IN-SITU LEACHING (ISL) URANIUM MINING: COULD NAMIBIA OVERTAKE KAZAKHSTAN?

By Zach Kauraisa

1. Introduction

Uranium has established itself as a mineral of major strategic importance to the superpowers of the world, not only by its ability to provide a stable power source but also its nuclear weapon applications.

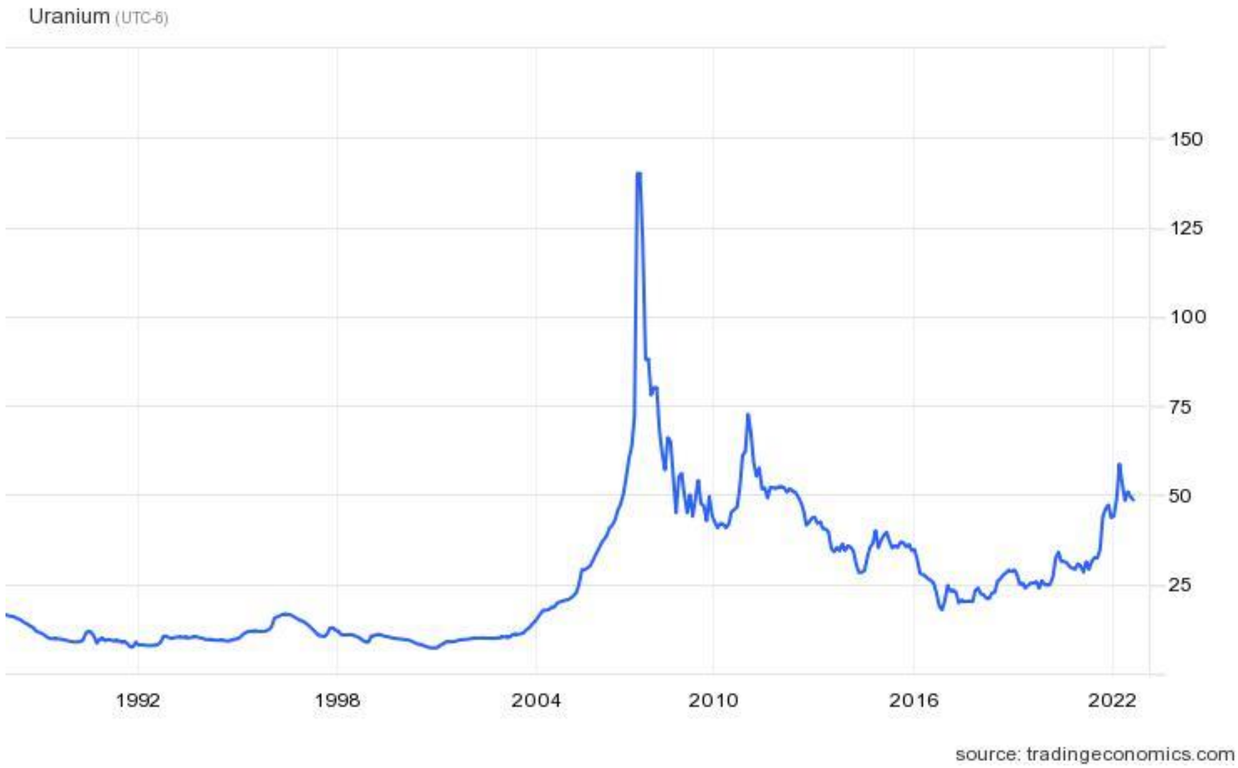
In 2021, total world uranium production was 48,332 tU, of which 45% was produced by Kazakhstan followed by Namibia (12%) and Canada (10%)[1]. Although uranium production has historically been dominated by open pit mining, due to decreasing uranium prices the production costs of many open pit uranium mines have compromised the profitability of these operations and forced mines into care and maintenance – this is particularly the case in Namibia.

In the wake of decreasing uranium prices, In situ leach (ISL) mining, also called in situ leaching or in situ recovery mining, has become a standard uranium production method. Its application to amenable uranium deposits in certain sedimentary formations has grown owing to competitive production costs and low surface impacts.[2] In 2000, ISL accounted for 16% of world uranium production, by 2021 it accounted for 66% of world uranium production at 32,088 tU produced by ISL in 2021[3] - this is largely due to Kazakhstan producing the majority of the worlds ISL uranium.

[1] World Nuclear Association. World Uranium Production. Available at https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx#:~:text=In%202021%20Kazakhstan%20produced%20the,%25)%20and%20Canada%20(10%25).&text=Uzbekistan%20(est.)&text=China%20(est.)&text=India%20(est.)

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, In Situ Leach Uranium Mining: An Overview of Operations, IAEA Nuclear Energy Series No. NF-T-1.4, IAEA, Vienna (2016)

[3] World Nuclear Association. World Uranium Production. Available at https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx#:~:text=In%202021%20Kazakhstan%20produced%20the,%25)%20and%20Canada%20(10%25).&text=Uzbekistan%20(est.)&text=China%20(est.)&text=India%20(est.)



In light of the above, this paper aims to look at Kazakhstan (as a leading producer of uranium by ISL) and Namibia (as a major producer of uranium by open pit mining), within the context of a shift in uranium mining from open pit to ISL. Considering proposed ISL operations in Namibia, This paper aims to identify whether Namibia is a competitive investment destination for ISL uranium projects in comparison to Kazakhstan and to explore the prospects of Namibia becoming a major ISL producer and a competitor for Kazakhstan in the years to come.

