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Biomonitoring and Ethnobiology: Approaches to Fill Gaps in Indigenous Public and Environmental Health

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Abstract. Ethnobiology is well positioned to work in tandem with biomonitoring research to create a more complete understanding of how people experience and are affected by contaminated environments. Indigenous communities in proximity to unconventional natural gas ("fracking") facilities face potential health risks that are often poorly assessed or not assessed at all. This contribution reviews a biomonitoring pilot research project in British Columbia (Canada) that was informed by Indigenous Peoples' concerns of contaminant exposure from traditional foods and their environment. Preliminary biomonitoring results indicate higher levels of a benzene metabolite in pregnant Indigenous women near fracking facilities, compared to what measured in non-Indigenous women. We investigate how Indigenous Peoples' concerns of exposure to industrial contaminants should inform biomonitoring and toxicological studies and, conversely, how biomonitoring studies can complement ethnobiological research with assessable data. By focusing on environmental knowledge and human health in the context of oil and gas development, we critically evaluate how action, environmental justice, and scientific research can and should contribute to more ethical and methodological frameworks and practices. Together, ethnobiology and biomonitoring can be used to fill in important knowledge gaps in environmental health and ethical research practices.

Keywords: community-based research, environmental knowledge, ethics, Indigenous health, hydraulic fracturing

Introduction

There are increasing health concerns regarding the effects of rapidly expanding unconventional oil and gas development (i.e., hydraulic fracturing, or "fracking") in North America. A growing number of scientific peer-reviewed studies conducted in the United States now highlight the potential impacts of unconventional oil and gas development on human health (Elliott et al. 2017; Kassotis et al. 2014, 2016; McKenzie et al. 2012, 2014; Sapouckey et al. 2018; Whitworth et al. 2017). However, criticisms have been made of the short length of the studies and the focus on measuring impacts on environmental "media," such as water and air, rather than human health impacts, which are inferred rather than evidenced (Werner et al. 2015). While short-term environmental studies are important for assessing potential health risks, there is still limited data on environmental *exposure* to contaminants directly from unconventional oil and gas development, which makes identifying health concerns a major challenge. For example, concerns have been raised about the 600+ chemicals used during fracking operations, 353 of which were determined to have potential negative health effects (McDermott-Levy

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et al. 2013). Over 75% of these chemicals could seriously harm sensory organs, as well as respiratory and gastrointestinal systems, but the extent of exposure-related adverse health effects has not been adequately studied (Finkel and Hays 2013; McDermott-Levy et al. 2013; Mitka 2012). Anecdotal and ethnographic evidence from people living near unconventional oil and gas operations has been used to assess health concerns, as there appears to be a correlation between health risk and proximity to fracking wells (Mitka 2012; Perry 2013). Providing a space for and valuing the observations of knowledgeable local people is, therefore, an essential step for biomonitoring and ethnobiology provides a productive framework for addressing this health research gap.

Biomonitoring is the systematic study and observation of changes in ecosystems, species, and/or populations. In health science research and toxicology, biomonitoring data collected from humans (typically urine, blood, hair, and/or nails), can identify changes to the inhabited environment and provide explicit measures of contamination in legal and medical language (e.g., quantitative data), in order to contribute to improved risk assessment and mitigation for local communities facing health challenges. Conversely, local knowledge of environmental contamination and exposure has the potential to directly inform correlations or vectors of change in the body burden (as measured by biomonitoring data).

Indigenous Peoples in northern Canada (First Nation, Inuit, and Métis) are intimately tied to their environments through animal and plant food harvesting, spiritual practices, employment, and other land-based lifestyles. As such, not only do they experience increased and exacerbated exposure to environmental contaminants (Hoover et al. 2012; Kinloch et al. 1992), they are also powerful and keen observers of environmental change and contamination. In this contribution to action ethnobiology, we consider how First Nation Peoples' environmental knowledge relating to unconventional oil and gas development in northern British Columbia (BC) and biomonitoring research can and should help inform one another.

