

Review

The Legacy of Uranium Development on or Near Indian Reservations and Health Implications Rekindling Public Awareness

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Academic Editors: Jose A. Centeno, Robert B. Finkelman and Olle Selinus

Received: 1 January 2015 / Accepted: 26 January 2015 / Published: 3 February 2015

Abstract: Uranium occurrence and development has left a legacy of long-lived health effects for many Native Americans and Alaska Natives in the United States. Some Native American communities have been impacted by processing and development while others are living with naturally occurring sources of uranium. The uranium production peak spanned from approximately 1948 to the 1980s. Thousands of mines, mainly on the Colorado Plateau, were developed in the western U.S. during the uranium boom. Many of these mines were abandoned and have not been reclaimed. Native Americans in the Colorado Plateau area including the Navajo, Southern Ute, Ute Mountain, Hopi, Zuni, Laguna, Acoma, and several other Pueblo nations, with their intimate knowledge of the land, often led miners to uranium resources during this exploration boom. As a result of the mining activity many Indian Nations residing near areas of mining or milling have had and continue to have their health compromised. This short review aims to rekindle the public awareness of the plight of Native American communities living with the legacy of uranium procurement, including mining, milling, down winders, nuclear weapon development and long term nuclear waste storage.

Keywords: uranium; Native Americans; community based participatory research; abandoned mines; reservations

1. Introduction

Native American communities on American Indian reservations located with natural resources on or near their lands may be at a greater risk for environmentally induced ailments [1]. The impact of natural

resource development has not always been fully recognized with respect to the cultural and health effects of the people and animals of these lands. Sometimes the effects are not realized until after the fact when problems associated with resource extraction or cleanup may already be impacting the health of the population [2–8]. On some reservations a lack of education and knowledge about the effects of geologic materials such as uranium and coal led to long term health problems when resources were developed [7]. In this short review the effects of uranium procurement will be addressed, though many other factors may also be contributing to poor health of the Native American populations with natural resources on or near their lands.

Technologically-enhanced, naturally-occurring radioactive material (TENORM) is produced when activities such as uranium mining or milling concentrate or expose radioactive materials that occur naturally in ores, soils, water, or other natural materials [9]. Radioactive materials can be classified under two broad headings: man-made and naturally occurring radioactive materials (NORM). Both of these materials affect many Americans but especially the Native American populations in the United States and Canada, whose designated lands host uranium deposits. Mining of uranium by underground and surface methods produces bulk waste material, including tailings and overburden. During mining the waste rock and soil have little or no practical use, they are generally stored on land near the mine site [10,11]. These materials contain NORM which may become dispersed in the environment through airborne dust and contaminated water. Continued exposure to these materials can cause severe health problems [10,12]. Abandoned conventional uranium mines often contain other hazardous contaminants, such as metals. For example, the carcinogen arsenic may be a problem at some uranium mines, contributing to increased health risks [11].

1.1. The Quest for Uranium

The origin of the Department of Energy is traced to World War II and the Manhattan Project effort to build the first atomic bomb [13]. The “Manhattan Project” was conducted mainly at the Los Alamos National Scientific Laboratory, a huge fortified compound created in 1943 [14] on the Pajarito Plateau, northwest of Santa Fe, New Mexico, on land supposedly reserved for the exclusive use and occupancy of the San Ildefonso Pueblo [15]. Uranium, the key material used in the lab’s experiments and eventual fabrication of prototype nuclear weapons, was mined and milled in four centers of the nearby Navajo Reservation [6,9,16] including reservation land near Shiprock, New Mexico; Monument Valley, Utah; Church Rock, New Mexico; and Kayenta, Arizona. Hanford, a uranium enrichment/plutonium manufacturing facility, was added in 1943, near the town of Richland, on Yakima land in eastern Washington [16,17]. The Hanford area bordering the Columbia River was home to several tribes of Native Americans for centuries. Remnants, artifacts, and burial sites associated with historical Native American activity are found throughout the Site and are protected by law [16]. On 16 July 1945, the world’s first atomic bomb was detonated 200 miles south of Los Alamos at Trinity Site on the Alamogordo bombing range [13,14], now the White Sands Test Range, adjoining the Mescalero Apache Reservation. It is this quest for uranium and these different aspects of the procurement plus the disposal and storage of waste that continues to contribute to poor health among many Native American populations. Many cancer clusters and other ailments are attributed to this quest.

