility for worker health and safety on the job.

Table 1

Reasons For Exclusion of Mines From The Project Mine Sample

Complete Enumeration of Mines	923
Removal due to Identification Ambiguity	111
Removal due to Insufficient Information	37
Removal due to Absence of At Least One On-Site Mine Radiation Assessment	235
Total	383
Total Number Removed	383
Number in Project Mine Sample	540

Table 2

Numbers of Project Mines That Operated Between 1950 and 1969 By Year

1950	30	1960	263
1951	58	1961	269
1952	104	1962	249
1953	128	1963	217
1954	146	1964	174
1955	165	1965	182
1956	212	1966	218
1957	246	1967	182
1958	234	1968	161
1959	258	1969	127

Table 3

Organizational Affiliation of Project Respondents

Organization	Preliminary Phase (Oct. 1972-Dec, 1972) Telephone Interview	Preliminary Phase (Oct. 1972-Dec, 1972) Personal Interview	Phase II (April 1973-July 1973) Telephone Interview	Phase II (April 1973-July 1973) Personal Interview
Government Enforcement Agency				
State Level	0	3	0	4
Federal Level	3	3	0	4
Labor Organization	9	2	0	4
Mining Company	0	0	0	6
Health Agency	6	8	0	0
Insurance Agency	2	5	0	0
Totals	20	21	0	18

The Project Variables

A word of caution about the eight variables operationalized for study is in order. While the variables hopefully measure what they purport to measure, they are not always testable with the precision common to experimental studies or survey research. This stems from infirmities of data collected from archival material, published directories and unstructured, "elite" interviews.[80]

A few examples illustrate. The chaotic state of the early uranium mining industry, characterized by wildcat prospecting and the rapid appearance and disappearance of mines, was reflected in the turbulence of the records. Miners with limited literacy skills maintained the mining records consulted for analysis. Partly as a result of this, the records were frequently incomplete, inaccurate, unstandardized and insensitive to subtle changes in radiation levels. Too, the variability of mine radiation itself presented a problem; radiation levels change day to day, hour to hour. Finally, since the study necessitated combining information on a single mine from a number of different sources, differences in the time of year during which various agencies collected information in mines had the potential to lead to misleading results.

Despite these problems, however, the utilization of the continuous records of public agencies was the only way of acquiring large amounts of longitudinal information. With all its shortcomings, information from archives may also have an element of non-reactivity that is not a feature of the interview or questionnaire.

In interviewing, no attempt was made to randomly sample respondents. Rather, individuals who proved themselves well informed and well connected with the problem were questioned in depth. They often suggested additional informants and tactics, secured additional information and offered comprehensive interpretations of the topic. Their influence on the project exceeded their numerical strength. The procedure, however, was the most appropriate for studying a relatively obscure and frequently technical subject. Although they were not suitable for statistical analysis, the interview results included useful suggestions on new sources of data and interview discussion topics. The unstructured, in-depth format also contributed to the favorable response to the interview.

THE DEPENDENT VARIABLE: WORKER HEALTH

The main dependent variable of the project is miner health. It is the actual incidence of death and disease among miners engaged in uranium mining. In this study, however, miner health is measured indirectly. It is assessed in terms of the environmental quality of the mine, i.e., the level of radiation and/or the rate of radiation decline. That this is a reliable indicator is proven in the accumulated evidence associating mine radiation with respiratory ailments.[81] Public Health Service studies of miner health have demonstrated that the uranium mining population is subject to significantly elevated risks of lung cancer, a risk often sixteen times the rate experienced by the non-mining population. Moreover, the incidence of malignancies among miners increases with prolonged and more intense exposure to mine radiation.

Since prolonged exposure to high concentrations of radiation leads to lung cancer, it is assumed that low levels of radiation and a rapid rate of decline of mine radiation will enhance the health of miners. Radiation levels are measured in terms of radon concentrations and the rate of decline thereof.

A slightly revised version of the hypothesis on worker health combining the incidence of disease with the level of radiation in mines is portrayed in Figure 2.

THE INTERMEDIATE INDEPENDENT VARIABLE: ORGANIZATIONAL CONCERN

Moving one step backwards in the hypothesized chain of events we come to "organizational concern." "Organizational concern" is measured not by the attitudes of those in the organizations in positions to become aware of the problem, but, rather, by actual actions taken by the organizations to meet the problem. Three variables handle the concern demonstrated by each organization of interest.

Company Concern was measured in terms of voluntary company activities represented by:

1. The average, yearly expenditures, per ton of uranium ore mined, for ventilation equipment made by the industry.

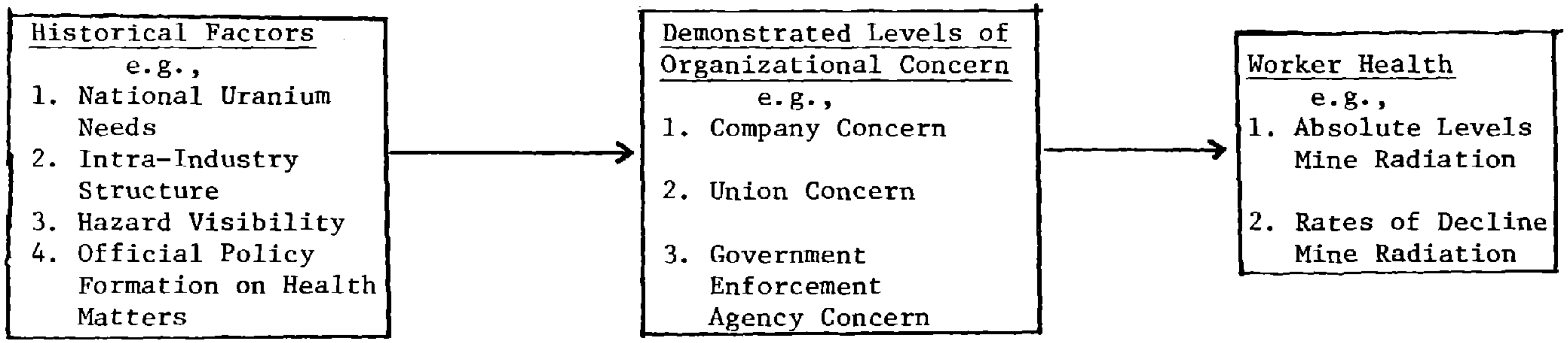
2. The average, yearly number of people employed by the industry for health and safety matters.

3. The number of times the problem of miner health is mentioned in the yearly policy statements of a mining industry association, The Colorado Mining Association.

Expenditures for ventilation and personnel directly measure efforts to reduce radiation. Mention in policy statements assesses the concern of decision-makers about the problem. It is assumed that the arousal of such concern is a pre-requisite for problem-solving activity.

Figure 2

Revised Model of the Historical Process
By Which A Health Hazard
To Uranium Miners
Was Solved



Government Agency Concern was measured in terms of the intensity of regulating activity, specifically:

1. The annual, average number of inspections conducted at each mine by government enforcement agents.

2. The annual, average number of sanctions of each variety, issued to mine operators by enforcement agents, for radiation violations.

Inspections and sanctions were the means available to government regulators to maintain health and safety standards in mines. Three types of sanctions were administered by the government to mine owners who violated health codes on radiation. General Orders invoked no penalty and were used to correct mild ventilation problems or first-time offenders. Remove Men Orders called for the withdrawal of miners (except for the purposes of installing ventilation equipment from mine sections found to be in extreme violation of radiation codes). A Cease Operation Order was a less frequently applied variant of the remove men order. It required a halt of mineral production at excessively radioactive mines until environmental conditions were improved.

Union Concern was measured in one way.

1. The number of uranium mines per year that were represented by a labor organization.

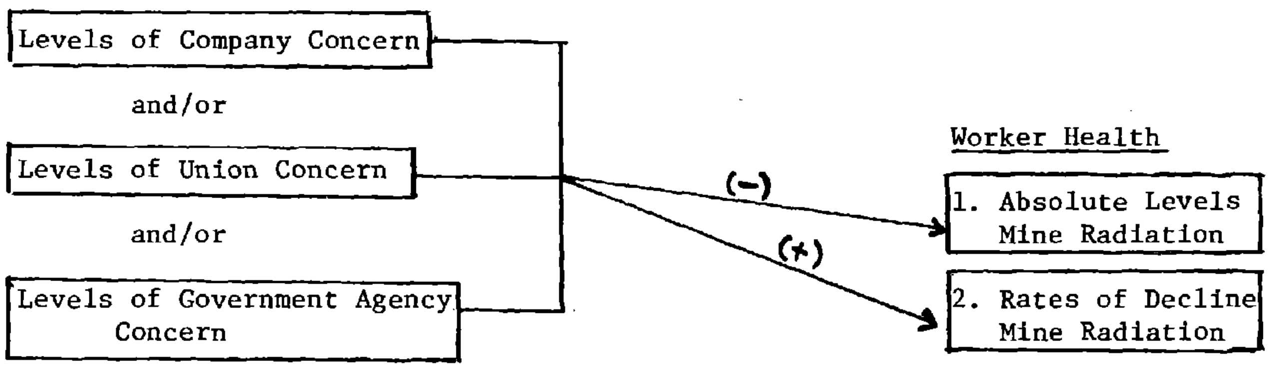
In the case of each measure, higher values are indicative of higher organizational concern; lower or nonexistent values represent a lower organizational concern. The higher the mean values of company, union and government agency concern, therefore, the more we would expect improvements in the radiation conditions in mines, and, in turn, the health of miners. The proposed relationships between organizational concern and worker health are portrayed in Figure 3.

THE PRIOR INDEPENDENT VARIABLES: HISTORICAL FACTORS

The so-called "historical" factors appear to explain why organizations displayed varying levels of concern at different points of time. Stated as a variable, National Uranium Needs means the demand for uranium over time. Hazard Visibility means the conspicuousness of the radiation hazard in uranium mines. Industry Scale and Stability means the structure and composition of the uranium industry over time. Official Concern means the role of upper level government agencies in formulating policies concerning the health hazard to miners (to be carried out by lower level agencies. See Government Agency Concern *supra*).

Figure 3

Proposed Relationships Between Organizational Concern Variables
And Worker Health



Key
(-) Inverse Relationship
(+) Direct Relationship

Variable measures were culled from official directories and the files of public agencies involved with uranium mining. National Uranium Needs, for example, were measured by the following items.

1. The annual tonnage of uranium concentrate purchased by the Atomic Energy Commission, 1947-1970.

2. The average annual price, per pound of uranium concentrate paid by the Atomic Energy Commission, 1947-1970.

3. The percentage of government owned mines, per year, 1947-1970.

4. The annual number of operating uranium mines, 1947-1970.

Tonnage measures demand for uranium in an indirect manner. The assumption here is that strong demands stimulated the industry to produce heavily and search for new uranium deposits. Government owned mines, production on government leases and the purchases of the ore by the government at guaranteed prices all measure preferential treatment of the industry by the government. It is assumed that such treatment reflected an underlying need for uranium supplies. The price paid for uranium over time is a direct measure of uranium needs. Price varied with levels of supply and demand.

The measure of Hazard Visibility included:

1. The annual number of deaths attributed (by the Public Health Service) to lung cancer contracted in uranium mining.

2. The average, annual expenditures made to compensate victims of lung cancer caused by mine radiation.

3. The annual number of compensation cases filed and awarded to miners claiming to have contracted lung cancer in uranium mining.

4. The annual number of articles on the subject of lung cancer among uranium miners that appeared in the newspaper, the Denver Post.

Deaths, compensation claims, dollars expended to afflicted miners and their families and articles on the subject appearing in the popular press measured the conspicuousness of the hazard to public agencies and the general public. It is assumed that awareness of the effects of exposure to radiation implied recognition of the hazard itself.

Measures of Industry Scale and Stability included:

1. The annual percentage of mines in the project sample owned by large mining companies.

2. The annual percentage of mines in the project sample producing 500 tons or more on a monthly basis.

3. The annual percentage of mines in the project employing sixteen men or more.

Mines owned by individuals or partnerships as opposed to large companies is a measure of industry scale and stability. "Infintesimal businesses"[82] are small-scale units with a short life expectancy. They are transient and economically marginal. It is assumed that to the extent that the uranium mining industry was composed of such forms of business organizations, it was unstable and small-scale. Modern giant corporations concentrate large supplies of capital and are relatively permanent. To the extent that the uranium mining industry was composed of this latter form of business organization, it was stable and large-scale.

Evidence of official concern was largely drawn from legislative records and state-level statutes bearing on radiation in mines. The demonstration of Official Concern by federal and state level agencies toward the hazard was represented by high values on the following items:

1. The number of bills relating to uranium health hazards, including agency appropriations, introduced in either house of Congress, per year.

2. The number of lines of regulations in the Federal Register related to uranium mine safety, per year.

3. The dollar appropriations to enforcement agencies in any uranium safety connection, per year.

VARIABLE RELATIONSHIPS

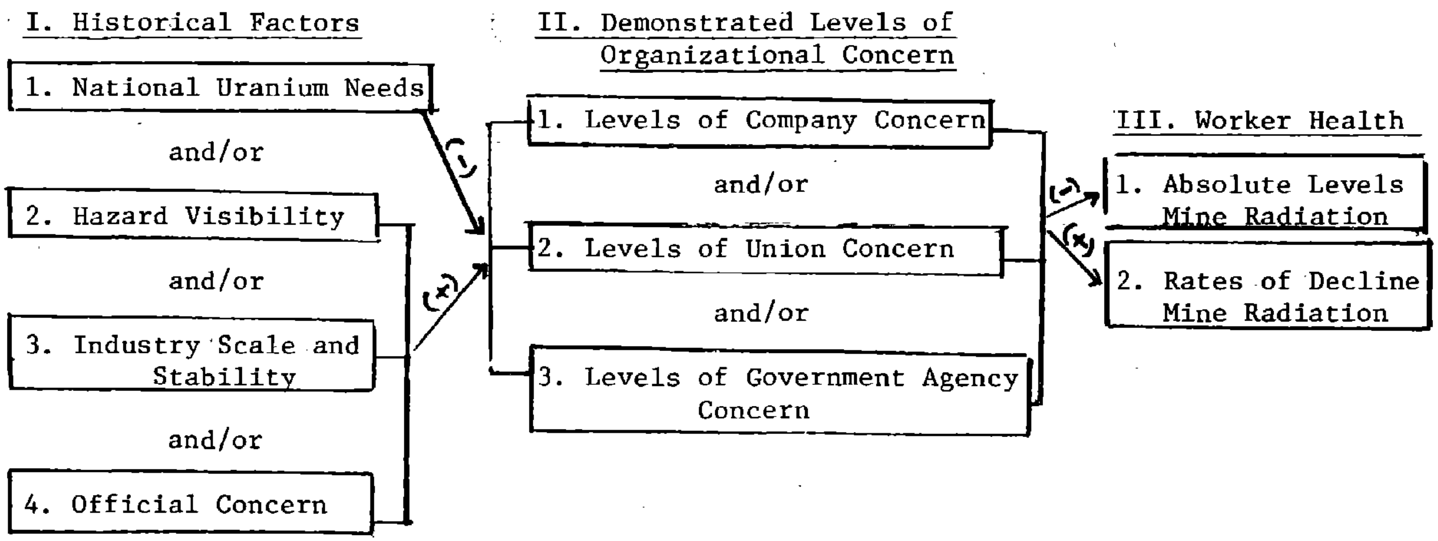
The hypothesis postulates that intense National Uranium Needs adversely affected the level of concern demonstrated by companies, unions and government agencies. Intense demands for the ore and official preoccupation with guaranteeing an adequate supply of uranium served to distract attention from the imperiled health of miners. Conversely, diminished demands for the ore are postulated to have enhanced worker health. Once the urgency for uranium production had subsided, companies, unions and government agencies devoted more attention to the problems of the worker.

Measures indicative of high levels of Hazard Visibility, Industry Scale and Stability and Official Concern, on the other hand, are all hypothesized to have stimulated the demonstration of concern by companies, unions and government agencies. For example, in the face of conspicuous evidence of injury to workers, organizational concern was aroused and efforts were made to control the problem. This had salubrious consequences for the worker. Official debate, study and the promulgation of nation-wide policies concerning mine radiation were also helpful in promoting an atmosphere attentive to health considerations. With the emergence of an official mandate, companies, unions and enforcement agencies were better able to achieve widespread compliance with radiation goals. The greater stability of the mining industry also enhanced the health picture of the miners. A large-scale and mature industry was easier to monitor by government agencies than a highly speculative and transient one. This type of industry also demonstrated greater responsibility for the welfare of its workers.

Figure 4 summarizes the proposed relationships to date. One can easily conceive of interactive effects between and among "concern" variables and variables portraying "historical" factors. For example, demonstrations of government concern might have sparked company actions to control mine radiation. Increased visibility of the uranium hazard might have fueled efforts to promulgate official policies concerning radiation in mines. There is also a possibility of feedback effects between the radiation situation and the concern displayed by organizations. Thus, sluggish rates of radiation decline may have triggered more intense government concern and rapid progress in decline, the opposite response. For the sake of simplicity, however, the model is assumed to be recursive; interactive and feedback effects will be ignored for the present.

Figure 4

Proposed Model of Variable Relationships



Key
(-) Inverse Relationship
(+) Direct Relationship

Chapter 5

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

This chapter will begin to test the model. The model, it is to be remembered, contends that a variety of specific "historical" factors affected the "concern" displayed by organizations to the hazard of excess mine radiation. The model further states the "concern" evidenced by companies, government agencies and unions shaped the rate and timing of radiation decline.

The analysis of the model will proceed in reverse order, starting with the dependent variable and working back through the chain of hypothesized relationships to what are believed to be ultimate historical factors of a "causal" nature. The chapter is organized as follows: first, there will be a preliminary, descriptive discussion of the dependent variable measuring worker health and safety; then, attention will turn to the "concern" exhibited by companies, government agencies and unions during the twenty year study period. Concern will be studied in terms of the actions taken by organizations to control the hazard. In the next chapter, the analysis will consider the influence of what are hypothesized to be more fundamental factors which actually explain the appearance or absence of organizational "concern."

MEASURING TRENDS IN THE DEPENDENT VARIABLE: WORKER HEALTH

Health conditions in the nation's uranium mines have improved tremendously in the quarter century since the industry began. Radiation in mines today is only a fraction of what it was in earlier times. In fact, most mines are free of any concentrations believed to cause bodily harm.

There has been much variation, however, in the pacing of the curtailment of radiation. Although modest advances occurred fairly regularly, dramatic progress transpired at only a few points in time.

Public Health Service information on radiation in the uranium mines of Colorado, Arizona, New Mexico, Utah and Wyoming, shows that the greatest inroads against excessive radiation were made immediately subsequent to 1960 and 1967. In the year 1960-1961, the average level of radiation declined by 46.4%. Between 1967 and 1968 it dropped another 40%. This compares to an average annual rate of decline over the 28 year time period of only 8.62%. In general, radiation has declined faster with each successive calendar year. See Table 4.

The irregular pace of radiation decline for the industry as a whole subsumes even more striking irregularities for the group of Colorado mines selected for intensive study. Consisting of more than 500 mines, this group exhibited extreme and fluctuating levels of radiation during most of the decade, 1950-1960. It was only after 1960 that radiation began to decline at a consistently very rapid rate. Great progress was made in all but three mid-decade years. Annual rates of decline between 30% and 40% were typical from 1960 to 1963. Between 1966 and 1967 annual decline rates peaked at 50%. During the decade, 1960-1969, the range of radiation scores found among the sample mines narrowed and the standard deviation associated with the mean grew smaller. Since the mines in the sample come from all sections of the state, lower ranges and standard deviations suggest the problem was being alleviated throughout Colorado. Table 5 summarizes this information. It presents yearly mean radiation levels, rates of decline, standard deviations, sample sizes and ranges of radiation values for the sample of Colorado mines between 1950 and 1969. See Table 5.

THE EFFECTS OF "CONCERN" ON THE DEPENDENT VARIABLE: GOVERNMENT REGULATION

It appears that dramatic decreases in radiation in mines were linked with the demonstration of "concern" by one or another government enforcement agency. Concern took the form of overtly regulating behavior. In Colorado, the government agency responsible for the uranium mining industry was the State Bureau of Mines. This agency was established in March 1895 by an act of the Colorado State Legislature.[83] Its responsibilities included maintaining records of mineral activities in the state and enforcing the laws relating to health and safety. In 1961 the Bureau of Mines began a state-wide program to reduce radiation hazards. This involved a stepped-up campaign of inspections and sanctions of various sorts against mine operators.

That this program had an effect on health conditions is shown in the agency's historical records of state radiation levels. While 39% of the Colorado uranium mines sampled by state inspectors in June, 1961, exhibited radiation in excess of 10.0 Working Levels, only 4½% had such high exposure levels six months later. (See Table 6)

The impressive achievements of this program continued throughout the decade. Ever greater proportions of the state's mining operations met stiffer quality goals. By 1969, workers in nearly 94% of Colorado's mines were exposed to radiation measuring less than 1.0 Working Levels. (See Table 7)

Table 4

Average Concentrations (in W.L.) to which Underground Uranium Miners were Exposed and Rates of Decline: 1940-1968

Year	Average W.L.	Absolute Decline	Rate of Decline (%)	Year	Average W.L.	Absolute Decline	Rate of Decline (%)
1940[a]	15.0			1955[b]	7.7		
		0	0			-0.3	-3.9
1941[a]	15.0			1956[b]	7.4		
		0	0			-0.4	-5.4
1942[a]	15.0			1957[b]	7.0		
		0	0			-0.2	-2.9
1943[a]	15.0			1958[b]	6.8		
		-1.0	-6.7			-0.3	-4.4
1944[a]	14.0			1959[b]	6.5		
		-1.0	-7.1			-0.9	-13.8
1945[a]	13.0			1960[b]	5.6		
		-2.0	-7.1			-2.6	-46.4
1946[a]	12.0			1961[b]	3.0		
		-0.5	-16.7			0	0
1947[a]	10.0			1962[b]	3.0		
		-0.3	-5.0			0	0
1948[a]	9.5			1963[b]	3.0		
		-0.2	-3.2			-0.7	-23.3
1949[a]	9.2			1964[b]	2.3		
		-0.3	-2.2			0	0
1950[a]	9.0			1965[b]	2.3		
		-0.2	-3.3			-0.2	-8.7
1951[a]	8.7			1966[b]	2.1		
		-0.2	-2.3			-0.6	-29.4
1952[b]	8.5			1967[b]	1.5		
		-0.3	-2.4			-0.6	-40.0
1953[b]	8.3			1968[b]	0.9		
		-0.3	-3.6				
1954[b]	8.0						
		-0.3	-3.8				

[a] Estimated values; [b] Calculated values.

Sources:

Average W.L. values based on testimony by Lou Gehrig, Acting Surgeon General, United States Public Health Service before Hearings by the Joint Committee on Atomic Energy, Radiation Exposure of Uranium Miners, 1967, p.106; and the Joint Committee on Atomic Energy, Radiation Standards for Uranium Mining, March 17 and 18, 1969, p.157

Table 5

Yearly Mean Radiation Levels, Absolute Declines, Rates of Decline, Standard Deviations, Sample Sizes and Ranges of Radiation Levels in the Sample of Colorado Uranium Mines, 1950-1969

Year	Sample Size	Mean Radiation (W.L.)	Absolute Decline	Rate of Decline (%)	Standard Deviation	Range
1950	30	26.5			15.70	60.5
			-0.1	-0.4		
1951	58	26.4			20.14	116.5
			-2.8	-10.6		
1952	103	23.6			26.54	183.0
			+6.4	+27.1		
1953	127	30.0			87.86	992.0
			-9.5	-31.7		
1954	146	20.5			16.68	148.0
			-5.7	-27.8		
1955	165	14.8			17.18	154.0
			-3.0	-20.3		
1956	212	11.8			16.07	154.0
			+7.8	+83.0		
1957	246	19.6			26.52	247.0
			-7.4	-37.8		
1958	234	12.2			18.20	140.5
			+3.2	+26.2		
1959	260	15.4			25.23	247.0
			-3.7	-24.0		
1960	262	11.7			19.77	156.0
			-4.0	-34.2		
1961	270	7.7			13.72	156.0
			-2.8	-36.4		
1962	249	4.9			7.38	63.6
			-1.8	-36.7		
1963	216	3.1			4.3	35.0
			0	0		
1964	174	3.1			4.1	27.9
			-0.2	-6.5		
1965	182	2.9			5.2	52.0
			-0.1	-3.4		
1966	218	2.8			4.2	39.0
			-1.4	-50.0		
1967	183	1.4			1.6	9.8
			-0.4	-28.5		
1968	161	1.0			1.1	6.9
			-0.4	-40.0		
1969	127	0.6			0.6	4.0

Sources:

The sample of Colorado uranium mines.

