William Herzog

Dr. Obrien

Global Studies

23 March 2025

Uranium Mining: The Unsustainable Half of Nuclear Energy

Nuclear Energy

The first commercial nuclear power stations were in the 1950s, well before the modern scope and influence of climate change. At the time, nuclear energy was not developed to be a renewable alternative, because climate change was generally unknown to the public. In the following decades, between the 1970s and 1980s nuclear energy gained momentum, but was later halted by catastrophic events such as Chernobyl. Today, nuclear energy has a limited impact globally as only 9% of the world's electricity. The 440 power reactors around the world that produce nuclear energy make up about a quarter of the total amount of low-carbon electricity globally, making it the second largest source of low-carbon power. Additionally, 220 research reactors in 50 countries are used for medical research, exploring industrial isotopes, and human training. Nuclear energy itself is implemented in 31 countries, as well as Taiwan, and more countries utilize regional transmission grids to capitalize on the energy.

Shone/Gamma-Rapho. *View of the Chernobyl Nuclear Power Station after the Explosion on April 26, 1986, in Chernobyl, Ukraine*. Getty Images, www.npr.org/2022/12/11/1138382531/ukraine-fears-nuclear-disaster-zaporizhzhia-chernobyl-memories.

Nuclear technology, the splitting of atoms of specific elements, was first developed in the 1940s during WWII amid research to produce powerful bombs. Once the war ended, the advancements made in nuclear fission led to a 1950s focus on peaceful uses of nuclear power generation. Using nuclear technology, progress was made in controlling spread of disease,

assisting doctors' diagnoses, improving patient treatments, powering space missions, and meeting the demand for electricity in less developed countries. In more recent years, with the increase of knowledge about climate science and fossil fuels, sustainability emerged as a new focus. In 2005, 66.5% of electricity was powered by fossil fuels and the amount did not significantly change by 2022, as it decreased to 61%. A major benefit of nuclear reactors is their capacity to output high amounts of energy for extended periods of time; there is no proven age-related trend in performance over the last five years. Nuclear energy has also been implemented to power submarines and other large surface vessels in major navies for five decades. About 160 ships, primarily submarines, are powered by around 200 marine reactors. The foundation of the nuclear energy industry is international commerce; countries supply each other with components and uranium, so nuclear energy is a global effort, despite countries' unique motivations.[1]

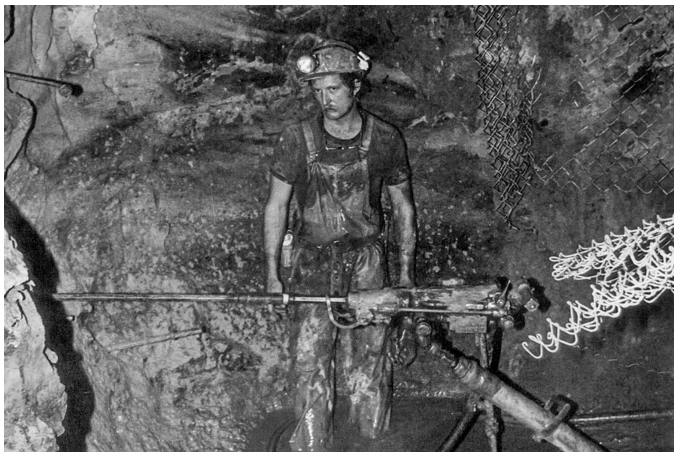
Ionizing Radiation

Nuclear reactors produce electricity via the energy of unstable, radioactive isotopes breaking down. This process, or similarly a weapon explosion, generates ionizing radiation, which is subatomic particles and electromagnetic waves with the energy to ionize atoms, or, more simply put, remove electrons. This same radiation also results from the cosmic rays of the sun or specific technology, such as x-ray machines. For nuclear reactors, fuel rods are utilized to enclose the ionizing radiation that is produced and prevent contamination. If these fuel rods fail, ionizing radiation may be exposed to humans or animals in which case it poses very significant health risks. Exposure to the radiation results in immediate damage and in high doses may result in sickness or death. In lower doses humans may suffer a cardiovascular disease, cataracts, or

[1] World Nuclear Association, "Nuclear Power in the World Today," accessed March 23, 2025, www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.