1.2. Uranium Production on Native American Lands

The uranium production peak spanned from approximately 1948 to the early 1980s primarily to produce uranium for weapons and later for nuclear fuel [9,10]. Thousands of mines, mainly on the Colorado Plateau, were developed in the western U.S. during the uranium boom. Native Americans in the area including the Navajo, Southern Ute, Ute Mountain, Hopi, Zuni, Laguna, Acoma, and several other Pueblo nations, with their intimate knowledge of the land often led miners to uranium resources during this exploration boom [5,8]. There are about 4000 uranium mines with documented production [10]. With information provided by other federal, state, and tribal agencies, the Environmental Protection Agency (EPA) has identified 15,000 abandoned uranium mine locations with uranium occurrence in 14 western states with about 75% of those on federal and tribal lands [10]. The majority of these sites were conventional (open pit and underground) mines [10]. Between 1950 and 1989 surface and underground mines in the U.S. produced more than 225 million tons of uranium ore [8]. Figure 1 shows the abandoned uranium mines in the western United States.

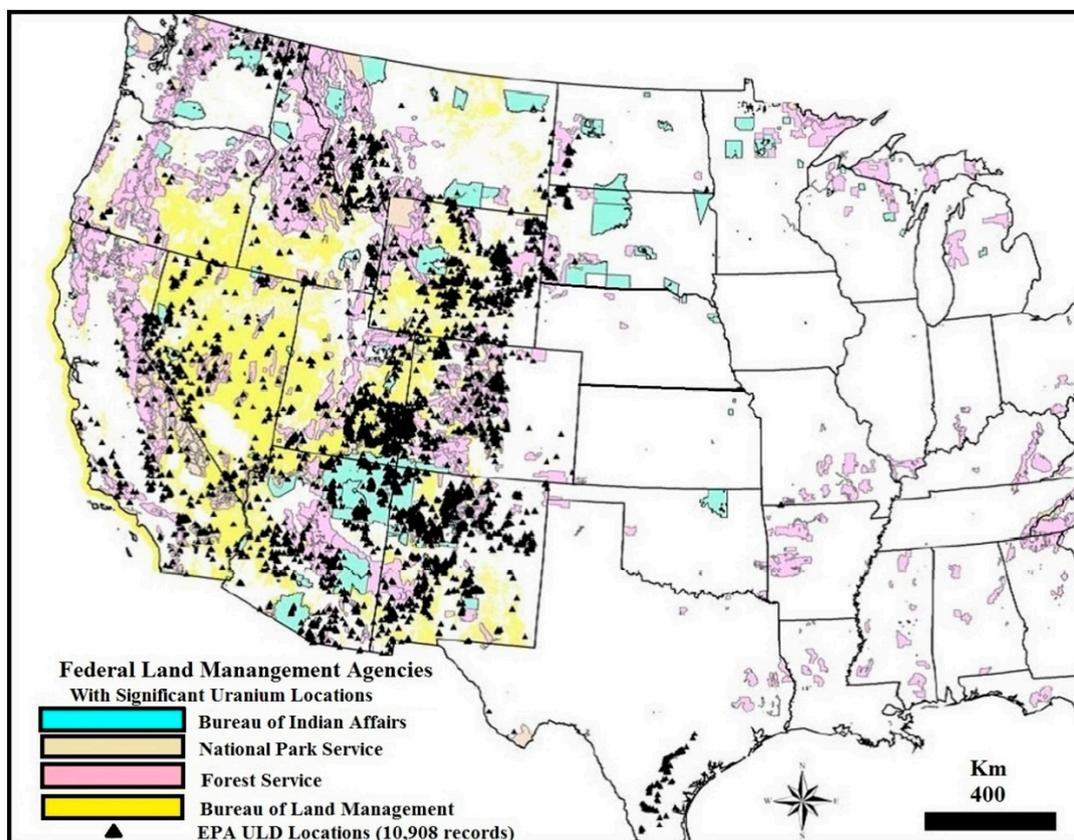


Figure 1. Uranium locations from Environmental Protection Agency (EPA) database and Federal Lands. The green federal lands are Native American reservations. About three-fourths of the uranium locations in the EPA Uranium Location Database are on Federal Lands. Figure is modified from Geographic Analysis on the Location of Uranium Mines [9].

1.2.1. The Navajo Nation

The Navajo Nation was one of the Indian nations heavily affected by this activity with more than a thousand mines and four uranium mills on the reservation lands [5,6,8]. When mining came to the

reservation the Navajo men were ready to gain employment and the close work seemed ideal. What they didn't realize was that they were being exposed to radiation when they worked and brought it home with them in their clothing to their families [6]. Energy material may contain harmful chemical substances that, if mobilized into air, water, or soil, can adversely impact human health and environmental quality [18]. As a result of the mining activity much of the population of the Navajo Nation residing near the areas of mining or milling has had their health compromised. Many of the miners developed cancers; some were lung cancer from inhalation of radioactive particles, *i.e.