We report on the research of one of the authors (Caron-Beaudoin), who, in 2016, was part of a research team from Université de Montréal that conducted the first biomonitoring study to assess human exposure to contaminants related to unconventional natural gas exploitation in Canada (Caron-Beaudoin et al. 2018). Together with First Nation communities in northeastern BC (Treaty 8 Tribal Association, West Moberly First Nation, and Saulteau First Nation), the researchers conducted a pilot study to estimate exposure to contaminants during pregnancy. While the biomonitoring research conducted was not explicitly ethnobiological, we highlight aspects of the research that focused on First Nation Peoples' perceptions of the contaminated environment, such as increased health concerns from consuming traditional foods (locally available and culturally accepted foods), and observations of sick or exposed animals while out on the land. We comment on future directions for the pilot study and address how biomonitoring research projects, in concert with ethnobiology, can: (1) demonstrate potential links between environmental health hazards and adverse health outcomes resulting from unconventional oil and gas operations; (2) develop research projects out of a call to social and environmental action; and (3) develop research guided by Indigenous and local community concerns. We conclude this contribution with a discussion on ethical frameworks and best practices involved in ethnobiological and biomonitoring research and the role that rigorous and ethical scientific standards can have for serving communities with potentially elevated health risks.

Ethnobiology of Contamination

People that rely on traditional and/or wild foods are acutely aware of potential contamination and exposure risks from their foods, and the condition of their inhabited environments. Despite this, and despite the fact that many Indigenous communities around the world are often at higher risk of environmental exposure than mainstream or settler populations (Kuhnlein and Receveur 1996), few biomonitoring research projects actually seek to articulate and understand local and Indigenous Peoples' environmental observations and concerns regarding environmental contamination.

How subsistence-oriented people perceive and understand the subtle nuances of their inhabited environment is a cornerstone of ethnobiological research and is increasingly appreciated and applied in mainstream scholarship (Savo et al. 2016; Turner and Clifton 2009). Indeed, ethnobiologists have long known and appreciated how local and Indigenous communities around the world infer biological and environmental relationships for their survival (Anderson 1996, 2016). Ethnobotanists have demonstrated the extent to which humans evolved bitter taste receptors to flag toxic contaminants and associated compounds in plant and animal foods (Behrens and Meyerhof 2006; Bradbury 2014; Johns 1986). On almost every continent, there are cultures whose sophisticated body of knowledge and understanding of poisonous and toxic compounds have developed out of generations of complex environmental monitoring and experimentation (Gangwar and Ramakrishnan 1990; Jones 2007; Schultes and Raffauf 1990). It is even common for highly toxic or poisonous plants, under the guidance of knowledgeable people, to be used as potent medicines (Armstrong 2018; Moshi et al. 2010)

Currently, First Nation communities in many parts of Canada are afflicted with the impossible dilemma that they may increase their risk of contaminant exposure when consuming traditional foods (Kuhnlein et al. 1995; Lemire et al. 2015; Van Oostdam et al. 2005) or be at risk of negative effects on health (e.g., increased diabetes, heart disease, obesity) when consuming market or mainstream foods (Kuhnlein et al. 2004; Receveur et al. 1997; Young et al. 2000). In northern Canada, the modifications of lifestyle and diet, brought on by colonial disruption and its disorganization, are major contributors to the high prevalence of chronic disease, yet the use and consumption of traditional foods is further stymied by the real and perceived effects of industrial contamination.

