REVIEW ARTICLE

"Low-Dose, Long-Term" Toxic Exposures Among "Indigenous Peoples in Canada": Impacts of Inequality, Environmental Health Challenges, and the Need for a Comprehensive Approach

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Abstract

Indigenous Peoples in Canada face disproportionate environmental health burdens from long-term, low-dose toxic exposures, driving marked health disparities. These exposures stem from the unequal siting and legacy of industrial contamination—including historical mercury dumping—compounded by socioeconomic inequities and ecosystem degradation. Drawing on our program of research, including a community-based mixed-methods case study that integrated community narratives with biomonitoring data, we synthesize evidence and propose countermeasure strategies that public-health toxicologists can apply in Indigenous contexts and, by analogy, to minority populations in low- and middle-income countries. Despite meaningful progress to reduce exposures and revitalize traditional practices, many communities still face risk—from contaminated food sources and from limited access to care that reflects their cultures and needs. These challenges are compounded by structural racism within health systems. We recommend a practical, culturally grounded approach to environmental health: listen first to Indigenous knowledge, design programs with communities (not for them), and place decision-making with Indigenous leadership. Done well, this confronts cumulative harms, strengthens community resilience, and—most importantly—reduces health inequities.

We outline population-level, sustainable actions for health authorities, including community-driven monitoring, food-system remediation, risk communication co-designed with Elders, and policy frameworks that honour Indigenous sovereignty and the principles of relevance, respect, and reciprocity. Implementing such collaborative strategies is essential to reduce toxic exposures among Indigenous Peoples in Canada and offers transferable guidance for protecting minority communities globally.

***Keywords*:** Social determinants of health, Health equity, Toxic exposure, Indigenous population, Persistent organic pollutants (POP)

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INTRODUCTION

Knowledge and practices of Indigenous populations are increasingly influencing integrative approaches to human health that acknowledge the deep interconnection between natural environments and human well-being. Some examples are the established Ecohealth field, and the emergent Planetary Health field. Moreover, scholars interested in public health are progressively acknowledging the role of Indigenous knowledge frameworks as part of the solution to complex challenges of environmental change and human health [1, 2], such as pollution and contamination.

Nonetheless, initiatives influenced by Indigenous Peoples' knowledge stand in stark contrast to the greater disease burden Indigenous peoples are experiencing in comparison to the general population. A study across 23 countries found evidence of higher burden of disease for Indigenous peoples when compared to non-indigenous populations, which is partly attributed to toxic exposures due to uneven distribution of pollution [3]. More than 90% of deaths attributed to total pollution occur in low- and middle-income countries, where Indigenous people are at high risk of exposure and disease development [4]. This is also the case in Canada where, for example, 54 Indigenous

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communities (excluding Saskatoon) had drinking water advisories in September 2021; open burning of waste is common; and concerning levels of contamination have been reported in communities near industrial complexes [5–7].

The data presented in this paper were mainly drawn from two original studies. One component involved the collection of qualitative narratives, capturing community experiences and perspectives through a participatory approach. The other component focused on quantitative data, including measuring environmental contaminant levels in non-commercially harvested seafood and seawater. These samples were collected in the field and analyzed using standardized quantitative methods.

The methodology for original quantitative study is described in detail in Andrade-Rivas et al 2022 [8] In brief, the research was designed in response to the lack of longitudinal data on long-term, low-dose environmental exposures through seafood and water on the West Coast of Canada—particularly in relation to health disparities experienced by Indigenous Peoples, which is the focus of this commentary.

The arguments we advance here were shaped by our work with Indigenous colleagues and in a marine toxicology project co-led by the Tsleil-Waututh Nation [8, 9], from which we have learned a great deal. We have already discussed the impact of industrialization and food safety among Tsleil-Waututh Nation residing in Burrard Inlet as measured by chemical levels in shellfish, crabs and sea water [9]. None of the three authors of this editorial are members of Indigenous nations in Canada.