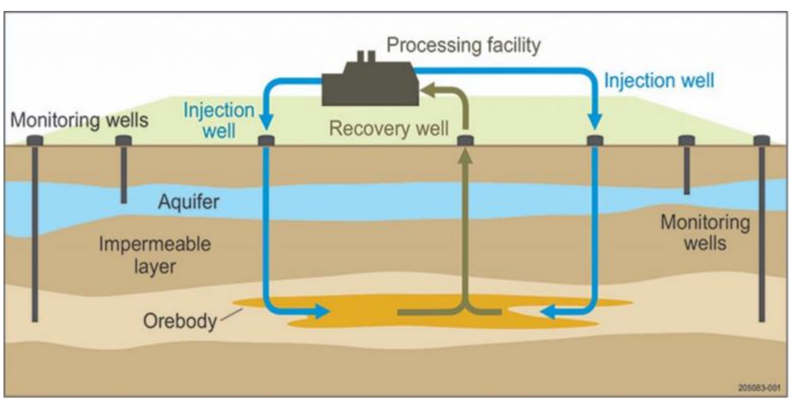
This paper begins with an explanation of what ISL is and is then divided into two broad sections, the first sections focusing on Kazakhstan and the second section focusing on Namibia. Both sections outline (1) historical or proposed ISL operation in the countries, (2) records of environmental damage caused by ISL, (3) the legal framework and sector structure for ISL and (4) the states' attitude towards, and involvement in, ISL.

This paper identifies why Kazakhstan possesses such dominance in ISL uranium production and the environmental price it pays for its dominance. This paper concludes that, despite very similar legislation, the unique Kazakh uranium sector structure and lax attitude towards environmental damage differentiate it from Namibia in a manner that would prevent Namibia from competing with Kazakhstan for ISL uranium investment.

Image: Uranium nitrate with uranium ore. (Source: RHJ via Getty Images)

2. What is ISL?[4]

ISL is defined as the extraction of uranium from the host sandstone (in general, sedimentary formations dominated by highly permeable sandstone) by chemical solutions (lixiviants) and the recovery of uranium at the surface. ISL extraction is conducted by injecting a suitable leach solution into the ore zone below the water table; oxidizing, complexing and mobilizing the uranium; recovering the pregnant (loaded) solutions through production wells (extraction wells or recovery wells); and, finally, pumping the uranium bearing solution to the surface for further processing.



[4] INTERNATIONAL ATOMIC ENERGY AGENCY, In Situ Leach Uranium Mining: An Overview of Operations, IAEA Nuclear Energy Series No. NF-T-1.4, IAEA, Vienna (2016)

Image: Conceptual model of an in situ recovery mining process (source: https://www.energymining.sa.gov.au/industry/minerals-and-mining/mining/major-projects-and-mining-activities/in-situ-recovery-ISR-mining)

Sites amenable to ISL are often very close to aquifers and ISL often used native groundwater in the orebody which is fortified with a leaching solution[5]. This factor has caused concerns regarding environmental pollution and contamination of drinking water (discussed below). Thus, there are certain general conditions under which ISL would be used in relation to a specific aquifer, these aquifer conditions include[6]:

1) It is not a source of drinking water.
2) It cannot serve as a source of drinking water in the future.
3) The total dissolved solids (contaminants) value is more than 3000 ppm and less than 10 000 ppm and is not reasonably expected to supply a public water system.

The above conditions are applied differently in different nations as the rest of this paper will reveal.

A. IN-SITU LEACHING URANIUM MINING IN KAZAKHSTAN

3. Background

In 2009, Kazakhstan became the world's leading uranium producer, with almost 28% of world production. By 2019, Kazakhstan produced 43% of the world's uranium despite only holding 12% of the world's uranium resources. Kazakhstan currently produces about 21,800 tU per year and sits firmly as a starting point for any operations, research innovations and discussions about Uranium.[7]

The aim of this portion of the paper is to consolidate the existing research on In-Situ Leaching (ISL) uranium mining in Kazakhstan and is comprised of the following sections: (1) A history of ISL in Kazakhstan, (2) an overview of the regulatory environment for ISL in Kazakhstan, (3) The role of the state owned uranium mining company: Kazatomprom, (4) the environmental damage

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[5] World Nuclear Association. 2020. In Situ Leach Mining of Uranium. Available at https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium.aspx

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, In Situ Leach Uranium Mining: An Overview of Operations, IAEA Nuclear Energy Series No. NF-T-1.4, IAEA, Vienna (2016)

[7] World Nuclear Association. 2022. Uranium and Nuclear Power is Kazakhstan. Available at https://world-nuclear.org/information-library/country-profiles/countries-g-n/kazakhstan.aspx

caused by ISL mining near the Syrdarya river and (5) identifying the concept of self-restorating groundwater systems after ISL operations.

This portion of the paper highlights that despite clear contamination of water resources by ISL in Kazakhstan, there has been little action to reform policy. The author has found no recorded fines for the researched contamination of water sources. This portion of the paper concludes by submitting that the relaxed attitude towards environmental protection for ISL projects is a result of the majority stake that the state holds in almost all uranium projects in Kazakhstan and the concept of self-restoration of groundwater systems which brings groundwater conditions back to pre-mining levels over time.

4. A history of ISL in Kazakhstan [8]

Kazakhstan's uranium industry was initially developed under the auspices of the former Soviet Union. Pre-1957 exploration by teams in this area focused mainly on hard rock deposits. Subsequently, conceptual models developed during a regional assessment led to the discovery of sandstone type uranium deposits associated with oxidation–reduction interfaces.

