# Uranium Mining and the Health of Communities

## 2018 Report

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## Introduction

This report addresses the health and environmental consequences for the communities close enough to sites of mining, milling, and processing of uranium to be placed at risk for adverse health consequences. While the dangers of underground mining for miners have been well documented for over a half-century[1], less attention has been focused on the community consequences of the extractive end of the uranium fuel cycle (Figure 1). In this report, we present findings of a literature review on research related to community health and uranium mining, as well as providing an estimate of the numbers of people at risk for exposure because of living adjacent to uranium mines, mills, or other facilities. A future report will address the impact of uranium mining on the health of the millions who have worked in underground and open pit mines.

### *Uranium Production and the Nuclear Fuel Cycle*

Uranium is the feed stock for making nuclear weapons and for fueling nuclear reactors. Mining of uranium for these purposes began in the 1940s, but uranium-containing ores were mined earlier for other uses, such as the extraction of radium for therapeutic and scientific uses, and gold and other ores may contain uranium.[2] While the geology of uranium is complicated, uranium deposits exist in many countries worldwide and it has been mined in most continents. Historically, uranium mining has been most prominent in the western United States, Canada, Eastern Europe, parts of Africa and Asia, and Australia. (Figures 2a and 2b). The uranium-containing ore is extracted through surface or underground mining and also by in-situ recovery, which uses chemical solutions to leach out the uranium underground. Typically, the ore is milled and the uranium extracted near the site of mining and then processed further at another location.

The uranium fuel cycle begins with the recovery of naturally containing uranium and ends with disposal of the by-products of utilization, such as spent fuel rods from nuclear reactors (Figure 3)[3]; of course, uranium is also mined for the production of nuclear weapons, but the initial steps are similar. In this report, the focus is on the initial components of the cycle, i.e., those involving mining, milling, and further processing of the extracted uranium (Figure 1). Across the mining, processing, and utilization of uranium, there are a number of points at which the environment can be contaminated and human health placed at risk. For uranium miners, the greatest threat is posed by the radioactive gas radon and its radioactive progeny or “daughter products,” which cause cancer through cell-damaging alpha decays (Figure 3). The millers are exposed to radon progeny, uranium itself, and the chemicals involved in the extractive processes.

Turning to exposures to communities, particularly those in proximity to uranium-handling facilities, exposures might come through pathways involving tailings piles, waste water ponds, and repurposing of contaminated materials for building purposes. For communities, potentially harmful radiation exposures come from the spread of dust from tailings piles into agricultural and grazing lands, water, and residences; and contamination of agricultural products and livestock that are in contact with tailings.[4] Tailings have also been used as fill under dwellings and for road construction.[4] Radon exposure could be increased by contamination of outdoor air from uranium-containing materials or of indoor air by tailings used in construction. Breaches of uranium mill tailings ponds have also occurred; for example, the 1979 breach at the United Nuclear Corporation's Church Rock facility dumped massive quantities of solid and liquid waste into the Rio Puerco in the US State of New Mexico.[5]

Worldwide production of uranium has peaked and valleyed since its extraction began; from the 1950s, the demand steadily increased and then leveled off around 1990, before surging again around 2008 when nuclear power regained favor because of concerns about greenhouse gas emissions and climate change.[6] Mining of uranium continues today to supply the 444 operational nuclear plants with 63 more under construction.[7] While Europe and North America have contributed the greatest amount to the cumulative uranium produced, accounting for over 30% each, the present production now comes from Kazakhstan (39%), Canada (22.5%), Australia (0.1%), Niger (0.05%), Namibia (0.05%), and Russia (0.04%) with the remaining 38.26 % coming from many additional countries.[8]

Over the millenia, mining of all types has caused environmental damage. In the specific case of uranium mining, the circumstances of the Cold War and the nuclear arms race set the context for the community consequences in the past and at present. With the United States and the Soviet Union, in particular, racing for nuclear hegemony, uranium was mined with limited attention to the health consequences for the miners and for the populations exposed through extraction and processing. Efforts have since been directed to clean-up some of these sites, such as through the Uranium Mill Tailings and Recovery Act (UMTRA) in the United States.

Particularly concerning is the legacy of uranium mining during the Soviet era carried out in Central Asia, including the countries of Kazakhstan, Kyrgyzstan, Usbekistan, and Tanjikstan

(Figure 4).[9] The mines were both open pit and underground, and tailings and other wastes have been left in many locations, some near inhabited areas.

***Radiation Exposures to Communities***

A key concern with regard to communities is possible exposure to radiation because of proximity to mining and ore-handling facilities. The exposures arise primarily from the potential for contact with uranium and its decay chain. Uranium isotopes decay through several series (Figure 5) that involve the release of inert, radioactive gases, primarily radon (from radium) and thoron (from thorium). In the mines, these gases diffuse through the air of a mine (or are absorbed into water) and contaminate the air breathed by underground workers. In outdoor air, the concentration of radon, which is naturally present, might be increased if there were extensive contamination near to places where people live and work. Such increases in radon concentration have been documented in some locations. Focusing on radon, the gas has a relatively brief half-life and decays into a series of decay products (radon progeny or radon daughters). The radon progeny include two solid, radioactive polonium isotopes, which release alpha particles as they decay. As a reminder, an alpha particle is charged and has a high mass, equivalent to the helium nucleus (two neutrons and two protons).

When these alpha decays occur within the lung, the alpha particles can reach the nuclei of the cells lining the lung and damage the cells, including the DNA in the nuclei.[1] How the radon progeny reach the lung has been well worked out. Unlike gaseous radon, the progeny are solid and form small clusters, attaching to water molecules and other small particles. Underground workers and exposed community members inhale the progeny, which may deposit on the lining of the lung. There, when an alpha decay occurs, the cell nuclei are within the range of the alpha particles. As the alpha particles pass through the cells, irreparable damage may occur that ultimately leads to the development of lung cancer. The decay series extends through several long-lived radionuclides, called “internal emitters”, that can remain in the body following inhalation or ingestion and result in radiation exposure that originates within the body. Gamma exposure may also result from proximity to radioactive tailings piles.

***Purpose of this Report***

This report addresses community exposures resulting from uranium mining and milling activities and the scope of the at-risk population, considering the legacy of decades of uranium extraction as well as contemporary exposures. The report also includes a systematic review of studies that have addressed exposures to nearby communities and the health risks associated with such exposures. Finally, we use the databases of Pure Earth’s Toxic Sites Identification Program (TSIP), the World Nuclear Association, and other entities to estimate the numbers of persons at risk from exposures to persons residing adjacent to current and former uranium mining and milling sites.[10,11]

We do not consider community exposures at the more distal end of the uranium fuel cycle from nuclear power generation or weapons production facilities where communities might be affected by both “routine” and sporadic releases of radioactivity, by disasters, and by contamination from abandoned or inactive sites. Previous Green Cross reports have addressed the consequences of the Chernobyl and Fukushima disasters.[12]

## Methods

### ***Uranium Mining and Community Health Effects***

We conducted a systematic review of the available literature to examine the effects of uranium mining on the health of surrounding communities.

*Search Strategy*

Key word searches were conducted on PubMed and Google Scholar using a series of relevant search terms (Table 1). We also utilized the TSIP database to identify reports and publications related to identified uranium sites worldwide.[10] Search results were limited to papers available in English; no date restrictions were placed on the searches. The searches were carried out between April 12, 2018 and April 30, 2018. For Google Scholar, only the first 50 results of each search, sorted by relevance, were reviewed because of the lack of specificity of the search engine, compared with others used.

*Study Selection*

Initially, publication titles and summaries were scanned for relevance to uranium mining and milling and effects on surrounding communities. We did not include studies of uranium exposure in the general environment, per se; rather, we included studies that specifically examined uranium exposure in areas surrounding current and former uranium mining and milling sites. Duplicates were removed. Publications eliminated included those specific to uranium miners' health outcomes, non-human studies, dissertations and theses, publications found to be outside of the scope of this review, any publication for which no full-text article could be obtained, and articles that were not in English. Thirty-seven publications were accepted for full-text review. Of the thirty-seven publications accepted for full-text review, sixteen publications were accepted for inclusion in this report.

*Data Abstraction*

The accepted publications were reviewed and classified by type of study: studies of potential exposures to communities, cross-sectional studies of exposed populations, and cohort studies of disease incidence and/or mortality. Tables were constructed to highlight the main findings in the accepted studies (Table 2a.-2c.). Study design, study population characteristics, and key findings were reported for studies of exposures to communities (Table 2a.) and cross-sectional studies of exposed populations (Table 3a.). Study design, study population characteristics (exposed and control groups), outcome measure(s), and key findings were reported for cohort studies of disease incidence and/or mortality (Table 2c.). As the included cohort studies were longitudinal, the time period of data collection was included in the table. The data were extracted by Meghan Buran.

***Estimated Number of People at Risk of Health Effects from Uranium Mining, Milling, and Processing***

We examined available information from various sources--including the TSIP database, the World Nuclear Association, government documents and reports, mining company documents and reports, available maps, and Wikipedia profiles--for historic, active, and proposed uranium mining sites and the communities in their proximity to estimate the number of people at risk of health effects from exposure to uranium mining and related processes. The general approach used multiple databases including the TSIP database, and further details are provided in the results for each type of data.

## Results

The peer-reviewed literature on uranium mining and related activities and communities is limited. Three broad classes of studies can be identified: 1) studies on exposures to communities associated with uranium mining and processing activities; 2) cross-sectional studies of exposed populations, generally with a control, unexposed population; and 3) cohort (longitudinal) studies comparing disease incidence and/or mortality in exposed and unexposed populations (Tables 2a-c).

A limited set of cross-sectional studies was identified that provided measures of exposure of communities to radioactivity. Several of the studies are quite small and are limited to single sites. The study in central Asia showed that use of mill tailings in construction could lead to high exposures; such uses of tailings were once common until the radiation hazard was recognized. For example, in the now non-existent town of Uravan, Colorado, tailings were widely used as fill under homes, a practice that extended to towns in the same region of southwestern Colorado. The studies also document the possibility of water contamination and ingestion.

Five quite diverse studies were found that addressed various indicators of community health impact. The studies included varied indicators of exposure, including place of residence and biomarkers. Two studies were directed at persons residing in the Navajo Nation in the southwestern United States; parts of the Navajo Nation are dotted with small inoperative mining sites and there is concern about long-term implications. A case-control study was carried out to determine whether exposures related to uranium mining were linked to birth outcomes and a second report explored associations of mining with several major chronic diseases. Other studies explored various biomarkers in a cross-sectional framework, Collectively, these studies share the limitation of being primarily cross-sectional and lacking comprehensive exposure assessment.