cancer due to gene mutations, since the radiation damages DNA. Children and adolescents are more sensitive to ionizing radiation than adults.[2]

Uranium Mining



"*A Worker Drills for Uranium in Church Rock Mine, N.M., Circa 1980.*" *In These Times*, 16 Mar. 2023, www.inthesetimes.com/article/uranium-mines-and-mills-reca-act. *Courtesy Post '71 Uranium Workers Committee.*

At its core, nuclear energy and its radioactive isotopes result from uranium. Since uranium is a naturally-occurring radioactive element, it is mined for its distinct chemical properties as fuel for nuclear reactors. Uranium is extracted from the Earth using two main methods. The first is by mining ore via open pits or underground mines. The second is known as in situ leaching, in which case chemicals are employed to dissolve uranium from porous rocks, such as sandstones, and the liquid containing uranium is then pumped back to the surface. This method is often used when uranium is saturated by groundwater at depths unrealistic for mining or at low concentrations. In situ leaching produces over 55% of harvested uranium globally. In 2022, the leading uranium producer was Kazakhstan, accounting for 43% of the world's 49,355 tonnes U, or tonnes of elemental uranium, with 21,227 tonnes. The next highest producers were Canada at 7,351 (15%), Namibia at 5,613 (11%), and Australia at 4553 (9%). Across all of these nations in 2022, the top ten companies made up 90% of the total uranium production worldwide.[3]

---

[2] National Cancer Institute, "Accidents at Nuclear Power Plants and Cancer Risk," *Cancer.gov*, May 12, 2022, https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/nuclear-accidents-fact-sheet.

[3] World Nuclear Association, "World Uranium Mining Production," accessed March 23, 2025, www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production#:~:text=About%20two%2Dthirds%20of%20the,from%20Kazakhstan%2C%20Canada%20and%20Australia.

Once uranium has been extracted, the ore either undergoes milling or heap leaching. For milling, the ore is crushed, ground up, and chemicals are used to dissolve the uranium. This results in a uranium solution, so the uranium is then separated from the solution, solidified, dried, and packaged. For heap leaching, chemicals are sprayed onto the ore to dissolve the metals. The liquid then contains uranium separate from the leftover rock and requires further processing to recover the uranium. This technique is not used in the United States for uranium.

After uranium is extracted, the decay products continue to contain up to 80–90% of the ore's radioactivity. The solid waste is known as tailings and the liquid waste is known as raffinates. Both tailings and raffinates are often stored in impoundments,[4] specially designed ponds, where the liquid remains are disposed of by evaporation or recirculation to the milling operation. Many mines, including most in Australia, have a "zero discharge" policy for pollutants.[5] Additionally as uranium decays, radium gas is released. Radium gas typically disperses into the atmosphere where it poses no health risk. In cases of open pit mining, if rock is piled outside of the mine, then wind can blow radioactive dust into populated areas as well as any groundwater used for drinking. In mine shafts without proper air ventilation, radon, a radioactive gas, collects and may be inhaled by miners. Typically, radon gas is pumped out of a mine and replaced with fresh air.[6]

Due to these risks, there has been international cooperation to prevent uranium mining exploitation and disaster. In 2009, an international conference presented a guide to in situ leach mining by the International Atomic Energy Agency (IAEA). Additionally, in 2014 the OECD

---

[4] US EPA, "Radioactive Waste From Uranium Mining and Milling | US EPA," January 29, 2025, accessed March 23, 2025, www.epa.gov/radtown/radioactive-waste-uranium-mining-and-milling#:~:text=Wind%20can%20blow%20radioactive%20dust,Without%20proper%20air%20ventilation%2C%20radon.

[5] World Nuclear Association, "Environmental Aspects of Uranium Mining," accessed March 23, 2025, www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/environmental-aspects-of-uranium-mining.

[6] US EPA, "Radioactive Waste From Uranium Mining and Milling."