Some First Nation harvesters in British Columbia have stopped gathering seaweed in the large amounts they once did, citing offshore pollution from pulpmills and domestic sewage contamination (Turner and Turner 2008) and fuel spills from large tankers (Turner and Clifton 2009). Tsleil-Waututh people, near the city of Vancouver, have stopped harvesting shellfish (a once staple food), due to the dumping of industrial debris and other pollutants in their inlet (Dana Lepofsky, personal communication, September 2018). Across Canada, environmental contamination is reported as a major deterrent to traditional harvesting practices and this is increasingly the case for contamination from oil and gas operations. The externalities of Alberta Tar Sands production have halted many First Nation communities from hunting, trapping, and fishing throughout their Treaty 8 Region of northern Alberta (Huseman and Short 2012). Specifically, perceptions of berry contamination in the Tar Sands have prevented many Fort McKay First Nation communities from harvesting their traditional berry foods (Baker 2017). The largest complex of petrochemical plants in Canada (40% of Canada's chemical industry) surrounds the community of Aamjiwnaang First Nation near Sarnia, Ontario. Here, high rates of cancer and respiratory diseases have required many to remain indoors and isolated (Fung et al. 2007; Hoover et al. 2012), to say nothing of their reduced ability or desire to hunt, fish, harvest, and take part in land-based ceremonial activities (Luginaah et al. 2010; MacDonald and Rang 2007).

While biomonitoring studies are based largely on data collected by scientists and scientific instruments, in many cases, ethnobiological research could parallel and inform environmental health research. Unfortunately, policy-makers and industry proponents are slow to accept or understand the accuracy of local knowledge, observation, and experience. Indeed, there is typically a long and muted gap between "preliminary evidence of harm" (e.g., local observations of contaminants and exposure) and "definitive evidence of harm" (e.g., longitudinal scientific studies [Steingraber 2010]). As such, a key to merging ethnobiological and biomonitoring research is to understand how Indigenous knowledge, experience, and observations can be used in conjunction with biomonitoring data, and not merely attempt to explain it. That is, Indigenous knowledge is an epistemology worthy of respect and stands on its own, and does not need to be measured by the yardstick of Western science. However, as a highly adaptive and informative epistemology, it can be valued with Western scientific biomonitoring data (see Hunn et al. 2003). For example, in 1991, healthy Navajo people were dying from an unknown illness. It was eventually concluded that a hantavirus, carried by deer mice (*Peromyscus maniculatus*), had spread through exposure to mouse urine and saliva (Schwarz 1995). By working with the community, Navajo researchers identified Navajo beliefs recognizing mice as disease carriers and, with an expansive corpus of Navajo knowledge, the researchers created special protocol and precautions to protect against mouse contamination.

Indigenous communities throughout North America have obtained specialized knowledge about their environments and have pinpointed specific vectors (e.g., mice) and developed practices for dealing with them. As such, biomonitoring projects should seek to target observations and concerns that communities have specifically raised or flagged. Addressing the concerns of unconventional oil and gas development in northeastern British Columbia, the author (Caron-Beaudoin) and her colleagues implemented a research program that took seriously the concerns and observations of contamination from local community members, then undertook the first biomonitoring study of its kind in Canada, underscoring the point made by Tuhiwai Smith's (2013) critiques of the Western research paradigm, specifically about communities' questions that are often left unaddressed or silenced.

Biomonitoring Pilot Study

Unconventional oil and gas development by hydraulic fracturing is characterized by the injection of large volumes of fluid (water, sand, and chemicals) into rock formations to create fractures, freeing trapped natural gas for extraction. Chemicals added to the fracking fluid have various functions; for example, to adjust the pH, prevent bacterial growth, and inhibit well corrosion. Some fracking fluids injected into the well during the hydraulic fracturing process return quickly to the surface (flowback water), while another portion of the fracking fluid remains in the rock formation and returns to the surface during the production of the well (produced water [Pichtel 2016]). Fracking is currently banned in the states of New York, Vermont, and Maryland as well as other US counties and cities. It is banned in Bulgaria, France, and Germany, and there are moratoriums on fracking in 4 out of 10 provinces in Canada (Quebec, New Brunswick, Nova Scotia, and Newfoundland and Labrador).

More than 30,000 wells of unconventional natural gas have been drilled in northeastern BC (Adams et al. 2016). The Peace River Valley region is currently undergoing especially intensive natural gas exploitation by fracking; the region sits on the largest and most productive natural gas reserves in BC, the Montney Formation[1], which contributes close to 67% of the BC province's production of natural gas (Natural Resources Canada 2017). Overall, there are major concerns raised by some First Nation communities in the Peace River Valley regarding the release of toxicants into the environment and the consequent potential health effects (Figure 1).