Finally, a number of studies compared disease indicators, including mortality, in exposed and comparision populations (Table 2c). Four of these were industry-sponsored studies carried out in New Mexico and Colorado in the United States by Boice and colleagues. These studies were carried out at a population level and compared mortality over some time period in the study and control communities. In such studies, exposure is based on place of residence and the population size often limits the precision of the studies. These four studies provided “negative findings”, i.e., not documenting associations other than increased risk for lung cancer in men, likely reflecting employment as miners or millers. While the design is insensitive, the findings weigh against any large and not anticipated community consequences for mortality, a relatively crude outcome.

A study in Spain examined mortality from hematopoietic malignancies in people residing within 30 km of four nuclear fuel facilities, in comparison to towns located further away. An increase in risk for leukemia mortality was found, along with increased risk for lung cancer and renal cancer. A case-control study was carried out in the US state of Ohio to examine association of uranium exposure with the autoimmune disease, systematic lupus erythematosus. Significant associations were found, although the biological basis for such associations is not clear.

***Estimated Number of People at Risk of Health Effects from Uranium Mining, Milling, and Processing***

To estimate the global population at risk from exposure to radiation from uranium mining and milling, we identified sites using multiple sources: Pure Earth's TSIP (Table 3a.), the World Nuclear Organization's lists of global sites (Table 3b.), the U.S. Department of Energy UMTRA Project and the World Nuclear Organization's list of U.S. sites (Table 3c.), and the World Nuclear Association's list of Canadian sites (Table 3d.). Table 3a. provides the TSIP site names, countries of sites, and population estimates made by TSIP investigators. No additional information was included for these sites outside of the information provided by the TSIP investigators. Table 3b. lists global sites that were not included in the TSIP database and identified from the World Nuclear Association website. This table is organized by country and includes the site name, type of site (mine, mill, heap leach, or in-situ-leach), current known operating status, nearest identified communities, and the estimated populations of these communities. Table 3c. details sites within the United States and includes former sites remediated under the UMTRA project[13], current and planned US mills, current and planned heap leach plants, and current and planned in-situ leach plants. The following information is provided for each: site name, U.S. state, current known operating status, nearest community, and estimated population at risk. Table 3d. details sites within Canada, including uranium operating mines and fuel cyles. The following information is provided for each site: site name, Canadian province, current known operating status, nearest community, and estimated population at risk.

*Pure Earth's Toxic Site Identification Program Sites*

TSIP sites were identified from the TSIP database by sorting for sites where uranium was listed as the main or secondary environmental pollutant.[10] TSIP site investigators provided estimates of populations at risk from radiation exposure but only in low and middle income countries. All of these estimates were included in Table 3a.

*Additional Global Sites*

The TSIP database, while extensive, is not intended to be a comprehensive list of uranium mining and milling sites. Thus, additional global sites were identified through the World Nuclear Association website.[8] Google searches were used to identify the communities close to identified uranium sites. These searches yielded information from government reports, mining company reports and records, as well as Wikipedia profiles. If a community was located for the site, a population estimate was included using the most recently available Census records; typically, estimates were from 2000-2016 depending on the last available records and community participation. Many sites were remotely located and thus an estimate of the at-risk populations was not possible, but the numbers of residents were likely very small. Such sites are so designated in the table. There were also sites for which no information on nearby communities could be found. Sites with no identified at-risk populations were included in the table and marked accordingly.

*United States*

In the United States, former uranium milling sites have been remediated under the UMTRA Act.[13] Former sites included in the population estimate were identified from the U.S. Energy Information Administration records.[13] Nearest community information was provided in the U.S. Department of Energy Legacy Management fact sheets available for each remediated site.[14] Population estimates were then made using the most recently available U.S. Census records (2000-2016). Current and planned mills, heap leach plants, and in-situ-leach plants were identified from the World Nuclear Association.[11] Google searches were used to identify communities nearby identified sites. These searches yielded information from government reports, mining company reports and records, as well as Wikipedia profiles. Population estimates for communities located near the sites were made using the most recently available Census records, which may not have aligned fully with the population at the time of operations. For the United States, these resources likely do not cover the many small mines, often referred to as “dog-hole” mines”, that were common in the early days of the industry. There were many small mines on the lands of the Navajo Nation that remain of concern today.

*Canada*

Until recently, Canada was the leading global uranium producer with multiple mines and mills.[15] Canadian sites were identified via the World Nuclear Association.[15] Google searches were used to identify communities nearby identified sites. These searches yielded information from government reports, mining company reports and records, as well as Wikipedia profiles. If a community was located for the site, a population estimate was included using the most recently available Census records; typically, estimates were from 2000-2016 depending on the last available records and community participation. Many sites were located in remote provinces, so that population estimation was not possible. There were also sites for which no information on nearby communities could be found. Sites with no identified at-risk populations were included in the table and marked accordingly.

Population estimates were made for people at risk for exposure from existing sites as well as 33 proposed sites for mining that were identified in this analysis. As proposed sites were not yet actively mining or processing and, in most cases, not yet past the prospecting or licensing stages, these estimates are made separately. We note that many sites, particularly in the U.S. and Canada, have been closed or placed on standby with companies citing the falling uranium prices as a deterrent to production.[11]

*Estimates of Exposed Populations*

Table 4 provides summary counts across Tables 3a-d. It provides the total counts for each category of estimation. For this analysis, we have included sites of all operating statuses, whether currently active or active in the past. For sites currently or previously active, an estimated total of about 6.4 million people globally were at risk from radiation and potentially other exposures due to uranium mining and milling at some point in time. An additional 400,000 people globally were estimated to become at risk for exposures if the proposed sites were approved and developed in the future. In many countries, the sites were remote, located hundreds of miles from the nearest identifiable population. Such sites likely pose little risk for the general population. However, there were a number of sites, particularly former sites, located near and within communities and cities, varying in size from below 50 to over 1.6 million people.

## Discussion and Conclusions

This review of the literature and compilation of data on sites of uranium mining and processing around the world documents the enormous scope of uranium mining worldwide. In the span of seven decades, the extraction and processing of uranium became a massive global industry. Focusing on the extractive end of the nuclear fuel cycle, the risks to uranium miners, particularly underground miners are well documented: lung cancer, chronic lung disease, and silicosis, along with the general risks of injury and death faced by all miners. Beyond these well-characterized hazards, communities adjacent to uranium mines and mills and processing facilities are also at risk for exposure.

The review of the literature yielded only a small number of studies that directly addressed exposures sustained by populations from uranium extraction. Several provided evidence related to pathways of exposure, but generally the radiation exposures documented were only a small increment above background. Of concern, however, was the use of tailings in the construction of buildings, potentially leading to unacceptably high radiation exposures. The extent of this practice is uncertain across the many sites of uranium mining and milling, but it has been documented.

Estimating the cumulative numbers of community residents exposed to radiation from the extractive end of the fuel cycle is not possible. We reviewed data from diverse sources that covered multiple spans of time. We could not readily align populations to time periods when mines and mills were either operative or non-operative. Additionally, the population counts are cross-sectional and not cumulative; that is, we obtained a population estimate for a particular moment in time, generally the most recent available. Given the boom-and-bust character of the industry, there is a potential that current counts may under-estimate the numbers cumulatively exposed. The determination of the proximity of the mines to nearby populations was uncertain as for many sites information was unavailable regarding the areas immediately surrounding the sites, particularly in some countries, e.g., China and Kazakhstan. Some identifiable communities were 30 or more kilometers away from the mining or milling site. A “safe” distance for exposure from a site can not be specified as we cannot accurately predict the distance that contaminated materials have or will travel through air, water, and construction material.

As such, the numbers provided in this report should be considered as providing an approximation of the numbers of people in close enough proximity to uranium mines and mills to be exposed to radiation. The available studies, while limited in number, suggest that incremental exposures above background would likely have been small. However, construction of homes and other buildings would have led to more substantial increases. In some countries, such as the United States, the government funded clean-up of tailings at substantial costs. In others, however, such as countries of central Asia, sites of mining and milling have yet to be remediated, a legacy that should be addressed.

