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EVALUATION OF REGIONAL EFFECTS OF EFFLUENTS FROM
URANIUM PRODUCTION IN NEW MEXICO

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NOTICE

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Foreword

This is the final technical report to the Lawrence Livermore Laboratory on the project by the above title. The study was conducted in the Fall Semester, 1976, while the author was Visiting Associate Professor in the Biology Department of New Mexico Institute of Mining and Technology. Students Roger Taft and Daniel McDonough participated.

Introduction to the Problem

Development is occurring at increasing rates in the energy-rich regions of the U.S. The future impacts on regional systems--traditional economics, populations, and environments--is of special interest to local, state, and federal agencies who are responsible for regulating growth. The Grants Uranium Region is a 2500 mile² area of northcentral New Mexico which has produced about 40% of all domestic uranium, and holds over one-half of the current reserves [1,2,3]. The increasing demand for uranium to fuel commercial nuclear power plants is resulting in rapid growth of the uranium industry around Grants, New Mexico, and economic, social, and environmental changes are occurring [4,5,6].

One of the environmental issues of this region is the concern for eventually unacceptable levels of air and water pollution from effluents from tailings piles. This study addresses these potential impacts in relation to industrial environmental control practices, siting features, and other regional/temporal variables, including rates of production, locations and sizes of new mills, and population distributions.

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Environmental Impacts from Milling and Tailings Storage

Uranium milling entails the chemical leaching of crushed ores to separate yellowcake, U_3O_8 , leaving behind essentially all of the ore mass but the small percentage of U_3O_8 in a partially neutralized slurry of fine sands which are used to build a tailings pile. Tailings piles are engineered for wall stability and rapid evaporation of water to control air and water emissions. Inactive tailings piles dry out, erode, and result in the slow but eventual dispersion of tailings by wind and water forces. Radon gas is emitted from the pile continuously as the result of radioactive decay of radium in the tailings. Mill practices result in direct releases of process water to stream channels and fugitive emissions to air and water.

A number of studies have been published in the open literature on the various routes of environmental contamination around mills and active and inactive piles [7]. There have been several evaluations made of the significance of environmental radioactivity from uranium milling [8,9,10]. For such analyses, documented data on emissions have been fragmentary and source strength data are derived from wide ranging studies. To my knowledge, there has not been a comprehensive material balance (input-output) study made at an operating uranium mill.

A number of pathways for nonoccupational exposures have been identified and evaluated (see Table 1). It is generally agreed that radon diffusion from piles and inhalation by people is the most intractable problem and is the likely highest contributor to human population exposures. This pathway is thought to be relatively more important than groundwater contamination by radium, although there are uncertainties about the long-term problem of groundwater contamination.

In the Grants Uranium Region, there is a paucity of environmental measurements around mills and tailings piles and in the general environment. Research programs have provided some data, along with licensing activities by the State [11].

Table 1. Principal Radionuclides Involved in Pathways from Tailings Piles to Man (Ref. 8)

Pathway	Radionuclides	Pathway Processes	Exposure Hazard
Radon Diffusion	^{222}Rn	<ol style="list-style-type: none"> 1. Diffusion to pile surface 2. Atmospheric transport. 3. Inhalation. 	Inhalation of ^{218}Po , ^{214}Pb , ^{214}Bi , ^{214}Po .
Airborne Activity	^{230}Th , ^{231}Pa	<ol style="list-style-type: none"> 1. Resuspension from pile surface. 2. Atmospheric transport. 3. Inhalation. 4. Body surface contamination. 	Inhalation of airborne activity carried by respirable particles.
Terrestrial	^{226}Ra , ^{210}Pb	<ol style="list-style-type: none"> 1. Resuspension from pile surface. 2. Atmospheric transport. 3. Deposition on soil or foliage. 4. Uptake by plants. 5. Uptake by animals. 6. Consumption of contaminated plants, meat, and milk. 7. Consumption of contaminated soil. 	Ingestion of ^{226}Ra , ^{210}Pb .
Aquatic	^{226}Ra , ^{210}Pb	<ol style="list-style-type: none"> 1. Dissolution of radionuclide in pile. 2. Migration through soil to water. 3. Migration in water. 4. <ol style="list-style-type: none"> a. Uptake by aquatic organisms. b. Consumption of aquatic organism. 5. <ol style="list-style-type: none"> a. Use of water for irrigation. b. Uptake by plants. c. Consumption of plants 6. Consumption of contaminated drinking water. 7. Immersion in contaminated water. 	Ingestion of ^{226}Ra , whole body gamma irradiation.
External Gamma	^{226}Ra daughters	<ol style="list-style-type: none"> 1. Attenuation by pile material. 2. Air-distance attenuation. 3. External exposure. 	External exposure to gamma radiation produced by the decay of ^{226}Ra and its daughters.