Nuclear Energy Agency published a 140-page report titled "Managing Environmental and Health Impacts of Uranium Mining." Years later, in 2017, the World Nuclear Association published an internationally standardized report on the sustainability of uranium mining performance and processing sites. Around the world, the most widely accepted environmental management system (EMS) is the International Organization for Standardization (ISO) 14001 framework. Major mining companies in Australia and Canada have either adopted the framework or are soon to. The framework's linked headings, being Plan-Do-Check-Act, account for routine hazards as well as abnormal situations to mitigate the unpredictability of uranium mining.[7]

Uranium Mining in the Congo During WWII

During the era of the Belgian Congo, Belgium gave the rights of almost 8,000 square miles, over half the size of its own country, to the mining company Union-Miniere du Haut-Katanga who owned the Shinkolobwe mine, which was rich in uranium. At this time after the Congo Free State, the private sector began extracting natural resources from the land instead of Belgium itself. Despite the transfer of power and resources, violence against the Congolese people and forced labor remained common. Edgar Sengier, a Belgian man, was the director of Union-Minière du Haut-Katanga. He had been tipped by Frédéric Joliot-Curie, son-in-law of Marie Curie, that uranium may become essential during WWII, so after the Nazis invaded Poland in 1939, he moved 2.6 million pounds of ore to Staten Island and left 6.6 million

Van Zuydam, Schalk. *A Worker in the Shinkolobwe Mine, the Source of the Uranium for the First Atomic Bomb. Wired*, 20 July 2023, www.wired.com/story/the-dark-history-oppenheimer-didnt-show/. AP Photo/Schalk Van Zuydam.

[7] World Nuclear Association, "Environmental Aspects of Uranium Mining."

in Shinkolobwe. With his company, miners worked in fenced compounds where they sorted uranium by hand, including massive blocks. Each family had around 43 square feet for living and relied upon weekly food rations. No one was able to move freely without permits or have the ability to vote, and everyone had to abide by a 9pm curfew, all while receiving terrible pay. “Natives” were excluded from unions, so they had no power to negotiate at all.

In 1941, Black workers at Sengier’s mines began to organize for higher wages and better labor conditions. There was a mining strike across Katanga on Pearl Harbor Day, December 7, 1941. In Elisabethville, present-day Lubumbashi, 500 workers went on strike and were joined by off-duty miners in front of management. They successfully won an agreement to bargain for a raise the following day. The next morning, negotiations with Sengier's company and the colonial governor of Katanga took place at a soccer stadium with around 800–2,000 strikers. The company complied and offered a verbal agreement for raised wages, but when a worker demanded written confirmation, the colonial governor denied his request and shot the man. Immediately, soldiers began to fire as well, leading to around 70 deaths and 100 injuries.

Though years prior uranium was placed aboveground as a byproduct of mining for radium, around the time of WWII, it was further realized that it could produce enormous amounts of energy during nuclear fission. In 1939, Albert Einstein wrote a letter to President Franklin D. Roosevelt regarding the danger of uranium for powerful bombs and cited the United States, Canada, Czechoslovakia, and the Congo as four known sources of uranium with the Congo being the most important. Jean Bele, a Congolese nuclear physicist today, claims that 100 kg of Congolese uranium ore has the potential to yield 1 kg of refined uranium compared to uranium from other sources which may only yield 2–3 g of refined uranium.

Knowing the power of Congolese uranium, General Leslie Groves, the head of the Manhattan Project, began his job in September, 1942 and suggested to President Roosevelt that the Shinkolobwe mine be taken control by the United States and reopened. The United States gained control of the mine and sent the Army Corps of Engineers to the Congo to begin mining operations. For security reasons, the location of the mines were scrubbed from maps and American spies ceased to use the word "uranium," opting instead for words like "diamonds." Ultimately, Congolese laborers were given quotas to supply the Allies with war materials. Black miners endured physical labor at day and worked the furnaces at night. There was a 24 stories deep mine for uranium in Katanaga in the southeast, where miners hauled and sorted the radioactive ore. Their salaries rose by 30–50% due to the earlier strike, but there continued to be some forced labor. From 1938–1944, fatal accidents doubled. The Congolese uranium was then sent to the United States where it filled the atomic bomb dropped on Hiroshima and was used to make plutonium, which powered the atomic bomb dropped on Nagasaki. A shipment of ore was even intercepted and sunk by the Nazis before it arrived in the United States. Jean Bele states that there are radioactive isotopes in the ground near Shinkolobwe today, which enter the water, crops, trees, soil, animals, and people living there. The total extent of the radioactivity remains unknown.[8]