**Figure 1.** The Nuclear Fuel Cycle and the Initial Components of the Nuclear Fuel Cycle[16]

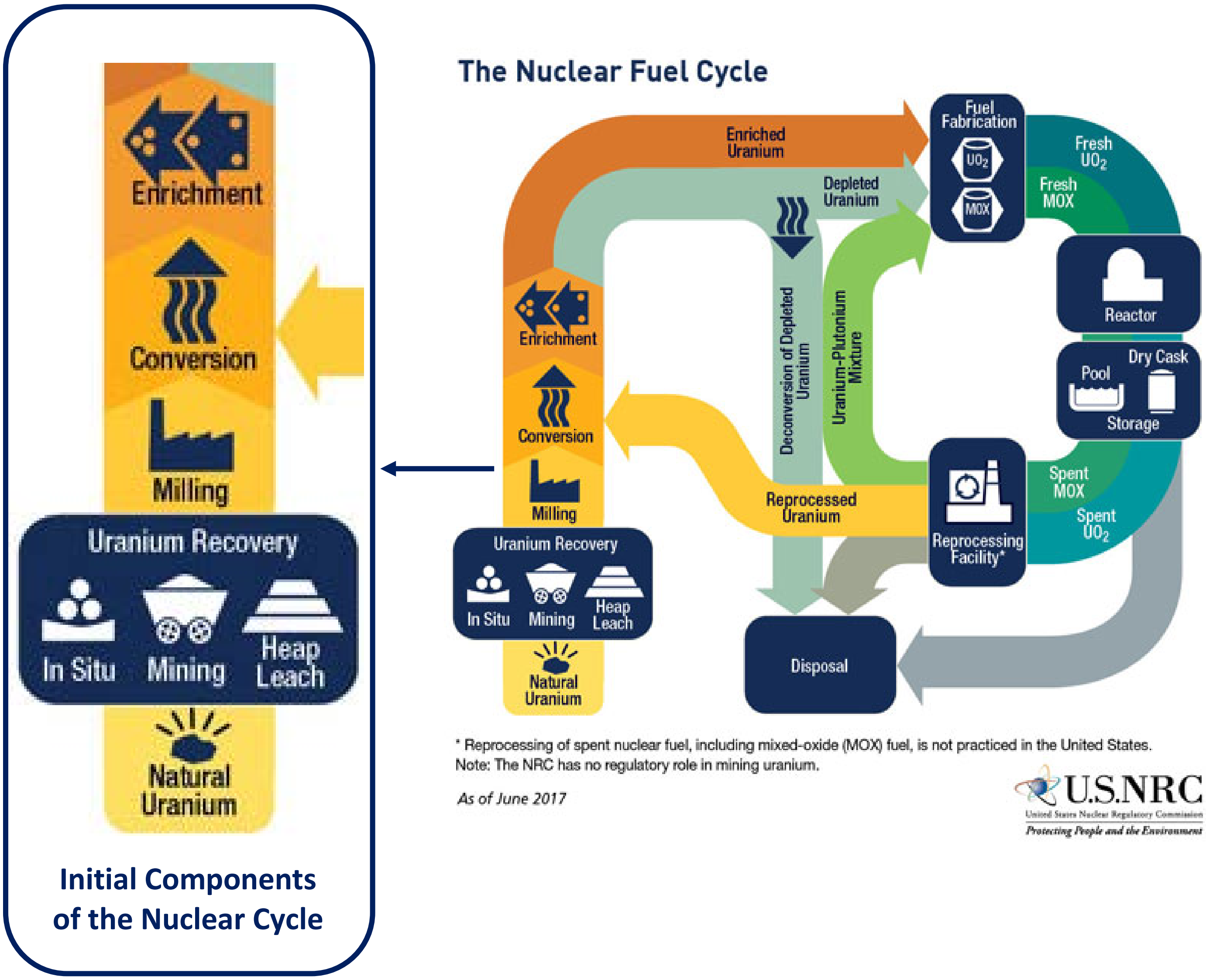
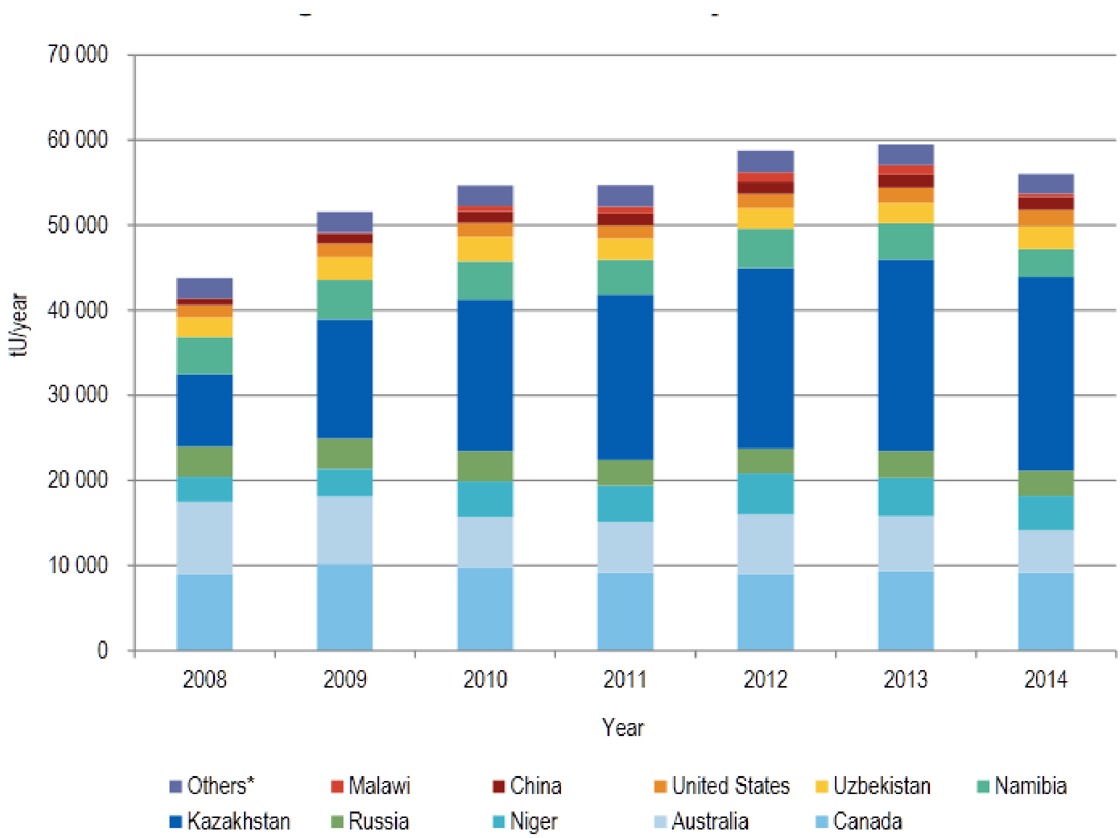


**Figure 2a.** Trends of world uranium production by country, 2008-2014[17] (Source: OECD-NEA)




* "Others" includes the remaining producers (see Table 1.21).