Following discussions with local communities and health care providers, Caron-Beaudoin and colleagues from Université de Montreal designed a pilot study and obtained funding from Université de Montréal Public Health Research Institute (IRSPUM) and West Moberly First Nation. Between September and November of 2016, researchers recruited 29 pregnant women in northeastern BC, 13 of them self-identifying as First Nation, and assessed exposure to volatile organic compounds and trace metals. Pregnant women were targeted for the pilot study because of the growing evidence that the fetus is particularly vulnerable to environmental toxic insults (Stillerman et al. 2008).

To estimate exposure to contaminants, the researchers measured volatile organic compounds (e.g., benzene), trace metals, and their metabolites in urine and hair samples. Benzene is a known human carcinogen and endocrine disruptor (IARC 2012; Reutman et al. 2002). Exposure to high levels of benzene and other volatile organic compounds is associated with increased risk of childhood leukemia (Carlos-Wallace et al. 2016; Whitworth et al. 2008) and reduced birth weight (Aguilera et al. 2009; Chen et al. 2000; Ha et al. 2002; Slama et al. 2009; Zahran et al. 2012).

Figure 1: The Peace River Valley in remote northwestern British Columbia, home to Dana-Zaa and Cree First Nation communities, including the research partners and participants from the Treaty 8 Tribal Association, West Moberly First Nation, and Saulteau First Nation. Photo: Élyse Caron-Beaudoin

Relatively high levels of one benzene metabolite in the samples suggested the potential for higher benzene exposure in these participants (Caron-Beaudoin et al. 2018). The median urinary level (180 μg/g creatinine) of this metabolite (trans, trans-muconic acid [t,t-MA]) was approximately four times higher than the median level in women from the general Canadian population (48 μg/g creatinine). In the same study, 17% of participants had urinary levels of t,t-MA above the guideline level (500 ug/g creatinine) from the American Conference of Governmental Industrial Hygienists, a guideline used to protect workers occupationally exposed to hazards and materials. Moreover, the median urinary level of t,t-MA was two times higher in self-identifying Indigenous participants (319 μg/g creatinine) than in non-Indigenous participants (142 μg/g creatinine; Caron-Beaudoin et al. 2018).

Ethnobiology and Biomonitoring

Exposure to environmental contaminants can occur through various pathways (e.g., air, diet). Animals, in particular, are exposed continually to air, soil, and groundwater and have more frequent reproductive cycles, making them a miner's canary for monitoring environmental contamination and human health (Bamberger and Oswald 2012). In 2012, West Moberly, Saulteau, Prophet, and Doig River First Nations reported concerns about the consumption of deer, moose, and elk—major food sources in the community. Specifically, they observed noticeable declines in ungulate populations and hunters reported several abnormalities (tumors, growths) in the ungulates they hunt that may have, based on their observations, been due to exposure to contaminants from increased oil and gas activities in the region over the last decade (Fraser Basin Council 2012).

First Nation and local community members were given an opportunity to provide input on potential health risks and identify areas of possible concern to the non-profit Fraser Basin Council but observations "did not include any validation or analysis of the concerns provided by respondents" (Fraser Basin Council 2012:1–19). Many respondents noted that the timeline to partake in the consultation was "too tight for them to participate effectively" (Fraser Basin Council 2012:1–19; see Fry et al. [2015a, 2015b] for contingencies of policy implementation in suburban US communities). Environmental observations were presented as a more-or-less anecdotal component in the Council's report to the BC Ministry of Health outlining health risks and concerns. It is in this context that the pilot study is pushing to include more studies on environmental knowledge and ethnobiological analyses. The challenge is to advance the scholarship that aligns toxicology [e.g., the higher levels of benzene metabolites and some trace metals from Caron-Beaudoin's (2018) study] with Indigenous Peoples' experiences and observations—not to bolster the observations themselves, but rather that both lines of evidence can be accurately tested against one another and both held to equitable standards. The authors note that, globally, health concerns in general are often excluded from discussion of "risk." In fact, we acknowledge the privilege non-Indigenous Canadians are given in the context of extractive industrial development.