Previous studies have not adequately addressed this critical information gap, especially regarding food-bome toxic exposures and their disproportionate impact on Indigenous communities.

To address this, we adopted a qualitative, community-based research approach, rooted in sustained collaboration with the Tsleil-Waututh Nation (TWN). The study began with a comprehensive review of available academic literature, national and provincial environmental health reports, and historical health records provided by TWN. Building on this foundation, the research team partnered closely with community members to develop a shared understanding of the existing knowledge gaps and jointly identify appropriate research strategies. This collaborative process included the formation of a working group, the development of focus groups, and the facilitation of regular meetings aimed at co-creating the research design.

Community members were integrally involved throughout the study, including in the design phase, conducting interviews, and collecting biological samples for biomonitoring purposes. The study protocol was formally reviewed and approved by the First Nation council, ensuring cultural and ethical accountability.

In line with principles of ethical research and relational accountability, findings were first presented to the community for validation. Results were only made public after receiving explicit approval from community representatives. The research team, acting as external collaborators, recognizes and affirms the sovereignty, leadership, and vision of Indigenous partners. This approach supports the development of Indigenous-led frameworks for environmental health equity—both within Canada and as potential models for addressing similar challenges in low- and middle-income countries.

Social and Ecological Extra Challenges for Indigenous Populations

There are differing approaches to characterize indigeneity, and no single definition of Indigenous Peoples exists [10, 11]. This is further complicated, because colonization and the ongoing displacement of sovereignty has deteriorated the social fabric in many Indigenous populations [12]. Nonetheless, Indigenous populations have sustained a close connection with their territory and often live in close proximity to natural environments. Thus, the existing negative feedback loop between the deterioration of the environment and human health impact Indigenous communities in a shorter time scale than non-indigenous populations, while increasing the risk to long-term low-dose exposures. This issue introduces additional challenges to reducing the health gap between Indigenous and non-indigenous populations. Government and health authorities around the globe are constantly facing challenges to reduce the excess risk of disease of Indigenous populations, including in high-income countries like Canada, where there is an astounding gap in health outcomes between Indigenous people and non-indigenous counterparts [13].

One of the challenges identified in Canada is the structural racism within healthcare systems and the limited understanding of health professionals of the historical and structural violence against Indigenous Peoples [14]. The occurrence of these disparities is particularly concerning in a country globally recognized for its universal healthcare system. In addition, researchers have highlighted the limited access of Indigenous Peoples in northern Canada to traditional medicine and healers, which is considered to have a crucial role in strengthening individual and collective health [15]. But the persistent health challenges go far beyond the healthcare system itself. For example, Indigenous populations in Canada have an increasing prevalence of overweight and obesity in all socioeconomic levels, attributable at least in part to limited access to healthy diets due to both market forces and disruptions to traditional food systems [16]. Historically, Indigenous populations had a high level of physical activity, but this situation changed due to reduced engagement in traditional activities such as hunting and dancing, and increased adoption of unhealthy habits [16]. The consequences of colonization and the residential school systems profoundly impacted Indigenous populations' healthy behaviours, contributing to dramatic increases in diabetes rates over the past 60 years [17].

Added to these challenges is the evidence of local and regional differences in the levels of exposure, and the

disparity in cumulative impacts of exposure, associated with poor socioeconomic indicators linked to historically marginalized populations [18].