Health Effects of Uranium Mining in Kazakhstan

In Kazakhstan, the leading uranium producer worldwide, there are both active and decommissioned uranium reserves. Since Kazakhstan dominates global uranium flow, specific companies in the country are significantly influential. For instance, according to the Kazakh Ministry of Energy, the Kazatomprom National Atomic Company, which is mainly owned by the

[8] Ngofeen Mputubwele, "The Dark History 'Oppenheimer' Didn't Show," *WIRED*, August 21, 2023. Accessed March 23, 2025. www.wired.com/story/the-dark-history-oppenheimer-didnt-show.

government of Kazakhstan, produces uranium across 26 sites in 13 deposits of Turkistian, Kyzylorda, and the North Kazakhstan Regions. Across the country there are many uranium extraction sites, which include Mynkuduk, Zhalpak, North Karaburun, South Karamurun, Kanzhugan, Moinkum, Inkai, Akdala, Zarechnoe, North Harasan, Budenovskoye, Irkol and Semizbai. Some deposits have been decommissioned and met with efforts to eliminate any consequences of the mining that ensued. At the beginning of 2023, Kazakhstan had 990,000 tons of uranium reserves. Kazakh uranium is primarily exported to China, France, Russia, and Canada, but not exclusively. A common practice in the country is for companies to operate in the same fields simultaneously at different mining sites.[9]

Pirogov, Vladimir. *A Kazatomprom Worker Checks the Radiation Level of Uranium Oxide at the East Mynkuduk PV-19 Uranium Mine in Southern Kazakhstan, May 11, 2006. Reuters*, 7 Jan. 2022, www.reuters.com/markets/commodities/transport-disruptions-wild-card-kazakh-uranium-shipments-2022-01-07/.

Most of the country's uranium mining is detrimental to the environment as well as the communities living at or near sites. In March 2023, a group of researchers published a study on the influence of uranium mining: "Epidemiology of Somatic Diseases and Risk Factors in the Population Living in the Zone of Influence of Uranium Mining Enterprises of Kazakhstan: A Pilot Study." The researchers studied people living in the Syrdarya uranium ore province. Data was collected from 5,605 residents from the village of Bidaykol, which was 4 km (approximately 2.5 miles), away from the uranium mining, and compared to data collected from the village of

[9] Kemelova, Fatima. "Kazakhstan's Uranium Industry: Sites and Production - the Astana Times." *The Astana Times*, August 12, 2024, astanatimes.com/2024/08/kazakhstans-uranium-industry-sites-and-production.

Sunakate in Kyzylorda region, which represented the control group. It was found that environmental contamination from in situ leaching, where chemically active substances were voluntarily released into the ground, resulted from the "open-pit mining process, transportation to and from milling sites, the milling and processing of ore, and the open-air storage of radioactive and nonradioactive mining wastes."

As a result of the uranium mining, residents from the village of Bidaykol were found to have a rate of chronic diseases 1.3 times higher than that of the village Sunakate. In the village of Bidaykol there were 1745.1 chronic diseases per 1000 people versus 1257.7 per 1000 people in the village of Sunakate. Specifically, in the village of Bidaykol 21.4% of chronic diseases were "genitourinary system pathologies," mainly tubulointerstitial kidney diseases, 18.1% were respiratory diseases, and 12.0% were digestive diseases. Compared to the control group, where 22.8% of chronic diseases were respiratory, 17.5% were genitourinary, and 13.6% were circulatory, the rate of genitourinary system diseases in the village of Bidaykol is nearly double; in the village of Bidaykol the rate of genitourinary system diseases was 641.6 per 1000 people, whereas in the village of Sunakate the rate was 343.9 per 1000 people. Of the multiple surveys conducted as part of the study, in one regarding agricultural product consumption, 55% of respondents from Bidaykol reported eating food grown in the area, rather than imported, which were therefore being grown in contaminated soils. The study's results concluded that uranium mining directly affects any nearby populations' health negatively.[10]

Impact on Indigenous Communities of Uranium Mining in Australia

[10] Elena Saifulina et al., "Epidemiology of Somatic Diseases and Risk Factors in the Population Living in the Zone of Influence of Uranium Mining Enterprises of Kazakhstan: A Pilot Study," *Healthcare* 11, no. 6 (2023): 804, https://pmc.ncbi.nlm.nih.gov/articles/PMC10048745/#:~:text=The%20mining%20and%20milling%20of,storage%20of%20radioactive%20and%20nonradioactive.

