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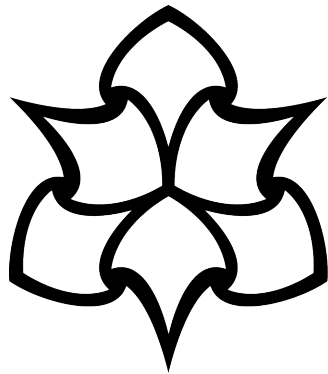
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Original article

Assessing the state of uranium research: Environmental justice, health, and extraction

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ABSTRACT

In this introductory essay for the Special Issue on Uranium, we provide an overview of the state of the research and ways forward for researchers and practitioners. We focus specifically on research and developments in: uranium and social justice, focusing on giving a brief historical overview; the global political-economic context; and environmental and social injustices related to uranium. We conclude with an overview of contributions to this discussion made by articles in the special issue and highlight ways forward for social scientists.

1. Introduction: uranium & the atomic age

Since the dawn of our atomic age in the early 20th Century, uranium has been a vital resource for the production of nuclear medicine, energy, and defense systems. While uranium has historically offered the means for significant techno-scientific development opportunities, the extraction and processing of uranium poses pertinent environmental, social, and cultural challenges. Gabrielle Hecht (interviewed for this special issue) has described these challenges as “entangled” in nature, with immediate and diffuse consequences to humanity and the environment (Hecht, 2011). While it seemed as if recent developments such as the Fukushima-Daiichi disaster had halted our collective appetites for nuclear technologies and uranium extraction and production, recent developments – such as the U.S. announcing intentions to build a ‘uranium reserve’ over the next decade – remind us that environmental and social justice issues related to uranium remain visceral. Indeed, they must be central to policy and defense discussions, lest we repeat the grave and on-going legacies of the past or continue to ignore them. Within this special edition of *Extractive Industry and Society*, our authors collectively address the challenges created by uranium across a variety of historical and contemporary spatial and social contexts.

The health effects of uranium were known of almost a century before nuclear energy or warfare existed, as uranium was historically extracted for use as a colorant for ceramic glazes and the glassmaking industry (Strahan, 2001). Long before this, Indigenous and Native communities living near the element knew of the risks of uranium – and warned their community members against prolonged interaction with uranium (Brugge et al., 2007). The biological consequences of uranium toxicity to animals were first documented by Christian Gottlob Gmelin

at the University of Tübingen in 1824, as part of a multi-element study that described the “poisonous properties” of uranium salts to animals (Gmelin, 1826; Hodge, 1973:5). Early European research into uranium toxicity helped scientists to forge links between the environmental conditions of uranium mining and the health of uranium workers, and the association between uranium mining and a lung disease was first academically identified and described in 1879 (Harting and Hesse, 1879; Brugge and Goble, 2002). However, it was an additional fifty-three years before Germany and Czechoslovakia addressed the health issues that arose among workers at the Erzgebirge-Krušnohoř extraction facility, and they described this condition as a “compensable occupational disease” (Albrecht, 2017; Brugge and Goble, 2002). This early action by the state could have improved public understanding of the health risks posed by uranium extraction, due to state recognition and acceptance of the health challenges arising among miners. However, it also represented a cultural turn towards compensatory rather than preventative measures for the protection of human health from the consequences of uranium extraction.

In the following introduction to this special issue, we review the global context and academic research on uranium, focusing on social and environmental justice issues. We then detail the interventions made by this special issue in enhancing those foci among academic research. Notably, this journal has published articles that begin to incorporate these questions related to uranium production and overarching social justice, environmental justice, and development issues (see Hansen and Johnstone, 2019; Issah and Umejesi, 2019; Volderbing and Warner, 2018; Postar, 2017; Haalboom, 2016; Procter, 2016; Bjørst, 2016; Vestergaard, 2015). This special issue intends to consolidate and amplify these issues in one issue, which we hope

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contributes to more formally establishing *Extractive Industries and Society* as a forum in which productive debates and scholarship are showcased that encourage and enhance these vital discussions of uranium production's development and social and environmental justice dimensions.