Table 6

Immediate Effects of the Colorado Program to Control Mine Radiation, June 1961 - December 1961

Average mine radiation levels (W.L.)	Percentage of Colorado mines at various radiation levels			
	June 30, 1961	August 31, 1961	October 31, 1961	December 31, 1961
0.0 - 1.0 W.L.	18	36	41	45
1.0 - 3.0	14	17	25	28
3.0 - 10.0	29	22	23	23
10.0 +	39	25	11	4

Source:
Annual Report for the Year 1961, Colorado Bureau of Mines, 1962

Table 7

A Summary of Radiation Exposure Levels in Underground Uranium Mines in Colorado, 1961-1969

Average mine radiation levels (W.L.)	Percentage of Colorado mines at various radiation levels during								
	1969	1968	1967	1966	1965	1964	1963	1962	1961
0.0 - 1.0	93.7	83.0	82.0	60.0	52.0	43.0	40.5	52.0	45.0
1.0 - 2.0	5.5	15.6	16.0	34.5	40.5	41.0	47.0	38.0	27.0
2.0 - 5.0	0.9	0.6	1.5	5.5	6.0	16.0	12.5	10.0	23.0
5.0 - 10.0	0.0	0.6	0.5	0.0	0.8	0.0	0.0	0.0	4.5
10.0 +	0.0	0.0	0.5	0.0	0.8	0.0	0.0	0.0	0.0

Sources:
Annual Reports for the Years 1961-1969, Colorado Bureau of Mines

The most striking features of the stepped-up control program initiated by the Bureau of Mines were inspections and sanctions. For example, between 1961 and 1962, the number of inspections conducted in an area of Colorado that contains the majority of the state's uranium mines, District 4, increased by more than 46% from 494 to 917 inspections. This increase reflects greater efforts to monitor the hazard. (See Table 8)

Over time, sanctions of each of several different degrees of severity were more frequently applied to mine operators who violated ventilation codes. While no mine had even been ordered to halt production because of hazardous radiation prior to 1960, Colorado inspection agents issued 65 halt orders in 1969. (See Table 8)

Information assembled on the study sample of Colorado mines tends to corroborate the aggregate trends in the data kept by the Colorado Bureau of Mines. The study sample shows that during the second decade of the study (i.e., the 1960's) the average number of visits to mines by inspection agents increased significantly. Concurrently, the percentage of mines subject to reinspection within a single year mushroomed. Prior to 1961, fewer than 1% of the sample groups was visited more than three times in a single year. In 1969, more than half of the 127 mines that operated experienced four visits or more within the year. One mine was reinspected seventeen times in one year. (See Table 9)

Punitive actions were also more common during the second decade of the study period. The percentage of operators receiving mild orders (See Table 10A) to correct ventilation rose over time and peaked in 1966. In that year, 32% of mine operators received at least two or more directives on the subject of radiation. 1966 was also the year during which radiation in the sample declined most drastically.

More stringent sanctions--remove men and cease operations--(See Tables 10B and 10C) were also applied with successively greater frequency. Fewer than 10% of mine operators had been required to remove men and halt productive abilities because of excess radiation prior to 1965. In 1969, however, a full 25% of mine operators experienced such restrictions. (See Table 11)

Thus, a preliminary review of the trends suggests that sharp elevations of government watchdog activities coincided with dramatic declines of mine radiation. Mines were visited more frequently by enforcement agents; operators who ignored health codes risked costly penalties. In the next section, this association will be explored more closely.

Testing the Implications of Government Agency "Concern"

To test whether the supervisory actions of the government actually enhanced worker health (and, if so, which actions were most beneficial) radiation conditions in mines with varying histories of inspections and

Table 8

A Summary of Inspection and Sanction Activities by Colorado Inspection Agents of the State Bureau of Mines, 1950-1970

Year	No. Mines	No. Inspections	Inspections Per Mine	General Order	Remove Men Order	Cease Order[a]	Total Order
1950	115	195	1.7	0	0	0	0
1951	167	195	1.2	0	0	0	0
1952	192	289	1.5	0	0	0	0
1953	215	264	1.2	0	0	0	0
1954	295	287	1.0	0	0	0	0
1955	335	334	1.0	0	0	0	0
1956	354	366	1.0	0	0	0	0
1957	378	393	1.0	0	0	0	0
1958	459	420	1.0	0	0	0	0
1959	424	451	1.1	0	0	0	0
1960	422	567	1.3	0	0	0	0
1961	402	494	1.2	120	11	0	131
1962	331	917	2.8	126	11	4	141
1963	333	806	2.4	120	14	1	135
1964	265	746	2.8	122	13	2	137
1965	279	874	3.1	125	40	1	166
1966	283	1006	3.6	229	48	4	281
1967	262	1483	3.7	167	35	8	210
1968	257	1582	6.2	134	50	3	187
1969	239	1556	6.5	95	62	3	160
1970	235	1531	6.5	97	39	2	138

Sources:

Columns 2, 3, 5, 6, 7, 8: Compiled from the <u>Annual Reports for the Years 1950-1970</u>, Colorado Bureau of Mines

Column 4: For inspections per mine, Col. (3) divided by Col. (2).

[a]Cease Order = Cease Operation Order

Table 9

The Sample of Colorado Uranium Mines: Inspection Activity

Year	Percentages of mines inspected				
	Not at all	One time	Two times	Three times	Four times or more
1950	n.a.	n.a.	n.a.	n.a.	n.a.
1951	n.a.	n.a.	n.a.	n.a.	n.a.
1952	12.6	63.1	23.3	1.0	0
1953	10.2	61.4	26.0	2.4	0
1954	24.8	40.7	26.9	7.6	0
1955	17.0	38.8	38.8	5.5	0
1956	20.8	56.6	17.9	3.8	0.9
1957	16.3	65.9	14.6	2.8	0.4
1958	14.6	54.5	26.2	4.3	0.4
1959	14.6	55.8	24.6	4.2	0.8
1960	10.7	42.7	28.5	12.6	0.5
1961	13.0	55.2	19.3	8.1	1.5
1962	12.1	45.6	28.2	7.3	6.8
1963	12.5	44.0	24.5	10.6	8.4
1964	9.8	36.8	28.2	14.9	10.3
1965	16.5	30.8	24.2	15.9	12.4
1966	11.0	25.7	18.3	16.1	29.0
1967	14.3	24.7	20.3	13.7	26.8
1968	5.6	24.8	14.3	8.7	46.6
1969	3.1	16.5	11.0	14.2	55.2

Sources:
The sample of Colorado uranium mines.

Table 10A

Sanction Activity in the Sample of Colorado Uranium Mines:
General Orders

Percentage of mines receiving general orders

Year	Not at all	Once	Twice or more
1959	67.6	27.2	5.1
1960	50.6	31.8	17.6
1961	47.5	35.2	17.4
1962	52.1	31.5	16.6
1963	47.1	34.4	18.6
1964	52.2	24.8	22.9
1965	36.4	37.7	25.8
1966	38.1	29.9	32.0
1967	49.4	25.9	24.7
1968	52.3	26.1	21.7
1969	46.8	29.0	24.2

Table 10B

Sanction Activity in the Sample of Colorado Uranium Mines:
Remove Men Orders

Percentage of mines receiving remove men orders

Year	Not at all	Once	Twice or more
1959	100	0.0	0.0
1960	93.1	6.5	0.4
1961	96.2	3.0	0.8
1962	96.3	3.2	0.5
1963	94.7	5.3	0.0
1964	93.6	5.7	0.6
1965	86.8	6.6	6.7
1966	79.4	15.5	5.1
1967	83.4	10.8	5.7
1968	84.2	7.2	8.6
1969	74.2	15.3	12.4

Sources:
The sample of Colorado uranium mines.

Table 10C

Sanction Activity in the Sample of Colorado Uranium Mines: Cease Operation Orders

Percentage of mines receiving cease operation orders

Year	Not at all	Once	Twice or more
1959	100	0.0	0.0
1960	97.8	2.2	0.0
1961	98.7	1.3	0.0
1962	99.5	0.5	0.0
1963	98.9	1.1	0.0
1964	99.4	0.6	0.0
1965	96.1	3.3	0.7
1966	95.9	3.6	0.5
1967	91.7	7.1	1.2
1968	96.7	2.0	1.4
1969	96.0	3.2	0.8

Table 11

Mean Inspections and Sanctions Per Mine in the Sample of Colorado Uranium Mines: 1950-1969

Year	Inspections	General order	Remove men	Cease operation
1950	n.a.	n.a.	n.a.	n.a.
1951	n.a.	n.a.	n.a.	n.a.
1952	1.2	0.0	0.0	0.0
1953	1.2	0.0	0.0	0.0
1954	1.2	0.0	0.0	0.0
1955	1.3	0.0	0.0	0.0
1956	1.1	0.0	0.0	0.0
1957	1.1	0.0	0.0	0.0
1958	1.2	0.0	0.0	0.0
1959	1.2	0.4	0.0	0.0
1960	1.6	0.8	0.1	0.02
1961	1.4	0.82	0.1	0.0
1962	1.6	0.82	0.1	0.0
1963	1.6	0.82	0.1	0.0
1964	1.9	0.9	0.1	0.0
1965	1.9	1.2	0.2	0.1
1966	2.6	1.2	0.3	0.05
1967	2.6	1.1	0.3	0.1
1968	3.6	1.1	0.3	0.06
1969	4.9	1.2	0.5	0.06

sanctions were compared. Since overt manifestations of agency "concern" were hypothesized to have driven down radiation levels, it was expected that there would be an inverse association between radiation and enforcement activities.

An initial analysis of inspections and radiation information from the study sample of mines, within the same calendar year, however, illustrated just the opposite. More healthful conditions were associated with mines that had escaped government regulation. For example, in almost every year following 1958, higher radiation was reported for mines that had experienced at least two inspections or more than for mines which had experienced none. (See Table 12A)

In the cases of sanctions, the trend was even more pronounced. Health conditions were considerably more favorable in mines avoiding sanctions of all types. (See Tables 12B and C)

There are several possible explanations for this superficially incongruous result. They all involve biases due to using information on regulation and radiation from the same calendar year. First, a single year was not long enough for regulations to sufficiently lower radiation in mines with stubborn problems. Second, within any single year, information on radiation and regulations, collected by two different agencies, were unstandardized. Third, the nature of the measurement of mine radiation itself was insensitive to changes in radiation within a single calendar year.

It appeared logical to reanalyze the information using radiation levels for the year following a given inspection. For example, a mine's 1968 inspection record would be compared with its 1969 radiation picture.

Results of the "year after" analysis suggested somewhat stronger relationships. At least after 1964, there was an association between regulatory activities in year one and reduced radiation in year two. Mines visited at least once or subject to some type of sanction exhibited lower radiation in the following year than those that escaped all government supervision. Prior to 1964, however, the opposite was true. Lower radiation levels were found among mines that had avoided inspections and sanctions in the previous year. (See Tables 13A and 13B)

There are two possible explanations for the discrepancy in the trends for the years prior and subsequent to 1964. Staff members of the Bureau of Mines attribute the earlier pattern to the failure of inspectors to report visits to mines with low radiation. This would account for the low scores found among mines listed as receiving no inspection or sanctions. After 1964, a more comprehensive system of record keeping was introduced to the agency. It required that inspectors report all their visits to mines regardless of radiation conditions encountered. This reduced the under-reporting bias _vis a vis_ mines with low radiation in the post-1964 period.

Table 12A

Mean Radiation Levels in Mines with Varying Histories of Inspections in the Sample of Colorado Mines, 1950-1969

(Radiation and regulation information from the same calendar year)

	Working Levels in mines receiving inspections that total to		
Year	None	One	Two or more
1950	n.a.	n.a.	n.a.
1951	n.a.	n.a.	n.a.
1952	23.4	24.2	21.8
1953	32.1	33.9	21.1
1954	19.3	21.5	20.0
1955	11.8	14.3	16 4
1956	8.4	12.4	12.1
1957	19.5	20.1	13.7
1958	14.5	11.3	16.1
1959	14.7	13.6	23.5
1960	6.9	10.1	13.8
1961	7.9	6.2	10.5
1962	2.3	3.9	5.2
1963	1.2	2.7	3.9
1964	2.6	2.8	3.8
1965	1.9	3.1	3.2
1966	2.6	2.2	3.0
1967	n.a.	n.a.	n.a.
1968	2.3	0.4	2.2
1969	0.3	0.4	0.6

Table 12B

Mean Radiation Levels in Mines Receiving Varying Numbers of General Orders in the Sample of Colorado Mines, 1959-1969

(Radiation and regulation information from the same calendar year.)

	Working Levels in mines receiving general orders that total to	
Year	None	One or more
1959	13.4	21.1
1960	12.0	11.9
1961	5.6	12.6
1962	3.6	8.4
1963	2.3	4.1

Table 12B (continued)

Year	Working Levels in mines receiving general orders that total to: None	One or more
1964	2.1	5.4
1965	2.4	4.4
1966	2.0	4.2
1967	1.0	2.2
1968	1.4	1.3
1969	0.5	0.8

Sources:
The sample of Colorado uranium mines.

Table 12C

Mean Radiation Levels in Mines Receiving Varying Numbers of Remove Men Orders in the Sample of Colorado Mines, 1960-1969
(Radiation and regulation information from the same calendar year.)

	Working Levels in mines receiving remove men orders that total to: None	One or more
1960	11.5	17.8
1961	6.5	32.9
1962	4.5	17.2
1963	2.8	12.5
1964	2.8	10.4
1965	3.2	5.8
1966	2.0	6.9
1967	1.1	2.9
1968	1.1	1.4
1969	0.5	n.a.

Sources:
The sample of Colorado uranium mines.

Table 13A

Mean Radiation Levels in Mines with Varying Histories of Inspections in the Sample of Colorado Mines, 1960-1969

(Radiation information for the year following regulations.)

Inspection Year	Working Levels in mines receiving inspections that total to: None	One or more
1959	11.37	12.23
1960	6.1	7.2
1961	7.23	4.5
1962	1.73	3.7
1963	2.08	3.2
1964	3.06	2.42
1965	2.55	2.34
1966	2.59	2.26
1967	2.35	0.8
1968	0.6	0.6

Table 13B

Mean Radiation Levels in Mines Receiving Varying Numbers of General Orders in the Sample of Colorado Mines, 1960-1969

(Radiation information for the year following regulations.)

Inspection Year	Working Levels in mines receiving general orders that total to: None	One or more
1959	12.8	15.6
1960	9.25	6.7
1961	4.1	5.22
1962	2.9	3.15
1963	2.7	2.97
1964	2.3	4.84
1965	2.1	2.1
1966	3.3	1.54
1967	2.3	0.86
1968	2.9	0.66

Sources:
The sample of Colorado uranium mines.

Another explanation stresses the greater effectiveness of regulation subsequent to 1964. After this date, most mines had the technology to reduce radiation. With this technology it often took little more than moving a fan closer to an entrance or turning it on a few hours before the working day began to reduce radiation even further. Prior to 1964, however, many operators still relied on natural ventilation. Without the requisite equipment, no amount of regulation could bring down levels in mines that presented severe problems.

A third approach was explored which appeared to be logically equipped to handle the impact (if there was an impact at all) of organizational concern on the elimination of the health hazard. In this approach, a mine's inspection and sanction record for a given year was matched against the difference between its radiation level in that and the following year. A positive difference between the two year's radiation levels indicated radiation was reduced, a negative difference, the opposite.

Using this approach, statistical analysis illustrated a clearer association between regulation and radiation reduction. Significant reductions in the hazard occurred among mines subject to each type of government "concern." In every year, the average radiation reduction was greater among mines that had experienced some inspections or sanctions than it was among mines that had experienced none. Subsequent to 1962, in fact, the absence of some type of regulation was generally accompanied by a deterioration in conditions in the following year. These findings were statistically significant at the .05 level. (See Tables 14A,B,C)

The analysis also showed that radiation decline from one year to the next varied directly with the type of government regulation imposed. Thus, while mines with one or more inspections experienced an average yearly decline in radiation of 1.6 working levels between 1959 and 1967, mines with one or more general and remove men orders in the same period experienced average yearly declines of 3.3 and 8.3 working levels, respectively. (See Tables 14A,B and C)

Thus, three methods were used to exposure the relationship between regulations and radiation levels in mines. The first approach suffered from various pitfalls as a result of using regulation and radiation information from the same calendar year. The second analysis, which used radiation levels for the year following a given inspection, was an improvement. It showed that after 1964 the lowest radiation levels were found among mines that had experienced inspections and sanctions. The third approach, however, was superior to both. It alone demonstrated the impact of regulation on the elimination of a health hazard. Even though regulation did not lead to the lowest levels before 1964, the third analysis showed that it was consistently associated with yearly, radiation declines. The absence of regulation was frequently accompanied by an increase in radiation and the largest yearly declines were found among mines that had experienced the most severe sanctions.

The government, however, is only one of three organizations of interest here. The next section examines "concern" shown by companies.

Table 14A

Mean Differences in Radiation Levels From One Year to the Next in Mines with Varying Histories of Inspections in the Sample of Colorado Mines, 1960-1969

Inspection Year	Working level differences in mines receiving inspections that total to: None	One or more		One or more - None
1959	5.8	7.9		2.1
1960	0.5	6.13		5.63
1961	2.9	4.5		1.6
1962	-0.05	1.7		1.75
1963	-1.5	-0.1		1.37
1964	-0.7	0.8		0.07
1965	-0.3	0.9		1.21
1966	-0.5	1.0		1.5
1967	-0.15	0.8		0.9
1968		0.2		
Average Annual Decline:	0.60	2.38	Average Annual Difference:	1.6

Regulation information matched against differences between radiation information in one year and the following.

Table 14B

Mean Differences in Radiation Levels From One Year to the Next in Mines With Varying Numbers of General Orders in the Sample of Colorado Mines, 1960-1969

Inspection Year	Working level differences in mines receiving general orders that total to: None	One or more	One or more - None
1959	1.25	6.1	4.85
1960	3.5	6.1	2.6
1961	0.97	5.5	4.53

Table 14B (continued)

Inspection Year	Working level differences in mines receiving general orders that total to		
	None	One or more	One or more - None
1962	0.03	7.8	7.5
1963	-0.4	0.25	0.15
1964	0.8	0.84	0.04
1965	0.6	0.95	0.35
1966	-1.1	2.5	3.6
1967	-1.15	1.18	2.33
1968	-2.3	1.79	4.09
Average Annual Decline:	2.5	3.3	Average Annual Difference: 3.0

Regulation information matched against differences between radiation information in one year and the following.

Table 14C

Mean Differences in Radiation Levels From One Year to the Next in Mines With Varying Numbers of Remove Men Orders in the Sample of Colorado Mines, 1960-1969

Inspection Year	Working level differences in mines receiving remove men orders that total to		
	None	One or more	One or more - None
1960	3.9	16.2	12.3
1961	1.8	22.24	20.44
1962	1.28	13.67	12.39
1963	-0.35	3.17	3.52
1964	-0.27	5.3	5.57
1965	0.1	6.6	6.5
1966	-0.37	5.0	5.37
1967	-0.46	1.84	2.30
1968	-1.08	0.87	1.95
Average Annual Decline:	0.51	8.3	Average Annual Decline: 7.8

Regulation information matched against differences between radiation information in one year and the following.

Sources:

The sample of Colorado uranium mines.

THE EFFECTS OF CONCERN ON THE DEPENDENT VARIABLE: COMPANY ACTIONS

Company "concern" consisted of attempts to reduce mine radiation in advance of mandatory requirements to do so. Such attempts took the form of direct expenditures for equipment and personnel to improve radiation. A superficial look at the trends in company "concern" suggests that it too tended to coincide with declines in mine radiation. On closer inspection, it appears that the companies demonstrated their most intense concern subsequent to the initiation of government regulation.

From the limited information available, there is some indication that at least the largest companies in Colorado took actions to control radiation in advance of government regulations. For example, the two largest companies both began to test for mine radiation in 1956. This was prior to the 1959 announcement by the Public Health Service that excessive numbers of lung cancers were occurring among American miners. On the other hand, it was well after initial efforts by Colorado health officials (in 1949 and 1950) to persuade industry representatives to prevent a repetition of the European tragedies in mining.

1956 also saw the introduction of at least one staff person in the two largest companies to deal with the problem of radiation. At this time, company expenditures for ventilation amounted to about 25¢ per ton.

A comparison between radiation in mines owned by large companies and small ones suggests that, for whatever reasons, large was better than small during the study period (1950-1969). While both groups exhibited a certain amount of fluctuation during the decade, 1950-1959, the group of mines owned by large companies generally had lower annual levels of radiation and faster annual rates of radiation decline. This group displayed considerable radiation decline at an average annual rate of -4.6% between 1950 and 1959. Mines owned by small companies, on the other hand, showed no regular decline between 1950 and 1959. It was not until 1959 that the smaller mines as a group began to show such decline. This coincided with the announcement of statistically significant excesses of mine radiation among United States miners. 1959 was also the year the Colorado Bureau of Mines began regulating ventilation conditions more closely. (See Table 15)

Intense company "concern" by the large operators, however, also followed the promulgation of restrictive standards and the initiation of stricter government control programs in the 1960s. In 1961, following the onset of the control program undertaken by the Colorado Bureau of Mines, the two largest companies reported a doubling of their expenditures for ventilation from 25¢ to 50¢ a ton. At approximately the same time, the number of employees devoted to the problem also rose. (See Table 16)

Company "concern" became even more striking after the Department of Labor regulation of June 1967 concerning acceptable radiation levels in mines. Spokesmen for the two largest firms reported that their expenditures for ventilation nearly tripled at about this time from pre-1966

Table 15

A Comparison of Mean Radiation Levels and Rates of Decline of Radiation in Mines Owned by Large and Small Companies, 1950-1969

	Yearly average Working Levels in mines owned by			
Year	Small Companies	Annual Decline %	Large Companies	Annual Decline %
1950	24.3		29.4	
		+34.3		- 8.2
1951	33.0		26.8	
		-38.5		- 4.3
1952	19.1		25.6	
		+172.2		-10.9
1953	55.9		22.7	
		-58.0		- 5.1
1954	22.9		21.5	
		-23.8		-23.6
1955	17.2		16.2	
		-17.0		-25.0
1956	14.1		11.9	
		+43.7		+69.8
1957	20.7		20.9	
		-39.6		-34.2
1958	12.1		13.4	
		+71.0		- 2.8
1959	21.4		13.0	
		-18.3		- 2.1
1960	17.3		10.1	
		-30.1		-36.9
1961	11.8		6.0	
		-32.0		-34.3
1962	7.7		3.5	
		-49.3		-23.0
1963	3.9		2.7	
		+ 5.1		- 7.4
1964	4.1		2.5	
		0		0
1965	4.1		2.5	
		+ 5.0		-12.0
1966	4.3		2.2	
		-61.0		-41.0
1967	1.7		1.3	
		+12.0		0
1968	1.9		1.3	
		-63.0		-53.8
1969	0.7		0.6	

Table 16

Estimated Expenditures for Ventilation and Personnel Devoted to Reducing Radiation by the Largest Uranium Mining Companies in Colorado, 1950-1971

Year	Expenditures Per Ton	Personnel Devoted to Radon Control
1950	$0.20	0
1951	$0.20	0
1952	$0.20	0
1953	$0.20	0
1954	$0.20	0
1955	$0.20	0
1956	$0.25	1
1957	$0.25	1
1958	$0.25	1
1959	$0.25	1.5
1960	$0.25	1.5
1961	$0.50	2
1962	$0.50	2
1963	$0.50	1.5
1964	$0.50	1.5
1965	$0.50	1.5
1966	$0.75	2
1967	$1.00	4.5
1968	$1.40	5.5
1969	$1.50	5
1970	$1.50	n.a.
1971	$2.50	n.a.

Sources

Information supplied by R.C. Beverly, Director of Environmental Control, Metal and Mining Division, Union Carbide Corporation; and Anthony M. Mastrovich, Vice President, AMAX Uranium Corporation.

levels of 50¢ a ton. When the new law became effective in 1967, expenditures immediately rose to $1.40 per ton. An industry-wide survey conducted by the Atomic Energy Commission between 1966 and 1968 suggests that this trend was typical. Although the survey did not use the same sample as that used in the current study, it represents basically the same types of companies. Within the 1966-1968 period, the Atomic Energy Commission report states that ventilation costs expended by a sample of Colorado companies rose 200% from 48¢ a ton to $1.47. In the six months immediately following the promulgation of the new law, ventilation costs mushroomed 75¢ from 84¢ to $1.47 a ton. At the same time, capital expenditures increased more than 500% and total installed fan capacity at the group of sampled mines increased by more than 50%. (See Table 17)

The policy statements of the state lobbying agency, the Colorado Mining Association, indicate the bulk of company "concern" was manifested subsequent to the onset of restrictive regulations. A content analysis of the policy statements of that body between 1950 and 1970 showed that prior to the Colorado control program of 1961, only 11 lines out of the total 1905 lines of statement were devoted to the general subject of health and safety in all types of mines. No explicit mention was made of the radiation hazard during this time although more than 11% of the space was devoted to the subject of uranium mining (i.e., 217 lines).

Subsequent to 1961, the subject of health and safety gained more attention. Between 1961 and 1967, 63 lines out of a total 1540 treated this topic. Uranium mining was discussed in 90 lines, although once again, no explicit reference was made to the problem of excess radiation.

It was after the promulgation of strict radiation standards in 1967, however, that the Colorado Association first mentioned the hazard in its official statements. Out of a total 883 lines of statement between 1968 and 1970, 31 lines dealt with the subject of radiation (3%). The space devoted to general health and safety also increased. Nearly 6% of the policy statements were devoted to the latter topic. This amounted to 51 lines. Attention to uranium mining remained relatively consistent at approximately 10% or 91 lines. (See Table 18)

Without fail, industry comments on the subject of radiation in mines expressed opposition to the duplication of policing and inspection activities by federal and state level agencies. Other statements conveyed industry opposition to the standards imposed by the Department of Labor on radiation. In the words of the industry, such standards were "untested, unlawful, unrealistic and unnecessary."[84] The remaining space devoted to these topics called for new efforts to update the technology and information necessary to achieve a "fair and reasonable radiation exposure standard."[84]

The behavior of national industry associations resembled that of the Colorado body. The American Mining Association created its first committee on mine safety in 1967, immediately after the June regulation of the Department of Labor. The first action of the newly formed committee was to request that the Secretary of Labor withdraw his order, or, alternatively suspend enforcement on it for 18 months.[85]

Table 17

Average Radiation Levels and Uranium Mining Costs in Colorado, 1966-1968

	January-June 1966	July-December 1966	January-June 1967	July-December 1967	January-June 1968
Operating Costs					
Per Ton	$ .48	$ .51	$ .61	$ .84	$1.47
Per Pound (U_3O_8)	$ .09	$ .11	$ .13	$ .19	$ .34
Capital Expended	$34,094	$2,500	$18,587	$31,394	$218,793
Average Production Ton/Month	14,967	14,044	15,245	14,880	11,502
Average Radiation Level (W.L.s)	3.16	4.13	2.40	0.93	0.89

Sources:
Atomic Energy Commission, Grand Junction Office, "Radiation Control Study," October 23, 1968, Table 3

Table 18

A Content Analysis of the Annual Policy Statements of the Colorado Mining Association, 1950-1970

Year	Total Number Statement Lines	Lines devoted to: Uranium Mining	Mine Radiation	General Health and Safety
1950	116	0	0	0
1951	169	3	0	0
1952	142	0	0	0
1953	165	10	0	0
1954	165	16	0	0
1955	178	37	0	0
1956	241	34	0	5
1957	n.a.	n.a.	n.a.	n.a.
1958	545	90	0	6
1959	184	30	0	0
1960	n.a.	n.a.	n.a.	n.a.
1961	120	0	0	0
1962	n.a.	n.a.	n.a.	n.a.
1963	326	7	0	14
1964	382	50	0	19
1965	300	3	0	15
1966	412	30	0	15
1967	n.a.	n.a.	n.a.	n.a.
1968	318	17	4	14
1969	345	17	14	19
1970	220	37	13	17

Sources:

Compiled from the National Western Mining Conference, "Resolutions and Declaration of Policy," The Colorado Mining Association, 1950-1970

Another industry association, the Atomic Industrial Forum, also established a committee on mining and milling. In 1971, it initiated discussions on coordinating an industry-wide effort to research the subject of radiation control. It was the first suggestion of this nature to ever appear.[86]

Thus, although mild efforts were made by some of the largest companies to monitor radiation in advance of government decrees to do so, the bulk of company "concern" followed in the wake of such orders.