During this period, the Chu-Sarysu Basin in central Kazakhstan was explored and discoveries were made of deposits potentially amenable to ISL extraction. These early discoveries included the Uvanas and Zhalpak deposits. During 1970 and 1971, ISL tests were successfully conducted at the Uvanas deposit and continuing exploration resulted in the discovery of additional deposits, including Kandjugan, Moinkum and Mynkuduk. Exploration experience gained in the Chu-Sarysu Basin was applied in the nearby Syr-Darya Basin between 1970 and 1975 with similar results, including the discovery of North and South Karamuran, Irkol and Zarechnoye.

ISL project development proceeded rapidly in the late 1970s and early 1980s under three mining groups: Stepnoye Mining Company, No. 6 Mining Company and Central Mining Company. Stepnoye production operations at the Uvanas and Mynkuduk deposits commenced in 1978. The No. 6 Mining Company began extraction from the Karamuran deposits in 1981 and Central Mining initiated production at Kandjugan in 1982. All production was based on sulfuric acid leaching.

Production continued, more or less, in steady state at these three production centres until 1994 when Kazakhstan became independent. Displacement of the former administrative structure, low

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, In Situ Leach Uranium Mining: An Overview of Operations, IAEA Nuclear Energy Series No. NF-T-1.4, IAEA, Vienna (2016) pp 18. See citations 88-100.

uranium prices and a lack of capital led to rapidly decreasing production. Some mines could not even afford to purchase sufficient acid to maintain production. Subsequently, recognition of the low cost nature of Kazakhstani ISL uranium production and its substantial resource base led to increased interest from foreign firms as well as from the Government of Kazakhstan itself. Increasing investment in existing mines resulted in higher output by 2000. With higher uranium prices seen in the 2000s, new mines began to be developed, including Akdala, Inkai and Moinkum. By 2005, the realization of these higher prices set off a flurry of new development driven by foreign investment which culminated, in 2009, in the elevation of Kazakhstan to the position of the world's largest uranium producer. In 2012, overall ISL production in Kazakhstan amounted to 20 890 t U annually.

Prominent uranium projects and players using ISL in Kazahkstan include:

- Tsentralnoye Mining Directorate - mines deposits at Kanzhugan and Kainor deposits in Shymkent Oblast.[9]
- Mining Directorate No. 6 - mines deposits deposits at North and South Karamurun, Irkol, North and South Kharasan, and Zarechnoye.[10]
- Stepnoye Mining Directorate - mines deposits at Mynkuduk, Uvanas, Akdala and Zhalpak in Shymkent Oblast.[11]

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[9] Heinrich Graul, "Uranium mining as seen in situ," The Uranium Institute, No. 6, pp. 17-18; Tatyana Shkolnik, "The Development of Uranium Reserves in the Republic of Kazakhstan," report provided to CISNP, August 1994, p. 2; Carole A. Grey, "Up Front in the CIS," *Nuclear Engineering International,* May 1994, pp. 16-20
https://www.nti.org/education-center/facilities/tsentralnoye-mining-directorate/

[10] ibid
https://www.nti.org/education-center/facilities/mining-directorate-no-6/

[11] ibid
https://www.nti.org/education-center/facilities/stepnoye-mining-directorate/

Image: Central Mynkuduk Uranium In Situ Leaching Complex in Kazakhstan. (Source: NAC Kazatomprom JSC/Kazakstan)

5. An overview of the regulatory environment for ISL

5.1. Overview[12]

Kazakhstan has a licensing regime for most of its natural resources. But for uranium (and petroleum), it relies on a contract regime for exploration and production[13].

Kazatomprom is the national operator of the uranium market of Kazakhstan and has exclusive subsoil use right on uranium deposits – which it acquires through direct contract negotiations with the competent authority a (i.e. the Ministry of Industry and New Technologies of Kazakhstan). Kazatomprom carries out uranium exploration and production within the contract territory, pursuant to the contract terms[14].

A subsoil use contract enters into force from the moment of its registration with the competent authority and compulsory issue of a certificate of registration. The contract validity period is divided into a period of exploration and a period of production. The contract may be prolonged

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[12] INTERNATIONAL ATOMIC ENERGY AGENCY, In Situ Leach Uranium Mining: An Overview of Operations, IAEA Nuclear Energy Series No. NF-T-1.4, IAEA, Vienna (2016) pp 24-25.
[13]Kuatbekov, A., Abdreyeva, N. 2018. Kazakhstan adopts new sub soil use code. Baker Mackenzie. Available at https://www.lexology.com/library/detail.aspx?g=3b6ff123-528a-425e-9447-0fd3b8f86fed
[14] NAUMOV, S.S., TARKHANOV, A.V., BIRKA, G.I., "Future development of Russian uranium industry", Developments in uranium resources, production, demand and the environment, IAEA-TECDOC-1425, IAEA, Vienna (2005) 43–49.

upon the agreement of the parties in accordance with the law on subsoil use[15]. The contract territory will be returned upon the completion of the exploration period, except for areas identified as commercial sites.

The enterprise needs to submit full information on programme implementation to the competent authority, including a geological report on the results of operation on the contract territory to the authorized State agency on subsurface study and use. The enterprise needs to pay all taxes and other compulsory payments, as well as any fines for inefficient use of subsoil or environment contamination, if they have been issued.

5.2. Environmental Permitting[16]

To perform subsoil use operations (exploration and/or mining) in Kazakhstan, the environmental legislation requires:

- a State Environmental Expertise (SEE) document or an approval issued by the Ministry of Ecology, Geology and Natural Resources (Environmental Authority); and
- an environmental permit.