Australia has three uranium mines: Ranger, Olympic Dam, and Beverley with Four Mile; uranium from Four Mile is processed through Beverley. The Ranger mine is located in the associated town of Jabiru, Northern Territory, which is around 230 km (approximately 143 miles) east of Darwin. It is surrounded by Kakadu National Park that doubles as a popular tourist attraction. Employees' radiation levels at the mine are below the recommended limits, meaning they are exposed to a healthy amount of radiation. Aboriginal Australians, who are considered the "traditional owners," own the land that the mine is located on through the Kakadu Land Trust, but they lease the land for uranium mining for around $200,000 annually. As a result, 4.25% of sales revenue from the uranium returns to Northern Territory Aboriginal groups. In total, $345 million from the revenue of the mine has been paid to Aboriginal people since 1980.

Campbell, Glenn. *The Ranger uranium mine in Kakadu National Park finished operations in 2021, and its output has yet to be replaced.* Mining Technology, 23 Mar. 2025, www.mining-technology.com/features/australia-uranium-albanese-future-outlook/. Photo by Glenn Campbell/Fairfax Media via Getty Images.

Olympic Dam is both a copper and uranium mine, but only 20% of its revenue comes from its uranium production. It is situated in the town of Roxby Down, South Australia, which is around 560 km (approximately 348 miles) north of Adelaide. It is the largest known uranium ore body in the entire world and produces around 12 million tonnes of ore annually. As an underground mine, it is well ventilated. Beverley and Four Mile is in South Australia, and is around 520 km (approximately 323 miles) north of Adelaide. This mine served as the basis of the first commercial in situ leach operation in Australia. Since the ore body and its radioactivity is

far underground, there is minimal radon release and no ore dust, lowering the risk of a negative environmental impact.[11]

In 1997, the Parliament of Australia presented a report on uranium mining and milling. This report acknowledged the environmental risks of "radioactive leaks, emissions, melt downs, and nuclear detonations" stemming from uranium mining. Documentations of the environmental impact of tailings waste cited both Olympic Dam and Ranger. Specifically, Olympic Dam contributed to a "depletion of water from the Great Artesian Basin in the Mound Spring area," which is 100 km (approximately 62 miles) north of the mine. The mine was stated to have used a "massive" amount of water from the South Australian section of the basin, despite being located in a "sensitive arid region."[12] While this concern is decades old, Olympic Dam continues to use water from the basin today; however, in recent years regulations have been imposed as part of rehabilitation efforts.[13]

Alongside the environmental impacts of the mines, a separate section of the same report considered the negative impact of the mines specifically on Aboriginal Australians, since most uranium mining in Australia takes place on Aboriginal land. In the Northern Territory, the original agreement of Kakadu National Park that took place in the 1970s excluded the uranium deposits. Though the Aboriginal people received ownership of the land, it did not grant possession of the uranium laying underneath. For the Ranger mine, the traditional owners received economic benefits, but the report considered the negative impact of relying on royalties. Evidence also supported the idea that Aboriginal people were forced to choose between

---

[11] World Nuclear Association, "Australia's Uranium Mines," accessed March 23, 2025, www.world-nuclear.org/information-library/appendices/australia-s-uranium-mines.
[12] Dee Margetts and Meg Lees, *Minority Report*, Senate Select Committee on Uranium Mining and Milling, Australian Parliament, 1997, section 2, "Environmental Impacts," www.aph.gov.au/Parliamentary_Business/Committees/Senate/Former_Committees/uranium/report/d03.
[13]World Nuclear Association, "Australia's Uranium Mines."