The biomonitoring research had several limitations that ethnobiological research could help address. First, the pilot project did not measure contaminants in the participants' environment (e.g., tap water, creek water, traditional foods), which made the estimation of levels of exposure challenging. Second, the benzene metabolite t,t-MA is not completely specific to benzene exposure. Indeed, t,t-MA levels can be influenced by other factors than benzene exposure, including the intake of sorbic acid. Sorbic acid is a widely used food preservative found in common processed food and is partially metabolized into urinary t,t-MA. On average, intake of sorbic acid in the diet results in 78–114 μg/g creatinine of urinary t,t-MA (Mischek and Krapfenbauer-Cermak 2012; Pezzagno and Maestri 1997). Finally, the small number of participants prevented the study from drawing conclusions on the sources of exposure and the potential need for exposure mitigation strategies.

Plans to continue biomonitoring in communities in the Peace Valley Region will benefit dramatically from ethnographic and ethnobiological research that considers: (1) a continued evaluation of participants' observations of their environment, both outdoors (observations of air quality, animal behavior) and indoors (tap water and indoor air quality), which will include recording perceived contamination from specific foods/harvesting places and the relative consumption of food types (traditional/mainstream); (2) building on the observations of community members and increased sampling and assessment of traditional foods and environments where foods are harvested (or previously harvested but now omitted); and (3) more comprehensive participation of willing community members regardless of age and sex (e.g., whether or not they are pregnant). The environmental knowledge gleaned from interviews with community members will build on the cursory indicators of environmental contamination observed in 2012. Currently, community members are aware of contamination risks, but are not sure how to reduce it. Observations of environmental change, phenology, and other land-based knowledge will help target specific areas of concerns and provide important feedback on exposure mitigation strategies.

The published preliminary results of the pilot study raised concerns regarding potential contamination exposure in communities already facing health inequities and a dearth of research interests in such inequalities (Caron-Beaudoin et al. 2018). Therefore, exposure scientists concerned about the health of their research partners would do well to add ethnographic and ethnobiological research methods and observations to help monitor the sociocultural and psychological determinants of community health (Hirsch et al. 2018). This is especially true for First Nation communities, who are at higher risks of exposure to the contaminated environment than mainstream Canadian populations, and for whom such exposures are poorly understood.

Ethics in Ethnobiological Biomonitoring Research

In addition to practical and methodological applications, ethnobiology can also inform more ethical and critical biomonitoring research strategies. Ethnobiologists are generally well aware of the colonial and imperial contexts within which research is conducted and such awareness has resulted in a new, "successful and necessary era…with ethical awareness raised, fora established for debate…and new tools evolving to assist us in treating one another as we agree we ought to within the research endeavor" (Bannister 2018:Abstract). Ethical dialogue and guidelines in ethnobiology, particularly with the International Society of Ethnobiology (ISE) and the Society of Ethnobiology (SoE), continue to prescribe more meaningful advocacy and inclusivity in scholarly research. In this sense, the era of ethics in ethnobiology has only begun and there are unique opportunities for cross-pollinating health sciences and allyship work in the context of action ethnobiology. Here, we consider how Caron-Beaudoin et al.'s (2018) pilot study intersects ethical practices in action ethnobiology and allyship in order to promote higher ethical standards for biomonitoring research conducted with Indigenous communities.

Ethical guidance in biomonitoring and health research has come a long way from the more overt (and tacit) colonial practices of the twentieth century. Innovative approaches to ethical medical research were applied to Caron-Beaudoin et al.'s (2018) pilot study. For example, concerns were raised over the ownership of the biological (urine) samples, so it was agreed that samples were "on loan" for the duration of the research project (cf. Arbour and Cook 2006). This "loan" method enables communities and participants to determine the future use of their samples; when acquiring the samples on loan, the researchers do not have the authority to store or conduct any secondary use of the samples (Nowrouzi et al. 2016). Prior to the recruitment and personal consent of pregnant women, support letters from First Nation community representatives were obtained. In addition, a research agreement between the research team and the Treaty 8 Tribal Association was signed. This research agreement included an overview of aspects of the study that were discussed between the research team and the communities, including: (1) a description of the research project; (2) copies of documents submitted to the participants (questionnaires and consent forms); (3) an outline of the benefits and risks associated with the research project; (4) an outline of all measures taken to protect the confidentiality of the participants; and (5) an overview and timeline of how the results would be presented to the participants and the communities.

