



Environmental Risk Perceptions and Community Health: Arsenic, Air Pollution, and Threats to Traditional Values of the Hopi Tribe

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Abstract

American Indian and Alaska Native populations experience chronic disparities in a wide range of health outcomes, many of which are associated with disproportionate exposures to environmental health hazards. In the American Southwest, many indigenous tribes experience challenges in securing access to sustainable and safe sources of drinking water, limiting air pollution emissions on and off tribal lands, and cleaning up hazardous contaminants left over from a legacy of natural resource extraction. To better understand how households perceive the risk of exposure to potential environmental health risks, we conducted six focus groups organized by age and geographic location on the Hopi reservation. Focus group participants ($n=41$) were asked to reflect on changes in their natural and manmade environment and how their health might be influenced by any potential changes. By investigating these environmental risk perceptions, we were able to identify arsenic in drinking water and indoor air quality as significant exposures of concern. These risk perceptions were frequently anchored in personal and familial experiences with health problems such as cancer and asthma. Older focus group participants identified ongoing shifts away from tradition and cultural practices as increasing environmental health risks. Similar to other communities economically dependent on the extraction of natural resources, focus group participants described the need for behavioral modifications regarding environmental health risks rather than eliminating the sources of potential health risks entirely. Our results suggest the need for including traditional values and practices in future interventions to reduce environmental health risks.

Keywords Risk perception · American Indian and Native Alaskan · Environmental health · Focus groups · Arsenic · Air pollution

Introduction

American Indian and Alaska Native (AI/NA) populations have long experienced significant health disparities in comparison to other populations, ranging from lower life expectancy, increased risk of cardiovascular disease, and higher rates of chronic disease factors, poor nutrition, and a lack

of access to quality health care [1–3]. These factors stem from systemic inequalities in economic opportunities and poor social conditions that lead to disproportionate levels of poverty, reduced educational attainment, and high rates of unemployment on tribal lands. Disparities in mental and behavioral health outcomes are commonly found within the AI/NA population, where morbidity rates in common conditions such as substance abuse, posttraumatic stress, interpersonal violence, and suicide have been found to be two to three times the national average [4]. These physical and mental health disparities are increasingly being linked to disproportionate exposures to environmental health hazards [5].

AI/NA populations also experience significant environmental health disparities. Many of these environmental inequalities on Native American land are associated with the toxic contamination left behind by the extraction of natural resources such as coal, oil, and uranium [6–9]. Native American reservations are targeted for hazardous land uses such as

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power plants, dump sites, and nuclear and weapons testing facilities [10]. All of these health and environmental risks interact in ways that reflect the historical political, economic, and environmental pressures associated with colonization and oppression, creating in complex patterns of inequalities affecting the health of Indigenous peoples [11].

Understanding these patterns of health and environmental inequalities is essential for assessing and addressing ongoing environmental health risks. Recent research in the field of environmental justice highlights the need to understand past patterns of disparities in power and privilege in both comprehending current inequalities and designing effective strategies for reducing them [12]. Responses to these environmental risks are shaped by individual and collective perceptions of these risks, where individuals observe, process, and share their attitudes towards, and interpretations of, potential threats to public health.

The literature on environmental risk perception examines the processes through which individuals make sense of the world around them and assign values to various threats [13]. Research indicates that risks perceived as uncontrollable, involuntary, or threatening future generations produce more concern and anxiety than threats that are seen as controllable or voluntary [14]. Perceived risks are informed by personal history, both in terms of past experiences with environmental health risks and general life history [15]. Minority populations are often well aware of their increased vulnerability to environmental hazards and comparatively lower ability to limit their personal exposures [16, 17]. Furthermore, minorities experience significant barriers to accessing information related to health effects and environmental exposures, which may increase perceptions of risk and hamper the ability of minority groups to respond effectively to environmental threats [10, 18].