preserving their environment or pursuing continued funding for their health, housing, or education. For instance, there was a dispute regarding whether contaminated water should be released from a retention pond into a river, and it was claimed that the royalties hindered the traditional owners "ability to oppose Ranger's operations." The Aboriginal people often lacked influence in the management of Ranger as well. For Olympic Dam, a "spokesperson for the Kokatha People's Committee, traditional owners of the actual mine site, told the Committee" that "there were promises of jobs, security, houses and all those types of things, none of which ha[d] materialised over the years." At this mine, the Aboriginal people also witnessed the use of buggies, motorbikes, and speedboats during weekends on the land, which was in many cases sacred sites. Here too, there was a lack of consulting with Aboriginal communities about the mine.[14]

Conclusion

While nuclear energy is considered sustainable, as well as the flow of uranium that it uses, the negative impacts of uranium mining on the environment and nearby communities, who are oftentimes indigenous, lack a key piece of sustainability: conservation. Regardless of whether or not there is enough uranium yet to be mined or piled in reserves to sustain nuclear reactors around the globe, the act of uranium mining, which is the basis of nuclear energy, fails to conserve entire communities, regions, and ecosystems. From a carbon standpoint, nuclear energy is renewable and significantly less harmful to the environment than fossil fuels, but that does not mean it has no broader negative impact. Nuclear energy is a great source of energy for the future of civilization, but if it is going to proceed sustainably, then during the course of uranium

[14] Dee Margetts and Meg Lees, *Minority Report*, Senate Select Committee on Uranium Mining and Milling, Australian Parliament, 1997, section 6, "Indigenous Concerns," www.aph.gov.au/Parliamentary_Business/Committees/Senate/Former_Committees/uranium/report/d07.

mining, human rights, indigenous communities, and the preservation of the environment must continue to be valued over profit and the geopolitical power of possessing uranium.

Bibliography

Kemelova, Fatima. 2024. “Kazakhstan’s Uranium Industry: Sites and Production - the Astana Times.” *The Astana Times*. August 12, 2024. Accessed March 24, 2025. https://astanatimes.com/2024/08/kazakhstans-uranium-industry-sites-and-production/.

Margetts, Dee, and Meg Lees. *Minority Report*. Senate Select Committee on Uranium Mining and Milling, Australian Parliament, May 15, 1997. www.aph.gov.au/Parliamentary_Business/Committees/Senate/Former_Committees/uranium/report/d01.

Mputubwele, Ngofeen. “The Dark History ‘Oppenheimer’ Didn’t Show.” *WIRED*. August 21, 2023. Accessed March 23, 2025. www.wired.com/story/the-dark-history-oppenheimer-didnt-show.

National Cancer Institute. “Accidents at Nuclear Power Plants and Cancer Risk.” 2022. *Cancer.gov*. May 12, 2022. https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/nuclear-accidents-fact-sheet.

Saifulina, Elena, Duisebai Janabayev, Yerlan Kashkinbayev, Aigerim Shokabaeva, Danara Ibrayeva, Moldir Aumalikova, Polat Kazymbet, and Meirat Bakhtin. 2023. “Epidemiology of Somatic Diseases and Risk Factors in the Population Living in the Zone of Influence of Uranium Mining Enterprises of Kazakhstan: A Pilot Study.” *Healthcare* 11 (6): 804. https://pmc.ncbi.nlm.nih.gov/articles/PMC10048745/#:~:text=The%20mining%20and%20milling%20of,storage%20of%20radioactive%20and%20nonradioactive.

US EPA. 2025. “Radioactive Waste From Uranium Mining and Milling | US EPA.” January 29. Accessed March 23, 2025. www.epa.gov/radtown/radioactive-waste-uranium-mining-and-milling#:~:text=Wind%20can%20blow%20radioactive%20dust,Without%20proper%20air%20ventilation%2C%20radon.

World Nuclear Association. 2025. “Australia’s Uranium Mines.” Accessed March 23, 2025. www.world-nuclear.org/information-library/appendices/australia-s-uranium-mines.

World Nuclear Association. 2025. “Environmental Aspects of Uranium Mining.” Accessed March 23, 2025. www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/environmental-aspects-of-uranium-mining.

World Nuclear Association. 2025. “Nuclear Power in the World Today.” Accessed March 23, 2025. www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.

World Nuclear Association. 2025. “World Uranium Mining Production.” Accessed March 23, 2025. www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production#:~:text=About%20two%2Dthirds%20of%20the,from%20Kazakhstan%2C%20Canada%20and%20Australia.