THE EFFECTS OF CONCERN ON THE DEPENDENT VARIABLE: UNION ACTION

Union influence in the control of radiation was virtually nonexistent during most of the study period. Prior to 1960, the attendance registers at most official[87] meetings on the subject of radiation fail to show any union presence. At the Governors' Conference on Health Hazards in Uranium Mines in 1960, only one labor representative appeared.

By its own admission, labor involvement in mine hazards dates only from 1967.[88] At that time the Department of Labor promulgated standards for the control of radiation. Labor representatives testified at government hearings on the topic and defended the Secretary of Labor's actions to a broad spectrum of critics.

In 1971, labor involvement increased. At that time, the Bureau of Mines proposed a variance from prevailing radiation codes. This program permitted workers to remain in mines where radiation exceeded permissible levels with the use of respirators. Union representatives felt that these provisions were not adequate and requested public hearings on the matter on July 16, 1971. In addition, unions adopted a list of provisions on the subject of variances. Labor organizations featured prominently in both the conduct of public hearings in New Mexico on January 7, 1972 and in the controversy surrounding their outcome.

The paucity of union efforts to reduce the radiation hazard reflects a more general absence of labor involvement with the industry. While several mines were organized by labor organizations in 1969, only one Colorado mine was represented by a union between 1950 and 1969.

Several reasons have been advanced for the lack of union involvement in the industry at an earlier time. One interviewee, for example, cited the National Labor Relations Board ruling making the individual mine the unit of organization. No sooner was a mine organized than operations would shift to a new site and organizers would have to petition anew for representation.[89]

Other respondents blamed the extremely small size of the uranium mining industry and the typical mining unit in Colorado. It is estimated that only 6,000 men have mined uranium in this country at some point of time. In Colorado, most miners worked in mines that employed fewer than five men. Such mines were termed "dogholes." Small mines were often inaccessible and uneconomical. In addition, their employees tended to reject the union. This was because the worker labored side-by-side with the owner. Such workers were unsympathetic to a formalized system of representation.

Another explanation puts the blame on the pay system in the industry. Miners were paid generous incentives for extra production; they resented any restrictions on the length of their working day or week. As one organizer puts it, "All they wanted was to work 25 hours a day, 8 days a week."[90]

The upshot was the unions never succeeded in organizing Colorado uranium miners. Until the late 1960s, labor organizations contributed little, if anything, to the process of reducing radiation in mines. Although some labor organizers interviewed in the project suggested that union influence in the mines was indirectly exercised through the uranium processing mills and plants which were represented by unions, a test of this hypothesis showed it to be untrue.[91] Rather, labor organizations were not associated with lower radiation in mines in any regular manner. For this reason the union will no longer be considered in the analysis of organizational "concern" on worker health.

Chapter 6

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

The previous chapter considered the impact of organizational "concern" on radiation in mines. "Concern," it was found, did make a difference. Government regulation was highly effective in lowering radiation. A stepped up program of inspections and sanctions against operators who violated radiation codes was associated with dramatic reductions in radiation. Mines subject to the costly sanctions involved forced removal of men from hazardous mines and cessation of production.

The efforts of the largest Colorado mining companies to monitor radiation in advance of government regulations requiring them to do so also had an effect. Mines owned by such companies had lower radiation levels than their small-company counterparts in the days before regulation. Most company efforts, by small and large firms alike, however, occurred in the 1960s following the initiation of official control programs and restrictive legislation.

This chapter will recede one step further in the hypothesized chain of events that created and ultimately cured a lung cancer epidemic among uranium miners. The question here is, What did it take to arouse the concern of those in a position to do something about the hazard? The answer to that question may also resolve why the mere availability of the necessary technology was not enough.

NATIONAL URANIUM NEEDS

Uranium's importance lies in its energy generating abilities. During the 1940s and early 1950s, it was mined primarily for use in the production and testing of atomic weapons. Today, uranium promises to be indispensable in meeting energy requirements. The demand for uranium, however, has fluctuated widely over the past quarter century. This fluctuation has been critical. It appears that only when demand for the ore has subsided have steps been taken to reduce the hazard. In fact, government and company actions to improve health conditions in mines has always tracked closely with waning demand and the financial decline of the industry.

The uranium industry experienced its greatest boom during the late 1940s and early 1950s. Under the impetus of government efforts to generate

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a domestic uranium capability, new producers flocked to the industry. Bonuses were extended to help defray initial production costs, and the government agreed to buy all uranium that was produced at a generous price. Public land was leased to producers for the extraction of uranium and transportation facilities were provided for producers who mined ore in remote places.

In the push for additional supplies during the 1940s and 1950s, there is even evidence that mineral production on public lands in violation of federal mining laws was overlooked. According to a 1972 news bulletin from the American Mining Congress, the federal government failed to take action to halt the illegal removal of uranium from public lands in the late 1940s and early 1950s because of "uranium shortages and the need for uranium production for national defense."[92] It was only in the late 1950s, the 1960s and then again in 1972 that the federal government considered seeking damages from producers who had violated the law. Such efforts were ultimately abandoned for a variety of practical considerations, including the expiration of the statute of limitations.

The impetus behind the expanded procurement program in the 1940s and 1950s, however, did not last long. As early as 1956, it was announced that there was no longer a uranium shortage, that prospective mineral deliveries would exceed military requirements and that the Atomic Energy Commission's policies would have to change accordingly. In a speech to the annual meeting of the American Industrial Forum in 1957, the director of the Atomic Energy Commission's mineral division stated that uranium deliveries were "adequate for military and power requirements...": and that it was no longer in the interests of the Government to expand production of uranium concentrate."[93] Subsequently, the Atomic Energy Commission announced it would discontinue its program of guaranteed ore purchases in 1962 and thereafter pursue a much modified procurement program. In 1962 all government lands were withdrawn from leasing arrangements.

Despite the ultimate extension of government purchasing of uranium until 1970 through a stretch-out program which delayed the termination of government procurement,[94] the scale of government activities to promote uranium in the 1960s was greatly reduced. Pressures for additional uranium supplies that had characterized the 1950s vanished. Uranium reserves in government possession during the 1960s were so adequate[95] that policies toward the industry changed dramatically. Instead of stimulating extraction, the government took steps to discourage uranium operators from producing altogether. In 1968, for example, the Atomic Energy Commission recommended that the United States remove protective restrictions on the use of foreign uranium.[96] A few years later, in 1971, the Atomic Energy Commission released a more damaging pronouncement. It announced its intention to sell 50,000 tons of uranium concentrate on the open market from its own stockpiles.[97] At the same time, government reserves were in excess of 246,000 tons. Both moves served to increase the supply of uranium at a time when demand was weak. As a result, prices fell and the scope of the market available to domestic producers was restricted even further.

Although this narrative account tends to support the notion that the demand for uranium supplies peaked in the early 1950s and thereafter declined, an attempt was made to quantify the level of demand for uranium during the study period. The aim of such quantification was to be able to associate trends in demand with the tide in organizational concern, a big link in the hypothesis of this study. The following section presents the quantitative evidence on the trend in demand for uranium over time.

Trends in Uranium Needs

The unparalleled interest in generating uranium supplies during the late 1940s and early 1950s is reflected in the rate at which new producers were attracted to the uranium industry over time, the price paid for the ore, the amounts of ore purchased by the government and the incentives extended by the government to enhance production.

Between 1947 and 1959, the number of uranium miners in the uranium producing states increased at an average annual rate of 13%. Between 1960 and 1970, on the other hand, the number of uranium miners in the nation declined at an average annual rate of -3.8%. (See Table 19)

In Colorado, similar patterns occurred. Between 1950 and 1959 the number of uranium mines increased at an average annual rate of 17%. In the subsequent decade they decreased at an average annual rate of -5.1%. (See Table 19)

Levels of government purchases of uranium underwent a parallel series of increases and decreases. Between 1948 and 1960, for example, purchases had grown at an average annual rate of 57.4%. After 1960, the government bought successively smaller amounts of uranium. During the 1960's these purchases declined at an average annual rate of -15.2%. (See Table 20)

In Colorado, the decline in government purchasing was approximately the same. Between 1947 and 1959, the amount of ore purchased by the government increased steadily at an average annual rate of 42.3%. In the next decade purchasing steadily tapered off. Between 1960 and 1969, the amount of Colorado ore bought by the government fell at an average annual rate of -22.7%. (See Table 20)

In addition to buying smaller amounts of ore in the 1960s, the government paid less and less for what it bought. During the 1950s, for example, the Atomic Energy Commission paid an average of $10.79 for every pound of concentrate. In 1953, 1954 and 1955, the price per pound exceeded $12. Such high prices were never realized again. During

Table 19

Average Numbers of Underground Uranium Miners in All Uranium Producing States and Uranium Mines in Colorado, 1947-1970

Year	All uranium producing states		Colorado	
	Miners	Percent Change	Mines	Percent Change
1947	450		n.a.	
1948	500	11	n.a.	
1949	520	4	n.a.	
1950	550	5	115	
1951	660	20	167	45
1952	733	11	192	15
1953	1,000	36	215	11
1954	1,210	21	295	37
1955	1,530	26	335	13
1956	1,630	6	354	5
1957	1,890	15	378	6
1958	2,925	54	459	21
1959	3,300	12	425	-7
1960	3,498	6	422	0
1961	3,881	10	402	-4
1962	3,617	-6	331	-17
1963	2,698	-29	333	0
1964	2,324	-13	265	-20
1965	2,177[1]	-6	279	+5
1966	2,177[1]	0	283	+1
1967	2,177[1]	0	262	-7
1968	2,177[1]	0	257	-1
1969	2,177[1]	0	239	-7
1970	2,177[1]	0	235	-1

[1] projections

Sources:

Joint Committee on Atomic Energy, Radiation Exposure of Uranium Miners, 1967, p.1012

Columns 4 and 5 compiled from the Bureau of Mines, Annual Reports for the Years 1950-1970, Colorado

Table 20

Atomic Energy Commission Domestic Uranium Concentrate Purchases in Tons of U_3O_8, 1947-1970

	Tons of Uranium Oxide purchased from			
Year	All Domestic Producers	Percent Change	Colorado Producers	Percent Change
1947	67		67	
1948	102	+52.0	102	+52.2
1949	177	+73.0	175	+71.5
1950	459	+159.0	452	+158.3
1951	766	+66	620	+37.2
1952	874	+14	743	+20.0
1953	1163	+33	940	+26.5
1954	1700	+46	1239	+31.8
1955	2784	+63	1483	+20.0
1956	5958	+114	1726	+16.4
1957	8482	+42	1966	+13.3
1958	12437	+46	2917	+48.3
1959	16239	+30	3278	+12.3
1960	17637	+8	3117	-5.0
1961	17348	-1	2951	-5.3
1962	17008	-1	2652	-10.0
1963	14217	-16	2134	-20.0
1964	11846	-16	1800	-16.0
1965	10442	-11	1290	-28.0
1966	9488	-9	1258	-2.4
1967	8425	-11	840	-33.2
1968	7337	-13	782	-7.0
1969	6184	-15	0	-100.0
1970	2521	-59	0	

Sources:

Atomic Energy Commission, Statistical Data of the Uranium Industry, (Grand Junction, Colorado: U.S. Atomic Energy Commission, January 1, 1972) page 9 ("AEC Concentrate Purchases by States").

the 1960's, the average price paid dropped to $8.02. In 1970, uranium was sold for $5.74 per pound. This was 60% less than the price it had commanded in 1953. (See Table 21)

The amount of public lands leased to private operators for uranium production also declined with the passage of time. For example, between 1948 and 1954, the number of leases issued by the Atomic Energy Commission to private producers increased from one to thirty-five. Mineral output on public lands during this time period increased by more than 1000% at an average annual rate of 74%. As the government realized that there was no longer a uranium shortage, these lands were gradually removed from production. Between 1954 and 1962, the number of government leases dropped from 35 to 6. The amount of ore obtained from public lands dropped 73% from 160,822 tons in 1954 to 42,891 tons in 1962. After 1962, all productive activity on these lands was halted. (See Table 22)

The sluggish uranium market in the 1960's and 1970's was in part due to delays in the diffusion of atomic reactors on a massive scale. Current levels of uranium commitments to utilities and power plant manufacturers falls far below both projected estimates of fuel needs and the productive potential of the industry.[98] The industry cannot hope to find relief from its slim volume of sales to commercial buyers in expanded trade with the government. Current projections put government reserves of uranium as adequate to meet defense needs for the next eleven years.[99]

The Relationship Between National Uranium Needs and Organizational Concern

Trends in the demand for uranium appear to be inversely associated with government and company concern. (See Figure 5) During the 1960's, there was a steady decline in the prices paid for the ore, the amounts of ore purchased by the government and the withdrawal of incentives to enhance production. This coincided with a doubling of government efforts to inspect uranium mines and punish operators who violated radiation codes.

To measure the strength and direction of the relationship between the need for uranium and the intensity of organizational concern, correlation coefficients were computed. Measures of government concern were the annual number of inspections and sanctions issued by government enforcement agents to mine operators. (See Chapter 5, Table 8) Measures of company concern consisted of the yearly expenditures for ventilation by the largest uranium mining companies in Colorado. (See Chapter 5, Table 16) Several measures of national uranium needs were explored. These included the annual price paid for each pound of uranium concentrate, the number of tons of ore purchased by the Atomic Energy Commission from Colorado producers and on a nation-wide basis, and the number of uranium mines that operated in Colorado each year. The best measure of uranium needs was the average price paid per pound of uranium concentrate between 1950 and 1970. The advantage of a price-per-pound measure lies in its ability to reflect both supply and demand. The remaining measures--levels of ore purchased by the Atomic Energy Commission and the number of operating mines--only reflect absolute levels of consumption. Information on these various

Table 21

The Average Price Paid For Uranium, 1948-1971

Year	Average price per pound uranium concentrate
1948	$ 7.14
1949	8.53
1950	9.11
1951	10.10
1952	11.28
1953	12.35
1954	12.27
1955	12.25
1956	11.51
1957	10.49
1958	9.45
1959	9.12
1960	8.75
1961	8.50
1962	8.15
1963	7.82
1964	8.00
1965	8.00
1966	8.00
1967	8.00
1968	8.00
1969	6.99
1970	5.74
1971	5.54

ources: Atomic Energy Commission, Statistical Data of the Uranium Industry, (Grand Junction, Colorado, January 1, 1972.) p.8 ("AEC Domestic Uranium Concentrate Purchases: 1948-1971")

Table 22

A Summary of Atomic Energy Commission Mineral Lease Production, 1948-1962

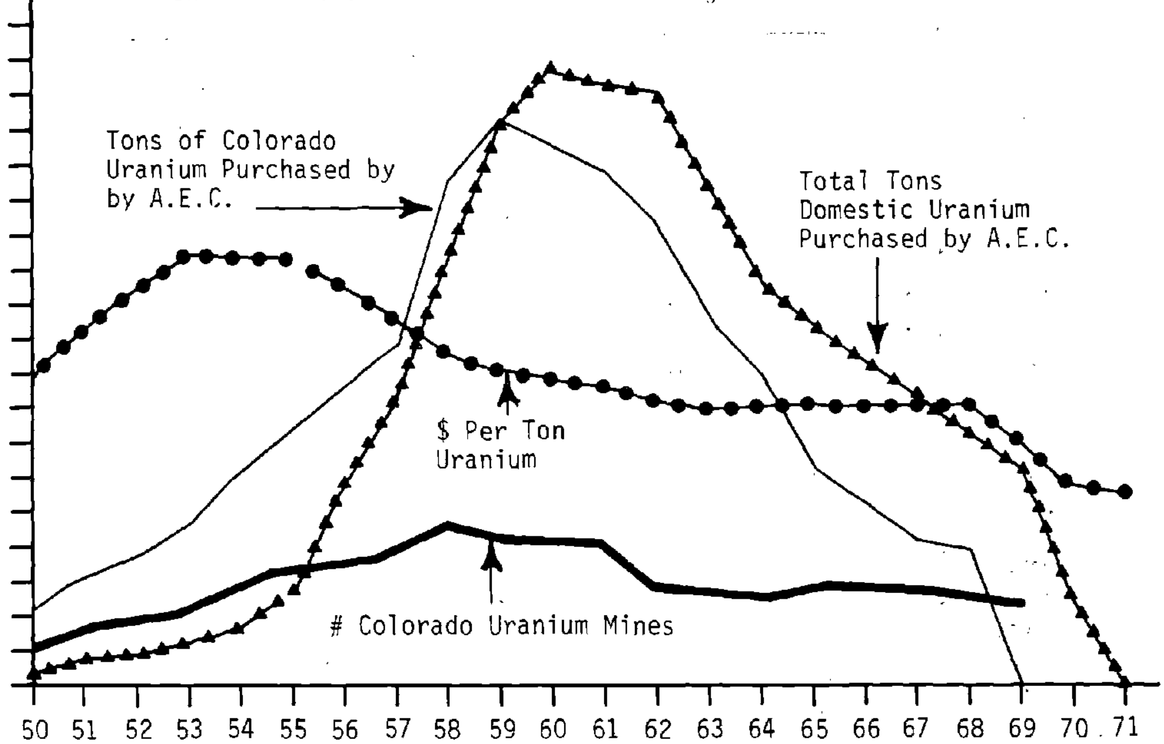
Year	Numbers of leases	Production (dry tons)	Percentage change
1948	1		
1949	8	12,109	+149
1950	12	30,261	+111
1951	17	64,146	+ 57
1952	30	101,050	+ 35
1953	35	136,780	+ 17
1954	35	160,822	- 13
1955	28	138,961	- 10
1956	22	125,048	- 20
1957	22	99,499	+ 21
1958	21	121,481	- 15
1959	16	102,157	- 4
1960	14	97,144	- 38
1961	11	59,625	- 28
1962	6	42,891	

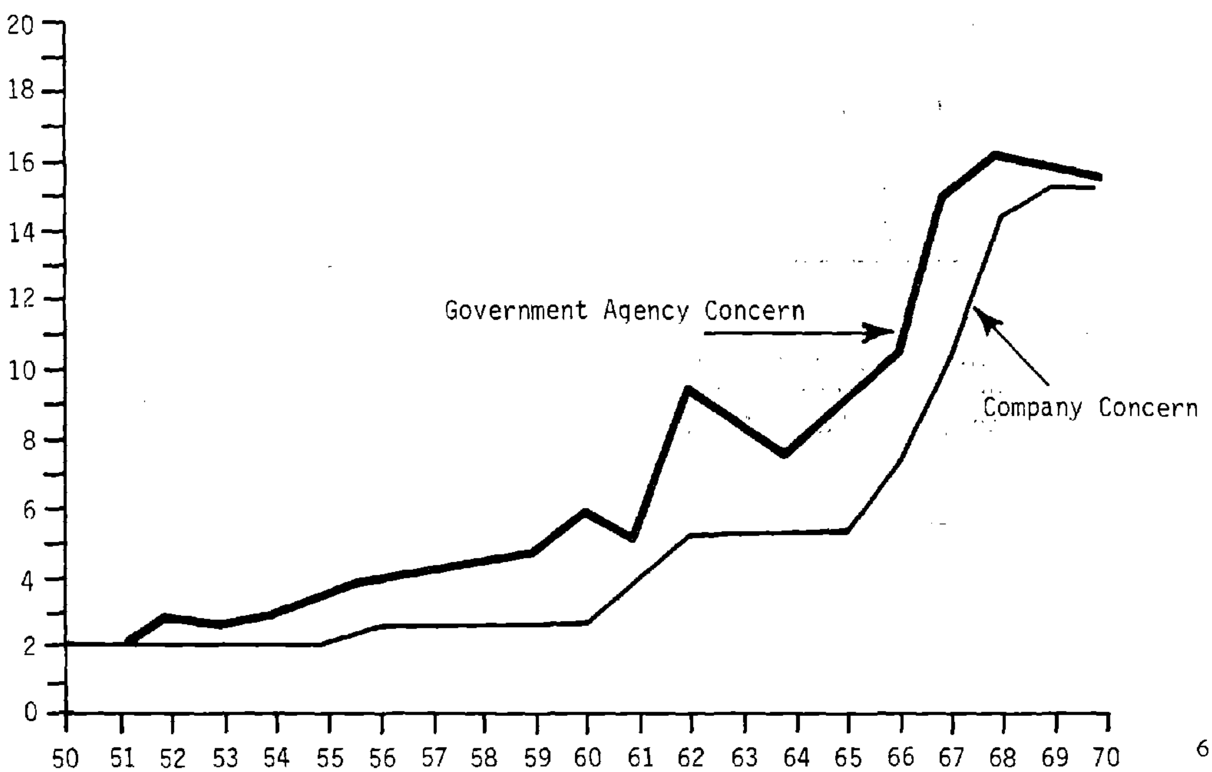
Sources:

Atomic Energy Commission, Summary of AEC Mineral Lease Production, (Obtained from Mr. Gilman Ritter, Grand Junction Office, Colorado, May 1973, Unpublished).

Figure 5

Trends in National Uranium Needs and Organizational Concern





measures of national needs is located in this chapter.

The analysis revealed that the relationship between uranium needs and organizational concern is a negative one for both companies and government agencies; but somewhat stronger for government agencies. The correlation coefficient for annual price per pound and government inspections was -0.779, while the r between price and company expenditures for ventilation was -0.737. (See Table 23) Thus, the relationships predicted were borne out.

HAZARD VISIBILITY

A second factor that appears to have influenced the level of concern demonstrated by companies and government agencies was the inconspicuousness of the hazard. Since radiation is invisible, scentless and intangible, those who campaigned against its danger often encountered reactions of disbelief. Public skepticism to the perils of radiation were reinforced by its elusiveness to measuring devices and its delay in manifesting evidence of bodily harm among the exposed population. Thus, it was expected that the concern of decision-makers would only be aroused with dramatic evidence that the hazard existed.

An analysis of trends in the visibility of the hazard and organizational "concern" suggests that this was indeed the case. The initiation of government regulations and company activities to reduce radiation coincided with the documentation of excessive deaths to United States miners due to radiation induced lung cancers. Perhaps more significantly, concern was aroused with the circulation of a series of newspaper articles on the plight of the uranium miners. In addition, concern was coterminous with expenditures to compensate afflicted miners and their families.

Trends in Hazard Visibility

Evidence of the hazard comes from the research efforts of the Public Health Service. Although medical research from Europe from the early twentieth century linked the incidence of lung cancers to mining uranium, the association was challenged by representatives of the domestic industry. Differences in the length of the working day and working conditions between the United States and European industries led many to argue that the two situations were incomparable. As a result, the Public Health Service initiated an investigation of health conditions in United States mines in 1950.

Three types of evidence eventually succeeded in arousing the concern of officials in government and business. One was a collection of lung

Table 23

Relationships Between National Uranium Needs and Organizational Concern

	Organizational concern shown by		
	Government Agencies		Companies
National uranium needs	No. Inspections	No. Sanctions	Dollars per ton for ventilation
Dollars per pound uranium	-0.779*	-0.731*	-0.737*
Tons Colorado ore purchased by A.E.C.	-0.352*	-0.215*	-0.488*
Tons domestic ore purchased by A.E.C.	-0.160*	-0.288*	-0.011*
Numbers of Colorado uranium mines	-0.113*	-0.127*	-0.220*

*Pearson correlation coefficients

cancer deaths among uranium miners. The second was a mounting tide of compensation claims filed by afflicted miners and their families and projections that the Colorado Workmen's Compensation Fund would be ultimately bankrupt by subsequent uranium miner claims. The third was a series of articles in the popular press that depicted the lung cancer risk confronting uranium miners and the pattern of official neglect.

Evidence of injury to United States miners accumulated gradually. During the 1950's, only a handful of lung cancer deaths occurred to miners who worked underground. Although health officials attached importance to each death in view of the European experience, the mortality experience of the uranium mining population during the 1950's did not arouse widespread concern. Only the New Mexico State Health Department and state mine inspector decided that the lives of miners were imperiled by exposure to radiation. As a result, in 1958, a program to control radiation was initiated in that state.

In 1960, the Public Health Service released information on the mortality experiences of their study group of miners from 1950 through December 31, 1959. This report showed that the incidence of lung cancer among men who had three or more years of uranium mining experience significantly exceeded the number expected among the population based on the mortality experience of a non-uranium mining control group. This announcement culminated in a meeting of the governors of uranium producing states in December of 1960 to discuss the problem. Subsequently, in 1961, Colorado initiated a formal program to reduce radiation.