Challenges related to toxic exposures in Indigenous populations

Amidst struggles of various Indigenous nations to reconstitute traditional healthy practices [19], traditional food sources may present a variety of toxic chemicals through local contamination and the long-range transport of contaminants from urban and industrial [20, 21]. Despite the apparent decreasing levels of most persistent organic pollutants (POPs) and metals among Indigenous population living in the Canadian Arctic, concentrations continue to be higher for Inuit when compared to the general population of Canada [21]. Communities in northern Canada are deeply connected to the oceans and rivers and their cultural practice include the consumption wild foods, such as marine mammals, that may increase their risk to toxic chemical exposures [21]. Reviews have noted that that there are persisting knowledge gaps to assess health effects of environmental exposures on specific outcomes among populations of the Arctic regions, partly due to small number of studies and regions included [22, 23]. Additionally, toxic exposures through wild foods consumption among Indigenous populations in Canada are not limited to Arctic populations. An infamous case is the Asubpeeschoseewagong/Grassy Narrows First Nation's (Ontario) ongoing struggle with mercury contamination originated from mercury waste dumped into the English-Wabigoon rivers system by the Dryden Chemical Company between 1962 and 1970 [24]. Five decades after the mandate to cease mercury dumping, this population still consumes fish as a rich source of protein, negotiations to clean the river have been ongoing, and Minamata disease symptoms and premature mortality consistent with mercury poisoning have been recently reported [25].

In the limited cases where traditional food sources are monitored by health authorities, this could lead to public consumption advisories to reduce exposure to high-risk food due to contamination with harmful chemicals. While such advice may be appropriate for populations with access to other healthy food sources, promoting the reduction of traditional healthy food consumption has potential trade-offs that may create a higher risk of disease in Indigenous populations by increasing the prevalence of unhealthy diets and decreasing the benefits of traditional food harvesting [26, 27], such as cultural continuity, social cohesion, physical activity, and collective mental health. Therefore, it is key to incorporate culturally sensitive risk communication strategies into exposure assessments conducted in collaboration with Indigenous populations as a strategy to minimize risk from toxic contamination and strengthen traditional food systems [28, 29].

Colonial Legacies

As a consequence of colonial oppression, there is indeed an increased rate of mental health concerns in Indigenous populations when compared with non-indigenous, also compounding challenges regarding toxic exposures. Higher rates of substance use, related harms, and drug overdose have been observed in Indigenous populations, not only leading to acute toxicities, but possibly increasing vulnerability to environmental toxic exposures [30]. This adds to the impact of deprived immune systems, under nutrition and exposure to other chemicals that may exacerbate toxic exposures [30–32]. These extra challenges also interact with problematic living conditions (e.g., house quality, dwelling location) related to colonial dispossession. Indigenous populations in Canada are more likely to live in low-quality dwellings than non-indigenous populations [31], and many Indigenous communities live near large industrial polluted areas, such as the "Chemical Valley" in Ontario [5].

A crucial point when addressing health issues of Indigenous populations is that the social determination of disease and exposure to toxic chemicals create cumulative impacts that cannot be fully understood if analyzed in isolation [33]. Thus, due to the numerous processes the health of Indigenous Peoples, emerging integrative models need to consider cumulative impacts and integrative health assessments to better elucidate the true effect of toxic exposures in these populations [34]. This includes methodological approaches and collaborations that account for long-term long-dose exposures.

A Needed Approach: "Nothing about us without us"

Although Indigenous Peoples in Canada are a diverse group with different perspectives, views, and socio-ecological contexts, there are some crucial overarching points that need to be considered. First, according to Indigenous scholars, Indigenous Peoples generally hold a holistic worldview that contrasts with Western compartmentalization of social problems and potential solutions [2].

Sovereignty Initiatives

While institutions and academics usually design projects and interventions using narrow conceptual frameworks, many Indigenous Peoples view the human healing process as a deep interconnection of the physical, mental, and spiritual realms [35]. Thus, broader conceptual frameworks that articulate Indigenous knowledge and include integrative solutions than can account for cumulative risk, collective health, historical and intergenerational trauma, colonialism, and social and ecological determinants of health need to be respected and embraced. Beyond the advantages of employing analytical frameworks that more effectively capture the complexity of toxic exposures in Indigenous communities, engaging in a collaborative and horizontal dialogue to co-create risk management and research initiatives may itself serve as a step toward reconciliation [15, 36]. Indeed, all investigations of toxicity and health in Indigenous communities must respect the 4 R's – relevance, responsibility, respect and reciprocity [37]; in this regard,

researchers need to keep in mind the insistence of Indigenous Peoples: “nothing about us without us.”