**Figure 2b.** Uranium production by country, 2014[17] (Source: OECD-NEA)

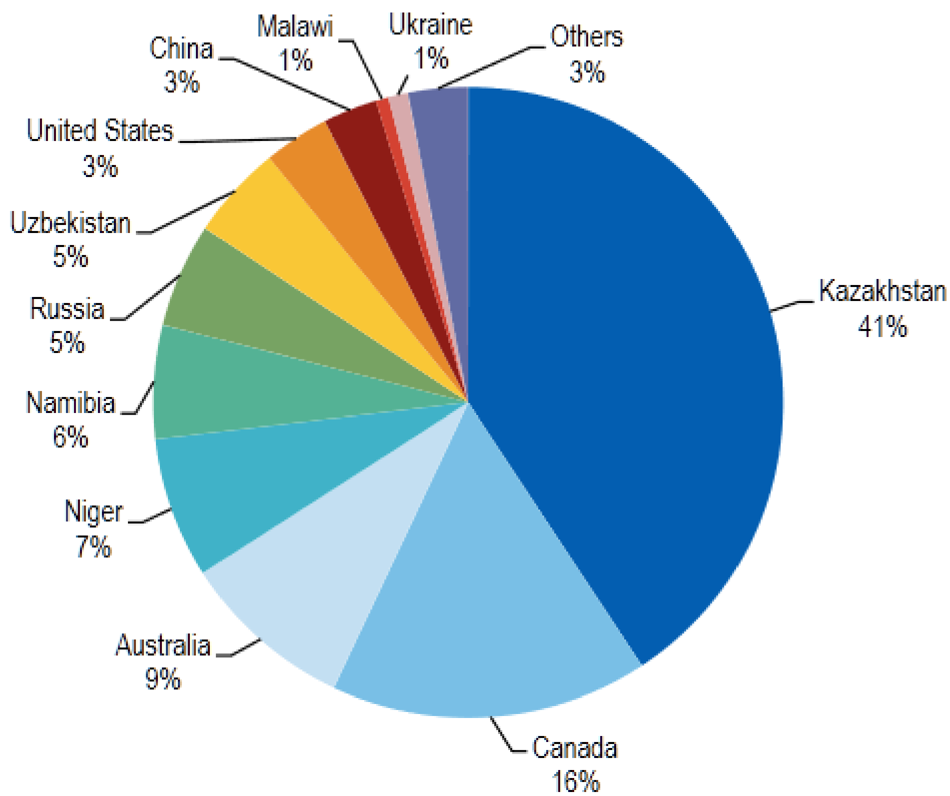


**Figure 3.** Alpha decays[4]

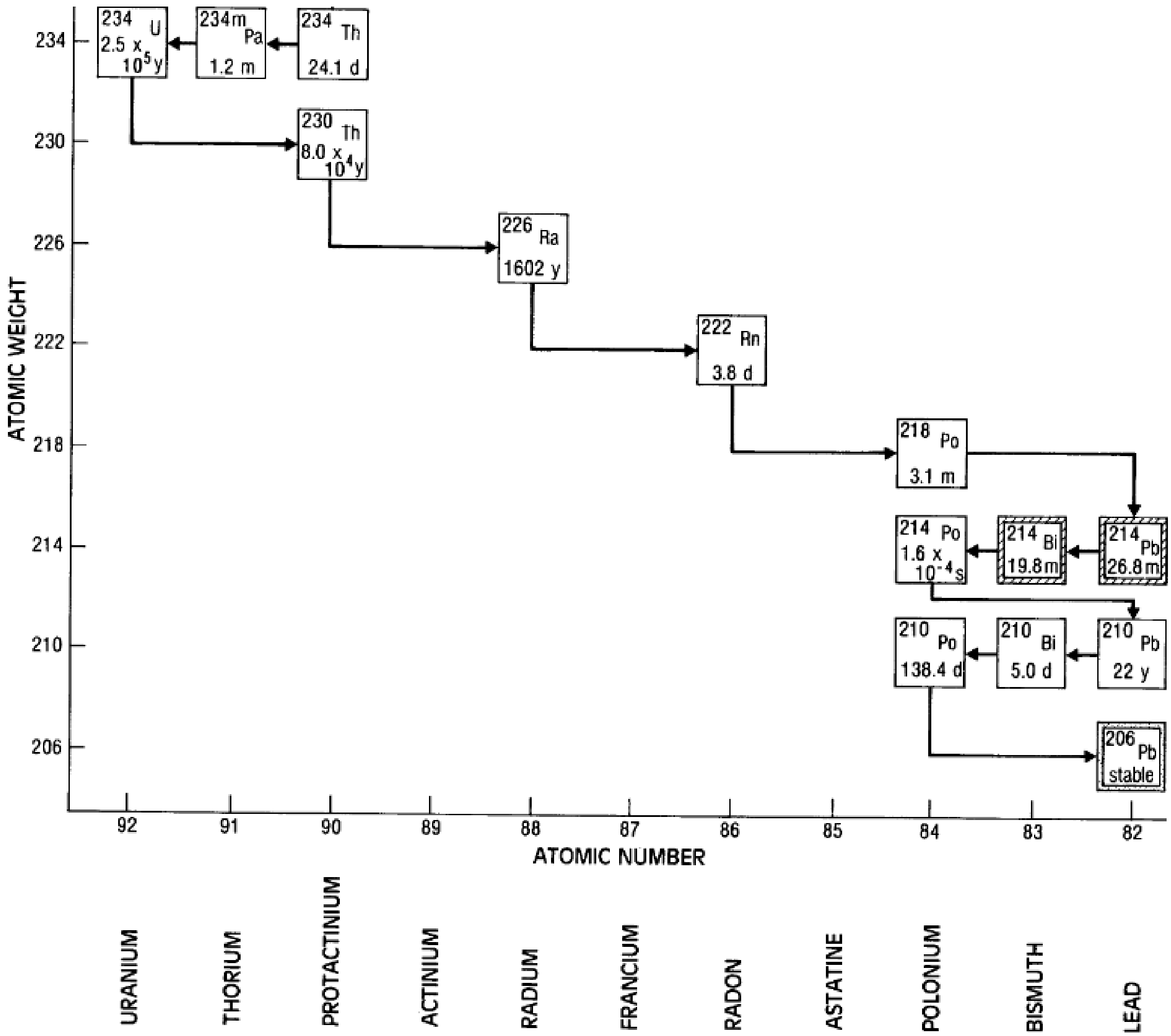


**Figure 4.** Uranium legacy sites in Central Asia[9]

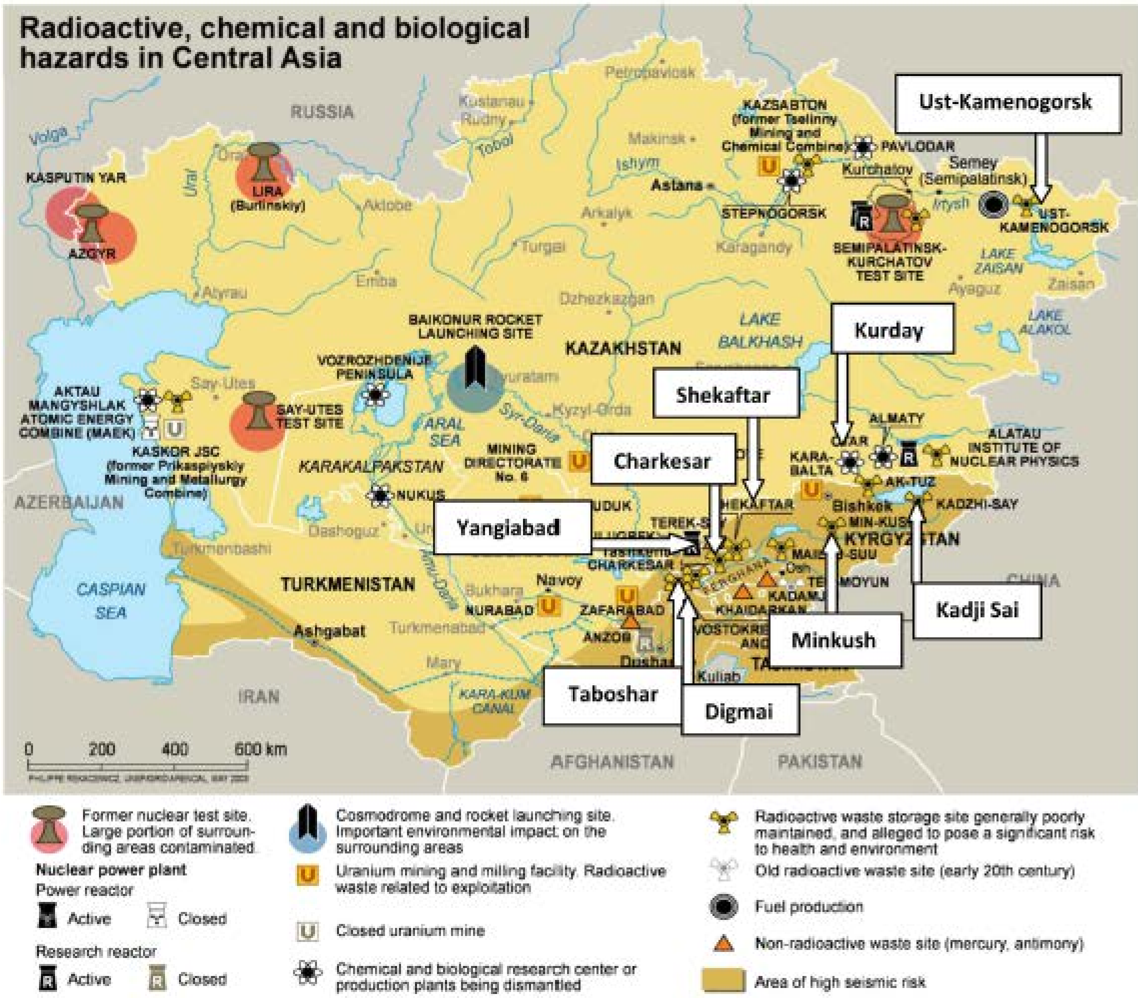



Fig. 1. Uranium legacy sites investigated within the NATO RESCA Project in Central Asia: Kurday, Ust-Kamenogorsk (Kazakhstan), Shekaftar, Minkush, Kadji Sai (Kyrgyzstan), Taboshar, Digmai (Tajikistan), Yangiabad, Charkesar (Uzbekistan).

**Figure 5.** Uranium 238 Decay Cycle[18]

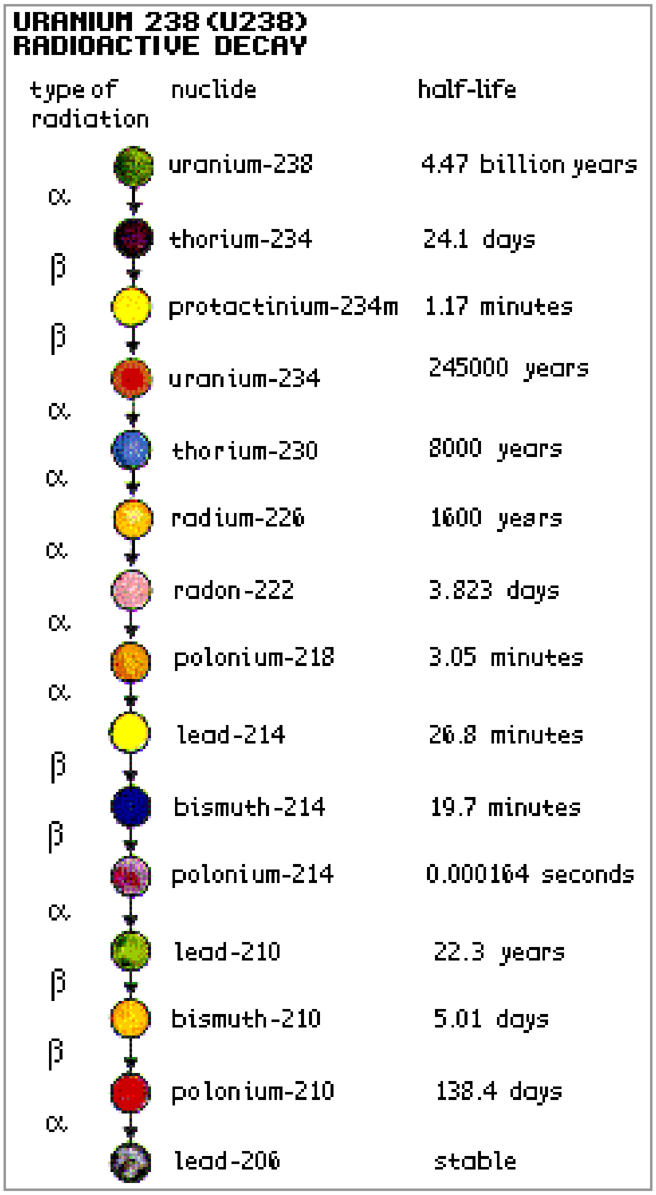


**Table 1.** Search Terms Used by Database/Search Engine

| **PubMed** |
| --- |
| Uranium mining + uranium milling + community health effects |
| Uranium mining + community health effects |
| Uranium mining + community health risks |
| Uranium mining + birth outcomes |
| Uranium mining + sex ratios |
| Uranium milling + community health effects |
| **Google Scholar** |
| Uranium mining + Czechoslovaki |
| Uranium mining + Central Asia |
| Uranium mining + communities |

**Table 2a.** Studies on potential exposures to communities associated with uranium mining and processing activities

| Study | Design | Population | Key Findings |
|---|---|---|---|
| Stegnar P, Shishkov I, Burkitbayev M, et al. Assessment of the radiological impact of gamma and radon dose rates at former U mining sites in Central Asia. | • Radiation dose assessment<br>• Measured indoor $^{222}Rn/^{220}Rn$ and gamma exposure to ionizing radiation at the investigated uranium legacy sites in Central Asia (note: most sites were partly or not at all remediated) | • Populations located near uranium legacy sites in Central Asia<br><br>Sites:<br>Kazakhstan: Kurday<br>Kyrgyzstan: Shekaftar, Minkush, Kadjii Sai<br>Tajikistan: Taboshar, Digmai<br>Uzbekistan: Charkesar and Yangiabad | • The Minkush site (Kyrgyzstan) had observed individual annual doses of ionizing radiation fo more than 100 mSv, likely due to usage of radioactive materials in homes for insulation purposes.<br>• All other legacy sites measured low in radiological risk (all below 30 mSv per year), suggesting that the current radiation doses for these sites do not represent a serious hazard to residents. |
| Au WW, McConnell MA, Wilkinson GS, et al. Population monitoring: Experience with residents exposed to uranium mining/milling waste. Mutation Research. 1998;405:237-245. | • Environmental exposure assessment (uranium)<br>o Measured uranium in environmental samples taken neare 2 mining/milling sites (Panna Maria and Susquenhanna) | • Populations living near mining/milling sites in Karnes County, TX<br>• Exposed N=24<br>• Control N=24 | • Environmental exposure assessments found increased levels of uranium in soil near the mining/milling sites |

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| | in Karnes County, TX | | |
| Singh L, Kumar R, Kumar S, et al. Health risk assessments due to uranium contamination of drinking water in Bathinda region, Punjab state, India. Radioprotection. 2012: | • Radiological risk assessment<br>• Measured 147 samples of groundwater (the main water source for residents), 6 samples of canal water, and 6 samples of reverse osmosis (RO)-treated water for uranium concentrations | • Populations within the Bathinda region, Punjab state, India—a region with excess cancer cases | • Uranium contamination in the drinking water samples was found to be 3.72 times higher than the Atomic Energy Regulatory Board, India (AERB) safe limit.<br>• The canal water and RO-treated water had levels within the AERB permissible limits suggesting that drinking water should be treated before consumption to reduce risk from uranium contamination |

**Table 2b.** Cross-sectional studies of exposed populations

| Study | Design | Population | Key Findings |
|---|---|---|---|
| Au WW, McConnell MA, Wilkinson GS, et al. Population monitoring: Experience with residents exposed to uranium mining/milling waste. Mutation Research. 1998;405:237-245. | Biomarker analysis | • Populations living near mining/milling sites in Karnes County, TX<br>• Exposed N=24<br>• Control N=24 | • Cells from exposed individuals showed more chromosomal aberrations than controls but difference not statistically significant<br>• Further analyses showed significant abnormal DNA repair response in exposed individuals |
| Lourenco J, Pereira R, Pinto F, et al. Biomonitoring a human population inhabiting nearby a deactivated uranium mine. Toxicology. 2013; 305: 89-98 | Cross-sectional with reference group<br><br>Peripheral blood samples were analyzed for:<br>• Genotoxic effects<br>• Immunotoxicity<br>• Trace elements<br>• C reactive protein (CRP)<br><br>Cunha Baixa village, Portugal<br>• Abandoned uranium mine | Total N=84<br><br>*Exposed Group:*<br>N=54<br>Inclusion critera = resident of Cunha Baixa village (Portugal); no drinking problems, smoking habits, or autoimmune diseases; village resident for > 5 years<br><br>*Reference Group:*<br>N=30<br>Inclusion criteria= resident of Vale de Acores, Mortagua or the district of Viseu; additional criteria same as | • Significantly higher levels of uranium (H=5.86; *df*=1; *p*=0.015) and manganese (F=29.3; *df*=1,39; *p*<0.001) were found in residents of Cunha Baixa village<br>• The control group had significantly higher levels of zinc (F=11.9; *df*=1,39; *p*<0.001)<br>• A significant loss of DNA integrity was observed in residents of Cunha Baixa village aged 40 to 60 (F=11.4; *df*=1,30; *p*<0.001) and 60 years and older |