The subject of the SEE document and approval is the project documentation. An SSE document will be issued, for example, for project documents such as artisanal mining plans, exploration and production plans for hydrocarbon deposits, and projects and plans relating to uranium production. The SEE document must contain conclusions about the admissibility and feasibility of the project document.

An environmental permit certifies the right of entities to make environmental emissions. These include emissions, discharges of pollutants, disposal of production and consumption waste in the environment, and the placement and storage of sulphur in the environment.

All companies, including subsoil users, that make emissions to the environment from fixed sources must have an environmental permit.

5.3. Rehabilitation/remediation of mine site and environmental compliance[17]

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[15] Law of Subsoil and Subsoil Use, No. 291-IV, 2010 (Republic of Kazahkstan).

[16] Yerkebulanov, Y.,Ilyassova, A., Makhmetova, L., Zhilkibagarova, L., Abdulov, M. 2020. Kazakhstan: Mining Comparative Guide. Available at https://www.mondaq.com/energy-and-natural-resources/975734/mining-comparative-guide

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, In Situ Leach Uranium Mining: An Overview of Operations, IAEA Nuclear Energy Series No. NF-T-1.4, IAEA, Vienna (2016) pp 24-25.

Returned sites need to meet the requirements of State legislation with respect to environmental protection. A mining company needs, at its own expense, to reclaim the returned territories and other natural sites disturbed as a result of exploration, production or both until they are fit for further use, in accordance with the applicable State legislation.

The competent authority has a right to monitor whether the subsoil user fulfils the terms of the contract, and its representatives may be present during exploration and production. The contract includes a section on an abandonment fund. The subsoil user needs to submit, to the competent authority for approval, the programmes on remediation with estimated charges until the end of the exploration period or at the beginning of the production period. The remediation programme needs to include removal or liquidation of facilities and equipment used during the operation on contract territory.

For financing remediation works, the subsoil user needs to establish the remediation fund in the amount of 1% from the total volume of investments during the exploration period and not less than 1% from operational costs during the production period.

Regional structures of the State Committee for Industrial and Mining Safety Supervision, consisting of the Ministry for Civil Defense, Emergencies and Disaster Response of the Republic of Kazakhstan, regularly check the enterprise's operation for its adherence to the safety of works at dangerous production sites. Due diligence of the enterprises, as well as the unscheduled inspections, are carried out once in three years.

6. The role of Kazatomprom - The state owned uranium mining company[18]

Kazatomprom is charged with managing the government's stake in companies and state enterprises involved in uranium mining and milling and the production of nuclear fuel for nuclear power plants. Kazatomprom is the national company for exporting and importing uranium and its compounds, nuclear fuel for nuclear power plants, special equipment and technology, and dual-use materials. Kazatomprom also approves regulations in these areas[19].

[18] Chikanayev, S. 2022. The Energy Regulation and Markets Review: Kazakhstan. Available at https://www.lexology.com/library/detail.aspx?g=2754dbab-9834-408e-8af7-664e75157986#footnote-001

[19] Kazakh Khabar Television, 14 July 1997; in "Kazakhstan: President Issues Decree on National Uranium Company," FBIS-SOV-97-199. "Ukaz Prezidenta Respubliki Kazakhstan. O sozdanii natsionalnoy atomnoy kompanii Kazatomprom," Kazakhstanskaya pravda, 16 July 1997, p. 1.

Kazakh law provides for a local participation requirement in the nuclear sector because, in accordance with Article 160 of the Subsoil Code, a subsoil plot for uranium mining can only be provided Kazatomprom. Current legislation does not provide for granting the right of subsurface use for uranium extraction to persons other than Kazatomprom.

Moreover Kazatomprom is granted the right of subsurface use for uranium extraction by way of direct contract negotiations as outlined above. Kazatomprom may then transfer this right to another legal entity, but only an entity in which Kazatomprom directly or indirectly owns more than 50 per cent of the shares or participation interests.

Of Kazakhstan's about 14 ISL uranium mining projects, two are wholly-owned by Kazatomprom and 12 are joint ventures with foreign equity holders – five of which are with Russian state-owned ‘Uranium One’.[20] See below a list of the joint venture uranium mining projects in Kazakhstan as reported by the World Nuclear Association as at June 2022. [21]

[20] Kazatomprom Annual Integrated Report 2021. Available at https://www.kazatomprom.kz/storage/d4/kazatomprom_iar_2021_eng_final.pdf

[21] World Nuclear Association. 2022. Uranium and Nuclear Power is Kazakhstan. Available at https://world-nuclear.org/information-library/country-profiles/countries-g-n/kazakhstan.aspx

Company, project or mine	Foreign investor and share	Value of share or project if known
Inkai JV (Inkai mines)	Cameco 40%	
Betpak Dala JV (South Inkai, Akdala mines)	Uranium One 70%	$350 million for 70% in 2005
Appak JV (W.Mynkuduk)	Sumitomo 25%, Kansai 10%	$100 million total in 2006
JV Karatau (Budenovskoye 2 deposit)	Uranium One 50% (bought from ARMZ in 2009)	117 million Uranium One shares (giving 19.9% ownership) + $90 million
Akbastau JSC (Budenovskoye 1, 3, 4 deposits)	Uranium One 50% (bought from ARMZ in 2010)	
Zhalpak	CNNC 49%	
Katco JV (Moinkum, Tortkuduk mines)	Orano 51%	$110 million in 2004
Kyzylkum JV now Khorosan-U (Kharasan 1 mine)	Uranium One 30%, Energy Asia (Japanese + 40.05% Kazatomprom) 20%	$75 million in 2005 for 30%, $430 million total in 2007 (both mines)
Baiken-U JV (Kharasan 2 mine)	Energy Asia (Japanese + 40.05% Kazatomprom) 47.5%	$430 million total in 2007 (both mines)
Semizbai-U JV (Irkol, Semizbai mines)	CGN 49%, also CNEIC	
Zarechnoye JSC (Zarechnoye & S.Zarechnoye mines)	Uranium One 49.67% (bought from ARMZ in 2010), Krygyzstan 0.66%	ARMZ paid $60 million total