2. Global uranium

Uranium extraction has become a globally expansive industry, and mines are now dotted across the world. Currently, uranium extraction occurs in thirteen countries across the world, with operations in Canada, the USA, Russia, Kazakhstan, Uzbekistan, Ukraine, China, India, Pakistan, South Africa, Niger, Namibia and Australia (WNA, 2019). The sector remains problematic, as historical operations such as mines and mills have left thousands of abandoned and contaminated sites, many on public lands and Indigenous lands (Malin, 2015), even as many mines are now privately owned by multi-national corporations (MNCs). These large non-state organizations often 'race to the bottom' when locating their operations, use regulatory arbitrage to geographically circumvent industrially unfavorable legislation that would offer better protections to mine workers, communities, and ecosystems (Tarko and Farrant, 2019). This has profound consequences to environmental and public health policy pertaining to uranium, particularly for less economically developed states (LEDCs), where economics may be prioritised over matters of environmental health, culture, society, and state.

Significantly, Indigenous peoples and Tribal communities have been some of the most affected populations worldwide, with many ancestral homelands and sacred lands permanently contaminated and scarred by uranium extraction as a consequence of state and MNC activities (Hoover et al., 2012). The enormous impacts to Indigenous peoples have been considered in a variety of contexts, including: in Aboriginal Australian communities (Banerjee, 2000) and postcolonial contexts of extractive land uses; in India's West Khasi Hills (Karlsson, 2009), where uranium deposits have been found near Indigenous and Tribal lands; and in the U.S., where multitudes of Tribal, Pueblo, and other Indigenous communities continue to live with the legacies of uranium contamination – and with contemporary threats of renewed development (Brugge et al., 2007; Pasternak, 2010; Malin, 2015). The Navajo Nation alone has over 500 abandoned uranium mines (Kapoor, 2018; Malin, 2018). The Jackpile-Paguete Mine in northern New Mexico, located on the lands of the Laguna Pueblo and near other Tribal Pueblos including the Acoma and Hopi, remains one of the largest open-pit uranium mines in the world and is still being remediated, despite its closure in the early 1980s.

Environmental justice and health issues abound in these spaces, and the work of the Southwestern Research and Information Center (www.sric.org) and community-based research such as the Navajo Birth Cohort Study (see https://www.atsdr.cdc.gov/sites/navajo_birth_cohort_study/) continue to address these historical, structural inequities. Yet we continue to actively pursue renewed uranium production in the U.S. (and in other nations such as Australia) on sacred and scarred lands, shrinking protected public lands such as the Bears Ears National Monument and opening up other fragile public lands, such as the North Rim of the Grand Canyon, to renewed mining. As we explore in this issues, contemporary uranium development multiplies the intersecting environmental inequities facing uranium communities and impacted species and ecosystems.

Consideration of the corporate social responsibilities pertaining to mining has led to some changes to environmental, sustainability and community reporting in some cases (Jenkins, 2004). However, the provision of "community development strategies to approach community relations" does not go far enough to support the autonomy of local communities, and this approach may have political repercussions for rural development policy (Jenkins, 2004:32; Heisler and Markey, 2013). Notably, corporations selectively apply social responsibility principles to only those communities that have adequate power

to impact project development (Heisler and Markey, 2013). This can be especially delicate and incommensurable when corporations attempt to work with Tribal or Indigenous communities, who often possess starkly different notions about extraction and privatization or 'ownership' of land.

3. Uranium and the state

Uranium continues to be a global resource with a complex global web of extraction, production, and trade relationships – and the state continues to play a key role, as it did in the mid-20th century. To give a sense of the multiple communities and places impacted by uranium production, it is important to see this from a global perspective. Current uranium mining occurs in many locations, showcased in Table 1, created by the World Nuclear Association, below.

There is a contemporary phenomenon of state investment in uranium extraction beyond that state's borders, which is well-described by the Chinese uranium scenario. For instance, there are currently in-situ leach uranium mining facilities in Yili Basin, following uranium exploration within Xinjiang Uyghur Autonomous Region, China (Dai et al., 2015). This facility operates within a designated Indigenous people's zone, and it is noteworthy that this region has a legacy of Uyghur cultural re-education. This raises questions pertaining to Indigenous autonomy and the regional economic and social influences of the Chinese state (Alexis-Martin, 2019). Moreover, Chinese state-owned companies have also been investing internationally in uranium since 2007 and their portfolio currently includes uranium mines in Namibia and Niger (Volberding and Warner, 2017; DeBoom, 2017; Alexis-Martin, 2019). Questions have arisen that pertain to the economic and social agency of these African uranium investment-recipient states and their agency in statecraft, with "mixed and uneven" results (Volberding and Warner, 2017:3). Further, as Table 2 from the World Nuclear Association indicates, the industry is shaped by state-owned corporations – but has also moved toward privatized investment and production and public-private partnerships, with multi-national corporations operating across national contexts.