*, exposure to radon [6]. Of the 150 Navajo uranium miners who worked at the uranium mine in Shiprock, New Mexico until 1970, 133 died of lung cancer or various forms of fibrosis by 1980 [19]. Other potential health effects include bone cancer and impaired kidney function from exposure to radionuclides in drinking water [12]. The government and the mining companies failed to inform the people of the Navajo Nation that working with uranium might be hazardous to one's health [2–8]. The Public health Service even conducted a study to document the development of illnesses as the mining progressed without consent or presenting the data to the miners involved [5,8]. Most of the 1000 unsealed tunnels, unsealed pits and radioactive waste piles still remain on the Navajo reservation today, with Navajo families living within a hundred feet of the mine sites [9,20]. Some of the homes were built with tailings material and much of the water is contaminated on the reservation [20]. Figure 2 shows a sign erected by the Navajo and U.S. EPA which is typical for many of the water sources on the reservation.



Figure 2. Sign erected by the Navajo and U.S. EPA which is typical for many of the water sources on the reservation. Figure from EPA Pacific Southwest Region 9 Addressing Uranium Contamination on the Navajo Nation [21].

1.2.2. Laguna Pueblo Tribe

The Village of Pagate (Laguna Pueblo), 40 miles west of Albuquerque, New Mexico was host to the largest open-pit uranium mine in the United States, the Jackpile Mine [22,23]. The mine was the largest producer of uranium ore in the Grants District [24]. Though the site was officially reclaimed in 1995 it is being considered for a National Priorities Listing (NPL) with the EPA after a Record of

Decision (ROD) Compliance Assessment for Jackpile-Paguate Uranium Mine was performed to determine if the post-reclamation had met the requirements of the Environmental Impact Statement and ROD. This report concluded that reclamation of the mine was still not complete. The Laguna Pueblo, representing a population of about 8000, rejected mining company offers to operate a uranium mill on tribal land. The mill was built just down the road at Bluewater, now another Superfund site [25].