7. Environmental damage caused by ISL mining near the Syrdarya river [22]

The Shu-Syrdarya uranium region, consisting of 15 deposits of commercial interest, has been the most important in Kazakhstan due to its significant reserves[23]. The Syrdarya river is the major source of irrigation in South Kazakhstan and Kyzylorda regions and a multiple studies were undertaken to outline the contamination of the Syrdarya river.

This twelve-year monitoring of Syrdarya revealed that radioactivity exceeded the permissible level in almost every water sample throughout the entire observation period. In general, it is most likely that elevated levels of radionuclide concentrations in samples from sites around mines and downstream of the river in 2008-2009 and onwards are caused by expansion of uranium production. Based on World Health Organization (WHO) drinking water guidelines, researchers

[22] Zhanbekov, K., Akhmetov, A., & Vundo, A. (2019). Twelve-year monitoring results of radioactive pollution in the Kazakh part of the Syrdarya river basin. *Environment and Natural Resources Journal*, *17*(1), 44-53.

[23] Fyodorov GV. Uranium production and the environment in Kazakhstan. Proceeding of the International Symposium on the Uranium Production Cycle and the Environment; 2000 Oct 2-6; IAEA-OECD, Vienna: Austria; 2000:191-8.

suggested that water from Syradarya is unpalatable due to excessive dissolved solids and dangerous radionuclide concentrations – and similarly not suitable for household and agriculture use.

Investigations of surface and drinking water at 21 sites in the Aral-Syrdarya area for uranium concentration during August, 2003 indicated that uranium concentration in drinking water samples from two sites with shallow wells exceeded WHO guidelines significantly[24]. It was suggested that phosphate fertilizers and uranium mining were the sources of contamination. A further 2008 study identified that radioactivity levels in ground and wastewaters at the production sites exceed the national standards[25].

In May 2013, another team of researchers analyzed concentrations of uranium and radium radionuclides from 12 surface water samples collected along Syrdarya between the cities of Turkestan and Kyzylorda. However, despite all but one sample indicating uranium concentrations exceeding the WHO guideline level, the research concluded that they were within the level accepted for drinking water. It was also suggested that the uranium mining does not affect the quality of Syrdarya waters.[26]

More studies outlining water contamination have been published by the Journal of Environmental Monitoring in respect of the uranium concentrations found in the Shu River in Kazakhstan. The Shu River runs from the city of Tokmak to the city of Shu and through some of the largest uranium deposits which were exploited for the programs of the former Soviet Union[27].

7.1. Lack of accountability for environmental damage

JE Conway, in a 2013 paper on political risk in the Kazakh uranium industry, submitted that Kazatomprom neglects environmental concerns related to ISL mining and considers investments

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[24] Kawabata Y, Aparin V, Nagai M, Yamamoto M, Shiraishi K, Katayama Y. Uranium and thorium isotopes from Kazakhstan. Journal of Radioanalytical and Nuclear Chemistry 2008;278(2):459-62.

[25] Kayukov PG. Ecological considerations related to uranium exploration and production. In: Salbu B, Skipperud L, editors. Nuclear Risks in Central Asia. Dordrecht, Netherlands: Springer; 2008. p. 219-23.

[26] Satybaldiyev B, Tuovinen H, Uralbekov B, Lehto J, Burkitbayev M. Heavy metals and natural radionuclides in the water of Syr Darya River, Kazakhstan. In: Merkel B, Arab A, editors. Uranium - Past and Future Challenges. Proceedings of the 7th International Conference on Uranium Mining and Hydrogeology. Cham, Germany: Springer; 2015. p. 155-60.

[27] Available at https://pubs.rsc.org/en/content/articlelanding/2012/em/c2em11014h

in the safety of operations as unnecessary capital costs and the operator also claims that nature will self-restore itself at the mining sites (this self restoration is further discussed below)[28].

Further research argues that the existence of corruption and rent-seeking undermine the integrity of environmental monitoring process because regional offices of the State Committee for Industrial and Mining Safety Supervision and the regional governments overlook adherence to the safety of the uranium mines[29].

8. <u>Self-restoration of groundwater systems post ISL</u> [30]

In simple terms, this process can be described as the contaminated groundwater purifying itself over a roughly 13 year period from the cessation of ISL activities through a series of natural ecological occurrences. Researchers in the 1980's put forward that the groundwater system tends to return to pre-mining condition by self-neutralization, or "natural attenuation", once the introduction of leaching solution is suspended.

The largest scale and most detailed studies of the natural hydrochemical processes and self-purification (i.e. natural attenuation) of the stratal water contaminated by the products of sulphuric acid uranium ISL were carried out at the Irkol deposit in Kazakhstan and Yuzhny Bukinay deposit in Uzbekistan. Similar surveys have been conducted at the Yuzhny Karamurun and Uvanas deposits in Kazakhstan.