Since the initial demonstration of significant excesses of lung cancer among uranium miners, evidence has steadily mounted which supports this contention. As Table 24 shows, 97 deaths were attributed to lung cancer contracted in the course of mining uranium before a national regulation on radiation was issued in 1967. Of that number, 70 occurred in Colorado. On the basis of trends prior to 1967, an actuarial firm projected that the death toll in Colorado to uranium miners between 1967 and 1985 would amount to 1,150 miners. Since the total population in Colorado that has ever mined uranium at one time or other is estimated not to have exceeded 6,000, this fatality projection was alarming. By 1970 the total number of deaths attributed to lung cancer due to uranium mining had risen to 150. (See Table 24)

The compensation of afflicted miners entered the picture in 1958 when the first workmen's compensation award was issued posthumously to a victim of lung cancer who had mined uranium. His compensation included $1,332.51 to defray medical expenses and $500 to cover funeral costs. His widow received $11,466.[100] (See Table 25)

The issue of compensating miners stricken with lung cancer was received with interest previously denied to the issue of the hazard itself. Attention was devoted to the removal of legal barriers that stood in the way of compensating victims of slowly developing diseases,

Table 24

Numbers of Lung Cancer Deaths Contracted in the Course of Mining Uranium

Year	Deaths	Year	Deaths	Year	Deaths	Year	Deaths
1945	1	1952	0	1959	5	1966	16
1946	0	1953	1	1960	9	1967	13
1947	1	1954	1	1961	6	1968	10
1948	0	1955	2	1962	7	1969	15
1949	1	1956	2	1963	10	1970	15
1950	1	1957	3	1964	9		
1951	1	1958	5	1965	16	Total:	150

Sources:

Joint Committee on Atomic Energy, Radiation Exposure of Uranium Miners, 1967, p.193 ("Mortality Summary by State and Year"), and Joint Committee on Atomic Energy, Radiation Standards for Uranium Mining, 1969, p.313 ("Deaths of Uranium Miners, 1954-1968")

Table 25

Colorado Compensation Claims Filed and Awarded to Uranium Miners Who Contracted Lung Cancer

	Number of Cases				
Year	Filed	Awarded	Denied	Pending	Total Amount Awarded
1957	1	0	1	0	$ 0
1958	1	1	0	0	11,000
1959	0	0	0	0	0
1960	0	0	0	0	0
1961	0	0	0	0	0
1962	4	3	1	0	37,794
1963	3	1	2	0	14,867
1964	6	4	2	0	59,390
1965	6	6	0	0	74,808
1966	9	6	3	0	93,899
1967	11	8	1	2	120,075
1968	10	5	3	2	95,395
1969	11	6	2	3	101,403
1970	8	4	0	4	n.a.
1971	12	4	0	8	n.a.

Sources:

Compiled from Digest of Lung Cancer Cases and Supplemental Digest of Lung Cancer Cases and records of recent compensation claims at the Department of Labor and Employment, Division of Labor, Workmen's Compensation Section, 200 E. 9th Avenue, Denver, Colorado.

and to devising more equitable ways of financing such compensation awards. The former problem was tackled in a session of the Joint Committee on Atomic Energy in 1959. Noting that it was generally impossible for lung cancer victims to comply with the requirement of most state compensation statutes that a claim be filed within six months after injurious exposure, the Committee concluded that

> If radiation cases (were) to be properly compensated, there must be provision for the removal of technical and procedural bars which may operate to exclude meritorious cases in which symptoms of disease and disability may occur long after initial or final exposure to hazardous agents, as in radiation disease. If cases of radiation are to be protected, these statutes must be written so that a claim may be filed within a reasonable period after disability (or the necessity for treatment) has transpired, and additionally not until after the employee knows, or should know, the nature of his disease, and its relation to employment. If all cases are to be protected, there can be no limit other than this for the filing of claims. (101)

Since 1959, twenty-two states have enacted legislation which modified the time limit provision of state workmen's compensation statutes. This has facilitated the process of compensating victims of lung cancer.

The problem of financing compensation awards to lung cancer victims was handled by the industry itself. Initially, the burden of such awards was borne by the victim's terminal employer. However, since job turnover is very high in the uranium mining industry, and so many employers have gone out of business during the past two decades, this arrangement generated dissatisfaction. It was felt that financial penalties were unfairly inflicted on the surviving firms in the industry and that firms responsible for causing injurious radiation exposure were escaping punishment. To remedy these ills, an industry-wide fund was created to finance the compensation of diseased uranium miners.[102]

Although some of the uranium producing states have persisted in ignoring compensation claims filed by victims of lung cancer, the number of claims filed in Colorado has increased considerably. At the close of 1966, for example, 21 cases had been awarded. The cumulative cost of these compensations amounted to $292,224. (See Table 25)

Publicity on the problem only gained momentum in the months preceeding and following the promulgation of a standard on radiation levels in mines by Secretary of Labor Wirtz. Although a few articles appeared on the subject in the Denver Post in earlier years, they tended to be more suggestive than conclusive. For example, in 1957, a Denver Post story reported that scientists were studying the possibility of a connection between mine radioactivity and lung cancer.[103] A 1960 story spoke of the "hinted risk" confronting uranium miners,[104] and even in 1962 an article reported on official but "inconclusive" surveys indicating an increase in lung cancer among uranium miners.[105]

In 1967, however, the tenor of the articles changed. In early March of that year an article appeared with the definitive assertion that uranium miners were contracting lung cancer from the gas in uranium mines.[106] This was quickly reiterated in an April story on the subject along with staggering projections of the disease and death that lay in store for uranium miners by the year 1985.[107] Four days later the Joint Congressional Committee on Atomic Energy announced it was planning a hearing into the matter within a matter of weeks.[108] In the interim, articles appeared announcing the 50th death of a uranium miner because of lung cancer[109] and efforts by Senator Lee Metcalf to organize Westerners in Congress to join in sponsoring a bill to fight the dangers of mining uranium.[110]

Wirtz's actions in May of 1967 served to stimulate new commentary and at the close of 1967, 20 articles had appeared in the Denver Post on the risk confronting uranium miners and the implications of that risk for the mining industry of the state and the state insurance compensation fund. (See Table 26)

The Relationship Between Hazard Visibility and Organizational Concern

In the wake of mounting deaths, compensation claims and publicity about both, the problem of excess radiation resulting in lung cancer was clearly established in the eyes of the industry and the government. Inspections of uranium mines increased and more money was spent for ventilation equipment. (See Figure 6)

To measure the strength of the relationship between evidence of the hazard and the actions taken by the government and companies to control radiation in mines, correlation coefficients were computed between measures of hazard visibility and organizational concern. It was expected that greater evidence of the hazard would induce government agencies and companies to take actions to reduce radiation. Measures of government concern included the annual number of inspections and sanctions to uranium mine operators issued by the Colorado Bureau of Mines. This information is located in Table 8 in the previous chapter. Measures of company concern consisted of the yearly expenditures for ventilation, per ton of ore mined, by the largest uranium mining companies in Colorado. (See Chapter 5, Table 16) Measures of the visibility of the hazard included the annual number of deaths attributed to lung cancer among uranium miners, the annual number of claims filed by uranium miners who suffered from lung cancer effects, and the annual number of articles appearing in the Denver Post on the subject of lung cancer among uranium miners. (See Tables 24, 25 and 26 in this chapter)

The analysis between all measures of hazard visibility and organizational concern was positive and strong. Relationships, however, were somewhat stronger in the case of government agencies. The best measure of hazard visibility appeared to be the annual number of compensation

Table 26

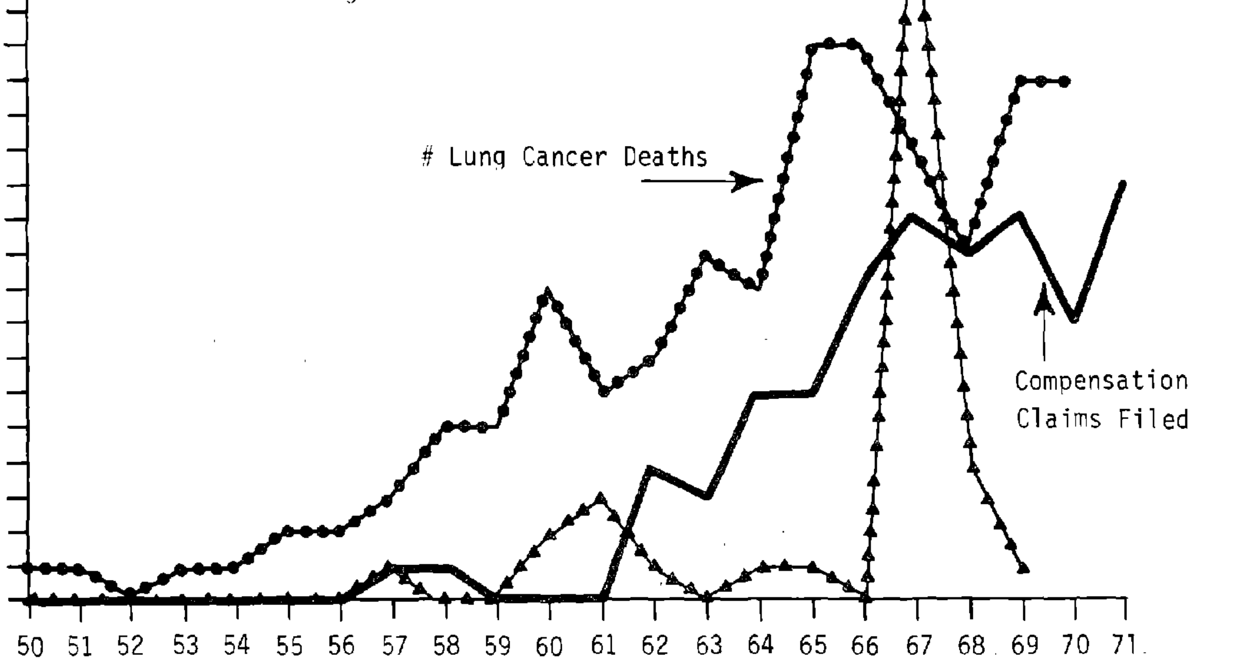
Number of Articles Appearing in the Denver Post on the Subject of Lung Cancer Among Uranium Miners

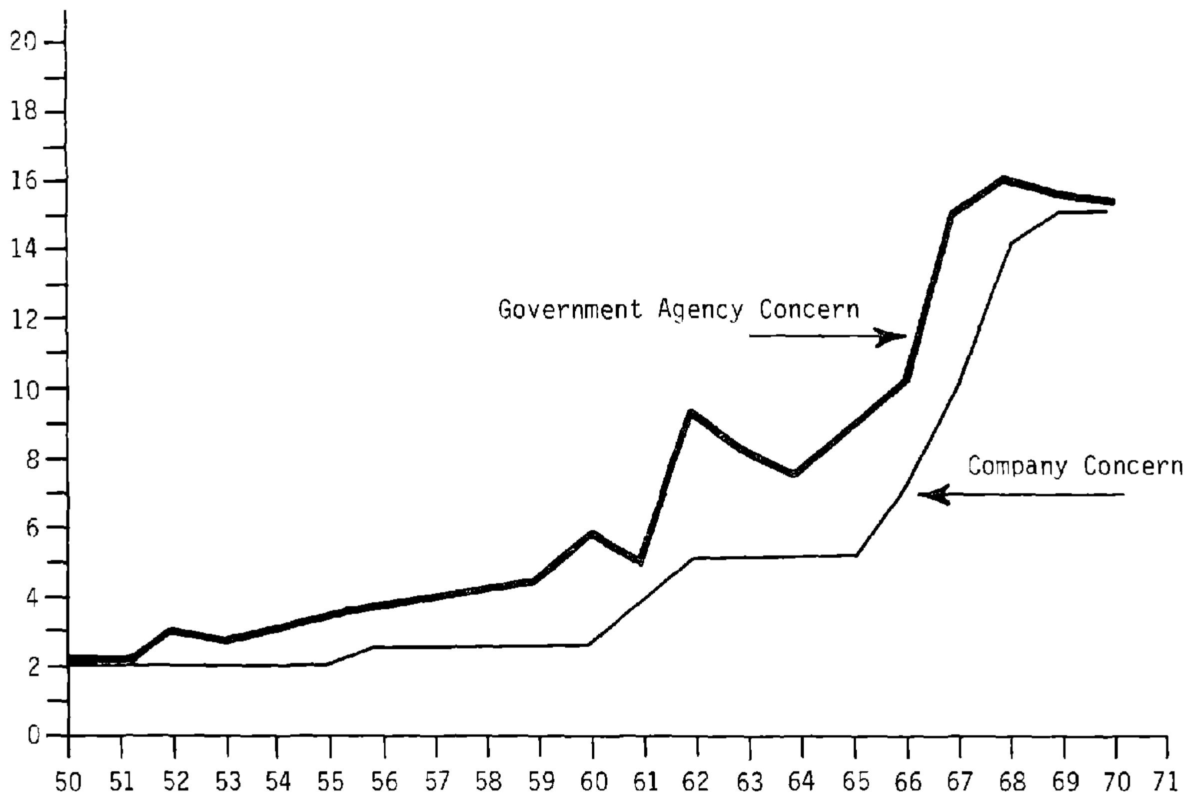
Year	Articles	Year	Articles
1950	0	1960	2
1951	0	1961	3
1952	0	1962	1
1953	0	1963	0
1954	0	1964	1
1955	0	1965	1
1956	0	1966	0
1957	1	1967	20
1958	0	1968	4
1959	0	1969	1

Source: The Denver Post, Morgue Clipping File, 1950-1969, (Topic Headings, "Cancer," and "Colorado Mining.")

Figure 6

Trends in Hazard Visibility and Organizational Concern





claims filed by uranium miners suffering from lung cancer. This suggests that the financial consequences of the hazard carried considerable weight in generating concern among government agencies and companies. (See Table 27)

INDUSTRY STRUCTURE

The structure of the uranium mining industry is also postulated to have affected the actions taken by government agencies and companies to reduce mine radiation. It was expected that to the extent that the industry became large-scale and stable it would and could more readily undertake the expenses of effecting adequate ventilation. At the same time, it was expected increased stability within the industry would make it easier for government regulators to keep track of the mining population; and, as a result, would produce a rise in government "concern" shown by successfully completed inspections.

Trends in Industry Structure

The supply and demand picture in the industry itself suggests that it became more stable and large-scale over time. The uranium industry can be shown to have passed through the three stages of supply and demand relationships posited by the economist, Alfred Marshall.[111] The three stages are: one, a momentary equilibrium, when supply is fixed; two, short-run equilibrium, when firms can produce more within given plants; and three, long-run equilibrium, when firms can abandon old plants, build new ones, and when old firms leave an industry and new ones enter it. In the case of uranium, the first stage resembles the late 1940's and early 1950's when uranium supplies were limited and demand was strong. Prices increased steadily until 1955. Phase II begins around 1956 when supplies are relatively abundant and demand begins to taper off. Prices drop at this time and stabilize at a lower level than those experienced under Phase I. The last stage emerges in the mid-1960's when supply is even more abundant and demand weak. Small, unproductive mines are closed down and the industry is gradually dominated by large, mature firms. The new price is far below the level of the monetary equilibrium price.

A look at the early uranium mining industry shows it to have been composed of small companies, partnerships, families and individuals. The preponderance of small producers is attributed to the enticing benefits the Atomic Energy Commission offered to those who mined uranium. Bonuses were offered to defray the initial costs of production and subsidized transportation was available to miners in remote areas for hauling ore.

Table 27

Relationships Between Hazard Visibility and Organizational Concern

Hazard visibility	Organizational concern shown by: Government agencies		Companies
	No. Inspections	No. Sanctions	Dollars per ton for ventilation
Annual number lung cancer deaths	0.851*	0.858*	0.757*
Annual number compensation claims filed	0.945*	0.873*	0.890*
Annual number articles in Denver Post	0.532*	0.420*	0.435*

*Pearson correlation coefficients

The government guaranteed the purchase of uranium at a generous price. For those who lacked the capital to purchase mineral lands, leasing arrangements were available with both the government and the large mining companies. Prior to 1960, all of the mines owned by Colorado's largest uranium producer, Union Carbide, were operated by private, independent miners through contract agreements.[112] Until 1962, the Atomic Energy Commission leased public lands to private operators. Motivated by government subsidies, small entrepreneurs flocked to uranium mines. The industry acquired a speculative, pioneering character. As one interviewee put it, "In the early days, there was a uranium prospector under every tree."[113] Thus, in 1951, 40% of the 98 mines that operated in Colorado were owned by small producers. Large companies owned another 40% of the operating mines and the remaining 20% were owned by the Atomic Energy Commission. (See Table 28)

Changes in the structure of the industry began during the late 1950's. The price paid for uranium declined and the bonus system was later terminated. In 1962 the Atomic Energy Commission removed a large supply of land formerly available to the small prospector. The stretch-out program and the decline in government purchasing after 1962 were fatal developments for many operators. In 1960, only 32% of the 352 mines that operated in Colorado were owned by small companies, families or individuals. Government leased lands had diminished to only a fraction of the mines that operated, (5%). The remainder of the industry was owned by the large companies having both mining and milling facilities. This accounted for 63% of the mines that operated in 1960. (See Table 28)

In the ensuing lean years, survival favored the integrated companies with both mining and milling facilities. In 1966 these few companies produced 79% of the domestic uranium and controlled 94% of the ore reserves in the nation.[114] Since 1965, the newest faces to appear on the uranium scene have been the large oil companies. At least 18 oil companies have invested heavily in producing and processing uranium. Although the petroleum industry only accounted for one-sixth of uranium production in 1970, it held 45% of all known uranium reserves. The large oil companies were also making more than half of the new discoveries in uranium at the time.[115]

By 1970, the overwhelming advantage of the large companies in Colorado was clear. Of the 139 mines listed as operating that year, approximately 72% were owned by companies with assets in excess of one million dollars. Sixty-six percent were owned by companies with assets in excess of one billion dollars. Union Carbide held a lion's share of the industry. It owned 56% of the operating mines in Colorado. (See Table 28)

Attempts to quantify changes in the structure of the industry in the sample over time, however, were only partially successful. The Colorado sample of mines is over represented with mines owned by large companies during the early 1950's. This bias reflects the greater availability of records on mines of this latter type at the Colorado Bureau of Mines.

Table 28

The Composition of the Uranium Mining Industry, 1950-1970

Year	Percentage of mines owned by			
	A.E.C.	Small companies	Large companies	Union Carbide Corp.*
1950	20.0	40.0	40.0	30.0
1951	18.5	39.2	42.3	31.0
1952	17.0	38.4	44.6	32.0
1953	15.5	37.6	46.9	33.0
1954	14.0	36.8	49.2	34.0
1955	12.5	36.0	51.5	35.0
1956	11.0	35.2	53.8	36.0
1957	9.5	34.4	56.1	37.0
1958	8.0	33.6	58.4	38.0
1959	6.5	32.8	60.7	39.0
1960	5.0	32.0	63.0	40.0
1961	3.3	31.6	63.9	41.6
1962	1.7	31.2	64.8	43.2
1963	0	30.8	65.7	44.8
1964	0	30.4	66.6	46.4
1965	0	30.0	67.5	48.0
1966	0	29.6	68.4	49.6
1967	0	29.2	69.3	51.2
1968	0	28.8	70.2	52.8
1969	0	28.4	71.1	54.4
1970	0	28.0	72.0	56.0

*Colorado's largest producer

Sources:

Compiled from Bureau of Mines, Report for the Years 1950-1951, August 15, 1952 (List of Operating Mines in Various Counties in Colorado) pp.51-101

Bureau of Mines, Annual Report for the Year 1960, May 1, 1961 (List of Mineral Operations) pp.61-87

Colorado Bureau of Mines, A Summary of Mineral Industry Activities in Colorado 1970, May 1, 1971 (Mineral Operations by County) pp.62-86

(Exact counts of operators were made for the years 1950, 1960 and 1970 with the abovementioned sources and records maintained at the Colorado Bureau of Mines, 1845 Sherman Street, Denver, Colorado; Figures for other years were extrapolated.)

Large companies regularly filed annual reports summarizing the activities of all their mining properties. This was in addition to information recorded by the state mining inspectors. It was thus generally possible to piece together a complete picture of such mining operations over time. Mines owned by individuals or families, on the other hand, were often never covered in the record, or, if covered at all, only haphazardly so. Thus, for lack or incompleteness of information, mines owned by small companies, partnerships or individuals were disproportionately excluded from the sample. As a result, the sample group fails to show trends suggesting the decline of importance of small operators relative to large over time. (See Table 29)

However, there is limited evidence from the sample that changes in the structure of the industry did occur.

There has been a gradual rise in the number of large Colorado mines. Although the average number of men employed in the sample between 1950 and 1969 was relatively constant and extremely small, e.g., 1.29, there was a slight increase in the number of larger mines during the 1960's. In 1956, the first mine employing fifty-one men or more began to operate. In 1962, it was joined by another. At the conclusion of the study period, 7.1% of the mines sampled employed 16 men or more. (See Table 30)

Colorado mines also tended to become more productive with passing time. Although the majority of mines produced less than 250 tons per month throughout the study period, a greater proportion yielded 500 tons or more during the 1960's. Between 1950 and 1969, approximately 5.4% of the 1581 mines sampled in the decade produced 500 tons or more on a monthly basis. In the next decade, the proportion of mines in this production category was 12.3%. (See Table 31)

The Relationship Between Industry Structure and Organizational Concern

Thus, it appears that the uranium industry gradually came to be composed of mature, stable and large firms. Concurrently, government agencies were better able to keep track of the mining population and firms were better equipped to undertake the expenses of effecting adequate ventilation. Inspections of uranium mines increased and more money was spent for ventilation equipment. (See Figure 7)

To test the implications of this transformation in the structure of the industry for the onset and intensity of organizational concern, correlation coefficients were computed between measures of industry structure and organizational concern. Industry structure was assessed in terms of the annual percentage of mines owned by large companies, the percentage of mines owned by Union Carbide in particular; the percentage of mines producing more than 500 tons on a monthly basis; and the percentage of mines employing more than 16 men. This information is contained in various tables in this chapter. Once again, measures of organizational concern included the annual

Table 29

Annual Percentage of Mines Owned by Small, Large and Government Producers in the Sample of Colorado Mines, 1950-1969

Year	Percentage of mines owned by			
	A.E.C.	Small companies	Large companies	Union Carbide Corp.
1950	30	6.7	63.3	43.3
1951	27.6	10.3	62.1	48.3
1952	25.2	13.6	61.2	36.9
1953	19.7	22.0	58.3	34.6
1954	22.6	26.0	51.4	32.9
1955	21.8	35.8	42.4	26.7
1956	16.0	30.2	53.8	35.4
1957	11.0	31.7	57.3	39.4
1958	9.4	31.2	59.4	37.2
1959	7.7	31.2	61.2	39.2
1960	6.9	29.4	63.7	39.7
1961	4.1	31.1	64.8	37.0
1962	2.4	33.3	64.3	31.7
1963	0.0	35.6	63.9	28.2
1964	0.0	46.0	54.0	16.7
1965	0.0	37.4	61.5	26.4
1966	0.0	28.0	71.1	35.8
1967	0.0	25.7	73.8	41.0
1968	0.0	24.8	75.2	52.8
1969	0.0	29.1	69.3	48.8

Source:
The sample of Colorado uranium mines.

Table 30

Percentages of Mines by Size of Work Force, 1950-1969

Year	Percentages of mines employing men that number	
	1-15	16 or more
1950	100.0	00.0
1951	96.6	3.4
1952	97.1	2.9
1953	99.2	0.8
1954	98.6	1.4
1955	96.9	3.0
1956	96.7	3.3
1957	96.0	4.1
1958	97.4	2.6
1959	95.8	4.2
1960	95.4	4.6
1961	94.5	5.2
1962	95.2	4.8
1963	94.9	5.1
1964	95.9	3.4
1965	94.5	5.5
1966	95.8	4.1
1967	96.7	3.3
1968	94.4	5.6
1969	92.9	7.1

Source:
The sample of Colorado uranium mines.