1.2.3. The Eastern Shoshone and Northern Arapaho Nations

Uranium mining and processing has also left a legacy of contaminated groundwater and tailings on the Wind River Reservation, Wyoming, home to Eastern Shoshone and Northern Arapaho Indians. Increased incidences of cancers among its peoples are attributed to the old Susquehanna-Western uranium mill tailings site [26]. The site is a few miles southwest of Riverton, the ninth most-populated city in Wyoming. In some areas of the Wind River Indian Reservation groundwater contamination is so bad that the Department of Energy (DOE) estimates drinking water from contaminated aquifers could make residents up to 10 times more likely to develop cancer than the general population [26]. Uranium was not mined on the Wind River Reservation but uranium mined in the Pryor Mountains, Montana and Northern Bighorn Mountains, Wyoming was some of the ore processed there.

1.2.4. The Sioux Nations

Uranium mining in South Dakota, Wyoming, Montana, and North Dakota began in the middle of the 1950s [1]. More than 1000 open-pit uranium mines and prospects can be found in the four state region according to U.S. Forest Service maps. There were numerous uranium mines throughout the southern Black Hills National Forest as well as in Custer National Forest near the Lakota-Sioux lands in the Black Hills of South Dakota, which also had mines [1]. Most of these have not been reclaimed.

1.2.5. The Spokane Nation

The only uranium mining in Washington State was on the Spokane Indian Reservation. The mines were the Sherwood Uranium Mine and the Midnite Uranium Mine, which opened in the 1950s to produce uranium for the U.S.-Soviet nuclear arms race [27]. Just as on the Navajo reservation the mines brought needed employment to the reservation at that time and the miners were not informed of the dangers uranium mining [28]. About 33 million tons of radioactive waste rock and ore remain at the 350-acre site above the Spokane River [27]. The mines have been closed since the 1980s. The Midnite Mine site, the larger of the two uranium mines on the reservation is a superfund site [27]. Newmont Mining Co. (Greenwood Village, Colorado, USA) and its subsidiary, Dawn Mining Co. (Ford, Washington, USA) expects to begin cleanup of the Midnite Mine in 2015 [27]. “The plan is to fill in open pits left from the mine excavations with the waste rock and ore. The pits would be capped to keep radon gas from escaping. Groundwater in the pits will be collected and treated and then piped 7 miles to the Spokane River” stated a consultant from Newmont [27]. “Newmont already collects and treats water at the old mine site, but that water is currently discharged into Blue Creek, a tributary of the Spokane River. Discharging the treated wastewater directly into the Spokane River will reduce the impacts to Blue Creek, where the tribe is working to re-establish a native redband trout run” stated the Superfund director for the Spokane

Tribe [27]. “The water discharged into the Spokane River must meet the tribe’s water quality standards for radionuclides, heavy metals and other pollutants, which are stricter than state and federal standards. The cleanup work is also subject to permits from the U.S. Environmental Protection Agency” [27] Members of the Spokane Tribe who worked at the mine or who live on the reservation are questioning the high rates of cancer on the reservation [28].

The Spokane Tribe teamed up with the Washington Department of Health and the Northwest Indian Health Board to track cancer rates among the tribe’s 2700 members living with the legacy of the mining from the Sherwood Uranium Midnite Uranium Mines [28]. Study results are pending [28].

1.3. Nuclear Weapons Development

Pacific Northwest tribal groups on nine reservations in Washington, Idaho and Oregon were impacted by Hanford Nuclear reservation activities [29]. The Hanford Nuclear site is located on 1518 square km of shrub-steppe desert in southeastern Washington State [17] surrounded by these nine reservations (Figure 3).



Figure 3. Hanford Nuclear Reservation, shown in red, was located in the state of Washington. Nine Native American reservations surround it. Figure modified from Edward Liebow in Hanford, Tribal Risks, and Public Health [29].