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| | | exposed population | (F=36.3; *df*=1,35; *p*<0.001)<br>• High levels of DNA damage were observed in peripheral blood leukocytes of Cunha Baixa residents as well as decreased levels of NK and T cells |
| Thakur H & Sapra BK. Baseline survey of health status of population in 2006 around a uranium mining site in Jaguguda, India. Radiation Emergency Medicine. 2013;2(1):14-22. | Cross-sectional study<br><br>Assessing the morbidity of residents living in villages within a 5 km radius of a uranium mining site:<br>• carcinomas<br>• infertility<br>• congential abnormalities<br><br>Data collection:<br>1. Household survey<br>2. Health check-up camp<br>3. Referrals to health centre for final diagnosis<br><br>Jharkhand, India<br>• Jaduguda Uranium Mines | • Household survey<br>  o N=34,953<br>• Health check-up camp<br>  o N=2,693<br>• Referrals for final diagnosis<br>  o N=1,523<br>• Completed most diagnostic tests<br>  o N=91 | • Household survey<br>  o 1.8% reported a lump<br>  o 1.4% reported bleeding from any site<br>  o 3.4% of women reported leucorrhoea<br>  o 0.3% reported mental retardation<br>  o 0.7% reported physical deformaties<br>• 56 people were referred to confirm cancer<br>  o 1 case of cancer confirmed<br>• 35 people were referred to confirm congenital anomaly<br>  o 6 cases confirmed |

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| Wagner S, Burch J, Bottai M, et al. Hypertension and hematologic parameters in a community near a uranium processing facility. Environmental Research. 2010;110:786-797. | Analysis of baseline data from a longitudinal study<br><br>Assessed potential health effects among residents living within 5 miles of a uranium processing facility<br>• Hypertension<br>• Hematology<br><br>Data collection:<br>• Hypertension:<br>o Systolic and diastolic blood pressure<br>o Physical diagnosis<br>• Hematology<br>o Differential counts of red blood cells, white blood cells, and platelets<br><br>Fernald Feed Materials Production Center (FMPC), Ohio<br>• Uranium processing facility | N = 8,216<br><br>*Inclusion criteria:* considered adults at time of 1st exam; had never worked at Fernald mill; lived within 5 miles of the mill<br><br>*Exclusion criteria:* had worked at Fernald mill; under 18 years of age; never lived within 5 miles of the mill; residential address was insufficient for geocoding; incomplete demographic information | • Cumulative uranium exposure levels:<br>o Low = 51%<br>o Moderate = 15%<br>o High (>0.50 Sievert) = 34%<br>• Participants with elevated uranium exposure (compared with those with low exposure) had<br>o Decreased white blood cell count (high exp – GM:6.28 thousand cells/µl, p=0.02)<br>o Decreased lymphocyte counts (moderate exp – GM:1.90 thousand cells/µl, p=0.3; high exp – GM:1.01 thousand cells/µl, p=0.02)<br>o Increased sosinophil counts (OR:1.07; 95% CI: 1.01, 1.13) |
| Shields LM, Wiese WH, Skipper BJ, et al. Navajo | Nested case control study | N= 266 pairs (532 individuals) | • Mothers who lived near uranijm tailings or dumps |

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| birth outcomes in the Shiprock uranium mining area. Health Physics. 1992; 63(5):542-51. | Assessed the role of environmental radiation in the etiology of<br>• Birth defects<br>• Stillbirths<br>• Other adverse outcomes of pregnancy<br><br>Data Collection:<br>• Adverse pregnancy outcomes:<br>  o Hospital records<br>• Exposure variables:<br>  o Parent and grandparent interviews about time prior to the birth:<br>    ▪ Residence within 0.5 miles of a uranium mine, mine dumps, or tailings<br>    ▪ Work in uranium mill or mine<br>    ▪ Living in home built of uranium mine rock<br><br>Navajo Indian Reservation; Shiprock, NM<br>• Uranium mines, mill tailings, mine dumps | Navajos born at the Public Health Service/Indian Health Services Hospital in the Shiprock, NM uranium mining area between 1964-1981<br><br>*Index group*: infants with congenital abnormalities, stillbirths, and development disorders, as well as infant deaths from causes other than injuries<br><br>*Control group*: infants selected were the chronologically nearest normal single birth, matched by sex, mother's age within 5 years, and within two pregnancies if more than prima-gravida | were more likely to have an adverse pregnancy outcome<br>  o OR=1.83, *p*=0.05<br>• There was a significant association between mothers living near tailings or mine dumps and outcomes such as hip dysplasias and dislocations, cerebral palsy and developmental delay, as well as stillbirths<br>  o OR=2.71, *p*=0.03<br>• There was no effect of reported duration of exposure |
| Hund L, Bedrick E, Miller C, et al. A Bayesian framework for estimating disease risk due to exposure to uranium mine and mill | Baseline of a longitudinal study<br><br>Examined the relationship between uranium mine waste exposure and:<br>• Kidney diseases<br>• Diabetes | N=1,304 residents of the Navajo Nation | • Active exposure (exposure of mine/mill workers) produced the strongest exposure associations |

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| waste on the Navajo Nation. J.R. Statist. Soc. 2015; 178(4):1069-1091. | • Hypertension<br><br>Navajo Nation<br>• Uranium mines | | |

**Table 2c.** Cohort (longitudinal) studies of comparing disease incidence and/or mortality in exposed and unexposed populations

| Study | Design | Population | Outcome Measure | Key Findings |
|---|---|---|---|---|
| Boice Jr JD, Mumma M, Schweitzer S & Blot WJ. Cancer mortality in a Texas county with prior uranium mining and milling activities, 1950-2001. J Radio Prot. 2003; 23:247-262. | Mortality study<br><br>Time Period: 1950-2001<br><br>Karnes County, TX<br>• 3 uranium mining mills and 40 mines were operated from the 1950s to the 1990s | *Exposed group:* residents of Karnes County, TX<br><br>*Control group:* residents of 4 comparison counties (Frio, La Salle, De Witt, Goliad) matched to Karnes County by sociodemographic variables; population of State of Texas; US population | Mortality caused by:<br>• Oesophagoel cancer<br>• Stomach cancer<br>• Colon/rectal cancer<br>• Pancreatic cancer<br>• Lung cancer<br>• Melanoma/skin cancer<br>• Breast cancer (women)<br>• Cervical cancer<br>• Uterine cancer<br>• Ovarian cancer<br>• Prostate cancer<br>• Urinary bladder cancer<br>• Kidney/renal cancer<br>• Liver cancer<br>• Bone cancer<br>• Connective tissue cancer<br>• Brain cancer and CNS<br>• Thyroid cancer<br>• Non-Hodgkin's lymphoma<br>• Hodgkin's disease<br>• Multiple myeloma<br>• Leukemia | • There was no observed increase in cancer mortality for Karnes County residents when compared to similar counties in South Central Texas, the State of Texas, and the US population |
| Lopez-Abente G, Aragones | Retrospective cohort | *Exposed Group:* | Mortality caused by: | Excess risk of |

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| N, Pollan M, et al. Leukemia, lymphomas, and myeloma mortality in the vicinity of nuclear power plants and nuclear fuel facilities in Spain. Cancer Epidemiology, Biomarkers & Prevention. 1999;8:925-934. | study<br><br>Time period: 1975-1993<br><br>Spain | Residents living in 173 towns within a 30 km radius of four nuclear fuel facilities (uranium processing facilities)<br><br>*Reference Group:*<br>Residents living in 174 towns within a 50-100km radius of four nuclear fuel facilities | • Leukemias<br>• Hodgkin's disease<br>• Non-Hodgkin's lymphomas<br>• Multiple myeloma | leukemia mortality was observed in the vicinity of uranium processing facilities in:<br>• Andujar (RR 1.303; 95% CI, 1.03-1.64)<br>• Ciudad Rodrigo (RR 1.68; 95% CI, 0.92-3.08) |
| Lopez-Abente G, Aragones N & Pollan M. Solid-tumor mortality in the vicinity of uranium cycle facilities and nuclear power plants in Spain. Environmental Health Perspectives. 2001;109(7):721-729. | Spatial mortality study<br><br>Time period: 1975-1993<br><br>Spain | *Exposed Group:*<br>Residents living in 99 towns (chosen randomly from 283 towns) within a 30 km radius of four nuclear fuel facilities (uranium cycle facilities) N=513,248<br><br>*Reference Group:*<br>Residents living in 97 towns (chosen randomly from 275 towns matched to exposed group by population size and sociodemographic variables) within a 50 to | Mortality caused by:<br>• Stomach cancer<br>• Colorectal cancer<br>• Lung cancer<br>• Bone cancer<br>• Connective tissue cancer<br>• Breast cancer (women)<br>• Brain cancer<br>• Thyroid cancer<br>• Bladder cancer<br>• Kidney cancer<br>• Ovarian cancer<br>• All malignant tumors<br><br>Latency period: | • Excess lung cancer mortality was observed in residents living in the vicinity of uranium cycle facilities (RR 1.12, 95% CI, 1.02-1.25)<br>• Excess renal cancer mortality was observed in residents living in the vicinity |

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| | | 100 km radius of four nuclear fuel facilities | 10 years | of uranium cycle facilities (RR 1.37, 95% CI, 1.07-1.76) |
| Lu-Fritts PY, Kottyan LC, James JA, et al. Association of systematic lupus erythematosus with uranium exposure in a community living near a uranium-processing plant. Arthritis & Rheumatology. 2014;66(11):3105-3112. | Nested case control study<br><br>Time period: 1990-2008<br><br>Fernand, OH | Total N=124<br><br>All participants lived within a 5 mile radius of an active uranium ore-processing facility in Fernand, OH for at least 2 consecutive years between January 1, 1952 and December 18, 1984<br><br>*Case group*: confirmed diagnosis of SLE<br>N=25<br><br>*Control group*: no SLE diagnosis; matched on age, race, and sex<br>Exclusion criteria: non-white race, abnormal lab findings<br>N=99 | Systemic Lupus Erythematosis (SLE) | • Presence of SLE was associated with high levels of prior uranium exposure (OR 3.92, 95% CI 1.13-13.59; P=0.031)<br>• Women with high uranium exposure had increased odds for SLE compared to women with low exposure (OR 7.15, 95% CI 1.52-33.73; P=0.01)<br>• Risk of SLE was increased with increased exposure to |