Table 31

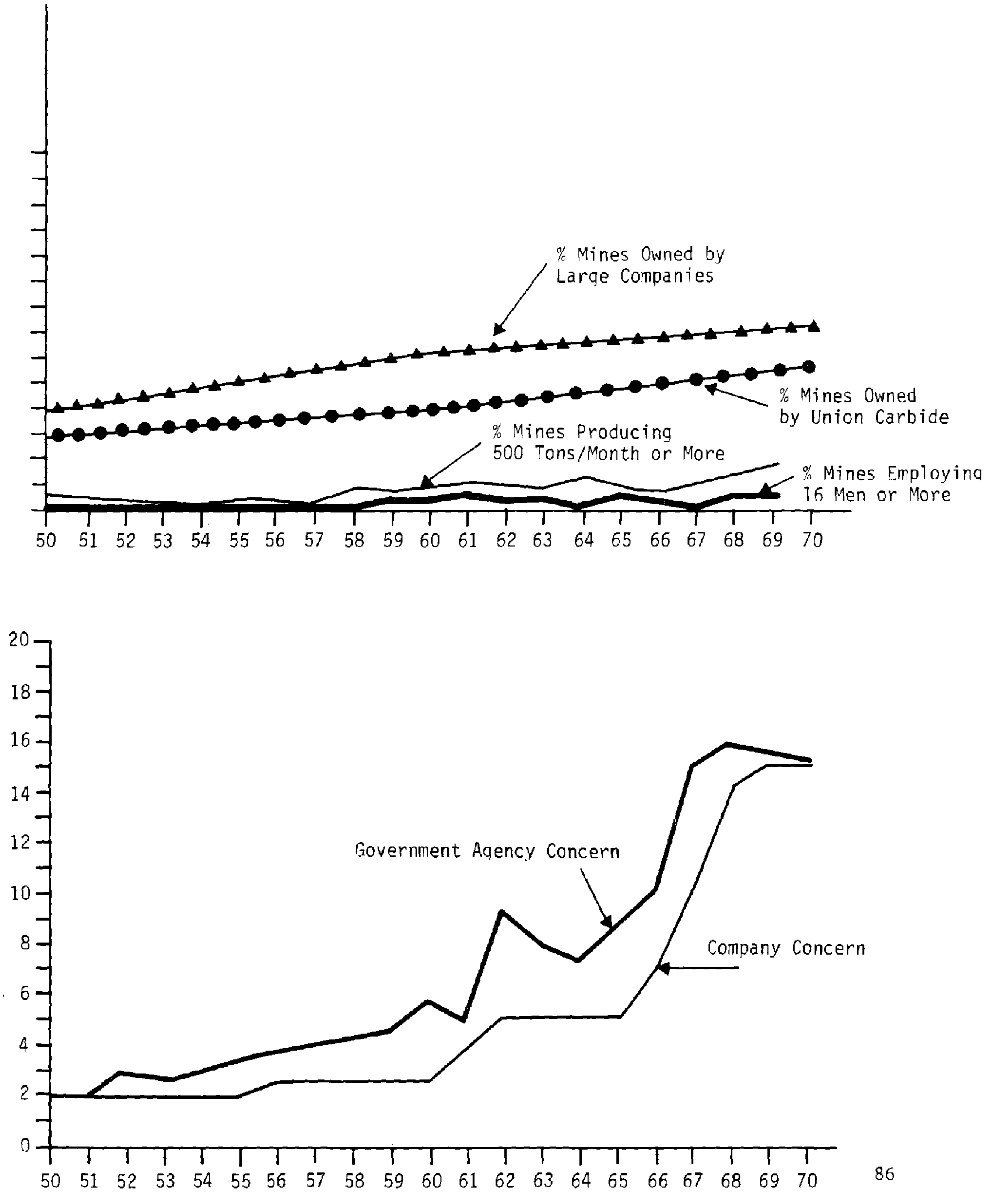
Percentage of Mines by Tons of Ore Produced, 1950-1969

Year	Percentages of mines producing on a monthly basis tonnage equal to 0 - 500	500 or more
1950	90.0	6.7
1951	94.8	5.1
1952	97.1	2.9
1953	97.6	2.4
1954	96.6	3.5
1955	94.5	5.4
1956	94.9	5.2
1957	96.0	4.1
1958	91.0	9.0
1959	90.4	9.7
1960	88.5	11.5
1961	87.4	12.6
1962	88.8	11.2
1963	89.8	10.2
1964	87.9	12.0
1965	89.0	10.9
1966	90.8	9.2
1967	89.0	10.9
1968	84.5	15.6
1969	81.1	18.9

Source:
The sample of Colorado uranium mines.

Figure 7

Trends in Industry Structure and Organizational Concern



number of inspections and sanctions issued by government enforcement agents and the number of dollars, per ton of ore mined, expended by the major Colorado producers for ventilation.

The analysis showed that scale and stability were directly related to the demonstration of concern by both companies and government agencies. The relationship between industry structure and concern by government agencies was stronger. The best measures of industry structure were proportions of mines owned by large producers in general. This suggests that the ownership profile of the industry was more significant than characteristics of mines themselves, as in the cases of size and productivity in arousing concern among government agencies and companies. The findings in this analysis tend to support the hypothesized relationships between industry structure and organizational concern. (See Table 32)

OFFICIAL CONCERN

The last historical factor postulated to have affected the response of enforcement agencies and companies to excess radiation in mines was federal level policy. Official guidance was believed to be critical in directing local caretaking agencies on the proper response to the problem. Thus, it was hypothesized that federal involvement in the regulation and supervision of radiation would be associated with a stringent control process. On the other hand, the absence of official, federal policies on the problem, would undermine radiation control. Faced with a vacuum of federal involvement, local enforcement agencies would inherit a problem for which they often lacked technical expertise, personnel, and statutory responsibility.

Trends in Official Concern

A look at information on federal agency concern suggests that little policy guidance was offered. There was a dearth of interest in the problem of excess radiation among the legislative and executive branches until well after the documentation of excess lung cancers among uranium miners. For example, a review of bills introduced into both Houses of Congress from the 81st Congress to the 91st Congress, shows that no legislation pertaining to the health of uranium miners was introduced until the first session of the 90th Congress in 1967. (See Table 33) In that year, no fewer than five bills were introduced; three in the Senate and two in the House of Representatives. All of the bills dealt with the issue of compensating miners afflicted with lung cancer.[116]

Two other bills on the subject of the health of uranium miners were introduced into the House of Representatives in 1969. They also handled

Table 32

Relationships Between Industry Structure and Organizational Concern

	Organizational concern shown by		
	Government agencies		Companies
Industry structure	No. Inspections	No. Sanctions	Dollars per ton for ventilation
Percentage of mines owned by large companies	0.849*	0.797*	0.742*
Percentage of mines owned by Union Carbide	0.958*	0.895*	0.899*
Number of mines employing 16 men or more	0.662*	0.560*	0.636*
Percentage of mines producing 500 tons or more	0.809*	0.665*	0.806*

*Pearson correlation coefficients

Table 33

Bills Introduced into Both Houses of Congress Relating to the Health and Safety of Uranium Miners From the 81st Congress to the 91st Congress, 1949-1970

Congress	Year	Senate Bills	House of Representatives Bills
81	49	0	0
81	50	0	0
82	51	0	0
82	52	0	0
83	53	0	0
83	54	0	0
84	55	0	0
84	56	0	0
85	57	0	0
85	58	0	0
86	59	0	0
86	60	0	0
87	61	0	0
87	62	0	0
88	63	0	0
88	64	0	0
89	65	0	0
89	66	0	0
90	67	S 2782; S 2686; S 1927	HR 14558; HR 16302
90	68	0	0
91	69	0	HR 7606; HR 11476
91	70	0	0

Sources: Compiled from Congressional Index, Commerce Clearinghouse, 81 Congressional Session through 91 Congressional Session the question of compensating uranium miners suffering from lung cancer.

None of the bills introduced to the 90th or 91st Congress were translated into public law. They did succeed, however, in generating public debate and interest in the problem. For example, on April 21, 1967, the Joint Committee on Atomic Energy announced that a series of public hearings would be held on the subject of radiation exposure of uranium miners. The ensuing hearings were conducted by the Joint Committee's Subcommittee on Research, Development and Radiation. It occupied eleven days over a four month period. More than fifty persons appeared before the committee as witnesses, and sixteen submitted statements for the record. In addition, a wealth of material, correspondence, reports and papers were presented. The proceedings of the Hearings were compiled in a two volume document that is 1373 pages long. In the words of Joint Committee Chairman Pastore and Price, "This two-part record constitutes the most comprehensive collection of information ever amassed concerning the exposure of human beings to radiation incident to the mining of uranium."[117]

On March 17 and 18, 1969, additional hearings were held before the Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy. The sessions were also on the topic of exposure of uranium miners to lung cancer. The proceedings of this set of hearings amounted to 411 pages.[118]

Thus, it is obvious that the interests of the legislative branch of government and the health and safety of uranium miners was aroused in the last part of the 1960's. Prior to this time, however, there was a dearth of legislative guidance concerning the protection of miners who were exposed to radioactive material in the course of their employment.

The interests of the executive branch of government in the problem was also extremely modest. For the most part, federal agency interest coincided with that of the legislature. In both cases, 1967 was the peak year of concern. Unlike the legislature, however, federal agencies have shown fairly consistent interest in the subject of procuring uranium throughout the two decades under study.

To assess the attention devoted to the subject of the health of uranium miners among federal agencies, a content analysis was conducted of the Federal Register between 1950 and 1969. For each year, the index of the Federal Register was scanned for reference to uranium mining. All references were then traced in the body of the Federal Register and the number of lines devoted to the subject of uranium were counted and recorded.

As Table 34 shows, the bulk of interest in uranium shown by federal agencies had dealt with the subject of procurement. During the 1950's Federal Register entries on uranium exclusively detailed modifications in the incentive program launched in 1948 by the Atomic Energy Commission to secure uranium reserves. In 1961, the first entry (85 lines) on the subject of the health aspects of mining uranium appeared. In it, the

Table 34

A Content Analysis of the Federal Register
1950-1969

Year	Total number of pages Federal Register	Ratio lines: pages on subject uranium mining (procurement and health and safety)	Ratio lines: pages on subject uranium health and safety
1950	9,562	.0028	0
1951	13,175	.082	0
1952	11,896	.0016	0
1953	8,912	.0089	0
1954	9,910	.044	0
1955	10,196	.0025	0
1956	10,528	.029	0
1957	11,156	.033	0
1958	10,579	.018	0
1959	11,116	.0086	0
1960	14,479	0	0
1961	12,792	.0066	.0066
1962	13,226	.018	0
1963	14,842	.0033	.0033
1964	19,304	0	0
1965	17,142	.043	0
1966	16,850	.014	0
1967	21,087	.064	.035
1968	20,072	.027	0
1969	20,466	.011	.0039

Sources:
Compiled from the Federal Register, National Archives and Records Service of the General Services Administration, 1950-1969

Federal Radiation Council, created in 1959 to furnish advice on radiation to the president, solicited comments on the protection of miners employed in uranium mines. In 1963, 50 lines of the Federal Register dealt with the subject of protecting uranium miners from radiation exposure. In 1967, however, 749 lines of the Federal Register dealt with the problem of radiation exposure to uranium miners. This included the promulgation by Secretary of the Labor, Willard Wirtz, lowering radiation standards in the nation's uranium mines. It was the first federal law designed to safeguard the health of uranium miners. In 1969, 80 more lines were devoted to this subject. They were isolated from a larger, general law on health and safety standards in all types of underground mines. (See Table 34)

The Relationship Between Official Concern and Organizational Concern

To examine whether trends in official concern were related to the actions of enforcement agencies and companies to control radiation, correlation coefficients were computed. Official concern was gauged by the annual number of bills introduced into both Houses of Congress relating to the health of uranium miners and the number of lines of the Federal Register devoted to the subject on a yearly basis. (See Tables 33 and 34) Organizational concern was measured by the annual number of inspections and sanctions made by the Colorado Bureau of Mines and the expenditures for ventilation made by the largest Colorado companies. (See Tables 8 and 16, Chapter 5) These relationships are graphically portrayed in Figure 8.

The relationships predicted between official and organizational concern are only partially supported by the evidence at hand. Only very weak associations were found between the attention devoted to the hazard in the Federal Register and inspections and company expenditures. Correlation coefficients between these variables were 0.476 and 0.378, respectively. No doubt, this is due to the extremely small number of lines on this subject in the Federal Register during the twenty year study period.

Correlation coefficients between the number of bills introduced into Congress on health and safety matters and organizational concern were somewhat stronger. For example, the r between Congressional bills and inspections is 0.698, and the r between Congressional bills and company expenditures for ventilation is 0.651. Despite this improvement, however, it appears that the role of federal policies in the control process was considerably weaker than that of the previously discussed factors of national uranium needs, hazard visibility, and industry structure. (See Table 35)

Figure 8

Trends in Official Concern and Organizational Concern

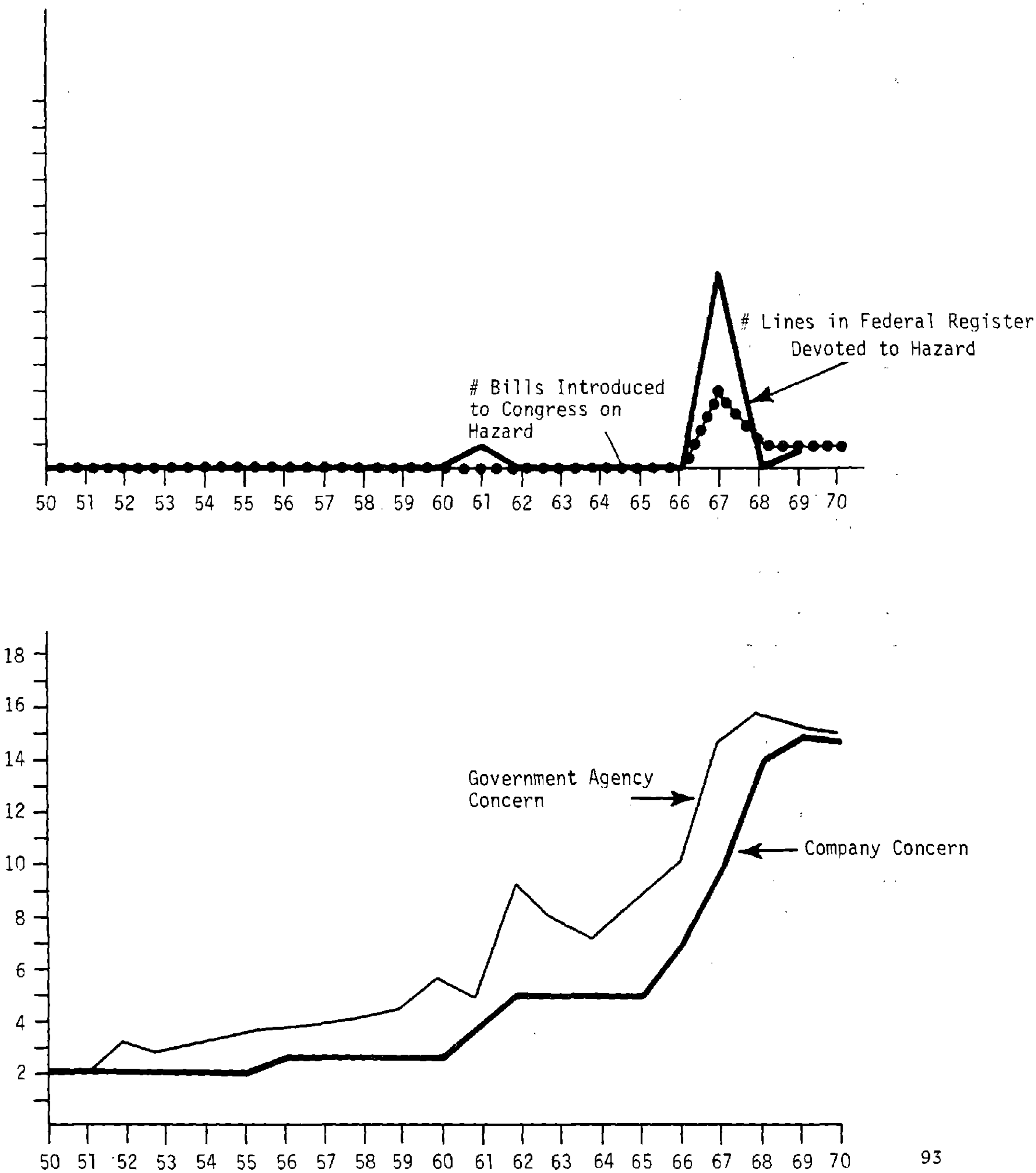


Table 35

Relationships Between Official Concern and Organizational Concern

	Organizational concern shown by		
	Government agencies		Companies
Official concern	No. Inspections	No. Sanctions	Dollars per ton for ventilation
Numbers of Bills introduced into Congress devoted to the health of miners	0.698*	0.465*	0.651*
Numbers of lines of Federal Register devoted to the helath of miners	0.476*	0.383*	0.378*

*Pearson correlation coefficients

Chapter 7

SEARCHING FOR CAUSES

The previous two chapters presented information on the two major objectives of this study. Chapter 5 examined whether specific actions by government enforcement agencies, companies and unions had succeeded in reducing radiation levels in uranium mines. Chapter 6 looked at the events and historical dynamics which aroused concern among those in a position to do something. It was shown that a stepped up program of inspections by government enforcement agencies and increased ventilation expenditures by companies coincided with dramatic declines in the level of radiation in mines. In turn, factors such as waning demand for uranium, increased visibility of the hazard, stabilization of the industry and new high-level official policies seemed linked to the government and company actions. These trends are summarized in the following figure. (See Figure 9)

Correlation coefficients between the variables representing these trends were computed and were generally very high. The strengths of association between the variables are summarized in Table 36.

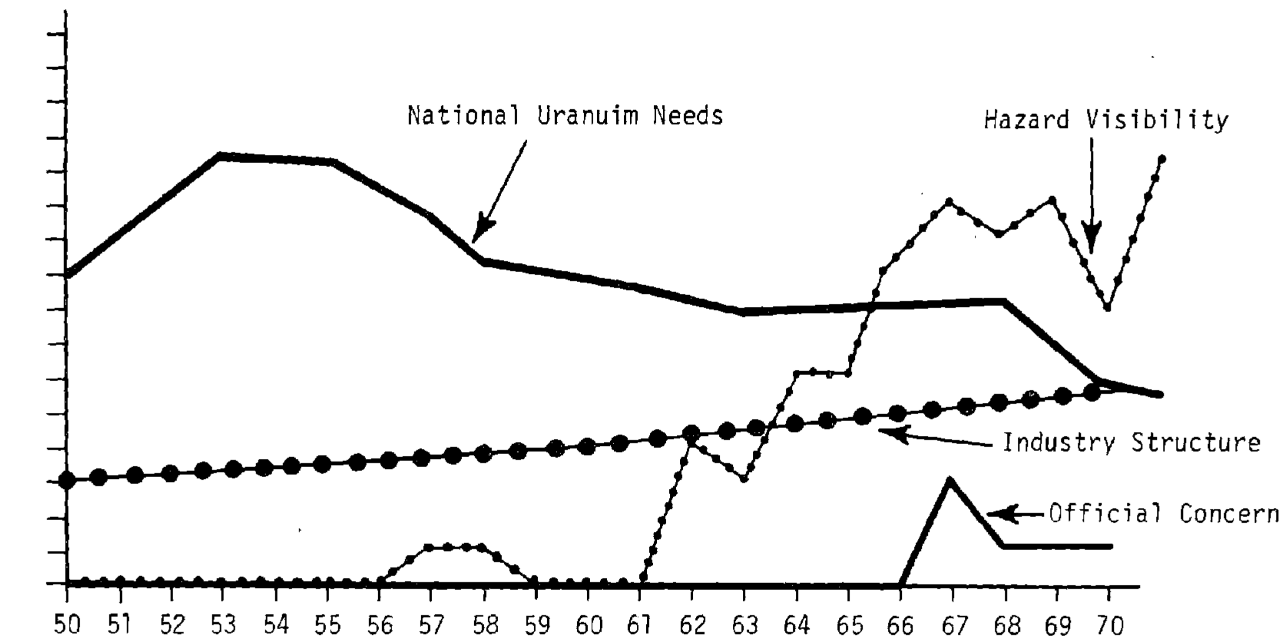
Correlation, however, is no proof of causation. Moreover, the model has not identified which historical factors, if any, were more responsible than others for the onset of organizational concern. Nor has it differentiated between respective influences of government and company concern on radiation. (See Figure 10)

At this point, the model, on the basis of the analysis presented in Chapters 5 and 6, singles out certain historical factors as "prime movers" and others as consequences. Among the concern variables, the influence of government and company actions on radiation will be distinguished.

Logically, it seemed plausible to hypothesize that national uranium needs and the tide of compensation claims filed by afflicted miners and their families touched off the process that eventually culminated in the reduction of hazardous radiation in mines. Both factors reflect financial considerations which are presumed to be critical in decision-making in industrial societies such as ours. Moreover, it seemed likely that company expenditures for ventilation were directly responsible for reduced levels of mine radiation, but that such expenditures followed only in the wake of relentless government regulatory activities. This hypothesis is supported by the work of Ralph Nader, Kohlmeier and others showing the need for watchdog agencies to supervise industry in order to solve a variety of consumer ills.[119]

Figure 9

Trends in Historical Factors, Organizational Concern and Worker Health, 1950-1970



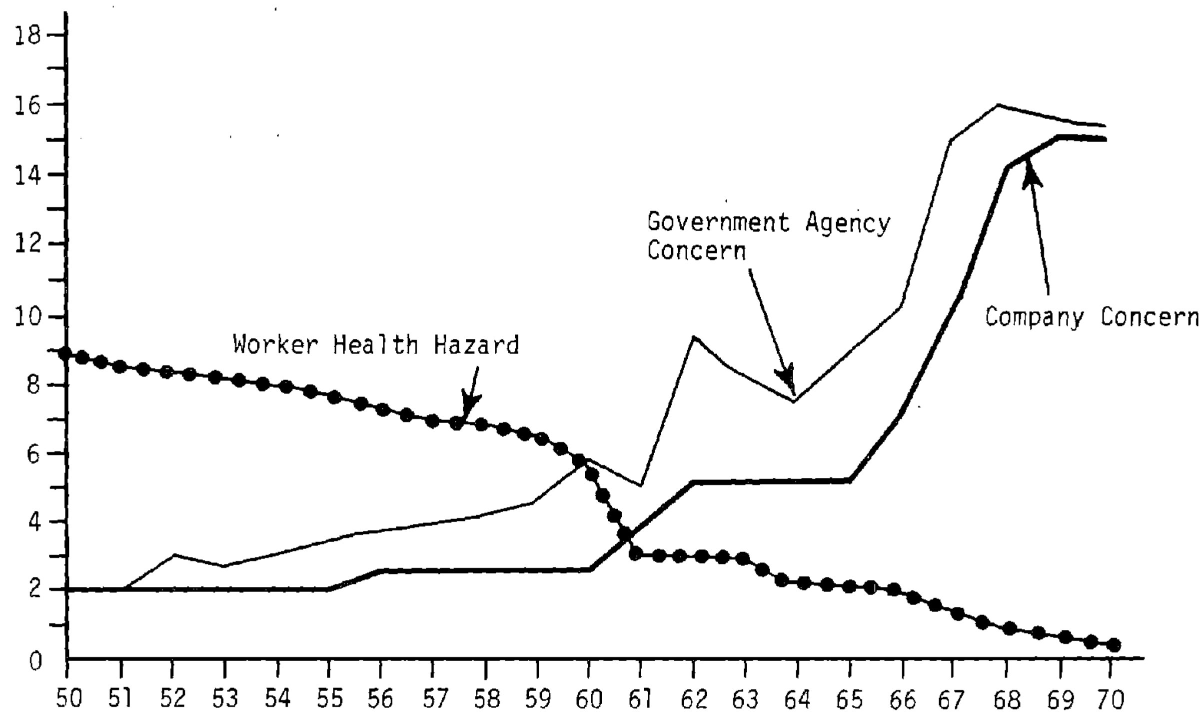


Table 36

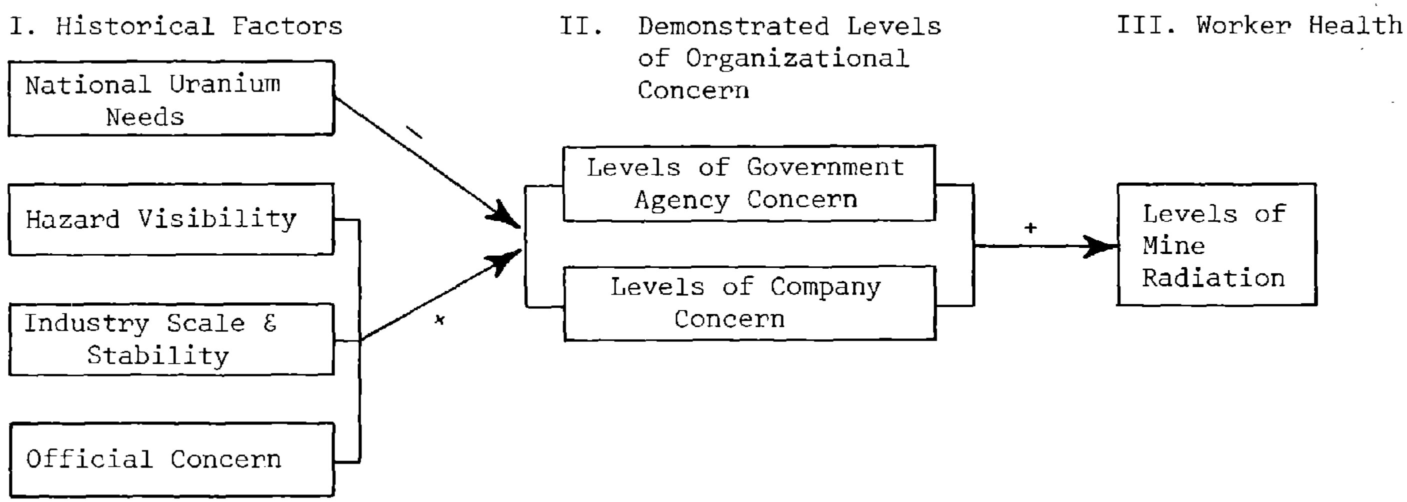
Correlations Between Historical Factors, Organizational Concern Variables and Radiation Levels in Mines, 1949-1970

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. National uranium needs[a] (dollars per ton ore)	1.00						
2. Hazard visibility[a] (numbers of compensation cases per year)	-0.696	1.00					
3. Industry scale and stability[a] (percentage of mines owned by Union Carbide Corp.)	-0.796	0.916	1.00				
4. Official concern[a] (numbers of bills introduced to Congress on the hazard per year)	-0.345	0.679	0.546	1.00			
5. Government agency concern[b] (numbers of inspections of uranium mines each year)	-0.747	0.945	0.959	0.647	1.00		
6. Company concern (dollars[c] expended per ton of uranium for ventilation each year)	-0.683	0.922	0.888	0.617	0.915	1.00	
7. Radiation levels (mean[d] radiation levels in U.S. uranium mines per year)	-0.849	-0.786	-0.950	-0.430	-0.879	-0.757	1.00

[a]Information assembled at time point #1, e.g., 1949, 1950, 1951
[b]Information assembled at time point #2, e.g., 1950, 1951, 1952
[c]Information assembled at time point #3, e.g., 1951, 1952, 1953
[d]Information assembled at time point #4, e.g., 1952, 1953, 1954

Figure 10

A Model of the Process of Solving the Hazard of Excess Radiation in Mines



The revised model of the problem-solving process is presented in Figure 11. As is readily visible, it underscores the importance of national uranium needs and mounting evidence of a serious health hazard. Both these variables are presumed to be causally unrelated to one another. Hazard visibility was a simple product of the passage of time. As time elapsed, lung cancers developed among uranium miners and mounting numbers of compensation claims were filed. Variations in the national need for uranium, on the other hand, were due to fluctuations in the supply of ore and the nation's concern with atomic weaponry. As uranium reserves grew and the cold war climate of the late 1940's and early 1950's slackened, demand tapered.