The people of these reservations traditionally used [17] and continue to use the lands and resources from the Columbia River Plateau region including land that was ceded to the government for which they retained hunting and gathering privileges [29]. Thus, they may have been exposed to more radiation and contaminants than the general public in practicing traditional lifestyles while fishing, hunting game, food gathering (berries, root plants, *etc.*) harvesting medicinal plants and traditional practices (*i.e.*, sweats),

as well as social and spiritual interaction networks [29]. This region was contaminated by Hanford activities through primarily two distinct forms: airborne and river-borne releases, both normal operations and some accidental releases [29]. During the period from 1944 to 1972 Hanford released 25 million curies of radioactive contamination into the environment as a comparison the Chernobyl plant released between 35 and 49 million curies of iodine-131 (I-131) [29]. Five of the reservations, the Colville Confederated Tribes, Spokane, Kalispel, Kootenai, and Coeur D'Alene are primarily downwind of Hanford Nuclear site's 1450 square kilometer area (Figure 3) and would have been exposed to the airborne release of radioactive contamination for the most part normal by-product of chemical reactions used to separate weapons-grade plutonium from enriched uranium reactor rods, *i.e.*, I-131 with less of a contribution of the river borne releases [29]. The other four reservations, the Nez Perce, Confederated Tribes of the Umatilla, Confederated Tribes and Bands of the Warm Springs and the Yakama Nation are known to consume large quantities of fish and likely received higher doses of river borne releases which resulted from both accidental releases and normal operations that used Columbia River water to cool weapon-production reactor cores [29]. Additionally, liquid waste that had been poured onto the ground or held in ponds or trenches at the Hanford reservation evaporated or soaked into the soil on the site [30]. The waste contaminated some of the soil and is thought to have also created underground "plumes" of contaminants [30] which could also affect the tribes who consumed native food sources in the area. These nine reservations were all part of the Intertribal Council on Hanford Health Projects established in 1994 when all tribal governing bodies involved agreed on bylaws and operations plans for the council [29]. The group sought to give the tribal perspective of the information needed for estimating radiation doses from distinctive traditional lifestyles of the represented tribes and protect their sovereignty in public health research while also ensuring the scientific integrity of the research involving their people and land [29]. The final report of the federal government's Hanford Thyroid Disease Study (HTDS), a dose-based analysis epidemiological study conducted under contract by researchers at the Fred Hutchinson Cancer Research Center in Seattle from 1989 to 2002 [30], showed northwest U.S. residents with childhood radiation exposures from Washington State's Hanford nuclear site had similar risk levels for thyroid cancer and other thyroid disease regardless of their radiation dose [31]. Many people were dissatisfied with the results of the report and have lawsuits pending [30]. The study was not specific to Native American communities though "the authorizing language which provided funding for the study specifically required that thyroid disease among Native Americans be studied. However, no study focusing on thyroid disease among Native Americans was ever completed." ([29], p. 152). According to the HTDS summary report: "based on information from Native American Tribes and Nations, a study such as the HTDS in Native American populations alone was not feasible because it would have too little chance of detecting any health effects from Hanford's iodine-131" [32]. Native Americans were included in the HTDS if they were identified in the group that made up the study cohort [32]. The study used computer programs from Hanford Environmental Dose Reconstruction Project (1987–1994) and interviews with participants to estimate I-131 doses for 3440 people born between 1940 and 1946 to mothers living in seven Washington counties, took nearly 13 years to complete and cost \$18 million dollars [31]. The site is an environmental cleanup project that approximately 11,000 Hanford employees are involved with today [30].