Based on the results of the long term monitoring, it was established that mineralization of the residual solution is reduced due to hydraulic dispersion, molecular diffusion, physical and chemical reactions with host rocks, mechanical sorption and monatomic ion exchange. Although the rate and efficiency of the process depends on the sorption properties of the aquifer host rocks.

The results of 13 years of monitoring of the self-purification process at the Irkol deposit supports the process. The Irkol deposit is located in Kzyl-ordinskaia oblast in Mining Group Number 6. The detailed exploration was finished in 1985. Following completion of leaching from 1985 to 1997,

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[28] Conway JE. The risk is in the relationship (not the country): political risk management in the uranium industry in Kazakhstan. Energy Policy 2013;56:201-9.

[29] Zhanbekov, K., Akhmetov, A., & Vundo, A. (2019). Twelve-year monitoring results of radioactive pollution in the kazakh part of the syrdarya river basin. *Environment and Natural Resources Journal*, *17*(1), 44-53.

[30] V.G. Yazikov, V.U. Zabaznov. Experience with restoration of ore-bearing aquifers after in situ leach uranium mining. IAEA-SM-362/43 pp 396-403. Available at https://inis.iaea.org/collection/NCLCollectionStore/_Public/33/032/33032936.pdf

systematic sampling of the remaining residual leach solutions was done using recovery and monitoring wells. The area of the leach-field aquifer returned to the nearly baseline hydrogeochemical state which existed prior to mining.

At the Yuzhny and Bukinay deposit similar monitoring was conducted after the ISL mining had stopped. Over 13 years, almost complete natural attenuation of the residual ISL solutions took place.

In comparison with active restoration (i.e. using the pump and treat method and/or chemical precipitation) natural restoration of groundwater is 10 to 100 times less expensive. The sole, but rather significant negative aspect of the self-restoration method is that this method is slow. Tens of years are required for returning to the baseline chemical condition of the groundwater.

However, scientists have patented a process to speed up natural attenuation. Percolating the residual ISL solutions through rocks unaffected by ISL was also found to return the concentration of the dissolved elements back to the background level. Water circulation through unoxidized rocks has been determined as an effective method of natural attenuation. The method ensures ground-water restoration within a relatively short period of time (i.e. from a few months to two or three years, subject to the size of the site to be cleaned).

It must be noted that the above research was only conducted in Kazakhstan and Uzbekistan and it is unclear whether the geology and environmental conditions in other uranium producing countries lends itself to this natural attenuation process in the same way.

9. Key takeaways

Kazakhstan differentiates itself as a uranium producing country by virtue of how its national uranium company holds more than 50% interest in almost all uranium projects in the country and holds the exclusive right to obtain subsoil rights to extract uranium.

The above type of sector structure lends itself to the notion that when environmental protection and financial gain are in conflict, where other countries may prioritize environmental protection because their sectors are highly privatized (with state participation ranging from 5%-10%), Kazakhstan may prioritize financial gains because of its major interest across the sector.

Kazakhstan has an orthodox regulatory environment in that the mining law provides for environmental permitting, abandonment funds and for mining sites to be returned to pre-mining conditions where possible. The existence of a clear environmental regulatory regime is not in question, however, researchers have hinted at whether the environmental legislation is firmly applied to Kazatomprom as it would be applied to companies mining other minerals where the state does not hold a significant stake.

Kazakhstan has clear incidents of water pollution to important water sources as a result of ISL mining which span back decades. However, despite such clear incidents it appears there has been no sweeping policy reforms and finding incidents where Kazatomprom was fined or otherwise penalized for environmental damage has been difficult.

The seemingly passive approach to water resourced polluted by ISL may also be a result of the self-neutralization, or "natural attenuation" process that occurs in aquifers once ISL activities are ceased. Since the impacted water resource restore themselves, this supports the notion that “if you do nothing for long enough, the problem goes away”. This long-term view may be what has allowed for any current environmental impacts to be overlooked in Kazakhstan.

B. IN-SITU LEACHING (ISL) URANIUM MINING IN NAMIBIA

10. Background

Namibia is ranked the 3rd most uranium producing country and the government has supported uranium mining. In 2021 Namibia produced 5753 tonnes of Uranium which accounts for about 12% of global uranium production. Namibia’s uranium production came from two open pit mines, namely Husab mine (controlled by Swakop Uranium (CGN)) and Rössing mine (controlled by the Chinese National Nuclear Corporation) with uranium production measured at 3309 tonnes and 2444 tonnes respectively[31].

[31] Uranium in Namibia. 2022. World Nuclear Association. Available at https://world-nuclear.org/information-library/country-profiles/countries-g-n/namibia.aspx

Image: Open pit uranium mining in Namibia at Rossing uranium mine (source: namibiauranium.com)

Although there are multiple other players in Namibia, almost none of the prospective uranium projects are amenable to ISL. Thus, in the midst of depressed uranium prices and the high costs of open pit mining[32], many of the uranium projects remain under care and maintenance.

This portion of the paper is broadly split into two portions (1) the history and new developments on ISL in Namibia and (2) an overview of the Namibian regulatory environment for ISL.

11. The history and new developments on ISL in Namibia[33]

Although Namibia has a history of uranium mining, it has no history of ISL mining in particular. Uranium One (A Russian state-owned company, through its Namibian subsidiary Headsprings Investments (Pty) Ltd) is currently proposing the use of ISL to extract uranium over the Stampriet Transboundary Aquifer System.