The other two historical factors, industry structure and official concern, are represented as causally dependent upon national uranium needs and visibility factors. The structure of the industry changed with declining demands for the ore. Declining demand caused the subsidies, incentives and bonuses extended by the government to uranium producers to be withdrawn, in turn causing small operators to leave the industry and only large companies to stay. The result was a stable, mature, large-scale industry. Official concern, measured in terms of the annual number of bills introduced into Congress concerning radiation in mines, on the other hand, was a byproduct of the visibility of the hazard. As compensation claims filed by miners multiplied, the attention of legislators and federal officials was aroused.

The next step in the chain is the demonstration of concern by the government enforcement agency. It is represented as a product of official concern. Charged with a mandate from federal agencies to solve the problem of excess radiation, local caretaking agencies embarked on a control program of inspections and sanctions.

Government agency concern, in turn, directly influenced the expenditures made by mining companies for ventilation. Faced with frequent inspections and costly sanctions, companies increased their outlays for ventilation. This was abetted by the transformation of the industry to a large-scale and stable one. Stable operators were more able financially to install fans and other ventilation equipment than the transient speculators that had mined uranium in the early days of the industry.

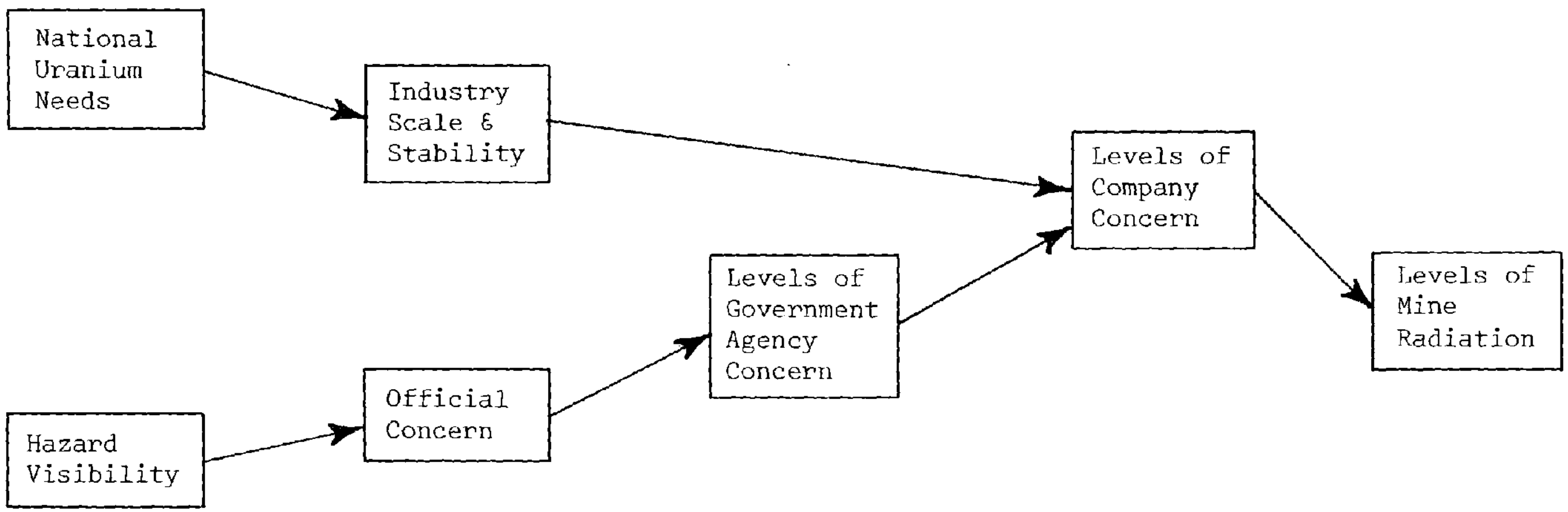
At last, increased company expenditures, a byproduct of vigorous government regulations and the changed structure of the uranium mining industry, reduced radiation levels in mines.

USING PATH ANALYSIS

To test the efficacy of this model, statistical techniques were needed which would permit causal inference. One such technique is path analysis. It amounts to a series of multiple regressions sensitive to the direct and indirect influence of variables on each other.

Figure 11

A Revised Model of the Process of Solving the Hazard of Excess Radiation in Mines



In addition, it takes account of all other influences on the variables in question, e.g., causes not recognized or measured, errors of measurement, and violations of assumptions basic to the technique. As Duncan puts it,

> An important feature of this kind of causal scheme is that variables recognized as effects of certain antecedent factors may, in turn, serve as causes for subsequent variables. For example, U is caused by V and X, but it in turn influences W and Y. The algebraic representation of the scheme is a system of equations, rather than the single equation more often employed in multiple regression analysis. This feature permits a flexible conceptualization of the modus operandi of the causal network. (120)

In order to use this technique properly, however, certain assumptions must be met. (121) The procedure requires a set of variables which have been measured on an interval scale. These variables are assumed to be related to one another in a linear, additive fashion. Certain variables are presented as linear functions of others. These are dependent variables. The remaining variables are assumed to be given and termed "independent." Each "dependent" variable must be regarded explicitly as "completely determined by some combination of variables in the system." Where such complete determination is absent, a residual variable must be introduced which is itself uncorrelated with any relevant, independent variable. In other words, it is assumed that there is no variable external to the model which is simultaneously affecting any two variables in the model causing a spurious correlation.

The technique of path analysis also requires one way causation among variables; feedback effects are not tolerated. Variables in a path model are assumed to have equal variances (homoscedasticity), and dependent variables in a path model are presumed to be uncorrelated with one another, or only weakly so (low multicollinearity).

The problems with path analysis in this study relate almost entirely to the assumptions of low multicollinearity. As Table 35 shows, the several measures of organizational concern and the measure of radiation levels are substantially intercorrelated with one another; the same intercorrelation prevails between the independent "historical" variables.

There are at least two reasons why. Since the information used in deriving the correlation matrix was obtained from various annual directories, it was aggregated and averaged. There is a possibility that such aggregation compromised the independence of various variable measures and produced elevated correlation coefficients. On the other hand, aggregate information and yearly means have been applied in path analytic models. In and of itself, such information should not lead to high interdependence. A second explanation is the intrinsic interrelatedness of the phenomenon at hand. Changing needs for uranium, the visibility of the hazard; the structure of the industry and government policies tracked closely with the onset of organizational concern. In turn, such concern was associated with declines in mine radiation. Given such a state of affairs, high intercorrelations are understandable. The problem may lie with the multiple regression technique itself. It is unable to handle highly interrelated phenomenon.

In any event, the high correlations among dependent variables obtained in this study do violate an assumption of the analysis. On the one hand, "the value of using path analysis may be seriously undermined if ...(its) basic assumptions are violated substantially;"[122] on the other hand there seems to be no necessity for each assumption to be met without deviation. The analysis will proceed despite the problems of multicollinearity regarding all results with healthy skepticism. The aim is not to test a causal model, but to suggest a chain of causality supported by the evidence at hand.

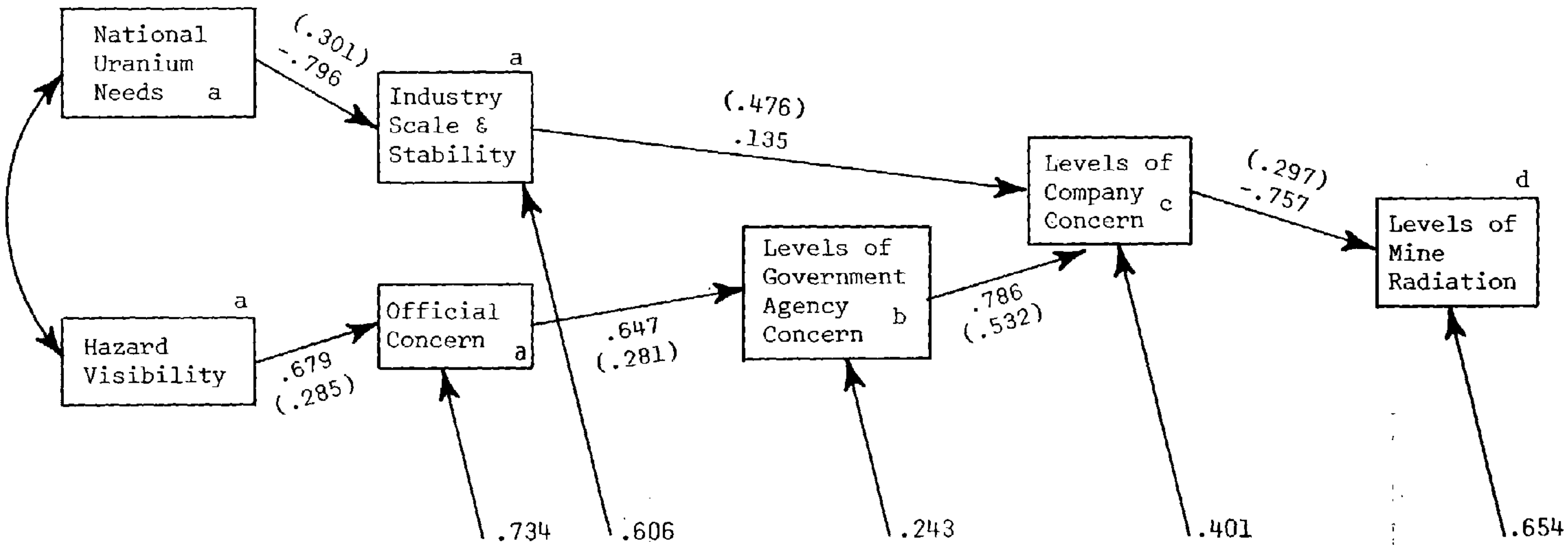
It should be noted that other assumptions of path analysis have been largely met in this study. All variables have been measured in terms of an interval scale; none is ordinal or nominal. Scatter diagrams and graphs of the project variables suggest that the assumptions of linearity and homoscedasticity are fairly well met. To the extent that a thorough historical search can be relied upon, it here uncovered no variable external to the model capable of causing a spurious correlation; thus the assumption of residuals uncorrelated with any independent variable seems to have been met. To meet the assumption of one way causation, a slightly different technique was used. The information collected for each variable was keyed to that variable's respective temporal role in the hypothesized chain of causation. Thus, data for the historical factors (national uranium needs, hazard visibility, industry structure and official policy) relate to the earlier time period, e.g., year one. Measurements of organizational concern were drawn from an intermediate time period, e.g., year two. Radiation information relates to the latest time period, e.g., year three. Since the total time period covered in this analysis is only twenty years, however, such staggering of the variable measures does reduce the number of "observations."

REVISING THE MODEL

To test the efficacy of the model presented in Figure 11, path coefficients were computed for all hypothesized relationships. The coefficients and standard errors associated with each relationship are presented in Figure 12. In most cases, the derived coefficient is greater than twice its standard error. This indicates that the coefficients are significantly different from zero. The exceptions to this are the paths leading from "Industry Scale and Stability" to "Levels of Company Concern" and from "Levels of Government Agency Concern" to

Figure 12

Path Model I of the Process of Solving the Hazard of Excess Radiation in Mines



Standardized Regression Coefficients
and
(Standard Errors)

* Information conbined from four different time points. "Historical Variables" (a) assembled at time point #1 (e.g., 1949, 1950...); Government Concern (b) at time point #2 (e.g., 1950, 1951...); Company Concern (c) at time point #3 (e.g., 1951, 1952...); and Radiation Levels (d) at time point #4 (1952,1953).

"Levels of Company Concern." The former path has a coefficient of 0.135 and a standard error of 0.476. In the latter case, the path is 0.786 and the standard error is 0.532. This suggests that the scale and stability of the industry was not an important factor in the generation of concern among companies mining uranium. Since the path coefficient between government agency concern and company concern was large, it was decided to alter the model to enhance the role of the government agency. It was postulated that the demonstration of concern by the government enforcement agency was a product of both official concern and industry scale and stability. The transformation of the industry to a large scale and stable one aided the program of government inspections and sanctions since stable operators were more readily supervised than the transient speculators that had mined uranium in the early days of the industry. The model was revised accordingly and path coefficients were recomputed. See Figure 13.

The revised model appears to handle the process of reducing radiation somewhat better. Paths between "Industry Scale and Structure," "Levels of Government Agency Concern" and "Levels of Company Concern" are both strong and significantly different from zero. The expenditures of mining companies for ventilation, thus, may be attributed solely to the activities of the government enforcement agency.

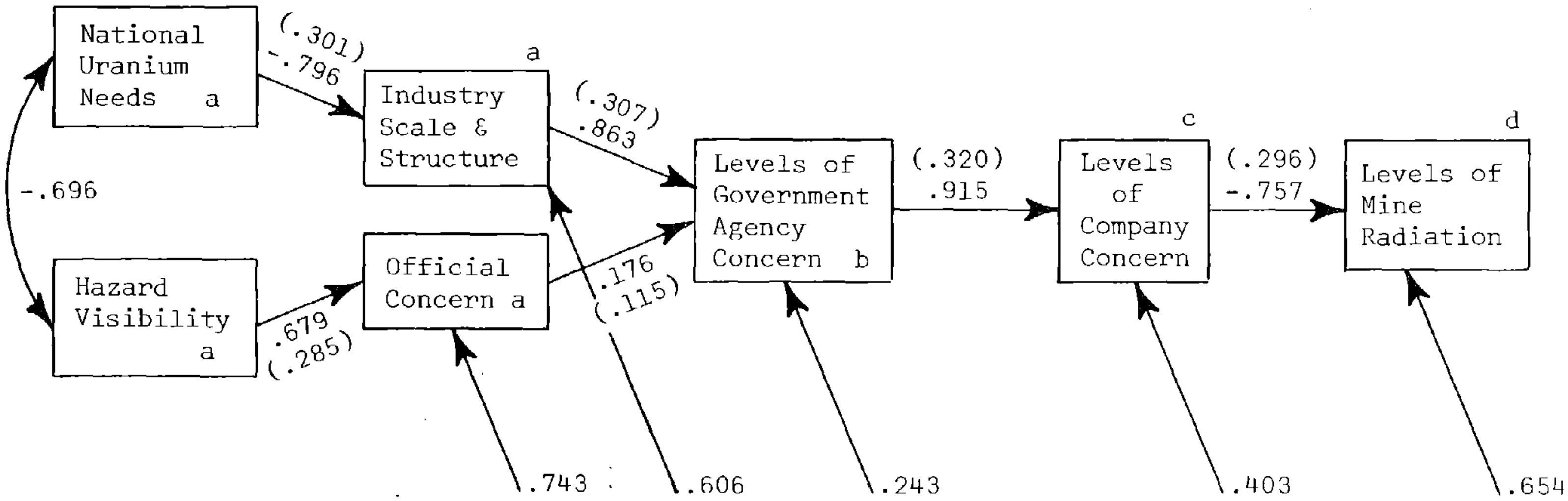
The path leading from "Official Concern" to "Levels of Government Agency Concern," however, is not significant. It has a coefficient of 0.176 and a standard error of 0.115. This suggests that the attention of federal officials and legislators was not critical in the initiation of inspection activities by the state enforcement agency. This conclusion is consistent with an analysis of the correlation coefficients between the variables representing historical factors and government agency concern. (See Table 35) While the correlation coefficients between national uranium needs, hazard visibility, industry scale and stability and government agency concern were -0.747, 0.945 and 0.959, respectively, the coefficient between official concern and government agency concern was 0.647.

In light of this finding, the model was once again revised. This time, "Official Concern" was excluded. Instead, it was postulated that evidence of the hazard itself directly influenced regulatory activities by the government agency. (Hazard Visibility ⟶ Levels of Government Agency Concern.) All path coefficients were recomputed for the new set of postulated relationships. They are presented in Figure 14.

The revision appears to be warranted. Although the coefficient for the path between Hazard Visibility and Levels of Government Agency Concern falls below the level required for statistical significance, (coefficient = -0.417, standard error = -.240; requisite coefficient for significance =0.480), it is only slightly below. All other paths of influence postulated in the model are strong and significantly different from zero.

Figure 13

Path Model II of the Process of Solving the Hazard of Excess Radiation in Mines

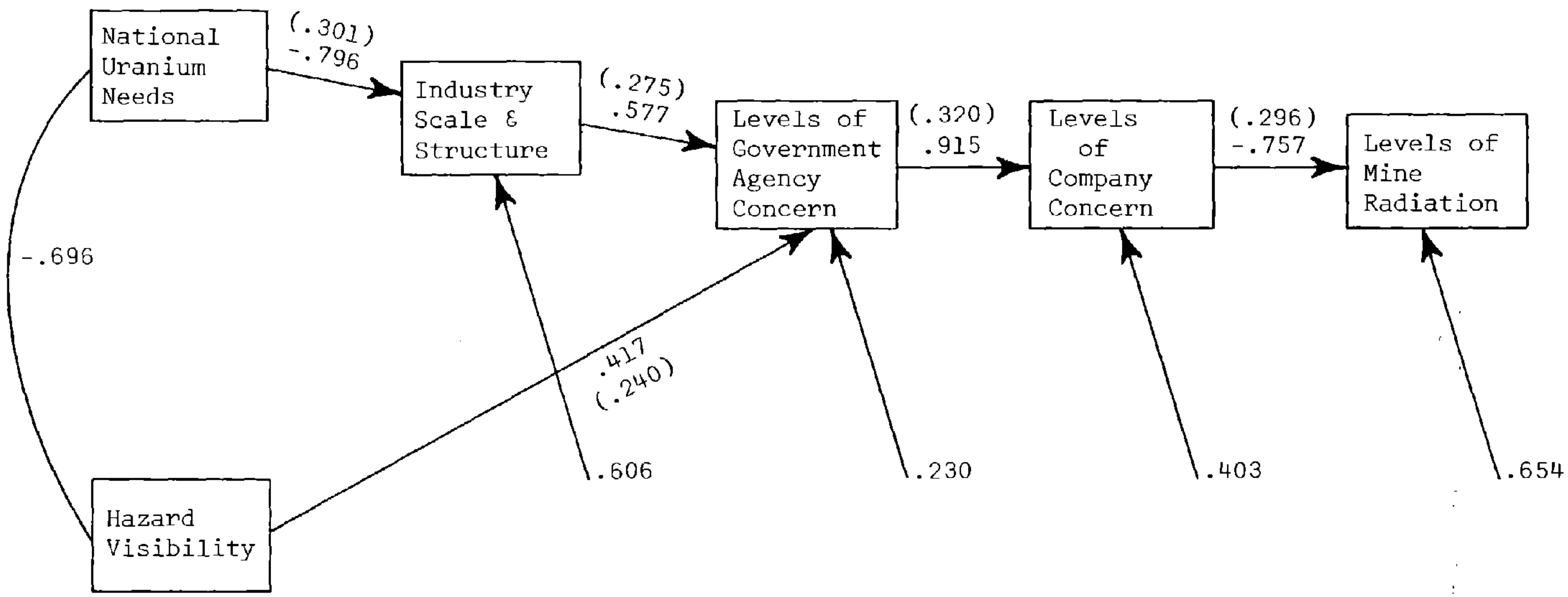


Standardized Regression Coefficients
and
(Standard Errors)

* Information combined from four different time points. "Historical Variables" (a) assembled at time point #1 (e.g., 1949, 1950, 1951...); Government Concern (b) at time point #2 (e.g., 1950, 1951, 1952...); Company Concern (c) at time point #3 (e.g., 1951, 1952, 1953...); and Radiation Levels at time point #4 (e.g., 1952, 1953, 1954...).

Figure 14

Modified Path Model of the Process of Solving the Hazard of Excess Radiation in Mines



Standardized Regression Coefficients
and
(Standard Errors)

Thus, the reduction of radiation in mines directly depended upon the expenditures mining companies made for ventilation equipment. Such expenditures were themselves a product of the increased vigilance of the government enforcement agency. Government inspections increased as the industry changed from a speculative one composed of transient operators to one composed of stable, large-scale companies. At the same time, this transformation was itself a product of changing levels of demand for uranium ore. Government inspections also depended upon the visibility of the hazard. As greater numbers of compensation claims were filed by afflicted miners and their families, the volume of regulatory activities surged.

Chapter 8

CONCLUSIONS

SUMMARY

This has been a case study of the organizational actions which ultimately solved an industrial health hazard. It has shown that the greatest reductions in hazardous radiation in mines followed inspection and sanction activities by a state enforcement agency. Continual surveillance by government agents and the imposition of costly penalties against operators who violated radiation codes led companies to invest the necessary capital for equipment capable of reducing underground radiation.

It has also been shown that a variety of non-technological barriers prevented an early solution of the problem. National needs for uranium ore, the invisibility of the radiation hazard and the unstable and transient nature of the early uranium mining industry all distracted attention from the damaging effects of radiation. When needs were great; the industry transient and small-scale; and the tangible results of bodily exposure to radiation invisible; the regulatory activities of those in a position to do something about the hazard were modest. As demands for the ore waned; as the industry became more large-scale and stable; and as lung cancer damage to miners began to make itself felt through deaths and compensation claims; the government adopted steps to stem the tide of death and disease, including a stepped-up program of inspections and sanctions.

POLICY IMPLICATIONS

More than 12,500[123] people are annually killed in accidents that are job-related and an additional 2.2 million[123] suffer temporary disabling injuries in the course of their job activities. Untold numbers suffer deteriorating health as a result of harmful work environments. It is estimated that 100,000 lives are claimed annually by work-related disease.[124] Frequently, such diseases do not explode until many years after exposure to harmful materials on the job. Recent evidence on occupational disease also suggests that health imperilment goes beyond the worker himself. The wives and children of asbestos workers, as well as anyone who works in the general vicinity of asbestos, for example, share elevated risks of mesolotheliona, stomach and lung cancer.[125]

Logically, the problems of industrial injury and industrial disease are distinct. On the job exposure to toxic materials like radiation, beryllium, and lead often occurs without any knowledge on the part of the worker that it is occurring. The harmful effects of such exposure are slow to manifest themselves and the worker frequently becomes aware of an industrial pathology only when it is irreversible. Nor does the worker know that the contamination can often be controlled with technology or innovative work procedure. The prevention of industrial accidents, on the other hand, is occasionally within the realm of the worker's control. On-the-job injury may sometimes be caused by his own carelessness. Unlike the worker who inhales unknown chemicals, the worker who engages in foolish and slipshod behaviors is or should be aware of the possible consequences.

Despite the logical distinction between industrial injury and industrial disease, a similar psychological framework has been adopted to explain the incidence of both.[126] In recent years, during which there has occurred the first recognition of occupational diseases, the long tradition of blaming the worker himself for on-the-job accidents has been generalized to the case of on-the-job diseases. The upshot has been that the causes of both industrial diseases and industrial accidents have been frequently attributed to the actions of the worker who becomes a victim. This psychological orientation to the problems of industrial disease and accidents has received additional support from some social scientists.

Numerous studies of miners blame the exceptionally high <u>accident</u> rate in mining on the carelessness of miners on the job.[127] One writer sees miners as fatalistic, apathetic and anxious about their masculinity.[128] These traits, it is argued, lead them to reject safety equipment and to refuse to adopt prudent behavior. Another writer sees the rejection of safety equipment by miners as a denial of the truly threatening nature of their work environment.[129] The miner, the argument runs, is more psychologically comfortable if he denies the need for safety equipment than if he admits that his physical surroundings are dangerous by requesting and using such equipment. A social worker views the miner as a resigned, apathetic and willing victim.[130] And other refer to the miner's high degree of "external locus of control"[131] or fatalism as causing an unwillingness to consider the possibility of accidents.

Individual carelessness has also been held up as a cause of industrial <u>diseases</u>. In smelting and pottery-glazing industries, for example, disease was blamed on the worker's handling of food and chewing tobacco without first washing his hands. This prejudice persisted despite the documentation of dangers arising from the lead infused atmosphere.[132]

A similar investigation into the hazards of asbestos was conducted by the journalist, Paul Brodeur. He unearthed a general unwillingness on the part of industry and government officials alike to associate conditions of the workplace, over which the individual worker exercised no control, with occupational disease, despite voluminous documentation of such an association. In response to Brodeur's questions concerning the connections between disease and exposure to asbestos fibers, for example, a medical consultant to the asbestos industry noted that cigarette smoking was a cause of asbestosis although available information indicates a limited effect of cigarette smoking on lung scarring.[133]

As has been seen, the tendency to blame the worker for occupational disease was also common in the uranium situation. Numerous respondents to interviews administered in 1973 persisted in stressing the importance of the smoking, drinking and eating habits of the uranium miner to explain his exceptionally high incidence of lung cancer. These arguments were offered many years after the Public Health Service had documented that "low living" could not be the cause of elevated rates of disease among the population that mined uranium.