1.4. Milling and Abandoned Mills

Over ninety percent of all milling done in the U.S. occurred on or just outside the boundaries of American Indian reservations [33]. Mills logically would be located near the production or mine sites for infrastructure, thus many mills were on or near the reservations where uranium mining was operating. A disaster of huge consequence for the Navajo Nation occurred at the Church Rock uranium mill spill on 16 July 1979, in New Mexico when United Nuclear Corporation's Church Rock uranium mill tailings disposal pond breached its dam [34]. Over 1000 tons of solid radioactive mill waste and 93 million gallons of acidic, radioactive tailings solution flowed into the Puerco River, and contaminants traveled 130 km downstream onto the Navajo Nation [35]. The mill was located on privately owned land approximately 27 km north of Gallup, New Mexico, and bordered to the north and southwest by Navajo Nation Tribal Trust lands [35]. Local residents, who were mostly Navajos, used the Puerco River for irrigation and livestock and were not immediately aware of the toxic danger [34]. The Navajo Nation asked the governor of New Mexico to request disaster assistance from the U.S. government and have the site declared a disaster area, but he refused, limiting disaster relief assistance to the Navajo Nation [34]. In terms of the amount of radiation released, the accident was larger in magnitude than the Three Mile Island accident of the same year [34] but received little public attention. This was likely due to the remoteness and sparsely populated area of the Navajo Nation which was impacted by the spill. The area was inhabited by mainly Navajo people, many who only spoke their native tongue [34]. This is in contrast to the highly populated area of Middletown, Pennsylvania located three miles from the Three Mile Island Nuclear Generating Station where the TMI accident occurred. Possibly the greater significance of a nuclear power plant *versus* a tailings dam may also have influenced media coverage.

2. Indian Health Service, Census Data and Health Disparities

2.1. Indian Health Service

To evaluate health issues of Native American populations one must be aware of the unique relationship that American Indians and Alaska Natives (AI/AN) have with the federal government. The provision of health services to members of federally-recognized tribes grew out of the government-to-government relationship, established in 1787, between the federal government and Indian tribes in exchange for tribal lands. This relationship is based on Article I, Section 8 of the Constitution, and has been given form and substance by numerous treaties, laws, Supreme Court decisions, and Executive Orders [36,37]. The Indian Health Service (IHS), an agency within the Department of Health and Human Services, is responsible for providing federal health services to AI/AN. Approximately 2 million of the 3.4 million AI/AN, members of 566 federally recognized tribes across the U.S., are served by the IHS [36,37]. The organization has fulfilled the federal government's responsibility since 1955. The AI/AN health system has evolved greatly since then and now consists of IHS hospitals and health centers managed by the federal government, tribally managed services, and urban Indian health programs [38]. There are 12 Area offices, which are further divided down into 168 Service Units that provide care at the local level; most of these are rural primary care systems and are staffed by 70% native employees [36].

Tribal involvement and collaboration is an important aspect of the IHS in meeting the health needs of its service population [37]. Tribal delegation meetings are a form of tribal consultation where elected

tribal officials meet with the IHS Director or senior staff to discuss health policy and program management issues related to the provision of health services to the Indian population. The IHS has an official Tribal Consultation Policy [37]. There are also programs with committees, task forces, boards and workgroups set up within the IHS system to address different aspects of policy and communication between the tribes and the federal government.

One of these programs is the Environmental Health Services (EHS) program. It includes the specialty areas of injury prevention and institutional environmental health. The IHS EHS program identifies environmental hazards and risk factors in tribal communities and proposes control measures to prevent adverse health effects. These measures include monitoring and investigating disease and injury in tribal communities; identifying environmental hazards in community facilities such as food service establishments, Head Start Centers, community water supply systems, and health care facilities; and providing training, technical assistance, and project funding to develop the capacity of tribal communities to address their environmental health issues [38]. The current IHS director is Yvette Roubideaux, M.D., M.P.H., a member of the Rosebud Sioux Tribe, South Dakota; she has served since May of 2009.