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| | | | | uranium (OR 1.38, 95% CI 1.03-1.86; P=0.03) |
| Boice Jr JD, Mumma MT & Blot WJ. Cancer and noncancer mortality in populations living near uranium and vanadium mining and milling operations in Montrose County, Colorado, 1950-2000. Radiation Research. 2007; 167(6):711-726. | Mortality study<br><br>Time Period: 1950-2000<br><br>Montrose County, CO<br>• Uravan mill (uranium) | *Exposed group*: residents of Montrose County, CO<br><br>*Control group*: residents of 5 comparison counties (Mesa, Delta, Montezuma, Logan, Yum) matched on similar population characteristics; population of State of Colorado; US population | Cancer Mortality<br>• Esophagus<br>• Stomach<br>• Colon/rectum<br>• Pancreas<br>• Lung<br>• Skin<br>• Malignant melanoma of the skin<br>• Breast<br>• Cervix uteri<br>• Corpus uteri<br>• Ovary<br>• Prostate<br>• Urinary bladder<br>• Kidney<br>• Liver and kidney<br>• Bone<br>• Connective tissue<br>• Brain & CNS<br>• Thyroid<br>• Non-Hodgkin lymphoma<br>• Hodgkin lymphoma<br>• Multiple myeloma | • No difference between the total cancer mortality rates in Montrose County and those in comparison counties (RR=1.01; 95% CI 0.96-1.06) |

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| | | | • Leukemia<br>  o Leukemia, CLL<br>  o Leukemia, not CLL<br>  o Childhood leukemia<br>• Childhood cancer | |
| Boice Jr JD, Cohen SS, Mumma MT, et al. Mortality among residents of Uravan, Colorado who lived near a uranium mine, 1936-84. J Radiol Prot. 2007; 27:299-319. | Retrospective cohort mortality study<br><br>Time Period: 1979-2004 (follow-up)<br><br>Uravan, Colorado<br>• Uranium mill | N=1,905<br><br>*Inclusion criteria*: alive after 1978; lived in Uravan, CO for at least 6 months between 1936 and 1984 | Cancer Mortality<br>• Buccal cavity and pharynx<br>• Oesophagus<br>• Stomach<br>• Colon<br>• Rectum<br>• Biliary passages and liver<br>• Pancreas<br>• Bronchus, trachea, and lung<br>• Breast<br>• All uterine<br>• Other female genital organs<br>• Prostate<br>• Kidney<br>• Bladder and other urinary<br>• Melanoma of skin<br>• Brain and CNS<br>• Thyroid and other endocrine glands<br>• Bone<br>• All lymphatic, | • No significant elevation of any cancers or causes of death were found for those who lived near the mills<br>• However, a significant elevation of lung cancer was found for men who had worked in the mines |

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| | | | haematopoietic tissue<br>o Non-Hodgkins lymphoma<br>o Hodgkin lymphoma<br>o Leukaemia and aleukaemia<br>o Chronic lympocytic leukaemia<br>o Leukaemia other than CLL<br>o Multiple myeloma<br>• Pleura and peritoneum and mesothelioma<br><br>Mortality caused by<br>• AIDS<br>• Diabetes<br>• Mental and behavioral disorders<br>• Diseases of the nervous system<br>• Cerebrovascular disease<br>• All heart disease<br>• Non-malignant respiratory disease<br>o Bronchitis, emphysema, asthma | |

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| | | | • Cirrhosis of liver<br>• Nephritis and nephrosis<br>• All external causes of death<br>  o Accidents<br>  o Suicides<br>• Unknown causes of death | |
| Boice Jr JD, Mumma MT & Blot WJ. Cancer incidence and mortality in populations living near uranium milling and mining operations in Grants, New Mexico, 1950-2004. Radiation Research. 2010; 174(5):624-636 | Retrospective longitudinal cohort study<br><br>Time Period: 1950-2004<br><br>Grants, New Mexico and surrounding counties<br>• Grants Uranium Mill | *Exposed group*: Cibola and Valencia County residents; residents of census tract regions near the Grants Uranium Mill<br><br>*Control group*: general population of New Mexico | Incidence of and Mortality due to Cancers | • Increased lung cancer deaths and incidents were higher among men, seemingly due to working in the mill, smoking, and other factors<br>• No increased cancer deaths and incidents were observed for women in the exposed group |

**Table 3a.** TSIP Global Sites

| TSIP Global Site | Country | Total Population at Risk (Estimated by TSIP investigators) |
|---|---|---|
| Jadugora Radioactive Sites, East Singhbhum District, Jharkhand, India | India | 1,000 |
| Arlit, Tuareg Region | Niger | 110,000 |
| Bathinda District, Punjab | India | 5,000 |
| Case INB - Caetit | Brazil | 3,000 |
| Chkalovsk hydrometallurgical plant tailing pond | Tajikistan | 5,000 |
| Chkalovsk Tailing Dump (maps 1-9) | Tajikistan | 3,000 |
| Degmai (or Degmay) Radioactive Storage Site, Degmai Village, Sughd Region | Tajikistan | 10,000 |
| Depósito de residuos de Mina de Uranio Don Otto, Dpto. San Carlos, Salta | Argentina | 25,000 |
| Dressing Mill (Asybylak) | Kazakhstan | 220 |
| Dressing Mill (Asybylak) – 2nd site | Kazakhstan | 45 |
| Ezeiza Atomic Center, Ezeiza, Buenos Aires Province | Argentina | 20,000 |
| Former Building of KIP Automatics (uranium production adit), Sarymsakli, Istiklol (Taboshar) - | Tajikistan | 2,700 |
| Former uranium mine | Tajikistan | 1,500 |
| Romanovka, Baikal | Russia | 20,000 |
| School, Iskatol (Taboshar) | Tajikistan | 3,760 |
| Shekaftar | Kyrgyzstan | 1,000 |
| Sumsar area | Kyrgyzstan | 2,140 |
| Tash-Komur | Kyrgyzstan | 95 |

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| Uranium Mining and Chemical Combine, Stepnogorsk town. | Kazakhstan | 40,000 |
| v. Kamyshanovka. | Kyrgyzstan | 35 |
| Village Jaisinghwala, Moga District, Punjab | India | 5,000 |
| Mailuu-Suu | Kyrgyzstan | 25,000 |
| Gozien Settlement near Digmay Tailings | Tajikistan | 4,200 |
| Aktau (formerly Shevchenko) | Kazakhstan | 10,000 |
| Charkesar | Uzbekistan | 8,900 |
| Mounana, Haut O Goove Province | Gabon | 4,000 |
| Navoi | Uzbekistan | 13,000 |
| Sillimae | Estonia | 20,000 |
| Taboshar Uranium Tailing Dump | Tajikistan | 12,000 |
| Yangiabad | Uzbekistan | 12,000 |
| Zavadivka Kirovograd | Ukraine | 1,000 |
| **Total Estimated Population At Risk: 368,595** | | |

**Table 3b.** Additional global sites not included in TSIP

| Site | Type | Operating Status | Nearest Community | Estimated Population at Risk |
|---|---|---|---|---|
| ***Australia*** | | | | |
| Ranger | Mine | Active (will close in 2021) | Surrounded by Kakadu National Park, which is home to a number of Aboriginal people; Jabiru Township is located 8km away from the site | 1,581 |
| Olympic Dam | Mine | Active | Nearest towns are Roxby Downs and Andamooka | 4,316 |
| Beverly & North | Mine | Suspended | No nearby towns or villages found | -- |
| Four Mile | Mine | Active | No nearby towns or villages found | -- |
| Honeymoon | Mine | Former | No nearby towns or villages found | -- |
| Nabarlek | Mine | Former (rehabilitated) | Fly in/Fly out operation; No nearby towns or villages | -- |
| ***Brazil*** | | | | |
| Lagoa Real/Caetité | Mine/Mill | Active | The Lagoa Real U-District extends 1200 km2 and hosts scattered villages | 60,000 |
| Engenho | Mine | Active | Could not identify any nearby towns or villages | -- |

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| | | | due to lack of available information | |
| Itataia/Santa Quitéria | Mine | Proposed | The proposed site is located in the Santa Quitéria, Ceará municipality | 42,822 |
| ***Bulgaria*** | | | | |
| Buhovo | Mine and Mill | Former (1992) | Site located in Buhovo, Bulgaria. Buhovo is located appx 9 miles from the country's largest city of Sofia | 1,685,222 |
| Zvezda | Mill | Former (1992) | Site is located near village of Eleshnitsa. Eleshnitsa is located appx 15 miles from the country's largest city of Sofia and appx 6 miles from Elin Pelin | 7,675[a] |
| Upper Thracian Valley | In situ leach plant | Former (1992) | Unable to determine nearby cities or towns | -- |
| ***China*** | | | | |
| Yining | In-situ-leach | Active | Yining | 542507 |
| Lantian | Mine, heap leach | Active | Unable to determine nearby cities or towns | -- |
| Benxi | Mine, block leach | Active | Unable to determine nearby cities or towns | -- |
| Qinglong | Mine, heap leach | Active | No known nearby cities or towns | -- |
| Fuzhou | Mine, Mill | Active | Unable to determine nearby cities or towns | -- |

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| Chongyi | Mine, heap leach | Active | No known nearby cities or towns | -- |
| Shaoguan | Mine, heap leach | Active | No known nearby cities or towns | -- |
| Hengyang | Mine | Suspended | Dongyangdu[b] | -- |
| ***Congo, Democratic Republic*** | | | | |
| Shinkolobwe | Mine | Former though unofficially being mined during country's destablization | 25km west of Likasi in Katanga | 447,500 |
| ***Czech Republic*** | | | | |
| MAPE Mydlovary | Uranium processing plant | Former (1991) - Remediated | Three villages Mydlovary, Olešník, and Zahájí are situated at proximity of former chemical processing plant of uranium ore, MAPE; also nearby to České Budějovice | 94,751 |
| Jáchymov | Multiple mines | Former (1962) | Jáchymov | 3,481 |
| Stráž pod Ralskem/Hamr and Brevniste pod Ralskem mines | Mill and Mines | Former (1996) – Under remediation | Stráž pod Ralskem, Hamr pod Ralskem, Brevniste pod Ralskem, and Hamr na Jezeře are nearby | 5,281 |
| Horní Slavkov | Multiple mines | Former (1997) | Horní Slavkov | 5,503 |
| Příbram | Multiple mines | Former (1991) | Příbramsko | 35,147 |
| Rožná | Multiple mines, including Dolni Rozinka, and | Former (2017) | Žď'ár nad Sázavou | 21,467 |