According to the traditional point of view which considers both industrial accidents and diseases as caused by worker carelessness, the remedy for hazardous working environments lies in the education of the employee in safety procedures.[134] Thus, government and company efforts to improve the health and safety of the workplace frequently concentrate exclusively on safety training sessions, safety posters and safety slogans. Plants dealing with toxic materials post signs urging workers to wash their hands before eating. Many corporations give Green Stamps to workers with outstanding safety records. The extent of this mentality, albeit not in an industrial disease setting, is illustrated by the New York manufacturing plant that has adopted "Operation PIG" (Prevent Injury and Grime), whereby the department with the poorest safety record over a given period of time must take care of a live pig until some other department compiles a worse safety record and thus qualifies for custody of the pig. A department with an accident free record over a given period of time also wins a pig, but in the form of a roast pork dinner.[135]

Official, high-level policies on health and safety matters also tend to reflect this emphasis on individual carelessness. During the 1969 House Hearings on the Occupational Safety and Health Act, the President of the National Safety Council testified that

> ...with all due respect to the desirable effects that the promulgation and enforcement of standards can have on the nation's occupational health and safety performance, we must recognize that the successes that have been achieved so far are largely the result of the dissemination of safety information, the implementation of proven counter measures and education and training of employers and employees. (136)

A cornerstone of the new Occupational Safety and Health Act is the education of careless workers. Since it became law on December 29, 1970, the program has included a series of radio commercials, such as the following:

> Grab a sack of safety, let it fill your bag,
> Workin' where you're careless is a hurtin' drag, yeah,
> Take a sec and check around your own two feet,
> Then sing a song of safety...
> It's a hap, happy beat, Yeah! (137)

The worker-carelessness argument, however, has a very shaky basis in reality. Some accidents are obviously causally related to the unsafe behavior of the worker. On the other hand, many others are undoubtedly caused by factors beyond the control of the worker: work procedures; equipment breakdowns; and unsafe practices by management. Moreover, industrial disease are generally caused by pollutants of which workers are ignorant altogether.

A Bureau of Mines survey of 270 accidents in 1961 concluded that 50.7% resulted from circumstances beyond the control of the individual but within the range of supervisory responsibility.[138] A similar study in the chemical industry concluded that only a slim minority of accidents (8%) could be attributed to human carelessness. On the other hand, 44% were due to faulty equipment and 40% to faulty methods of operation dictated by management.[139]

A study of British factory deaths caused by inadequate design of safety devices in machines has noted the legislative failure to enforce safety provisions for machine design. Although laws did exist specifying design requirements, the purchasing of machines was left to the discretion of individual factory management. It was found that cheaper and faster models with high sales appeal were frequently purchased at the expense of safety considerations.[140]

Even the world's most hazardous occupation is less dangerous in certain legislative and organizational climates.[141] A comparative study of mining accidents in Europe and America concluded that the system of private ownership and operation of American mines and the ensuing emphasis on profit and production was responsible for the extreme hazardousness of United States coal mining. The American coal mining industry is simultaneously the most productive and dangerous in the world. Its fatality rate between 1965 and 1969 was at least twice that of its European counterparts although the mines in Europe are deeper and inherently more dangerous. The differences appeared to stem from the often costly safety procedures adopted by the European industry and neglected in American mines. These include the Longwall technique of mining, sophisticated methods of detecting lethal gas and alerting endangered men, fire blockades and elaborate watering systems to reduce coal dust. As one scientist familiar with the United States and European coal mining industries has put it:

> The difference is that while our management people are also striving for production and profit just as their counterparts are in the United States, the push to produce is not as hard and the punishments for violating safety standards are a bit swifter, so our people aren't as quick to break the law or endanger a man's life. (142)

It is in connection with the mounting evidence that worker injuries and diseases are beyond the control of the victim that the findings of this study are relevant. The reduction of hazardous radiation in mines, it was found, was due to the relentless inspection activities of government watchdog agencies. Faced with costly penalties for violating mandatory standards imposed by government agencies, mining companies made the necessary expenditures to implement ventilation equipment. As a result, radiation levels dropped and the health of the miner improved.

This study suggests that reduction of hazards beyond the control of workers can only come through strict government supervision of industry. To the extent that legislation designed to solve health and safety problems includes strong regulatory provisions, it promises to be effective in achieving the goal of safer work places. On the other hand, legislation which fails to establish strong regulatory mechanisms promises to be ineffective in reducing industrial health hazards. In this light, the new Occupational Safety and Health Act is disappointing. The Act provides no mechanisms for the mandatory and regular inspection of workplaces and where inspections do occur, the employer is notified in advance. In the first ten months of operation the Labor Department proposed penalties totalling $1,711,995 for 75,864 violations--an average proposed fine of $23 per violation.[143] If the predictions of this study are borne out, the Act as it is currently constituted will accomplish little in the way of achieving safer and healthier working conditions for the nation's labor force. Until and unless industry is relentlessly inspected and severely punished for violations of health and safety codes, hazards beyond the control of the worker will persist and the worker will continue to suffer.

GENERAL IMPLICATIONS

Although the study is a case study, and, as has been argued, has implications for policies that aim to improve the health and safety of workers on-the-job, it also has practical applicability to a large number of other substantive and theoretical concerns. Neither its findings nor its methodology and theoretical underpinnings are necessarily bounded by its substantive content.

First as to the general relevance of the theory and methodology underlying this study to the broader issue of how complex societies solve their problems. The basic approach and methodology used to examine the lung cancer epidemic among uranium miners went far beyond the specific factual parameters of the problem situation. Rather, both theoretical approach and methodology sought to portray the problem-solving process in terms of its two analytical stages, the goal-formulation and the goal-realization stage. Within each stage the model took account of a variety of general economic, political and legal factors; and in addition it took account of various interorganizational influences which shape the behavior of organizational problem-solvers. The analytical constructs used in the process of developing a model of the problem-solving process stand on their own feet. Others can apply them to problem-solving situations involving (a) a particular societal problem (b) organizational actors and (c) historical and organizational pressures generated in the relevant societal climate.

As to the study's substantive relevance, a brief effort will be made to suggest how similar problem-solving dynamics are at work in numerous social problem areas other than uranium.

Trade imbalances, consumer shortages and financial crises are varieties of national needs with the potential to affect the process of problem-solving. The asbestos situation provides an obvious and analagous example.[144] There, the sluggishness that characterized government and industry response to the hazard of asbestos dust was in part due to the dependence of the national economy on critical asbestos products. e.g., insulation materials. There are currently no near substitutes for asbestos; in addition more than four million jobs in this country deal directly or indirectly with asbestos. National needs have also featured in recent moves to lower the permissible threshold on the sulfur content of coal that is burned in the atmosphere. Despite voluminous documentation of the detrimental effects of sulfur pollutants, the national fuel crisis distracted attention away from these humanitarian considerations.

Hazard visibility, which was shown to feature strongly in the decision to control underground levels of radiation, finds analogues in the casual use of X-rays, pesticides, sedatives and other drugs and chemicals which were or are used without restraint despite the warnings of a variety of scientists and consumer advocates.[145] Predictably, the promiscuous use of such materials tends to cease only in the wake of tragedies of major proportions: a series of hideous birth deformities; elevated mortality from radiation exposure; or the contamination of plant and animal life with toxic pollutants that ultimately make their way into the human food chain.

Industry structure has been also shown to feature in a variety of problem-solving situations other than uranium. Ralph Nader and his associates weight it heavily in their studies of consumer ills. Many economists, also, see industry structure as a determinant of price levels, inflation and product quality. Nader himself goes so far as to blame excessive corporate concentration and the attendant decline of competitive capitalism for polluted air and water.[146]

The languid pace in the formulation of official, upper-level policies concerning the radiation hazard characterizes a great number of problem situations. It characterizes so many in fact that Professor K. C. Davis has offered a legal scholars' argument in favor of abandoning any search for policy guidance for problem-solving from legislative bodies.[147] According to Davis, Congress has so typically and consistently failed or refused to specify standards when it delegates authority to administrative agencies that it no longer should be depended upon to do so. More effective administration, says Davis, would be achieved by independent administrative agencies with court involvement in the elaboration of standards and administrative rules. In the uranium situation, where Congress neglected to initiate any legal action, Davis' diagnosis hits home.

THEORETICAL IMPLICATIONS

In addition to the utility of the problem-solving famework for other substantive issues, the study suggests a theory of problem-solving in complex societies. The central elements of the theory are so-called "historical" factors that feature in problem-solving and the impact of interorganizational influence on problem-solving.

First as to the role of "historical" factors. Sociological literature on complex organizations notes that a variety of technological, legal and economic factors affect problem-solving in its goal-formulation and goal-realization stages. None is singled out as particularly important. The findings of this study permit the observation that such factors are not equally important in problem-solving. For example, technology to handle the problem of excess radiation in mines was available throughout the problem-solving period. But technology did not play a critical role. The impact of official, upper-level government agencies was also extremely modest. This appears to cast some doubt on the importance of legal considerations in the problem-solving context.

What emerges from this study is the overriding significance of factors in problem-solving that can loosely be classified as "economic." National needs, the visibility of the hazard (measured in terms of compensation claims), and the structure of the industry all have had a primary bearing on profit and loss statements. National needs reflects the supply and demand picture for a product or service. Hazard visibility enters the balance sheet through the added costs to industry of compensating victims of an occupational hazard. Industry structure reflects the financial capability of firms and thus the ease with which they are able to withstand the costs of implementing equipment to reduce a hazard.

The problem-solving process bore the imprint of an economic calculus designed to minimize costs. Only when the demand for uranium fell, the number of compensation claims rose and the industry changed to one composed of wealthy, large-scale firms that could afford to provide effective ventilation equipment did the economic calculus yield to the health interests of the voiceless miners. The study provides a confirmation of the frequent observation that the interests of the unorganized come to the fore only when their ills are translated into monetary terms. It suggests that the varieties of insults to the environment and the individual that occur as a byproduct of industrial processes will receive the audience they merit only when they cease to be borne inaudibly by the general public and enter the equation of economic gain or loss. This study has shown that humanitarian interests are articulated effectively only when economic considerations permit. Thus, to explain the evolution of problem-solving strategies, the attention of policy makers and scholars may focus to advantage on the economic degrees of freedom that characterize organizational contestants rather than on other theoretically interesting but practically trivial variables.

The second component of the theory of problem-solving offered here is that of interorganizational influence. As has been noted in Chapter IV, the literature on organizations has rarely gone beyond the stage of acknowledging that organizations affect one another in the course of acting with respect to problems. Although sundry writers have argued that organizational goal setting is affected by competitive, bargaining, co-optative and coalitional relationships, they have failed to specify the precise modifications in organizational behavior introduced by such relationships and the consequences of such modifications.

This study goes one step further in demonstrating the implications of a form of organizational influence. It will here be referred to as interorganizational coercion. Interorganizational coercion is used to mean the process by which organization A forces the leadership or policy determining structure of organization B to accomodate its (B's) behaviors to the wishes of a dominant organization (A) which can threaten the former's (B's) stability or existence. This implies that interorganizational relationships are characterized by conflict and imbalance. A dominant organization succeeds in achieving its ends; a subservient organization is forced to accomodate.

In this study, coercion may be seen in the relationship between uranium companies and government enforcement agencies. As such, it is a two-way street. Prior to the initiation of regulatory activities, including inspections and costly sanctions, the expenditures of the largest mining companies for ventilation were stable and minimal. During this period, through effective lobbying or negotiations, it is possible that the mining companies in effect were able to "coerce" government into ignoring the health hazards confronting underground miners. As one interviewee put it

> You have to remember that the mining industry is an old industry which has a history of limited regulation and a limited history of outside control. Ten years ago you just didn't jump in with regulations and orders and rules. The (mining) lobbies had more impact on the federal and state level. On the state level, of course, they still have a big impact, but it was really only in the last five to ten years that people started saying that life and not cost is the overriding factor. (148)

Then government becomes the coercer. Once government regulatory activities were initiated, the expenditures by mining companies rose. This was crucial to the solution of the problem of excess radiation. Radiation levels in mines began to drop and the threat of imperilment to the health of workers diminished.

It is also worth noting that the absence of union coercion probably caused the deterioration of the health picture of the uranium miner. It seems likely that if unions had overcome the practical and financial barriers that made the unionization of uranium miners uneconomical and difficult, they would have exercised the needed coercive force on management to achieve a healthy environment for miners sooner.

Taken together, economic considerations and interorganizational coercion constitute the backbone of a theory of problem-solving among organizational actors. The theory asserts that problem-solving is determined by the economic interests of the organizational actor which can coerce its opposition. Thus, industry's interests will prevail to the extent it can head off coercion from government and union sources. Similarly, the worker will benefit to the extent that his union can coerce management to comply with its demands. As for the interests of the general public, the consumer and the unorganized worker, their hope lies in the independent advocacy actions of an enforcement agency which can coerce companies and unions whose actions threaten the public interest. Along with numerous other accounts, this study reiterates the urgent necessity for regulatory agencies that are uncompromisingly independent. At minimum, this requires the promotion and policing of industry to be separated. In point are the words of the Atomic Energy Commission's first chairman, David E. Lillienthal, on the dual role of the Atomic Energy Commission as both industry promoter and regulator:

> It is unfortunate that the AEC is not only the overall protagonist of a nationwide atomic power program; it is also the body that must sit as judge of the safety to the public of the design, mode of construction, and site of particular atomic power plants. In short, the AEC, as a general promoter of atomic power, must also decide the quaisi-judicial issue of whether a license is issued. With a word of goodwill and integrity and technical competence on the part of the AEC, how well is the public protected by this dual and conflicting role? (149)

Responsible representation of the public interest requires that independent regulators pursue the exclusive task of overseeing industry in the interests of the public.

APPENDIX A

CHRONOLOGY OF EVENTS IN THE HISTORY OF THE RADIATION HEALTH HAZARD OF URANIUM MINING AND ITS CONTROL: 1940-1972

1940 Recommendation by Evans and Goodman that radon exposures to man should not exceed 10 picocuries per liter of air.

1947 A.E.C. samples several uranium mines. It finds radon concentrations comparable to those recorded for Central European mines where high lung cancer rates were reported.

1949 Several meetings of officials from Colorado, AEC, research groups, and U.S. Public Health Service, concerning health hazards in uranium mines; conclude there is possibility of "severe internal radiation hazards in many operations."

1949 Researchers meet with representatives of industry and inform them of environmental findings; U.S. P.H.S. formally invited to conduct study of uranium mines and mills and workers in them.

1950 Field work begins in P.H.S. studies of uranium mines and mills and health of uranium workers.

1951 Researchers identify principal hazard as internal alpha radiation to lungs from radon daughters attached to dust.

1951 Industrial Hygiene Engineers visit principal mining companies to inform them of study findings. No effects among American miners yet found but mine ventilation stressed in light of European experience. P.H.S. continues medical and environmental surveys.

1951 Conferences held for official agency representatives and mining companies to inform them of environmental findings with discussion of methods for measuring radon and its daughters in mines.

1952 Meetings with state health officers on future of P.H.S. study. Extensive environmental survey work begun.

1953 Medical examination of miners, environmental mine surveys and mortality study of non-uranium miners begun (resisted by large mining companies and during 1953 no arrangements could be made with any of them). Utah State Health Department surveyed all mines operated in Utah and U.S. Bureau of Mines conducted some environmental measurements of mines located on Indian Land.

1953 Conference of A.E.C., N.C.I., P.H.S., and Colorado State Health Department; agreed that enough environmental evidence existed to define problem and that control was likely to come only with extensive evidence of injury to American miners. A long term epidemiological study was thought necessary to do this.

1953 Publication of method for measurement of radon daughters in air.

1954 Publication of reports on control of radon daughters in mines by ventilation.

1954 Medical teams dispatched to remote mining areas in an attempt to include all uranium miners in an epidemiological study. Environmental survey work continued.

1955 Seven-state Conference on Uranium Mining Health Problems held in Salt Lake City, Utah. Agreement reached on standard for atmospheric concentration of radon daughters (300 pico curies per liter of air) but as practical consequence

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little improvement noted. Census of uranium miners begun, and continued annually until 1972.

1956 First practical field method for measurement of radon daughter concentrations in mine air published.

1956 Uranium mines in South Africa and Belgian Congo visited to explore the possibility of doing mortality studies on their workers who had been exposed to radon and radon daughters for many years. Records on negro workers found to be inadequate.

1957 Second extensive medical study conducted.

1957 Publication of book by P.H.S.: "Control of Radon Daughters in Uranium Mines and Calculations on Biologic Effects." This officially proposed a radon daughter standard of 1 Working Level as 1.3 x 10^5MEV/L of potential alpha energy.

1958 Study reveals that four uranium miners died of lung cancer, not statistically significant. Some state mine inspectors feel they cannot require control measures on the basis of available data. New Mexico State Health Department decides the data justifies enforcement of ventilation measures and this was required in statutes.

1959 Mine surveys and medical work continue. Joint Committee on Atomic Energy Hearings held on Workmen's Compensation and Atomic Energy. U.S. P.H.S. prepares testimony on uranium mining health hazard. Seminars held to instruct mine personnel in techniques of radon daughter evaluation and control.

1960 Third general medical examination conducted. Life table analysis of mortality experience of study group (1950-1959) reveals a significant excess of lung cancer deaths among men with three or more years uranium mining. American Standards Association makes recommendation that maximum permissible concentration of radon be set at 1 Working Level as defined by P.H.S.

1960 Secretary Fleming (DHEW) holds meeting of Governors of uranium producing states to discuss health hazards of uranium mining and P.H.S. findings.

1961 As a result of Governors' Conference, Colorado obtains funds and initiates a control program. Inspection and control work added to duties of mine inspectors in Utah, Wyoming, New Mexico. Only Arizona lacks such program. Salt Lake meetings held with operators to discuss P.H.S. findings. Wyoming and Utah Mine Operators' Associations respond with disbelief.

1962 Congress appropriates $50,000 for continuation of P.H.S. uranium studies, and additional funds sought from other sources. Annual sputum cytology program begun in an attempt to detect early stages of cancer development.

1963 Continuation of medical, environmental, census, and mortality analysis. P.H.S. findings presented at 1963 Symposium on Radiologic Health and Safety in Uranium Mining and Milling, Vienna, Austria.

1964 Study of lung cancer histologic types show predominance of one type which is peculiar among uranium miners.

1965 Study demonstrates existence of exposure-response relation between airborne radiation and lung cancer incidence. Smoking excluded as confounding factor in that relationship.

1966 Federal Radiation Council begins study of Radiation Hazards in Uranium Mining.

1966 Passage of Federal Metal and Nonmetallic Mine Safety Act which extends federal authority over radiation control in uranium mines.

1967 Hearings, Joint Committee on Atomic Energy, Radiation Exposure of Uranium Miners, Washington, 1967.

1967 Secretary of Labor, Willard Wirtz promulgates 12.0 W.L.M. per year standard (effective immediately) with gradual transition to 4.0 W.L.M.: Johnson administration authorizes January 1, 1971 as date for enforcement of 4.0 W.L.M.

1967 Federal Radiation Council issues Report No. 8. Guidance for the Control Radiation Hazards in Uranium Mining.

1968 National Academy of Sciences - National Research Council reviews the data on uranium miners. It concludes that uranium miners should not smoke cigarets and their radon daughter exposure should be kept low.

1969 Interagency Uranium Miner Review Group created to study new standard. Joint Committee on Atomic Energy holds hearings to postpone 4.0 W.L.M. Termination of A.E.C. contracts with uranium suppliers marks end of Department of Labor authority over radiation conditions in mines.

1969 I.U.M.R.R.G. requests postponement of 4.0 W.L.M. standard to continue its study which is granted by President Nixon for a period of six months. Federal reorganization results in Federal Radiation Council being dissolved and its duties transferred to the Environmental Protection Agency.

1969 P.H.S. given additional money to update and evaluate mortality study of uranium miners.

1970 National Academy of Sciences - National Research Council endorses the new P.H.S. study.

1970 The Environmental Protection Agency recommends the 4.0 W.L.M. standard and Bureau of Mines abdicates its standard setting responsibilities and announces it will enforce radiation standards recommended by the E.P.A.

1971 Publication by P.H.S. of Monograph "Radon Daughter Exposure and Respiratory Cancer: Quantitative and Temporal Aspects."

1971 The 4.0 W.L.M. goes into effect July 1971 as opposed to January 1971 and two days later a petition for Variances from the maximum standard is published in the Federal Register. Secretary of Bureau of Mines Advisory Committee, Boyle, challenges the P.H.S. data used for setting the new standard.

1972 Hearings on Variances from standard held in Albuquerque. Bureau of Mines rules that it will permit variances to maximum standard under specified conditions.

APPENDIX B

FOOTNOTES

1. H. Peter Metzger. The Atomic Establishment. New York, Simon and Schuster, 1972, p. 118.

2. Frank E. Lundin, Jr., Joseph K. Wagoner, and Victor E. Archer. Radon Daughter Exposure and Respiratory Cancer: Quantitative and Temporal Aspects. U.S. Department of Health, Education and Welfare, Public Health Services, 1971, p. xvii (Preface).

3. Geno Saccomanno. Incidence of Cancer of the Lung Among Uranium Miners: 1954-1972. Unpublished paper.

4. U.S. Congress, Joint Committee on Atomic Energy. Radiation Exposure of Uranium Miners. Hearing, 90th Congress, 1st Session, May-August, 1967. Washington, Government Printing Office, 1967, p. 603. (Testimony by Mr. Duncan Holaday).

5. Woodward and Fondiller. Probable Numbers and Costs Through 1985 of Lung Cancer Cases. Reprinted in Hearings before Joint on Atomic Energy. Ibid., pp. 992-1015. Other estimates put the number of deaths at 529. Ibid., p. 143.

6. Lundin. Op. cit., p. 72, citing G. Agricola, De Re Mettalica, (Basel: n.n. 1597).

7. For a list of references on the Schneeburg and Joachimsthal mining studies see: Ibid., p. 72; see also Duncan Holaday, W. David and H. Doyle. An Interim Report of a Health Study of the Uranium Mines and Mills. (Unpublished paper prepared for the Federal Security Agency, Public Health Service, Division of Occupational Health, and the Colorado State Department of Public Health, May, 1952), p. 4.

8. Robert L. Rock and D. K. Walker. Controlling Employee Exposure to Alpha Radiation in Underground Uranium Mines. Vol. I. Washington, Department of Interior, Bureau of Mines, 1970.

9. Egon Lorenz. Radioactivity and Lung Cancer: A Critical Review of Lung Cancer in the Mines of Schneeberg and Joachimsthal. Journal of the National Cancer Institute. 5:1-5, 1955. Cited in Metzger, op. cit., p. 120.

10. Information supplied by Charles A. Rasor, Atomic Energy Commission geologist, in an address ("Uranium Ores of the Colorado Plateau and Their Procurement") at the San Juan Sub-Section of AIME, Ouray, Colorado, June 23, 1951, p. 1, (speech supplied by Gilman Ritter, Director, Mining Division, Lucius Pitkin, Inc., Grand Junction, Colorado).

11. P. W. Jacoe. Report on the Uranium Study. (Unpublished paper prepared for the Colorado Department of Public Health, Division of Occupational and Radiological Health, August 1964, p. 1, 3; see also H. N. Doyle, Radiation Hazards in Uranium Mining. (Unpublished paper prepared for the U.S. Public Health Service, Occupational Health Program, 1957).

12. Holaday, et. al. Op. cit., p. 4.

13. Jacoe. Op. cit., p. 1. (By early 1949 members of the Colorado State Health Department and the Atomic Energy Commission were agreed on the probability that "severe internal radiation hazards existed in many (mining) operations.") (See also the remainder of the Jacoe report.)

14. Ibid., p. 1.

15. Ibid., p. 2.

16. Ibid., p. 4.

17. Proceedings of the Second United Nations Conference on Peaceful Uses of Atomic Energy. Geneva, United Nations, 21, 62, 1958. Cited in Metzger, op. cit., p. 120.

18. Arthur D. Little Inc. An Assessment of the Economic Effects of Radiation Exposure Standards for Uranium Miners. Commissioned by the Atomic Energy Commission in 1970. The report concluded that somewhat better ventilation measures than those advocated by the French would add only 3% to the cost of mining uranium. This position was also adopted by the National Academy of Science and the National Research Council in their report on the problem in 1971. See also National Academy of Science and the National Research Council. Epidemiological Studies of Uranium Miners. Prepared for the Interagency Uranium Mining Review Group, January, 1971.

19. Jacoe. Op. cit., p. 10.

20. The control of radiation environments in uranium mines was completely a matter of individual state action since the authority of numerous federal agencies had rarely been interpreted to extend to the extraction of uranium ore from the earth. For example, despite the fact that the Atomic Energy Commission was the sole purchaser of extracted uranium ore until nearly 1970 and the owner of more than a dozen uranium mines, it interpreted its regulatory authority to include "source material . . . after removal from its place of deposit in nature." (A.E.C. Commissioner Ramey in testimony before the Joint Committee on Atomic Energy, op. cit., p. 159.) The Bureau of Mines obtained responsibility for setting and enforcing radiation standards with the passage of the 1966 Federal Metal and Nonmetallic Mine Safety Act. Prior to the passage of this act, however, it had not enforcement authorities. The Department of Health, Education and Welfare featured in providing technical assistance in the matter of health standards and the control of health conditions. It included no enforcement measures. (See the Federal Radiation Council,

Staff Report No. 8, "Guidance for the Control of Radiation Hazards in Uranium Mining," September 1967, p. 2). The Department of Labor did have authority to control mining conditions under the provisions of the Walsh-Healy Act of 1936 and the Atomic Energy Commission was advised that it too had authority over mining procedures and methods of operation under the Walsh-Healy Act at hearings held by the Joint Committee on Atomic Energy in 1959 entitled "Employee Radiation and Workmen's Compensation," cited in Metzger, op. cit., p. 130.

21. Jacoe. Op. cit., p. 10.

22. Proceedings of the Governors' Conference on Health Hazards in Uranium Mines, United States Department of Health Education and Welfare, Public Health Service. Denver, December 16, 1960.

23. Ibid., p. 22.

24. "In 1961, as a result of the Governors' Conference, Colorado obtained sufficient funds to employ five additional mines inspectors (D.O.H. supplied about $10,000 additional worth of equipment) and initiate a control program in June, 1961. None of the legislatures in the other states provided funds for additional men so different actions were taken in each case. In Utah, the U.S. Bureau of Mines assisted the state mine inspector in surveying uranium operations and a control program was initiated. The Division of Occupational Health entered into a contract with the New Mexico State Health Department which, among other items, provided funds with which to employ an engineer to assist the state mine inspector in his control program. The control program in Wyoming was added to the regular duties of the mine inspectors. In Arizona, the mine inspector could not obtain authority to regulate exposure to radon and its daughters . . ." Jacoe, op. cit., p. 16-17.