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[32] Reuters reports on low uranium prices caused by post fukushima demand slump and an oversupply of uranium and how the current industry is not economic at the current price point. Available at https://www.reuters.com/article/us-uranium-nuclearpower/desperate-uranium-miners-switch-to-survival-mode-despite-nuclear-rebound-idUSKCN1230EF

[33] The following are two newspaper article published in 2022 which outline the story:
https://www.namibian.com.na/6217855/archive-read/Uranium-mining-controversy-rages-on
https://www.namibian.com.na/114689/read/Uranium-miner-accused-of-sugar-coating-radioactivity-danger

Representatives of Uranium One are cited as promoting the economic benefits of the promising uranium deposits they intend to mine. Uranium One's project manager stated that the company has invested USD 50 million to date (including local community projects).

However, the community (represented by the Stampriet Aquifer Uranium Mining Committee) has accused Uranium One of hiding the detrimental impacts of ISL. ISL could contaminate the Stampriet artesian basin aquifer on which the arid south-eastern Kalahari Desert of Namibia and the neighboring countries of Botswana and South Africa depend.

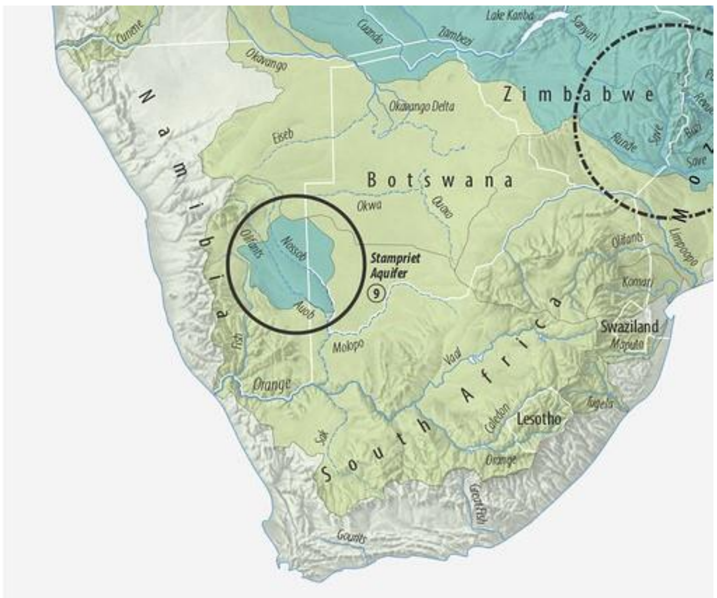

Image: The Stampriet artesian basin aquifer (Source: unknown)

In October 2021, after conducting a site visit, the Ministry of Agriculture, Water and Forestry of Namibia cancelled two water drilling permits belonging to the Uranium One subsidiary developing the project on the basis that the drilling pattern used and planned activity were not in line with the conditions upon which the permits were granted i.e. leaving boreholes open instead of closing them after drilling.

The uranium deposits that are the subject of Uranium One's interest are said to occur in underground sandstone layers containing high-quality drinking water in a transboundary aquifer that covers 87,000 square km and extends into Botswana and South Africa. The Namibian communities of Leonardville, Aranos, Aminuis, Onderombapa, Derm, Stampriet, Gochas and Koës are said to rely on this aquifer. It is estimated that at least 20 million cubic metre per year is abstracted; 65% of this volume comes from Kalahari aquifers, 33% from the

Auob aquifer and 2% from the Nossob aquifer. The breakdown of overall water use is as follows: 52% for irrigation, 32% for stock watering and 16% for domestic use.[34]

Uranium One intends to build a pilot plant to test the feasibility of the proposed operation and is in the process of developing an Environmental Impact Assessment, which the ministry of Tourism and Environment of Namibia will assess before issuing an environmental clearance certificate (without which the project cannot proceed).

12. Overview of the regulatory environment for ISL[35]

Overview

Minerals in Namibia belong to the state and uranium has been identified as a strategic resource for Namibia. Namibia prizes its mining sector and has broad legislation covering multiple areas within the sector. ISL is not directly regulated in Namibia but there are a host of mining and environmental laws applicable to mining in general, and uranium in particular, that would be applicable.

Mining

The Minerals Act[36] contains comprehensive provisions with regard to entitlements in relation to the country's minerals, as well as a number of provisions aimed at the protection of the environment.

The Act prohibits anyone from carrying any reconnaissance, prospecting or mining operations in Namibia except in accordance with the respective required licenses, as well as applicable regulations. The issuance of licenses is subject to several conditions, including complying with environmental laws. The Act is applicable to all uranium mine facilities in Namibia.

The Atomic Energy and Radiation Protection Act (AERPA)[37] aims to minimize the exposure of persons and the environment in Namibia to the effects of harmful radiation; to ensure that adequate control is exercised over the possession, production, processing, sale, export and import of radiation sources and nuclear material; and to create the necessary mechanisms to

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[34] International Groundwater Resources Assessment Centre. Stampriet Aquifer. Available at https://www.un-igrac.org/case-study/stampriet-aquifer#:~:text=It%20is%20estimated%20that%20at,and%2016%25%20for%20domestic%20use.

[35] https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.836.7658&rep=rep1&type=pdf

[36] Available at http://www.lac.org.na/laws/1992/564.pdf

[37] Available at http://www.lac.org.na/laws/2005/3429.pdf

facilitate compliance with the country's obligations under international agreements relating to nuclear energy, nuclear weapons and protection against the harmful effects of radiation.

The AERPA is of direct relevance to the regulation of uranium mining in as far as it prohibits the handling of uranium without a license for the specific post-mining activities listed above.