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| | processing mill | | | |
| ***France*** | | | | |
| Gueugnon | Mill | Former (remediated as of 1996) | Located near Gueugnon | 8,218 |
| Les Bois Noirs | Mill | Former (remediated as of 1996) | Located near St. Priest la Prugne | 448 |
| Le Cellier | Mill | Former (remediated as of 1996) | Located near commune of Le Cellier | 3448 |
| L-Ecarpière | Mill | Former (closed 1990-91) | Within the urban unit of Clisson (consisting of 4 municipalities) and 30 km SE of Nantes | 321,264 |
| Bessines | Mine | Former | Bessines[b] | -- |
| Saint Pierre du Cantal | Mill | Former | Saint Pierre du Cantal | 136 |
| Bertholène | Mill | Former | Bertholène | 999 |
| Jouac | Mine | Former | Jouac | 211 |
| Lodève | Mine | Former | Lodève | 7345 |
| Crouzille Mill Division | Multiple mines | Former | Haute-Vienne department | 375856 |
| ***Gabon*** | | | | |
| Franceville-area mines (Mounana, Oklo, Boyindzi, and Mikouloungou) | Multiple mines | Former (1999, 1985, 1991, and 1999, respectively) | Located near Franceville and Mounana | 123,005 |
| ***Germany*** | | | | |
| Königstein | Mine | Former (1991), production from mine water treatment | Königstein, Saxony | 2128 |
| Niederschlema-Alberoda | Mine | Former (1991) | Aue, Saxony; Hartenstein, Saxony | 20886 |
| Pöhla | Mine | Former (1991) | Schwarzenberg | 17191 |
| Lichtenberg | Mine | Former (1977) | Ronneburg and Gera | 99765 |

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| Reust-Lichtenberg | Mine, in-situ leaching, heap leaching | Former (1991) | Ronneburg and Gera[c] | -- |
| Schmirchau | Mine, in-situ leaching, heap leaching | Former (1991) | Ronneburg and Gera[c] | -- |
| Paitzdorf | Mine | Former (1991) | Ronneburg and Gera[c] | -- |
| Beerwalde | Mine | Former (1991) | Ronneburg and Gera[c] | -- |
| Drosen | Mine | Former (1991) | Ronneburg and Gera[c] | -- |
| Menzenschwand | Mine | Former (1991) | St Blasien | 4016 |
| ***Hungary*** | | | | |
| Pécs (Uranvaros) | Multiple mines | Former | Pécs & Uránváros | 170347 |
| ***India*** | | | | |
| Tumalapalli | Mine | Active | Located in Tumalapalli village; near KK Kotala; Could not confirm populations of either village | -- |
| ***Kazakhstan*** | | | | |
| Uvanas | Mine | Active | No known nearby communities | -- |
| East Mynkuduk | Mine | Active | No known nearby communities | -- |
| Akdala | Mines; In-situ leach (Inkai) | Active | No known nearby communities | -- |
| Inkai and South Inkai | Mines; In-situ leach (Inkai) | Active | No known nearby communities | -- |
| Tortukuduk (Moinkum North) | In-situ leach | Active | No known nearby communities | -- |
| Moinkum (Muyunkum) | In-situ leach | Active | Sholaqqkorghan | -- |
| Kanzhugan (Kyanar and South | Mines | Active | Sholaqqkorghan | 10,836 |

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| Moinkum mines) | | | | |
| North and South Karamurun | Mines | Active | Shieli (Shieli district) | 78427 |
| Irkol | Mine; in-situ leach | Active | No information available | -- |
| North and South Kharasan | Mines | Active | Zhangaqorghan | 21339 |
| Zarechnoye | Mine | Active | No known nearby communities | -- |
| South Zarechnoye | Mine | Suspended as of 2012 | No known nearby communities | -- |
| Vostok/Zvezdrioye | | Active | No information available | -- |
| Semyibai | In-situ leach | Active | No information available | -- |
| Central & West Mynkuduk | Mines | Active | No known nearby communities | -- |
| Akbastau (Budenovskoye) | Mine, in-situ leach recovery | Active | No known nearby communities | -- |
| Karatau (Budenovskoye) | Mines | Active | No known nearby communities | -- |
| Zhalpak | Mine | Active | No information available | -- |
| Ulba Metallurgical Plant (Ust Kamenogorsk) | Mill | Active | Oskemen | 321,251 |
| Ulba Conversion LLP | Mill | Proposed | Oskemen[d] | -- |
| ***Malawi*** | | | | |
| Kayelekera | Mine | Suspended | 52 km west of Karonga | 42555 |
| ***Mali*** | | | | |
| Bala | Mine | Proposed | No information available | -- |
| Madini | Mine | Proposed | No information available | -- |
| Falea | Mine | Proposed | No information available | -- |
| ***Mauritania*** | | | | |
| Tiris | Mine | Proposed | No known nearby communities | -- |
| ***Mongolia*** | | | | |
| Dornod (Mardai) | Mine | Former (1995) | Mardai (abandoned) | 0 |

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| Gurvanbulag | Mine | Proposed | No known nearby communities | -- |
| Sainshand | Mine | Proposed | Sainshand | 28712 |
| ***Namibia*** | | | | |
| Rössing | Mine | Active | 15 km from Arandis | 5214 |
| Langer Heinrich | Mine | Active | No known nearby communities | -- |
| Husab | Mine | Active | Swakopmund | 44725 |
| Trekkopje | Mine | Active | No known nearby communities | -- |
| Omahola Project (multi-site) | Mine | Proposed | 40 km from Walvis Bay | 62096 |
| ***Niger*** | | | | |
| SOMAIR | Mines | Active | Mining towns of Arlit and Akokan[e] | 50,154 |
| COMINAK | Mines | Active | Akokan and Arlit[f] | -- |
| SOMINA | Mines | Former | No known nearby communities | -- |
| Madaouela | Mines | Proposed | Arlit[e] | -- |
| Dasa | Mines | Proposed | 30km SE of Imouraren[b] | -- |
| Akokorum | Mines | Proposed | 40 km northwest of Agadez | 118244 |
| ***Portugal*** | | | | |
| Urgeiriça | Mine | Former | Canas de Senohorim (civil parish) | 3509 |
| Quinta do Bispo | Mine | Former | Mangualde (municipality) | 19880 |
| Prado Velho | Mine | Former | São Pedro do Jamelo e Pínzio | 311 |
| Bica | Mine | Former | Sortelha | 444 |
| Forte Velho | Mine | Former | Panoias de Cim | 608 |

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| Fabrica de Sais de Radio | Mine | Former | No information available | -- |
| Cunha Baixa | Mine | Former | Mangualde (municipality)[b] | -- |
| ***Romania*** | | | | |
| Crucea-Botuşana | Mine | Active | No known nearby communities | -- |
| Băiţa Plai | Mine | Former | No known nearby communities | -- |
| Avram Iancu | Mine | Former | Avram Iancu | 3317 |
| Dobrei | Mine | Former | 56 km from Gătaia | 5449 |
| Natra | Mine | Former | Oraviţa | 15265 |
| Ciudanoviţa | Mine | Former | Ciudanoviţa | 622 |
| Feldioara | Mill | Proposed | Feldioara | 5685 |
| ***Slovakia*** | | | | |
| Novoveská Huta | | Former (1990) | Novoveská Huta (village that's part of the town of Spišská Nová Ves) | 37326 |
| Johodná (Kosice) | | | Within 6 km of the city of Košice | 240688 |
| ***Spain*** | | | | |
| Salamanca Project (Retortillo, Alameda) | Mines and Processing plants | Under Construction | Retortillo municipality | 216 |
| Mina Fe | Mine | Former (2000) | 10km North of Salamanca | 154462 |
| Elefante Plant | Heap leach plant | Former (1993) | Saelices el Chico township (Salamanca) | 152 |
| Quercus Plant | Heap/Dynamic leach plant | Former (2003) | Saelices el Chico township (Salamanca)[b] | -- |
| Andújar | Mill | Former (1981) | 1.5 km south of Andújar | 37975 |
| La Haba | Mine | Former | Don Benito municipality | 37011 |
| ***South Africa*** | | | | |

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| Ezulwini-Cooke | Mines | Suspended as of 2017 | Nearby towns include Randfontein and Westonaria; (Johannesburg is located 30-40km NE) | 90751 |
| Vaal River | Mines, Mill (gold; uranium by-product) | Active | Orkney | 13435 |
| ***Sweden*** | | | | |
| Ranstadsverket | Mines | Former (1969) | Falköping municipality | 33075 |
| ***Russia*** | | | | |
| Priargunsky | Mines | Active | Krasnokamensk | 55666 |
| Dalur | In-situ-leach | | Uksyanskoye[b] | -- |
| Khiagda | In-situ-leach | Active | Bagdarin | 4735 |
| Gornoye | Mine, heap leach | Proposed | Unable to determine | -- |
| Olovskaya | Mine, heap leach | Proposed | Unable to determine | -- |
| Elkon | Mine, processing | Proposed | Unable to determine | -- |
| Lunnoye | Mine (gold; uranium) | Proposed | Unable to determine | -- |
| ***Ukraine*** | | | | |
| Zheltye Vody | Mines and Mill | Active | Kirovograd | 47509 |
| Ingulskaya | Mine | Active | Loacted in southern neighborhood of Kirovograd; 22km away from Kropyvnytskyi | 234322 |
| Smolinskaya | Mine, heap leach | Active | Smolino (2km) | 9800 |
| Novokonstantinovskoye | Heap leach | Active | Kropyvnytskyi (27 km)[b] | -- |
| Safonovskoye | In-situ-leach | Former; Proposed re-opening | Unable to determine | -- |
| Pridniprovsky Chemical Plant | Mill | Former (1991) | Kamianske (formerly Dniprodzerzhynsk) | 239237 |

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| ***Uzbekistan*** | | | | |
| Kanimekh | In-situ-leach | Active | No known nearby cities or towns | -- |
| Alendy | Mine, Mill | Active | No known nearby cities or towns | -- |
| Aulbek | In-situ-leach | Active | No known nearby cities or towns | -- |
| Meylisay and Tutlinskaya ploshchad | In-situ-leach | Proposed | No known nearby cities or towns | -- |
| Northern mining district: Uchkuduk, Kyndyk Tyube | In-situ-leach | Active | Uchkuduk | 28000 |
| Central mining district: Sugraly | In-situ-leach | Active | Zarafshan | 68365 |
| Mining Directorate #5: North and South Bukinay, Beshkak, Istiklol, Kukhnur, Lyavlyakan, Tokhumbet, South Sugraly | In-situ-leach | Active | Unable to determine | -- |
| Southern mining district: Sabirsay, Ketmenchi, Jaarkuduk, Yogdu, Shark, Ulus | In-situ-leach | Active | Unable to determine | -- |
| Chauly | Mine | Former | Krasnogorsk | 19176 |
| ***Zambia*** | | | | |
| Mutanga project | Heap leach | Proposed | 31 km northwest of Siavonga | 58864 |
| Lumwana project expansion | Heap leach | Proposed | Chirundu (26km) | 47344 |
| **Total Estimated Population at Risk from Existing Sites: 6,045,501** | | | | |
| **Total Estimated Population at Risk from Proposed Sites: 363,767** | | | | |