Notwithstanding these efforts, applied ethics (e.g., ethics policy and practice) are generally inadequate for addressing the concerns and uncertainties specific to Indigenous communities in research contexts (see Golan et al. this volume). Despite an overall raised ethical awareness of human health research, the relatively recent colonial legacy of "Indian hospitals" (Lux 2012), medical experimentation on residential school prisoners (Mosby 2013), and the forced sterilization of First Nations women (Browne and Fiske 2001), is still violently carved into the recent memory of many communities. In fact, in 2017 sixty First Nation women in Saskatchewan sued the provincial government claiming they were forced into medical sterilization before being allowed to see their newborn babies (Soloducha 2017). An upcoming research contribution by ethnobiologist Leslie Main Johnson and First Nation knowledge holders who work and live in northern Canada will outline how, in order to achieve health and well-being, Indigenous Peoples require overcoming a huge amount of historical trauma (Johnson 2019, but see also Bombay et al. 2014; Mosby 2013). Emerging perspectives and ideas from ethnobiological research ethics and allyship work build on institutional requirements (ethics approval, research agreements, etc.) to transform how biomonitoring research is proposed and undertaken in Indigenous communities in a restorative and just way (Johnson 2019).

Indigenous communities throughout North America face disproportionate health burdens and environmental health risks compared to average North American populations (Adelson 2005; Hoover et al. 2012). As a result, the overwhelming majority of environmental and climate justice movements in Canada over the last forty years have been led by First Nation communities (Belanger and Lackenbauer 2014, but see also Wilkes 2006). It is in these contexts that non-Indigenous allyship work has been deconstructed, iteratively codified, and best practices continuously (re) defined. For example, commitment, humility, and honesty are often deeply rooted values and tactics for doing allyship work on the frontlines (Hermez 2011; Sanford and Angel-Asani 2006; Waziyatawin 2009). Ethics in ethnobiology is similarly codified to encourage these values, for example, to commit to long and involved relationships with the communities we work in, and to work honestly and humbly. Honesty in research ethics is a longstanding pillar in academic scholarship but is based largely on the integrity of research itself (e.g., trustworthiness, reliability of data, etc. [Guba 1981]). Ethnobiologists, however, have struggled with the deeper truths surrounding the production of knowledge and the honesty of profiteering from the communities we work in (e.g., biopiracy) (Wolverton et al. 2016). Hunn (2007) notes four developmental phases of ethnobiology and exposes the colonial underpinnings of the discipline and that the current phase should seek to emphasize the rights of Indigenous Peoples. Wolverton (2013) expands on this and calls on ethnobiologists to broaden our community to include non-academic specialists (e.g., Elders, Knowledge Holders). Humility means taking our research cues from the community and standing behind (not merely beside) Indigenous colleagues (see Fowler this volume).

This pilot study embodied and addressed some of the major tenants and values of ethnobiological and allyship work and went beyond rote ethical standards in biomonitoring research. Researchers were aware of the humility and honesty that goes into research partnerships, careful not to promise too much, nor patronize research participants. The limitations of the pilot project were constantly communicated and intentions to address these limitations were openly discussed with the community. Researchers in the pilot project were also aware of the time and energy required from communities (and participants) involved. To limit additional burdens, the research protocol was designed to accommodate participants (e.g., samples were retrieved at their home and in their own time). Regular updates were provided to the communities and participants by email and phone, and the level of their participation was determined by the communities in order to respect the availability of time, resources, and capabilities.