25. Hearings before Joint Committee on Atomic Energy, op. cit., p. 106. (Testimony by Lou Gehrig, Acting Surgeon General, United States Public Health Service.)

26. Statement by Willard Wirtz, Secretary of Labor, in a news release ("Radiation Standards for Uranium Mining") on June 10, 1967, p. 3 and 4. The quality goal widely adopted by the states was 1 Working Level or 12 Working Level Months.

Bureau of Mines Findings in Inspections of 164
Uranium Mines Between April and August, 1967

Working level range	Number of mines	Percentage of mines
0.0 - 0.3	39	23.8
0.4 - 1.0	34	20.7
1.1 - 3.0	41	25.1
3.1 - 5.0	14	8.5
5.1 -10.0	24	14.6
10.1 and over	12	7.3
	164	100.0%

Source:

Testimony of Secretary of Labor Wirtz before the Joint Committee on Atomic Energy Hearings, op. cit., p. 757.

Levels of Radiation in Uranium Mines at which State Mine Inspectors Issue Close Mine Orders, 1967

State	Working Level at which Mine Closed
Arizona	n.a.
Colorado	3.0*
New Mexico	5.0**
Wyoming	10.0
Utah	n.a.

*The American Standards Association recommendations adopted by the State of Colorado recommends that mines be closed when working level readings of 10.0 or more are discovered, however, the state mine inspector applied more stringent standards.

**The New Mexico mine inspector issues an order to correc within 24 hours to all mine operators found to have mine radiation levels of 3.0 working levels or more.

Source:

Joint Committee on Atomic Energy, Hearings, op. cit., p. 355.

27. The Walsh-Healy Act of 1936 provides that no part of a contract with the Government will be performed "under working conditions which are unsanitary or hazardous or dangerous to the health and safety of employees engaged in the performance of said contract." Statement by Secretary of Labor Wirtz, Ibid., p. 3.

28. Secretary of Labor Wirtz testimony before Joint Committee on Atomic Energy, op. cit., pp. 45-93.

29. The 12 W.L.M. standard for radiation exposure was recommended by the International Commission on Radiological Health (1954); the Commonwealth of Massachusetts (1957); the Public Health Service (1957); the American Standards Association (1960); the Atomic Energy Commission (1960) and New York State (1963). Testimony by Dr. Evans before the Joint Committee on Atomic Energy, Ibid., p. 281.

30. When the Environmental Protection Agency ruled to retain the 4.0 Working Level Month maximum exposure standard it emphasized that "the exposure level of concern was not 'low' in the context of usual occupational radiation protection practices; an annual exposure greater than 4 W.L.M. would probably result in a dose in rems (1 WLM=2 rad=6 rems) to the critical tissue of the lung that exceeds occupational radiation standards

generally accepted in the nuclear industry. Federal Register, Vol. 36, No. 132, (July 9, 1971). Indeed, a standard of 1 Working Level would mean future death rates among uranium miners of more than three times the normal death rate from respiratory cancer. Testimony by the Surgeon General, Joint Committee on Atomic Energy, Ibid., p. 61.

31. U.S. Congress, Joint Committee on Atomic Energy. Radiation Standards for Uranium Mining. Hearing, 91st Congress, 1st Session, March, 1969. Washington, Government Printing Office, 1969.

32. "The Interagency Uranium Mining Radiation Review Group (IUMRRG) was established to assist the Federal Radiation Council in its periodic review of radiation protection in uranium mines. It was composed of representatives from agencies of the Council: The Department of Health, Education and Welfare, the Department of Agriculture, the Department of Interior, the Department of Labor, the Department of Commerce, the Department of Defense, and the Atomic Energy Commission. The Surgeon General, U.S. Public Health Service was appointed the chairman," Federal Register, Vol. 36, No. 101, May 25, 1971.

33. Variance: Mandatory Standards Relating to Exposure to Concentrations of Radon Daughters, 57.25 to Part 57, Subchapter N, Chapter I, Title 30, Code of Federal Regulations, described in Federal Register, Vol. 37, No. 124, June 27, 1972. See also the Leglislative Department of the United Steelworkers of America, Legislation . . . and You, Vol. 3 , 1972, pp. 210-223.

34. Based on correspondence between James Boyd, Chairman to the Department of Interior, Secretary's Advisory Committee, and the Secretary of the Interior, November 30, 1971. Memo exchanged entitled "Request for Information on Mine Radiation Standards." "From our investigations of this matter it appears to the Committee that there is at least some question as to the validity of some of the data which have been used in support of conclusions now cited as authoritative . . . ."

35. Jacoe. Op. cit., p. 1.

36. Atomic Energy Commission, Domestic Uranium Production. Circular 5 and Circular 6. Revised, Amended October 9, 1953.

37. William Liscum Borden. There Will Be No Time: The Revolution in Strategy, (1946). Cited in Philip M. Stern, The Oppenheimer Case: Security on Trial. New York, Harper and Row, 1969. Pp. 90-91.

38. Stern. Op. cit., pp. 193 and 196.

39. Statement by Robert Rock, mining geologist, in a personal interview, Denver, Colorado, April 27, 1973.

40. Statement by Norman Blake, director of Colorado Bureau of Mines, in a personal interview, Denver, Colorado, October 17, 1972.

41. Joint Committee on Atomic Energy, Hearings, (1967) op. cit., p. 54.

42. Duncan Holaday, W. David and H. Doyle. An Interim Report of a Health Study of the Uranium Mines and Mills. (Unpublished paper prepared for the Federal Security Agency, Public Health Service, Division of Occupational Health and the Colorado State Department of Public Health, May, 1952. P. 4.

43. Metzger. Op. cit., pp. 115-144.

44. Joint Committee on Atomic Energy, Hearings (1969). Op. cit., p. 128.

45. Statement by Ludwig Koch, Executive at Continental Oil Company, in a personal interview, Denver, Colorado, July 13, 1973.

46. Joint Committee on Atomic Energy, Hearings (1967) op. cit., p. 159.

47. Ibid., p. 243.

48. Ludwig Koch. Op. cit., (personal interview).

49. Joint Committee on Atomic Energy, Hearings (1967) op. cit., p. 260.

50. Ibid., p. 260.

51. Norman Blake. Op. cit., (personal interview).

52. Jacoe. Op. cit., p. 21.

53. Statement by Thomas High, Chief Mine Inspector, District 4, in a personal interview, Denver, Colorado, April 13, 1973.

54. Bureau of Mines, Report for the Years 1950-1951. Denver, Colorado: n.n. 1952.

55. Bureau of Mines. Report for the Year 1970. Denver, Colorado: n.n. 1971.

56. Colorado Mining Association. Policy Statement, 1953.

57. Joint Committee on Atomic Energy. Hearings (1967) op. cit., p. 173.

58. Ibid., p. 47.

59. Ibid., p. 47.

60. Statement by P.W. Jacoe, Colorado Department of Health, in interview with Metzger, cited in Metzger, op. cit., p. 126.

61. Statement by Willard Wirtz, Secretary of Labor, in a news release ("Radiation Standards for Uranium Mining") on June 10, 1967. P. 3-4.

62. Metzger. Op. cit., p. 119

63. Otis Dudley Duncan. From Social System to Ecosystem. Sociological Inquiry, Vol. <u>31</u> (1961):145.

64. Ibid., p. 145.

65. The arrows are meant only to suggest the existence of cause, influence or response at work in the uranium situation.

66. Amitai Etzioni. Modern Organizations. Englewood Cliffs, Prentice-Hall, 1964. P. 6.

67. See Daniel Katz and Robert J. Kalhn. The Social Psychology of Organizations. New York, John Wiley and Sons, Inc., 1966. Harold L. Wilensky. Organizational Intelligence. New York, Basic Books, Inc., 1967. Max Weber. The Theory of Social and Economic Organization, trans. A. M. Henderson and Talcott Parsons. New York, The Free Press, 1947.

68. Statement by Jim Dougherty, federal mine inspector, in a personal interview, Denver, Colorado, April 27, 1973.

69. James D. Thompson. Organizations in Action. New York, McGraw Hill, 1967. See also Shirley Terreberry. The Evolution of Organizational Environments. A.S.Q., Vol. 12, No. 4, March, 1968:590-613. William Dill. Environment as an Influence on Managerial Autonomy. A.S.Q., Vol. 2, No. 4, March, 1958:409-443.

70. Aaron Wildavsky. The Politics of the Budgetary Process. Boston, Little Brown and Company, 1964.

71. See Paul R. Lawrence and Jay W. Lorsch. Organizations and Environment: Managing Differentiation and Integration. Cambridge, Harvard Graduate School of Business Administration, 1967. Charles Perrow. A Framework for the Comparative Analysis of Complex Organizations. A.S.R., Vol. 32, No. 2, April, 1967.

72. Richard Hall. Organizations: Structure and Process. Englewood Cliffs, Prentice Hall, Inc., 1972. Pp. 301-2.

73. See Brian Aldrich. Relations Between Organizations: A Critical Review of the Literature. Unpublished paper, University of Minnesota, 1970, cited in Hall, op. cit., and Eugene Litwak and Lydia Hylton. Inter-organizational Analysis. A.S.Q., Vol. 6, No. 4, March, 1962. James D. Thompson and William J. McEwen. Organizational Goals and Environment: Goal Setting as an Interaction Process. A.S.Q., Vol. 23, No. 1, Feb. 1958.

74. William M. Evan. The Organization-Set: Toward a Theory of Interorganizational Relations. In Approaches to Organizational Design, ed. James D. Thompson. Pittsburgh, University of Pittsburgh Press, 1966.

75. Norton Long. The Local Community as an Ecology of Games. A.J.S., Vol. 64, No. 3, 1958, pp. 251-61.

76. David Rogers. 110 Livingston Street: Politics and Bureaucracy in the New York City School System. New York, Vintage Books, 1969.

77. Philip Selznick. TVA and the Grass Roots. New York, Harper Torchbook, 1966.

78. The majority of the information on mines was obtained from the Colorado Bureau of Mines. Two types of intra-office files were consulted. Information Reports supplied general yearly information on mine ownership and operation. Inspection Reports provided yearly accounts of government enforcement activities. Information on mine radiation environments was obtained from the Public Health Service. Information on labor organizations was supplied by the unions associated with the Colorado mining industries and the Atomic Energy Commission, Western Division in Grand Junction, Colorado. A.E.C. records showed the mills to which each uranium mine transferred ore and the distance in miles from mine to mill. Labor organizations supplied information on the affiliation of the uranium mills under consideration.

79. Approximately 400 of the original 923 uranium mines were eliminated from consideration for three reasons. These are explained in the following: First, if there was a question as to the identity of the mine over time. This problem arose in cases where a mine name changed from year to year; and where ownership transfers were incorrectly reported by agents maintaining the mining archives. Second, if mine records were missing. In cases where a mine operated for only a very short time, for example, mining records were not maintained. Only a small fraction of the mines excluded from study was rejected for this reason. Third, if there failed to be at least one direct measurement of a mine's health environment during the twenty year study period. Health assessments were made by the Public Health service. They are quantitative indicators and the same measuring scale has been used over the entire study period. Frequently, however, indirect methods of assessment were employed. These methods included extrapolations from previous years' measurements of mine radiation and estimations based on radiation values obtained from other mines in the same locality. While several studies have employed indirect assessments to explore the relationship between radiation exposure and lung cancer, it was felt that this study required more sensitive indicators of mine radiation. A mine was included in the project if at least one of its twenty health assessments between 1950 and 1969 was derived from actual measurements at the mine site; it was excluded if it failed to undergo at least one such on-site measurement.

80. Lewis Anthony Dexter. Elite and Specialized Interviewing. Chicago, Northwestern University Press, 1970, and Raymond Gorden. Interviewing: Strategy, Techniques and Tactics. Homewood, The Dorsey Press, 1968.

81. See Chapter 2, HISTORY OF THE PROBLEM.

The Working Level (WL) is employed as a unit of radon daughter product concentration. Its value is defined as any combination of radon daughters in 1 liter of air that will result in the ultimate emission of 1.33×10^5 of potential alpha energy. See Federal Radiation Council, Guidance for the Control of Radiation Hazards in Uranium Mining. Staff Report No. 8, September, 1967, p. 11.

82. Paul A. Samuelson. Economics: An Introductory Analysis, (7th ed.). New York, McGraw Hill, 1967. Pp. 76-77.

83. Bureau of Mines. Report for the Years 1950-1951. Colorado, August 15, 1952. Pp. 13-14.

84. Colorado Mining Association, National Western Mining Conference. Resolutions and Declaration of Policy. Denver, Colorado, 1970. P. 4.

85. American Mining Congress. Newsletter. July, 1967.

86. Minutes of Meeting of the Atomic Industrial Forum, Committee on Mining and Milling. August 16, 1971.

87. Official meetings include Governmental Hearings, State-Wide Conferences and other meetings listed in the Chronology of the Problem by Robert J. Catlin. Uranium Mining Health and Safety. March 23, 1971.

88. United Steelworkers of America. Background on Variance Proposal for Radon Daughters Standard. December 17, 1971. P. 1.

89. Statement by Sam Franklin, former director of United Mineworkers, District 50, in personal interview. Denver, Colorado, April 24, 1973.

90. Statement by Wilbur McCready, former organizer for United Mineworkers, District 50, in a personal interview. Denver, Colorado, April 25, 1973.

91. The mill and processing plant phase of the uranium industry did experience union influence. Between 1950 and 1969, approximately one-third to one-half of uranium mills to which Colorado miners shipped ore were represented by unions. Unions representing this group of workers were the United Mineworkers, District 50, the A.F. of L., and the Oil, Chemical and Atomic Workers. Labor organizers interviewed in the project suggested that union influence in the mines was indirectly exercised through the uranium processing mills and plants. Their theory was that since mill workers and underground miners were in contact with one another in the course of shipping ore, benefits that accrued to the unionized mill workers sometimes filtered down to the miners. Some interviewees held that management used the automatic transmission of mill worker benefits to underground miners as a means to thwart attempts to organize in the mines.

    In order to test this thesis, a comparison was made between mines which shipped and mines which did not ship ore to unionized mills. The organizers thesis would predict that mines having regular shipping contracts with unionized mills would have lower radiation levels. Such was not the case. Although a sizeable percentage of mines in the project did ship to unionized mills, the percentage varied from year to year. There is no clear explanation for this variation. Moreover, there were no obvious consequences for radiation levels flowing from shipping ties. While for 15 of the 20 years under investigation mines affiliated with unionized mills did display lower radiation than their non-union counterparts, the magnitude of these differences was not very great. In 1950, 1952, 1961, 1963, 1965, and 1966, mines shipping to nonunionized mills exhibited lower radiation. Thus, affiliation with unionized mills was not associated with lower radiation in mines in any regular manner. See the following tables for details.

Annual Percentage of Mills to Which Colorado Mines Shipped Uranium That Were Represented by a Labor Organization, 1950-1969

Year	Percentage mills represented by a union	Year	Percentage of mills represented by a union
1950	33.3	1960	33.3
1951	33.3	1961	44.4
1952	33.3	1962	55.5
1953	28.6	1963	62.5
1954	25.0	1964	37.5
1955	37.5	1965	42.9
1956	33.3	1966	37.5
1957	37.5	1967	37.5
1958	37.5	1968	37.5
1959	37.5	1969	50.0

Source:
The Sample of Colorado uranium mines.

Annual Percentage of Mines that Shipped Ore to Unionized Mills, 1950-1969

Year	Percentage mines shipping to unionized mills	Year	Percentage mines shipping to unionized mills
1950	50.0	1960	64.5
1951	62.1	1961	77.4
1952	52.4	1962	92.8
1953	48.8	1963	93.0
1954	47.9	1964	51.1
1955	59.4	1965	57.7
1956	65.6	1966	61.9
1957	66.2	1967	67.2
1958	62.4	1968	75.8
1959	65.8	1969	78.8

Source:
The sample of Colorado uranium mines.

A Comparison of Mean Radiation Levels Between Mines That Shipped Ore to Unionized Mills and Mines That Shipped Ore to Non-Unionized Mills, 1950-1969

Year	Radiation levels (in W.L.) in mines that shipped ore to	
	Unionized Mills	Non-unionized mills
1950	28.5	24.5
1951	25.2	28.5
1952	23.7	23.2
1953	21.8	37.6
1954	19.2	21.5
1955	14.6	15.4
1956	11.4	12.5
1957	16.3	22.0
1958	10.2	13.9
1959	14.4	18.2
1960	11.7	12.5
1961	10.6	5.5
1962	5.6	6.7
1963	3.2	2.5
1964	3.1	3.5
1965	3.7	2.6
1966	2.8	2.7
1967	1.4	1.9
1968	1.4	2.0
1969	0.5	0.9

Source:
The sample of Colorado uranium mines.

92. American Mining Congress. News Bulletin. July 28, 1972.

93. Remarks by Jesse C. Johnson, Director Division of Raw Materials, Atomic Energy Commission, in an address before the Fourth annual conference of the Atomic Industrial Forum. New York, October 28, 1957, ("Uranium Production in the United States"), p. 9.

94. Although initial plans called for the cessation of all government purchases by the end of 1966, a "stretch-out" program was adopted by the Atomic Energy Commission in 1962 which delayed the termination of government procurement. Under the new program, a portion of the production formerly scheduled for delivery to the Atomic Energy Commission in 1963-1966 was deferred for delivery until 1967 and 1968. In addition, the A.E.C. agreed to purchase an equal quantity of ore until 1969 and 1970, but at lower prices. Thus, A.E.C. purchasing was effectively extended until 1970 and it was not until 1971 that uranium was sold exclusively on the open market.

95. Atomic Energy Commission Uranium Concentrate Reserves, 1947-1971

Year	Tons of Uranium-oxide	Year	Tons of Uranium-oxide
1947	2200	1960	231785
1948	2200	1961	178885
1949	2200	1962	167738
1950	3000	1963	160231
1951	5800	1964	150921
1952	7346	1965	144702
1953	15203	1966	140835
1954	27582	1967	147741
1955	67595	1968	160819
1956	164055	1969	204080
1957	210109	1970	246100
1958	225644	1971	273200
1959	240996		

Source:

Atomic Energy Commission, Statistical Data of the Uranium Industry, (January 1, 1972) p. 14. ("Uranium Ore Reserves and Production").

96. Atomic Energy Commission, Release of September 7, 1968, as reported in Release No. 0-178, October 13, 1971. "A.E.C. Seeks Public Comment on Proposed Uranium Supply Policies."

97. Remarks by Wilfred E. Johnson, Commissioner, U.S. Atomic Energy Commission, in an address ("Status of the Uranium Producing Industry"), to the American Mining Congress in Las Vegas, Nevada, October 13, 1971.

98. Projected United States Uranium Requirements and Supplies, 1971-1975

Year	Requirements	Contracted Deliveries	Cululative Inventory	Inventory as % of Requirements
1971	6,900	12,800	13,300	193
1972	10,200	11,300	14,400	141
1973	14,000	13,000	13,400	96
1974	16,700	11,800	8,500	51
1975	18,400	12,000	2,100	11

All figures = tons of uranium-oxide.

Source:

American Mining Congress, Comments to the Secretary of the Atomic Energy Commission, December 6, 1971, p. 3.

99. Joint Committee on Atomic Energy. Authorizing Appropriates for the Atomic Energy Commission for Fiscal Year 1970. July 8, 1971.

100. Digest of Lung Cancer Cases, Department of Labor and Employment, Division of Labor, Workmen's Compensation Section, Denver, Colorado.

101. U.S. Congress, Joint Committee on Atomic Energy. Employee Radiation Hazards and Workmen's Compensation. Hearing, 86th Congress, 1st Session, March 1959. Washington, Government Printing Office, 1959. P. 419.

102. Information supplied by Ronald C. Jaynes, Senior Referee, Division of Labor, Workmen's Compensation, in personal interview in Denver, Colorado, November 2, 1972.

103. The Denver Post. February 8, 1957. P. 17.

104. ________. December 16, 1960. P. 13.

105. ________. August 30, 1962. P. 19.

106. ________. March 10, 1967. P. 34.

107. ________. April 20, 1967. P. 67.

108. ________. April 24, 1967. P. 13.

109. ________. May 21, 1967. P. 37.

110. ________. May 22, 1967. P. 16.

111. Paul A. Samuelson. Economics: An Introductory Analysis, (7th ed.). New York, McGraw-Hill Book Co., 1967. Pp. 369-70.

112. Union Carbide Corporation. Data on Mine Radiation Control in Union Carbide Mines. Unpublished paper, April, 1971, p. 1.

113. Statement by Elzie Ray, mine inspector in Colorado's District 2, in personal interview. Denver, Colorado, April 23, 1973.

114. Joint Committee on Atomic Energy. Hearings (1967) op. cit., p. 156.

115. Morton Mintz and Robert K. Warner. Big Oil Companies Acquire Grip on Competing Fuels. Washington Post, August 23, 1970.

116. For example, S.2882, introduced by Senator Yarborough and H. R. 14558, introduced by Representative O'Hara, authorized the Secretary of Labor to pay supplemental workmen's compensation benefits to persons receiving state payments for disabilities or deaths due to lung cancer caused by radiation in uranium mines. Senate Bill 1927, introduced by Senator Metcalf also called for the federal government to subsidize states making compensation payments for injuries, disabilities and deaths due to exposure to radiation while mining or processing uranium. Senators

Allot and Dominick also introduced legislation in 1967 to compensate persons injured or killed as a result of mining radioactive materials. Their bill, S.2686, called for the extension of federal civil service benefits to the victims of radiation induced lung cancer.

117. Joint Committee on Atomic Energy. Hearings (1967) op. cit.,.p. iii.

118. Joint Committee on Atomic Energy. Hearings (1969) op. cit.,.

119. See Mark J. Green (ed.) The Monopoly Makers: Nader Study Group Report on Regulation and Competition. New York, Grossman Publishers, 1973; and Louis Kohlmeier, The Regulators: Watchdog Agencies and the Public Interest. New York, Harper and Row, 1969.

120. Peter M. Blau and Otis Dudley Duncan. The American Occupational Structure. New York, John Wiley and Sons, Inc., 1967. P. 171.

121. G. T. Nygreen. Interactive Path Analysis. American Sociologist 6:1 (February):37-43; and Otis Dudley Duncan. Path Analysis: Sociological Examples. A.J.S., Vol. 72, 1966, pp. 1-16.

122. Ibid., p. 13.

123. National Safety Council, Accident Facts: 1972. Chicago, 1972, p. 3.

124. President's Report on Occupational Safety and Health. Commerce Clearing House, ed. May 22, 1972, p. 111.

125. See Robert Sherrill. Asbestos, The Saver of Lives, Has a Deadly Side. The New York Times Magazine. January 21, 1973, and Paul Brodeur, Annals of Industry: Casualties of the Workplace. The New Yorker, October 29, 1973-November 26, 1973..

126. Joseph A. Page and Mary-Win O'Brien. Bitter Wages: Ralph Nader's Study Group Report on Disease and Injury on the Job. New York, Grossman Publishers, 1973. Chapter 5 ("Pennies and Posters").

127. See: Rex A Lucas. Men in Crisis: A Study of a Mine Disaster. New York, Basic Books, 1969. Jack Weller. Yesterday's People. Lexington, Ky., University of Kentucky Press, 1966. Herman R. Lantz. People of Coal Town. New York, Columbia University Press, 1958.

128. Lantz, Ibid.

129. C. Weisel and M. Arny. Psychiatric Study of Coal Miners in Eastern Kentucky Area. American J. Psych, February, 1952. P. 619.

130. L. G. Schultz. Rural America: Our Gross National Product. Social Welfare in Appalachia. Vol. 2, 1970, p. 8.

131. Cited in a contract report by the Naval Ammunition Depot at Crane Indiana for the Bureau of Mines. Chapter III (Personality and the Mine Social System). P. 19.

132. Alice Hamilton. Exploring the Dangerous Trades. (Boston:[n.n.], 1943) Cited in Page and O'Brien, op. cit., p. 147.

133. Brodeur. Op. cit., p. 47.

134. Page and O'Brien. Op. cit., chapter 5 ("Pennies and Posters").

135. Ibid., p. 145.

136. U.S. Congress, House Hearings on the Occupational Safety and Health Act. Part 2, 1969, p. 866. Cited in Page and O'Brien, Ibid., p. 79.

137. Ibid., p. 204.

138. U.S. Code Congressional and Administrative Notes. Leglislative History: Federal Metal and Non metallic Mine Safety Act, 1966. P. 2848.

139. Ray Davidson. Peril on the Job: A Study of Hazards in the Chemical Industries. Washington, Public Affairs Press, 1970.

140. Bruce Archern. Murderous Machines. New Society, 9, 1967. P. 248.

141. Davitt McAteer. Safety in Mines: A Look at the World's Most Hazardous Occupation. Unpublished paper prepared for the Center for the Study of Responsive Law. Washington, 1972.

142. Ibid., p. 46.

143. Page and O'Brien, op. cit., p. 200.

144. See Brodeur, op. cit., and Sherrill, op. cit.

145. Morton Mintz. By Prescription Only. Boston, Beacon Press, 1967.

146. The Nader studies refer to the following works: James S. Turner, The Chemical Feast: Report on the Food and Drug Administration, New York, Grossman Publishers, 1970; Mark Green, The Closed Enterprise System, New York, Grossman Publishers, 1970; John Esposito, Vanishing Air, New York, Grossman Publishers, 1970; Robert Fellmeth, The Nader Report on the Federal Trade Commission, New York, Grossman Publishers, 1969; and Ralph Nader and Mark J. Green, Corporate Power in America, New York, Grossman Publishers, 1973.

147. K.C. Davis. Discretionary Justice. ([n.p.], [n.n.], 1969). P. 59.

148. Statement by Donald Walker, Director of Bureau of Mines Federal Inspection Staff, Region 8, in personal interview. Denver,Colorado, April 27, 1973.

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