[a]*This site shares the exposed population of Sofia with the Buhovo mine. The exposed population will only be counted once.*

[b] *We were unable to determine the population size for this location.*

[c]*These sites share the exposed population of Ronneburg and Gera with the Lichtenberg mine. The exposed population will only be counted once.*

[d] *This site shares the exposed population of Oksemen with the Ulba Metallurgical Plant site. The exposed population will only be counted once.*
[e] *Arlit, Niger is included in the TSIPs population estimates. The exposed population will only be counted once.*
[f] *This site shares the exposed population of Akokan with the SOMAIR site. The exposed population will only be counted once.*

**Table 3c.** US Sites

| Site | State | Operating Status | Nearest Community | Estimated Population at Risk |
|---|---|---|---|---|
| ***Closed Uranium Sites Under the UMTRA Project*** | | | | |
| Ambrosia Lake (Phillips) | NM | Former, site remediated | Appx 25 miles north of Grants, NM | -- |
| Belfield | ND | Former, site remediated | Appx 1 mile SE of Belfield, ND | 1,013 |
| Bowman | ND | Former, site remediated | Appx 7 miles NW of Bowman, ND | 1,713 |
| Durango | CO | Former, site remediated | Appx 0.25 miles SW of Durango, CO | 18,503 |
| Edgemont | SD | Former, site remediated | Appx 2 miles south | 739 |
| Falls City | TX | Former, site remediated | Appx 8 miles SW of Falls City | 656 |
| Grand Junction | CO | Former, site remediated | Site within city limits of Grand Junction | 61,881 |
| Green River | UT | Former, site remediated | Appx 0.5 miles east of the Green River; 1.5 miles SE of Green River (city) | 952 |
| Gunnison | CO | Former, site remediated | Appx 0.5 miles SW of Gunnison | 6,261 |
| Lakeview | OR | Former, site remediated | 1.5 miles N-NW of Lakeview | 2,261 |

| | | | | |
|---|---|---|---|---|
| Lowman | ID | Former, site remediated | Appx 0.5 miles NE of Lowman | 42 |
| Maybell | CO | Former, site remediated | Appx 5 miles SW of Maybell | 72 |
| Mexican Hat | UT | Former, site remediated | Appx 1.5 miles SW of Mexican Hat and 1 mile South of San Juan River | 31 |
| Monument Valley | AZ | Former, site remediated | Located on the Navajo Reservation, about 15 miles South of Mexican Hat, UT | 864 |
| Naturita | CO | Former, site remediated | 2 miles NW of Naturita | 530 |
| Rifle | CO | Former, site remediated | Old Site: 0.3 miles East of Rifle; New Site (replaced old site in 1958): 2 miles SW of Rifle | 9,665 |
| Riverton | WY | Former, site remediated | 2 miles SW of Riverton and within the boundaries of the Wind River Indian Reservation | 10,997 |
| Shiprock | NM | Former, site remediated | Site is within the Navajo Nation, near the town of Shiprock, appx 28 miles West of Farmington | 8,156 |
| Slick Rock | CO | Former, site remediated | Appx 22 miles north of Dove Creek, CO | 129 |

| | | | | |
|---|---|---|---|---|
| Spook | WY | Former, site remediated | Appx 32 miles north of Glenrock, WY | 2576 |
| Tuba City | AZ | Former, site remediated | Site is within the Navajo Nation and close to the Hopi Reservation (Moenkopi, AZ), appx 5 miles East of Tuba City, AZ | 10,448 |
| ***Current and Planned US Mills*** | | | | |
| Shootaring Canyon Uranium Mill | UT | Standby | A small town, Ticaboo, is located 2.6 miles south of the site | 134 |
| White Mesa Mill | UT | Operating - Processing Alternate Feed | Site located three miles North from the Ute Mountain Ute Tribe's White Mesa community and 6 miles south of Blanding, UT | 4411 |
| Sweetwater Uranium Project | WY | Standby | Site located 42 miles NW of Rawlins, WY. Other communities nearby include Wamsutter, Creston, Fort Steele, Muddy Gap, and and Riner--all to the south/SE of the site. | 9,873 |
| Pinon Ridge Mill | CO | Proposed<br>*License has been pulled as of 04.18.18 | Site was to be situated between Naturita and Paradox, CO | 618 |

| | | | | |
|---|---|---|---|---|
| ***Current and Planned US Heap Leach Plants*** | | | | |
| Sheep Mountain | WY | Undeveloped | Site is located 8 miles south of Jeffrey City, Wyoming | 58 |
| ***Current and Planned US In-situ-leach Plants*** | | | | |
| Reno Creek | WY | Partially permitted and licensed | The project is less than 10 miles from the nearest town, Wright WY. | 1,834 |
| Dewey Burdock Project | SD | Partially permitted and licensed | The project is located near the towns of Dewey and Burdock, SD | 7 |
| Crow Butte Operation | NE | Operating | Site located 4 miles southeast of the city of Crawford | 961 |
| Church Rock | NM | Partially permitted and licensed | Site is located near the city of Church Rock and appx 17 miles north of Gallup, NM | 23,798 |
| Crownpoint | NM | Partially permitted and licensed | Site is located adjacent to the town limits of Crownpoint, NM | 2,278 |
| Lost Creek Project | WY | Operating | Site is located 15 miles SW of Bairoil, WY and 38 miles NW of Rawlins, WY | 9,179 |
| Alta Mesa Project | TX | Standby | Site is located appx 25 miles SW of Falfurrias, TX | 4,981 |
| Smith Ranch-Highland | WY | Operating | Site is located appx 23 | 6,541 |

| | | | | |
|---|---|---|---|---|
| Operation | | | miles NW of Douglas, WY and appx 14 miles NW of Orpha, WY | |
| Hobson ISR Plant | TX | Standby | Hobson, TX is the site of the plant. The site is located appx 3.4 miles SE of Falls City, TX and appx 7.6 miles NW of Karnes City, TX | 4,076 |
| La Palangana | TX | Standby | No known nearby communities | -- |
| Ross CPP | WY | Operating | No known nearby communities | 1,834 |
| Kingsville Dome | TX | Restoration | Site is appx 8 miles NW of Kingsville, TX | 26,071 |
| Rosita | TX | Reclamation | Unable to determine nearby communities | -- |
| Vasquez | TX | Restoration | Site near towns of Las Lomitas, Realitos, Hebbronville, and Bruni, TX | 5,388 |
| Nichols Ranch ISR Project | WY | Operating | Nearest city determined: Casper, WY (undetermined distance from site) | 59,316 |
| Goliad ISR Uranium Project | TX | Standby | Nearest city determined: Goliad, TX (undetermined distance from site) | 1,981 |
| Jab and Antelope | WY | Developing | Site is located appx 38 miles NW of Rawlins, | 9,075 |

| | | | | |
|---|---|---|---|---|
| | | | WY | |
| Moore Ranch | WY | Permitted and Licensed | Site near Linch and Wright, WY | 1,875 |
| Willow Creek Project | WY | Operating | Site near Sussex, WY | -- |
| **Total Estimated Population at Risk from Existing sites: 270,401** | | | | |
| **Total Estimated Population at Risk from Proposed sites: 39,543** | | | | |

**Table 3d.** Canadian Sites

| Site | Province | Operating Status | Nearest Community | Estimated Population at Risk |
|---|---|---|---|---|
| ***Canadian Uranium Operating Mines*** | | | | |
| McClean Lake | Saskatchewan | Active | Nearest camp settlement is Points North Landing | 0 |
| Rabbit Lake | Saskatchewan | Suspended | Site is located appx 24 miles from Wollaston Lake (hamlet) and Wollaston Post (village) | 1,350 |
| McArthur Lake | Saskatchewan | Suspended as of January 2018 | Site is located appx 31 miles from Wollaston Lake (hamlet) and Wollaston Post (village) | 1,350 |
| Key Lake | Saskatchewan | Suspended as of January 2018 | Site is located 138 miles north of the | 1,052 |

| | | | | |
|---|---|---|---|---|
| | | | village of Pinehouse | |
| Cigar Lake | Saskatchewan | Active | Nearest camp settlement is Points North Landing | 0 |
| Port Radium | Northwest Territories | Former | None | -- |
| Beaverlodge | Saskatchewan | Former | Site was in the community of Eldorado and was 4.3 miles East of Uranium City | 73 |
| Cluff Lake | Saskatchewan | Former | None | -- |
| Elliot Lake | Ontario | Former | Nearest city is Elliot Lake | 10,741 |
| Bancroft | Ontario | Former | Nearest city is Bancroft | 3,881 |
| Midwest Project | Saskatchewan | Proposed | Nearest camp settlement is Points North Landing | 0 |
| Dawn Lake | Saskatchewan | Proposed | Site located 9 miles northwest of McClean Lake uranium mine and mill; nearest camp settlement to McClean Lake is Points North Landing; Unable to determine a population for the nearest settlement | -- |
| Millenium | Saskatchewan | Proposed | Site is located 174 miles north of the | 1,052 |

| | | | | |
|---|---|---|---|---|
| | | | village of Pinehouse | |
| Michelin | Labrador | Proposed | Site is located appx 25 miles SW of Postville | 177 |
| Wheeler River | Saskatchewan | Proposed | Site is located appx 27 miles SW of the McArthur River mine, which is located appx 31 miles from Wollaston Lake (hamlet) and Wollaston Post (village) | 1,350 |
| ***Uranium Fuel Cycle*** | | | | |
| Blind River | Ontario | Active | Site is located just outside of Blind River, Ontario | 3472 |
| Port Hope | Ontario | Active | Site is located near the municipality of Port Hope, Ontario | 16,753 |
| **Total Estimated Population at Risk from Existing Sites: 38,672** | | | | |
| **Total Estimated Population at Risk from Proposed Sites: 2,579** | | | | |

**Table 4. Summary of Estimates**

| Site Source | Estimated At-Risk Population | | Data Sources |
|---|---|---|---|
| ***TSIP*** | 368,595 | | Pure Earth's TSIP Database[10] |
| | *Existing Sites* | *Proposed Sites* | |
| ***Additional Global Sites*** | 6,045,501 | 363,767 | World Nuclear Association[11] |
| ***United States*** | 267,825 | 39,543 | World Nuclear Association[16] |
| ***Canada*** | 38,672 | 2,579 | World Nuclear Association[15] |
| **Totals** | **6,351,998** | **405,889** | |

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