These issues represent just a few of the dynamics that make uranium one of the most charged, controversial, and important elements in the Anthropocene age (or Capitalocene, if you prefer). The articles in this Special Edition tackle these fascinating questions from a variety of perspectives. In Malin and Alexis-Martin's article on Polanyi, for instance, the authors examine the ways that uranium community members can mobilize movements *supporting* risky renewed uranium production, given the strong move to market-based logic in the U.S. since the 1980s.

We can see that significant research and community-based inquiries have been done regarding uranium and its complex socioenvironmental legacies and contemporary outcomes, including:

- Environmental justice issues, from distributive injustices (where uranium contamination is located) to procedural injustices (what groups have had, and not had, a seat at the table in making these decisions)
- Public and environmental health legacies and ongoing outcomes, often for workers and marginalized populations
- Geopolitical conflict and strategic use of uranium by various states, as well as relationships to national security and ongoing diplomatic and military maneuvers
- Economic outcomes of uranium markets, from booms to busts and
- Cultural and community-based relationships with uranium extraction, production, and markets, which can vary drastically across time, space, and political-economic circumstances

Table 1
Mine production (tons of U).

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Kazakhstan	14,020	17,803	19,451	21,317	22,451	23,127	23,607	24,586	23,321	21,705
Canada	10,173	9783	9145	8999	9331	9134	13,325	14,039	13,116	7001
Australia	7982	5900	5983	6991	6350	5001	5654	6315	5882	6517
Namibia	4626	4496	3258	4495	4323	3255	2993	3654	4224	5525
Niger	3243	4198	4351	4667	4518	4057	4116	3479	3449	2911
Russia	3564	3562	2993	2872	3135	2990	3055	3004	2917	2904
Uzbekistan (est)	2429	2400	2500	2400	2400	2400	2385	2404	2404	2404
China (est)	750	827	885	1500	1500	1500	1616	1616	1885	1885
Ukraine (est)	840	850	890	960	922	926	1200	1005	550	1180
USA	1453	1660	1537	1596	1792	1919	1256	1125	940	582
India (est)	290	400	400	385	385	385	385	385	421	423
South Africa	563	583	582	465	531	573	393	490	308	346
Iran (est)	0	0	0	0	0	0	38	0	40	71
Pakistan (est)	50	45	45	45	45	45	45	45	45	45
Czech Republic	258	254	229	228	215	193	155	138	0	0
Romania (est)	75	77	77	90	77	77	77	50	0	0
Brazil (est)	345	148	265	326	192	55	40	44	0	0
France	8	7	6	3	5	3	2	0	0	0
Germany	0	8	51	50	27	33	0	0	0	0
Malawi	104	670	846	1101	1132	369	0	0	0	0
Total world	50,772	53,671	53,493	58,493	59,331	56,041	60,304	62,379	59,462	53,498
tonnes U ₃ O ₈	59,874	63,291	63,082	68,974	69,966	66,087	71,113	73,560	70,120	63,087
% of world demand*	80%	84%	87%	94%	91%	85%	98%	96%	93%	83%

* Data and Table from the World Nuclear Association.

Table 2
Top uranium corporations globally*.

Company	Tonnes U	%
Kazatomprom	11,074	22
Orano	5809	11
Cameco	4613	9
Uranium One	4385	8
CGN	3185	6
BHP	3159	6
ARMZ	2904	5
Rio Tinto	2602	5
Navoi Mining	2404	4
Energy Asia	2204	4
CNNC	1983	4
General Atomics/Quasar	1663	3
VostGok	1180	2
Sopamin	1002	2
Other	4701	9
Total	53,498	100%

* Data and Table from the World Nuclear Association.