Baseline, regionally oriented air and water measurements programs are beginning. The U.S. Environmental Protection Agency has reported a groundwater study [12], and the New Mexico Environmental Improvement Agency is considering more detailed groundwater and air monitoring programs [13].

The Grants Uranium Region

The boundaries of the region are defined by the limits of the known deposits of uranium in the deep sandstone beds of the Morrison Formation [14]. Parts of McKinley, Valencia, and Sandoval Counties lie in the region, with Grants, the McKinley county seat, as the center of commerce and living. The eastern boundary of the region is the Rio Puerco, 25 km west from Albuquerque (Fig. 1). The western boundary is near Gallup, some 210 km west from Albuquerque. The north-south dimension is 24-32 km. The geology of the region has been the subject of over 350 technical papers [15].

New Mexico mountains, plateaus, and mesa land resource types prevail. Most of the annual precipitation falls as rain between May and September and an increasing amount with altitude. Plant communities reflect altitude, rainfall, and soil types and range from hot, dry desert communities to pine forests. The San Mateo Mountains are a major topographic feature. These mountains cross the region in a north-south direction. An environmental baseline study has been reported for the Mt. Taylor area [16].

The major surface watershed of the region is an intermittent tributary of the Rio Grande (Fig. 1). The Grants Uranium Region is a recognized concern to the New Mexico Water Quality Commission for impacts on New Mexico surface and groundwater quality by the uranium industry [17]. A number of point sources of uranium effluents are identified and licensed by the Commission.

Uranium Industry in the Region

In 1975, there were 31 uranium mines operated by 16 companies in the region [18]. Today, five mills are operating, capable of processing 18,000 tons of ore per day (Table 2).

Fig. 1. Map of the Grants Uranium Region

Legend

Fig. 1. Map of the Grants Uranium Region

The map is reproduced from Ref. 17, and shows, encircled, the uranium industry point sources to the surface watershed. Surface drainages are intermittent in flows, and fled into the Middle Rio Grande north of Socorro through the confluence of the Rio San Jose and the Rio Puerco:

- 57 Anaconda Corporation Bluewater Mill
- 58 Kerr-McGee Section 30 W Mine
- 59 United Nuclear-Homestake Partners Ion Exchange Plant
- 60 Kerr-McGee Corporation Ion Exchange Plant and Mill
- 61 United Nuclear Corporation Ion Exchange Plant
- 62 Kerr-McGee Section 35 and 36 Mines
- 63 Gulf Mineral Resources Mt. Taylor Site
- 64 Ranchers Exploration Johnny M Mine
- 65 United Nuclear-Homestake Partners Mill
- 75 Anaconda Corporation Jackpile Mine

Table 2. Uranium Mills in the Grants Uranium Region (Ref. 2)

McKinley County

United Nuclear Corp., Churchrock	3000 tons/day
Kerr-McGee Corp., Grants	7000 tons/day

Valencia County

Anaconda Co., Grants	3000 tons/day
Reserve Oil & SOHIO, Laguna	1500 tons/day
United Nuclear-Homestake Partners, Grants	3500 tons/day

New Mexico, through 1975, had produced more than 112,600 tons of U_3O_8 from over 40 million tons of ores. Current reserves (Tables 3 and 4) show New Mexico is likely to continue to figure prominently in future domestic uranium development. One possible future is that the State will continue to supply 40-45% of the domestic demands through the century [2]. Depending upon the directions and rates of commercial nuclear power (such as influenced by environmental costs of nuclear environmental controls in the reactor and waste management parts of the fuel cycle), and on features such as recycle [9], the currently stated reserves may well be depleted by the year 2000. Thus, the tailings burden of the region may increase from some 40 million tons to some 340 million tons of tailings.

Thus, over the next 20-25 years, the region may experience an approximate 8 to 10 fold increase in uranium tailings burden.

Potential Environmental Impacts from This Development

The current practice in the region is to build relatively small mills for short lifetimes--2500 tons/day for 10 years of life, could be considered a realistic "small-mill average". About 40 such mills will be required to extract the current reserves over the next 20-25 years. The siting and licensing of 2-4 facilities per year would require an extreme effort and would be a difficult task to accomplish.