There are still improvements that need to be made in order to move from biomonitoring/ethnobiological research done with Indigenous communities to research done by Indigenous communities. For example, the pilot project was conducted entirely by non-Indigenous researchers. In the spirit of an action ethnobiology, and the call for allies to reduce their leadership roles, the project's ongoing investigation will bring in First Nation researchers to join the research team, which will also include a dedicated budget to engage youth in the project—going beyond the mere tokenism of Indigenous participation and seeking to build capacity within communities. Here, an ethnobiological approach to biomonitoring also promotes more community participation; while many people on remote reserves are not trained in toxicology, they are experts in local scientific observations, are "on the ground" more than the scientists, and have infinitely more stake in the results of the project. As the biomonitoring project moves forward, environmental sampling (e.g., water, soil, traditional food sources) will be systematically implemented and undertaken by community members who are interested in participating. Environmental sampling, directed by community knowledge holders (e.g., where to sample), will further fill knowledge gaps on environmental impacts.

Concluding Thoughts

In the last decade, various communities and associations (Canadian Association of Physicians for the Environment [CAPE], Council of Canadians) have raised concerns regarding the potential impacts of fracking and unconventional oil and gas development. There is also an increasing awareness of the legacy of environmental racism in North America as it relates to the oil and gas industry and its longstanding effects on marginalized communities (Dhillon and Young 2010; Johnston et al. 2016). Aamjiwnaang First Nation is a famous example, where oil tanks and the "Chemical Valley" of petrochemical plants are at relatively safe distances from the settler (non-Indigenous) city of Sarnia, yet directly adjacent to the Aamjiwnaang reserve (Luginaah et al. 2010). These are not coincidental or isolated occurrences but feature prominently in neo-colonial landscapes of settler nations (LaDuke and Churchill 1985;

Vicenti 2000). The decision by Goshute Native Americans in Tooele County, Utah, to host a high-level radioactive waste facility derived from a prolonged process of colonialism, produced a "landscape of injustice" in which the Tribe's choices were structurally limited; they opted for potential health problems in the long term in exchange for financial relief in the short term (Ishiyama 2003).

The participation of communities and the application of local knowledge have already been shown to improve the understanding of fish contamination in Brazil (Silvano and Begossi 2016), and increase the comprehension of changes in marine environments in the Canadian Arctic (Berkes et al. 2007). Yet, there is a remarkable lack of meaningful consultation regarding industrial development with First Nation Peoples in Canada, even if proponents are obligated by law to consult with communities (Baker and McLelland 2003; Booth and Skelton 2011; Parfitt 2017). For example, First Nation bands are asked to analyze and respond to industrial development applications one by one. This contravenes the issue of cumulative impacts of large-scale industrial development, such as regional-scale contamination, noise, and landscape fragmentation (see Armstrong and Brown this volume). Natural gas exploitation by fracking represents a potential threat to natural resources (e.g., water), but it can also negatively impact many of the aspects of First Nation communities' access to resources and resource rights (see Armstrong and Brown this volume). Given the lack of current research and the negligible decision-making power afforded to those who are most affected, research based on community needs with the objective of contributing to important knowledge gaps in environmental exposure from intensive unconventional natural gas exploitation is imperative. Since land-based foods and medicines are a cornerstone of diet and lifestyle for many First Nation communities, their observations and a valuation of their knowledge bears special attention by biomonitoring and exposure scientists.

By fusing biomonitoring research methods with an action oriented ethnobiology, we show that the effects of environmental contamination and exposure in First Nation communities can be studied and understood in more meaningful and effective ways. Action ethnobiology works from a place of ethical solidarity, while providing novel tools and methods for valuing and critically analyzing peoples' acute knowledge and observations of environmental contamination. Such data is invaluable to biomonitoring researchers and, as such, developers and government-sanctioned environmental assessments should consider the role of expert environmental knowledge for flagging and understanding environment health impacts.

Notes

[1] After this paper was submitted, in November of 2018, a major 4.5-magnitude earthquake struck the town of St. John's (on the Montney), and it was confirmed that the epicentre of the quake occurred where there is active fracking.

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