4. Advances in this issue – creating a forum for justice-based discussions on uranium

In this special issue, we add to this body of research by focusing on structural *power dynamics* link to the injustices of uranium extraction, production, waste, and political-economic upheaval. By providing unique and important perspectives on historical, cultural, environmental justice, and health aspects of uranium, we have consolidated insights in to some of the vital aspects of uranium that, nonetheless, often get lost or buried in contemporary concerns over who has the capacity to enrich uranium or our collective obsession with volatile uranium markets. While technical aspects of uranium extraction and production are, of course, vital to understand, here we offer a ‘state of the social science’ perspective on uranium’s socio-ecological, cultural, and historical outcomes. We offer vital contributions regarding the contested power dynamics related to uranium’s use, communities’ interactions with the element over time, and the ways that national security and secrecy have been used to make these power struggles invisible. Intergenerational justice, temporal complexity, and the ways we can and should communicate risks about uranium and nuclear technologies across

enormous time scales feature centrally and progress ongoing scholarship and policy discussions.

The content we provide digs deeper into the grounded, ethnographic narratives about uranium as it interacts with and ‘comes alive’ in the communities that host its extraction and production, or store its waste. We also consider wider narratives related to nuclear technologies and testing, as our use of uranium remains inseparable from those outcomes and the choices various nations have made about how to harness such a powerful and controversial element.

In our interview with Gabrielle Hecht, she illuminates some of the ongoing challenges with uranium markets globally, as well as the international political tensions that revolve around uranium’s production and the power struggles it can initiate and amplify. In our interview with Larry Johns, who has represented multiple groups affected by nuclear testing and uranium production in the American West, we see how often invisible laborers and community groups have struggled to protect themselves from nuclear technologies, often with limited success. In his interview, we see how the burden of proof lands on these already disempowered groups to establish their exposure to nuclear contamination and its sometimes fatal health outcomes.

Research articles in this special issue take us to communities and peoples around the world impacted by uranium production and its waste products – focusing on the ways that uranium can truncate social justice, historically and in contemporary contexts. In Kinsella’s article, nuclear waste becomes a central focus, as he examines social justice, intergenerational justice, and communication and analyses of risk related to uranium. As he establishes, uranium provides unusual temporal and environmental justice challenges, given its unique nuclear risks and the enormous time scales at play when human systems interact with nuclear technologies. Malin and Alexis-Martin interrogate the ways uranium can become part of socioeconomic and cultural fabrics. Here, we see how market-based systems can allow even risky technologies to be embraced by some communities, given their own complex histories with persistent poverty, spatial isolation and injustice, and earlier periods of national security and war-making. In Pitkanen’s article, we visit the Eldorado uranium refinery in Port Hope, Ontario, a state-corporation that has a complicated, onerous history. We are treated to an insightful interrogation of the ways in which that facility ingratiated itself into local community fabrics and national nuclear-capitalist agendas. Though the facility contaminated surrounding communities

and populations, the Crown Corporation was able to exercise substantial meta-power, controlling information about the facility and its pollution, setting the terms of discussions about environmental justice and its culpability in polluting people's homes, limiting its own legal liability when contamination was discovered, and manipulating people's economic fears to such an extent that it captured the loyalties of the very people most affected by the facility's environmental health violations and injustices. This assessment offers another invaluable interrogation of the surprising and pernicious ways that some of the riskiest facilities and nuclear practices can become so woven into local social fabrics that the very people most direly impacted by their practices become apologists for rampant contamination and power imbalances.

This special issue also grapples with some of the current 'technological fix' approaches to global climate crisis, which seek to establish uranium and nuclear as necessary and vital to rapidly mitigating our global climate emergency. Proponents of energy independence, the buzz-phrase of the last two decades, continue to argue that smaller-scale nuclear reactors could allow less dependence on centralized, fossil fuel-based, or import-centered sources of fuel. Here, we critically analyze and problematize these technological and market-centric approaches, given the under-addressed legacies of the industry to date and the potential socioenvironmental costs of these newer approaches, even if their scale is smaller. In McKie's article, she uses a green criminological lens to analyze current attempts in the UK to expand their nuclear power production capabilities through the use of smaller nuclear reactors and smaller-scale power generating stations. Utilizing a treadmill of production lens fused with green criminological assessments, McKie concludes that social and environmental risks and harms associated with nuclear power are not diminished through smaller-scale deployment of nuclear reactors and other technologies. Economic instability, reliance on volatile capitalist markets and practices, and even intergenerational injustices are just as likely, finds McKie, even when utilizing smaller-scale nuclear reactors. Rather than continuing to rely on socially, environmentally and economically risky modes of uranium extraction and nuclear technologies, other truly renewable resources must be our immediate focus.