Environmental

The Environmental Management Act (EMA)[38] serves as the flagship environmental protection legislation in Namibia. The EMA provides a set of environmental management principles and environmental protection measures.

The environmental management principles listed in section 3 of the EMA guide the implementation of the Act, they serve as framework within which environmental plans must be formulated and guide organs of state when decisions regarding environmental protection must be made.

Under EMA a uranium mining company would have to prepare an environmental impact assessment outlining the damage that may be caused, the location of a mine (relative to environmentally sensitive areas) and plans for environmental conservation. After these steps are completed, the uranium company would be considered for an environmental clearance certificate – which is an essential requirement for obtaining a mining license.

The Environmental Investment Fund of Namibia Act (EIFA)[39] establishes the Environmental Investment Fund (EIF). The aim of EIF is to procure money for the maintenance of an endowment fund that generates income in perpetuity to allocate such income to activities and projects aimed at sustainable development, amongst others.

Money within the EIF is used for improved conservation, protection and management of natural resources, biodiversity and ecosystems; environmental training and education; producing, monitoring, using and disseminating environmental information in order to broaden the knowledge base of Namibia's environmental resources; and developing and implementing environmental policies and strategies.

[38] Available at http://www.lac.org.na/laws/2007/3966.pdf
[39] Available at http://www.lac.org.na/laws/2001/2669.pdf

The Water Resources Management Act (WRMA)[40] provides for the management, development, protection, conservation and use of water resources in a manner that is consistent with and conducive to the fundamental principles contained in the Act. Some of the principles of water resource management are applicable to the environmental regulation of uranium mining facilities as water is extensively used during uranium mining operations.

These principles may establish and enhance environmental protection as it provides for, amongst others, the harmonization of human needs with environmental ecosystems and the species that depend upon them while recognizing that those ecosystems must be protected to the maximum extent; integrated planning and management of surface and underground water resources in ways which incorporate the planning process, as well as economic, environmental and social dimensions so as to promote sustainable development; the preventative and polluter pays principle; as well environmental awareness and training, in order to establish openness and transparency by making water resources information available and accessible to the public.

13. <u>State and local participation in mining industry</u>

The Namibian regulatory environment is not intrusive in comparison to other legal regimes, particularly in that there is not mandatory state participation in mining projects. Although the state mining company ('Epangelo') does hold a minority stake in some mining operations, this stake is held on arm's length terms – typically 5% to 7%.

In terms of local participation outside of the state mining company, the Ministry of Mines and Energy issued a notice in March 2021 with the following effect: Where a mineral license is first obtained by a Namibian entity, the Ministry of Mines and Energy has placed a restriction on local entities, when selling such mineral license to foreign entities, to retain 15% of such mineral license with Namibians (effective since March 2021)[41].

It is clear that although there is an attempt to create mandatory local participation in the mining sector, it is not all state participation and it is typically a minority stake.

[40] Available at https://www.lac.org.na/laws/2013/5367.pdf
[41] A link to the public notice made by the Ministry of Mines and Energy can be found here: https://www.mme.gov.na/files/publications/eb0_Public%20Notice_Effective%201%20April%202021.pdf

14. Key takeaways

Namibia possesses a robust mining regulatory regime with an appropriate focus on environmental factors. Companies intending to execute ISL projects will have to state their case by way of environmental impact assessment and the relevant government ministries will vet their intended plans. Namibia has shown a willingness to regulate and act against non-compliance with the cancellation of the water drilling permits referenced above, even at the expense of potential investment.

Further, the state does not have a direct stake in the proposed ISL project which gives the government no conflict of interest when assessing the impacts of the proposed project. In the event that an ISL project is granted the necessary permissions to operate in Namibia, it will be likely that the assessed environmental impact of the project is deemed acceptable – relative to other mining projects.

15. Conclusion

Kazakhstan and Namibia both have substantial reserves of uranium and similar legislation regarding environmental permitting and ownership of natural resources belonging to the state.

Outside of the above similarities, the differences are stark. Most notably, Namibia does not participate in its uranium sector as substantially as Kazakhstan. It is suggested that Kazakhstan holding a majority stake in all uranium projects creates a conflict of interest when it comes time for government to deliver penalties for pollution because the fines paid would come from state revenues. Kazakhstan has created a rare situation wherein the financial interests of uranium producers and the state are aligned – to the possible detriment of strict environmental protection. The cost of Kazakhstan's booming ISL industry is the pollution of several rivers and water sources.

The absence of a substantial financial interest in the Namibian uranium sector has allowed the Namibian government to be strict in its application of environmental legislation. This strict application of environmental laws differentiates Namibia from Kazakhstan to the effect of discouraging investment in ISL in Namibia – relative to Kazakhstan.

To gain a deeper understanding of the issues, it is recommended that further research be carried out into Australia. Namibia is still a frontier territory for ISL and thus there is no recorded history of pollution and how the government addressed these incidents. Australia is likely to provide useful insights into what a 'normal' ISL sector would look like and whether it is sustainable (assuming that the Australian government does not hold a significant stake in ISL operations).

The environmental incidents in Kazakhstan also suggest that one of the major drivers for ISL uranium being considered low cost is because the environmental costs are not factored in. An economic analysis into ISL costs will be required to fully understand whether ISL uranium is considered cheaper because environmental costs have not been factored into its price or whether the ISL method (pumping solution into and out of the ore body) is just genuinely cheaper than open pit mining in a significant manner – which is what the literature categorizes it as.

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