Table 3. Domestic Uranium Resources (Ref. 2)

New Mexico, Tons U_3O_8				
Cost Category ¹	Reserves	Probable	Possible	Speculative
\$10	151,000	186,500	249,600	49,700
\$15	206,200	255,900	368,700	60,400
\$30	302,700	389,000	567,800	92,500
U.S. Total				
\$10	270,000	440,000	420,000	145,000
\$15	430,000	655,000	675,000	290,000
\$30	640,000	1,060,000	1,270,000	590,000

Table 4. Uranium Reserves of New Mexico (Ref. 2)

Cost Category ¹	Tons Ore	% U_3O_8	Tons U_3O_8	% U.S.	# of Deposits
\$10	57,100,000	0.26	151,000	56	73
\$15	115,900,000	0.18	206,200	48	106
\$30	302,000,000	0.10	302,700	47	173

¹Each category includes all lower cost categories. Estimated operating costs and costs not yet incurred are used in calculating reserves. Profit and costs already incurred (past expenditures for land acquisition, exploration, mine development) are not included. Cost categories do not represent the price at which the estimated reserves would be sold.

The "small mill" case approaches a limit which carries a maximum of environmental impacts from effluents. Small piles, dispersed randomly in the region would be difficult to monitor for their individual contributions to regional air and water pollution. Small piles would tend to maximize the need for land committed to tailings storage and public exclusion areas. Small piles, likewise, would promote the importance of short-range transport forces and local conditions on population exposures. The conventional tailings piles, in the active and inactive stages are becoming recognized as inadequate containment for uranium tailings. They are difficult to stabilize, and tend to maximize the pathways described in Table 1.

A large mill limiting case would involve a high degree of centralization of milling and tailings management. From one to a few very large sites would be developed to handle all of the regional tailings burden. Siting criteria would require careful consideration of groundwater and surface water properties and wind flows relative to population centers such as Grants and Gallup. Topographic features would be used to achieve a high degree of containment. Deep, narrow canyon country could be engineered to keep tailings dry and immobile. Radon diffusion would be attenuated to a maximum. Such large facilities could be designed for future tailings recycle, perhaps by large scale, in situ leaching techniques.

The "large mill" case appears to be an environmentally attractive option among future siting alternatives. There is, however, a need to consider the full implications of the alternatives, a process which is often referred to as integrated assessment.

Conclusions

The Grants Uranium Region will continue to develop its uranium resources over the next 20-25 years. By the turn of the century, the 2500 mile² region may contain 8-10 times the current tailings burden. Environmental impacts from effluents

from the future development will be from radon emissions, groundwater/surface water contamination with radium, and from airborne alpha emitters from resuspended tailings particles.

The dose to man which results from this increased tailings burden and from the milling of some additional 300,000 tons of U_3O_8 in the region will depend on environmental control and siting parameters. The development and application of specific siting criteria could essentially eliminate the problems of slow redistribution of tailings by air and water erosion, and radon emissions and intersection with populations could be minimized.

A research program which addresses the future development through a siting study would be able to evaluate a range of region-specific alternatives to current practices. These evaluations should be carried out in an integrated framework which promotes a common perspective among the interests--public, private, and governmental, and allows economic analysis of the alternatives.

The measurement of baselines at site specific and regional scales is a requirement for establishing the impacts from current and past tailings burdens and practices. Material balance models should be developed on sites and for the regional airsheds and watersheds in relation to existing sites. Mining features would need a similar, parallel analysis.

A survey of the region for possible locations for central tailings processing and storage would facilitate the development of alternatives. Environmental costs and benefits would be calculated in a feasibility study framework, including a consideration of the range of economic factors involved in site procurements, engineering costs, and long-term commitments of land.

There are several innovative techniques which could be applied to developing siting criteria. Aerial based topographical studies could be used to locate geographical subregions of interest because of a combination of specifications regarding geology,

topography, hydrology, and land use. Aerial techniques using NaI(Tl) gamma-ray detection and ground truth mobile GeLi spectroscopy could be combined to evaluate the regional distribution of surface activities. Modern meteorological and analytical systems using automated data acquisition/reduction such as has been used in plutonium resuspension studies would be capable of defining effluent fluxes from mills and tailings areas, toward calculating accurate material balances. Stable isotopic tracers would be valuable tools for investigating transport processes. A recently demonstrated heavy methane atmospheric tracer [20], and SF₆ would be applicable to evaluating future regional radon burdens from a variety of future site configurations.

The initial step in developing such a program would require a more quantitative definition of the range of population exposures which would result from the limiting cases. At the first order, this would be an assessment of the influence of multiple sites on regional radon buildup. By carefully considering site locations with respect to populations and regional meteorology, a first order estimate of likely ranges in population dosages due to radon can be obtained for a range of siting cases.

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