Finally, this special issue endeavors to shine a bright light on the very human impacts of the industry – and especially power imbalances – often ignored or rendered invisible by our focus on nuclear power as a potential solution to global climate crisis or on geopolitical spats over uranium enrichment and weapons. The instrumental treatment, risky livelihoods, and potential suffering of workers and communities often remain in the shadows of these flashier issues, but here we challenge that dissatisfying pattern. For instance, Brugge and Ifran offer an unprecedented examination of production's "toll on uranium miners", comparing two different state-led programs to compensate uranium workers, in the US and in Germany. They observe that blue collar uranium workers often suffer some of the worst consequences and health risks of the industry, and yet remain unjustly under- or uncompensated for the life-and-death risks they take on, often in the name of national military and political 'progress'. Brugge and Ifran conclude that both compensation programs could be drastically improved and call for a more comprehensive, scientific assessment of impact to uranium workers' health worldwide, with the goal of extending compensation to a much wider swath of affected workers. In their article, Le Berre and Bretesché interrogate the risks faced by underground uranium miners, examining some of the dissociative patterns that emerge when miners are faced with basic risks of mining, such as cave-ins or immediate exposure to toxic gasses, accompanied by the immense and invisible risks of radioactive exposure. They find that these risks related to uranium's radioactivity have been historically minimized by miners, given the "opacity" of the risks to the everyday working lives of miners, despite their very real public health risks. Adeptly, Le Berre and Bretesché trace these patterns over time, showing that changing political and cultural landscapes since the 1970s have affected these dynamics,

leading to the eventual shift in perspective that uranium mining was in fact "high-risk" because of workers' potential radioactive exposure as health problems and nuclear accidents became more publicized and politicized starting in the 1970s.

5. Conclusion

Taken together, these articles establish that it is an ahistorical and environmentally unjust mistake to claim that uranium-based nuclear technologies provide some sort of magic bullet as we face the existential, economic, and environmental crises of climate emergency. We aim to refocus the discussion on power imbalances and the very real risks they can create. As we see from the social and environmental justice perspectives of this special issue – which privilege community, health, and socioenvironmental aspects of uranium production – continuing to pursue nuclear technologies without first addressing the numerous and serious legacies of uranium production would be gravely irresponsible. These dated and unimaginative approaches instead lead us down a familiar path where capitalist market expansion, global geopolitical tensions, and the meta-power of nuclear states and MNCs dictate the agenda.

Given this void in research, then, we encourage future research to more rigorously build on these social and environmental justice foundations. Future research should privilege historical, community-based, and community-led research that prioritizes the lived experiences of people in uranium communities. In this way, researchers can make this rather invisible part of the nuclear fuel cycle more visible, rendering arguments about reliance on nuclear power more problematic and ethically dubious. Cross-national, comparative, and more mixed methods research would add to the rich research we have started to present here. Focusing on the potential role of renewable energy sources in these places, examining the socioeconomic potential for just transitions, and critically examining how uranium communities can avoid natural resource dependence and boom-bust economies using these approaches emerge as vital research agendas for scholars. Finally, because so many Indigenous, Native, and Tribal communities in uranium production zones, research done by these communities, or deeply grounded in these spaces, should be given special priority to enhance our collective understanding of the relationships between uranium production and socio-environmental justice. While we begin this work here, and build on other exemplary work in this vein, much more can be done.

Thank you for reading this special issue and letting it inspire you to take these charges forward. Let's utilize these lessons of environmental injustices driven by power imbalances to instead choose newer, innovative, and more imaginative paths that lead us to distributive economies, regenerative models of production, and ethics of care and humanitarianism – even as we combat the climate crisis.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.exis.2020.02.006](https://doi.org/10.1016/j.exis.2020.02.006).

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