2.2. Census Data and Disparities

In the 2010 U.S. Census, 5.2 million people (about 1.7% of the U.S. population) identified themselves as AI/AN, solely or in combination with one or more racial/ethnic groups [39]. This population is concentrated in the west and south and proximate to AI/AN areas (reservations/trust lands) for most of the population [39]. AI/AN people consistently experience lower health status when compared with other Americans. The health status of AI/AN is affected by a number of environmental hazards, such as living in remote and isolated locations that expose residents to severe climatic conditions, hazardous geography, and disease-carrying insects and rodents, limited availability of housing and extensive use of sub-standard housing, unsanitary methods of sewage and waste disposal, and unsafe water supplies [40]. Lower life expectancy and the disproportionate disease burden exist possibly due to inadequate education, disproportionate poverty, discrimination in the delivery of health services, cultural differences and geographic location [40]. This population is concentrated in the west and south and proximate to AI/AN areas (reservations/trust lands) for most of the population [39]. AI/AN have the highest national poverty at 27.0%; nine states had poverty rates of about 30% or more for AI/AN: Arizona, Maine, Minnesota, Montana, Nebraska, New Mexico, North Dakota, South Dakota, and Utah [39]. There are many interwoven quality of life issues associated with life in native settings. These are broad issues deeply rooted in economic adversity, poor social conditions and a struggle to maintain a cultural identity while assimilating with U.S. society. A major cause of poverty in Native American communities is the persistent lack of opportunity; even most of the communities with natural resources on their lands are faced with high poverty. The Economic Research Service reports that Native American communities have fewer full-time employed individuals than any other high-poverty community. Mortality rates in AN populations are 60% higher than those of the U.S. white population [41,42], and mortality in AI populations are about twice that of the general U.S. population [43]. In addition, AI/AN have the lowest cancer survival rates among any racial group in the United States [44]. Native Americans in the Northern Plains region have a cancer mortality rate approximately 40% higher than that of the overall population [45].

There is sufficient evidence of disparities in health care financing, access to care, and quality of care to conclude that American Indians and Alaska Natives are disadvantaged in the health care system [33,34]. Comparing per capita personal health care expenditures on user population the IHS expenditure is \$2741 while the total U.S. population expenditure is \$7239 [37]. Due to the remoteness of many of the IHS facilities and funding available not all IHS facilities have the capabilities to address all the needs of the population. Contract health services (CHS) are purchased based on a priority system. The IHS is the Payor of Last Resort which requires patients to exhaust all health care resources available to them from private insurance, state health programs, and other federal programs before IHS can pay through the CHS program [40].

2.2.1. Toxic Waste Storage

When conditions exist of such extreme poverty for many Native American communities they have been approached by companies wanting to store toxic wastes on their lands. This creates hard situations for some tribes who would like the added “income” but desire to have a safe environment to live in. The Mescalero Apache, Prairie Island Mdewakanton, Minnesota Sioux, Skull valley Goshutes, Lower Brule, two Alaskan native communities, Chickasaw, Sac and Fox, Eastern Shawnee, Quassarie, Ponca. Tribes have all applied to be sites for Monitored Retrievable Storage (MRS), a temporary solution to the problem of storing vast amounts of high-level nuclear waste [46]. The safety of these sites is still under question.

2.2.2. Radiation Exposure Compensation Act

The Radiation Exposure Compensation Act passed in 1990 and amended in 2000 [46], was set up to make partial restitution to the people who contracted cancer and a number of other specified diseases as a direct result of mining, mill working or their exposure to atmospheric nuclear testing undertaken by the United States during the Cold War [6]. For miners the requirements such as whether the miner was a smoker, how long they had worked, whether the mine(s) they were employed in had radon exposure monitoring, medical proof of lung cancer or a nonmalignant respiratory disease, *etc.* made it very difficult for the people to be accepted in the program. Many miners were designated as smokers even though they may have only smoked the equivalent of a pack of cigarettes over a year, in ceremonial practices which increased the WLM (working level months—a measure of radon exposure based on Social Security work records and exposure to radon) required to 500 unless they contracted lung cancer under age 45 then it was 300 WLM [6]. The stringent, often impossible requirements made attaining this compensation hard for most of the victims involved. Many of the people are still trying to be compensated.