This dialogue towards building integrative approaches can be achieved by using participatory strategies and community-based projects where community members lead or at least are meaningfully involved at all levels of the research process according to the characteristics of the community and the project (e.g., design, conducting fieldwork, community communication). For instance, to guide environmental health policies, numerous participatory and community-based biomonitoring studies have been carried out in Canada to examine food consumption patterns and long-term low-dose toxic exposures among Indigenous Peoples [38]. Despite the logistical and conceptual challenges of participatory research comprised of multiple interested groups and academic disciplines [39] there is mounting evidence of the benefits of such collaborations, such as enhancing local capacity building, improving risk communication, and supporting self-reliance and decision-making within communities [40].

Indigenous-led initiatives are particularly important and have been implemented around the globe to reduce health disparities between Indigenous and non-Indigenous populations. These include the development of Indigenous-led, culturally-sensitive healthcare services in Norway, New Zealand, Colombia, and Canada [41]. For example, the First Nations Health Authority took responsibility over the administration of healthcare services for First Nations in British Columbia, Canada formerly provided by the Federal government, with a special focus on culturally safe community-based health promotion. This initiative includes the coordination of environmental health services and research to identify and prevent environmental public health risks mainly in drinking water, waste disposal, housing, and food safety [42]. Other local Indigenous-led, science-based initiatives have been conducted in Canada, such as the Burrard Inlet Action developed by the Tsleil-Waututh Nation [19], which includes monitoring shellfish for chemical hazards [43], and working with provincial environmental authorities to set locally relevant benchmarks [44]. Moreover, Indigenous leadership has also led to global action, such as it is the case of Inuit central role to advocate banning polychlorinated biphenyls (PCBs) and organochlorines (Ocs) [45]. Such Indigenous-led initiatives require provincial, national or international support [41], factors that are not always present.

The growing recognition of Indigenous and traditional knowledge systems within academia must extend beyond theoretical discussions and actively contribute to reducing the health disparities between Indigenous and non-Indigenous populations. In this regard, recognizing the importance of sovereignty is key. Environmental health research on toxic exposures among historically oppressed populations needs to be in line with the remarks by Indigenous scholar, Eve Tuck, who promotes moving beyond “damage-centered” to “desired-based” research whereby affected populations are active agents in finding meaningful solutions for the community [36].

Indigenous communities worldwide continue to face systemic inequalities concerning their rights and access to resources, with persistent challenges that underscore the global and universal nature of these issues. In addition, addressing long-term, low-dose toxic exposures within populations presents significant challenges, mainly due to the difficulty in assessing individual impacts. These effects tend to manifest gradually over time, often making establishing clear, immediate associations challenging. In addition, Indigenous people face increased risks due to different rates of exposure to environmental toxicants that lead to amplifying existing health disparities [46]. These communities are disproportionately affected by environmental injustices, where exposure to harmful chemicals is often coupled with broader socio-economic inequities. As a result, the effects of toxic exposures on Indigenous populations are more pronounced and, in turn, contribute to a cycle of inequality that demands urgent attention and targeted interventions.

This study is subject to several limitations. Notably, the findings are highly context-specific and may not be generalizable beyond the studied setting.

CONCLUSION

To address the long-term low-dose toxic exposure challenges faced by Indigenous Peoples in Canada, a comprehensive and culturally respectful approach to environmental health is essential. Due to the many structural challenges in these communities, researchers and policymakers aiming to reduce toxic exposures must not be naïve and simply use the frameworks adopted for the general population; the socio-economic and ecological extra challenges can only be addressed by meaningful long-term collaborations that recognize the sovereign aspirations and leadership of Indigenous Peoples in implementing their visions for a healthy and sustainable future, and contributing to research-informed decision-making. Further research is essential to validate and extend these findings in different contexts.

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