3. Discussion and Conclusions

The legacy of uranium procurement has left a legacy of long-lived health effects for many Native Americans and Alaska Natives in the United States. There have been a number of studies that are starting to address the health impacts of this legacy. The largest population and some of the most impacted people are the tribes living in the southwestern USA, especially the Navajo. A consortium of federal and tribal agencies reported that a five-year, \$110 million project to clean up uranium contamination in the Navajo

Nation had addressed the most urgent risks there [47]. But the report also said that in the last five years the agencies have learned much more “about the scope of the problem and it is clear that additional work will be needed” [47]. The consortium included the U.S. Environmental Protection Agency, the Bureau of Indian Affairs, Nuclear Regulatory Commission, Department of Energy and Indian Health Service. The project started in 2007 to tackle the widespread uranium contamination on Navajo lands left over from the nation’s atomic weapon production programs. Among their accomplishments, the agencies reported that they have cleaned up nine abandoned uranium mines, rebuilt 34 homes and replaced contaminated soil at 18 sites, many near homes. The agencies also assessed the status of 520 mines, 240 water sources and 800 homes and public structures, exceeding goals set in the five-year plan, the report said [48,49]. It added that officials shut down three contaminated wells and hauled clean water to affected areas of the Navajo Nation or started projects to pipe in water.

Another study in the Eastern Agency of the Navajo Nation in New Mexico [50], studied environmental uranium contamination in a former mining and milling area. Despite decades of inactivity in the mines and mills, environmental contamination was widespread, often in proximity to homes, areas grazed by livestock, and locations frequented by children and families. The uranium contamination in this area was predominantly in the highly soluble chemical forms that could be spread when disturbed or by the bursts of precipitation that occur in this semiarid region at certain times of the year [50].

The Navajo Birth Cohort Study will use Community Based Participatory Research (CBPR) methods [51] and is a collaborative effort to better understand the relationship between uranium exposures and early developmental delays on the Navajo Nation [52]. The five-year Study is funded by Congress at the request of the Navajo Nation and in response to concerns expressed by women about health impacts of living near abandoned uranium mines [53]. Partners in the Study include the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry, Navajo Area Indian Health Service, Navajo Nation Division of Health, University of New Mexico Community Environmental Health Program, UNM Pediatrics Department Center for Development and Disability, and Southwest Research and Information Center [53]. Eligible women are between the ages of 14 and 45 who have lived on the Navajo Nation for five years, are pregnant, and will deliver at the designated hospitals in Chinle, Gallup, Shiprock, Ft. Defiance, and Tuba City [53].

This short review only provides a quick glance at the continuing legacy of long-lived health effects for many Native American populations due to uranium procurement in the United States. The reader is encouraged to explore some of these topics and become aware of the issues. Native American communities, those on and near reservations, consistently experience lower health status when compared with other Americans. To be able to set up medical geology studies as collaborations within these separate nations, it is important that traditional knowledge is incorporated into the study plans. The non-Native American exposure doses and other variables within each unique study may underestimate necessary values within a study related to Native American communities. Without weighting standard values differently in applied models, or considering different types of variables in GIS and other geospatial tools, the results of the studies may not truly represent the Native American or Alaska Native populations and the effects of the environment or toxic indicator which is studied.

Medical Geology has been shown to be an effective tool in many applications around the world. The sample size of many of the Native American and Alaska Native communities is small for large statistical studies, but increased homogeneity in the small sample sizes due to cultural and traditional values may

provide good results, which can be implemented to improve health conditions of the people involved. Funding for projects will also need to be collaborative. Working with programs like the Tribal ecoAmbassadors Program, National Institute of Health, National Science Foundation, the U.S. Geological Survey, IHS and Tribal colleges may yield productive studies that can be used to help improve the overall health of these communities. The use of community-based participatory research approaches that incorporate Native American social networks can be effective in helping to achieve policy changes to address health issues.

Acknowledgments

Funding for research: Alfred P. Sloan Graduate Scholarship Programs—Minority Ph.D. Component/Sloan Indigenous Graduate Partnership; Montana State University—Dennis and Phyllis Washington Foundation Native American Graduate Fellow; HOPA Mountain Program. Note: The content is solely the responsibility of the author; it has not been formally reviewed by any of the funders.

Conflicts of Interest

The author declares no conflict of interest.

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