Paradoxically, levels of perceived risks have been found to be lower than expected for some minority communities experiencing chronic environmental exposures and associated health risks [19]. Research on these vulnerable communities suggests that their economic dependence on an environmentally harmful activity actually reduces levels of perceived health risks and instead can lead to support for the source of the health risk [20, 21]. However, most research examining this complex relationship between economic dependence on environmentally harmful activities and environmental risk perceptions has focused on non-Native communities. In a tribal context, additional attention is necessary to understand indigenous concepts of risk and harm that are grounded in cultural values and traditions.

This study was designed to gather formative research on the perceptions of environmental health risks of the Hopi Tribe, located in the American Southwest and experiencing a number of environmental health threats linked to social and environmental inequality. Convening focus

groups allowed us to collect important contextual information on the assessment of cumulative health risks from environmental contaminants on the Hopi lands linked to a larger environmental health study. This larger community-based participatory research project is designed to investigate common household exposures such as combustion, by-products from heating and cooking, particulate matter (PM) from nearby mining and other land uses, and other contaminants of water and food sources. Findings from our focus groups were utilized to develop additional survey measurements of household behaviors, risk perceptions and social determinants of health that can help the Hopi Tribe develop policy actions to address exposures of key concern. Here, we report on several themes around specific environmental health risks and the social and cultural changes potentially increasing those risks as observed by participants in the six focus groups.

Method

In the spring of 2017, our research team conducted a series of six focus groups organized for each of the three Mesas (First, Second, and Third) that geopolitically demarcate the Hopi reservation. The Hopi Tribe is one of the 22 federally recognized sovereign tribes in Arizona. The Hopi land is located in the northeastern part of the state and consists of more than a million and a half rural acres. The Hopi people have continuously occupied their land for the past 1500 years and are organized in 12 autonomous villages located across three Mesas on the reservation. Today, approximately 7000 members of Hopi's official population reside on the reservation, with 40% of all individuals living below the federal poverty level and close to a third lacking electricity in their households [22].

The focus groups were implemented through a community-based participatory research project between the Hopi Tribe and the University of Arizona. The project team created a semi-structured interview guide with questions ranging from identifying common health-related concerns, ideal housing construction materials and home maintenance strategies, to changes in the natural and physical environment on Hopi.

Approvals

The Hopi Tribal Council approved this research on 5 August 2016. Approvals were received from the Institutional Review Board from the UA Office of Human Subject Research Compliance on 19 January 2017.

Participants

Participants for the focus groups were recruited through flyers, radio announcements, and word-of-mouth through the Hopi Department of Health and Human Services. Eligible participants were identified as being (1) currently enrolled members of the Hopi Tribe, (2) age 18+, and (3) living the majority of the year on Hopi. In total, we recruited 41 participants for the 6 focus groups ranging in size from 5 to 9 individuals. Participants were divided into two age groups, those aged 18–40 and those over 40, which was identified by the project team as a culturally appropriate demarcation between the stages of life related to youth and carrying for family followed by having adult children and becoming an elder.

After consenting to participate in the study, participants were asked to fill out a short demographic survey and provide information on their age, education, employment status, and the type of materials used to construct their primary residence.

Procedures

The six focus groups were held in community centers located on each of the three Mesas. Multiple members of the project team were present for each focus group, which were facilitated by a Hopi Project Team Member. Following the introduction to the overall research project, an informed consent document was read aloud to participants. Focus groups lasted between 45 and 90 min and were conducted primarily in English. The focus groups were audio-recorded and transcribed verbatim. Handwritten facilitator notes were then annotated into the transcripts and reviewed by the project team. Participants were provided with food during the focus groups and \$25 for their time.

Analysis

Completed transcripts were entered into the QSR Nvivo 10 software for computer-assisted qualitative data analysis. The focus group transcripts were first sorted according to age group and Mesa and auto-coded for responses following each question. We then used open coding to identify emergent themes and topics across all of the questions, followed by a closed-coding scheme that structured these findings into broader components based on common underlying factors. Findings were discussed and reviewed among the research team to confirm their validity in relation to cultural aspects and experiences specific to Hopi.

Results

The average age of the 41 participants was 47 years (33 years in the < 40 groups and 58 years in the 40+ groups) (see Table 1). The focus groups were generally homogenous across the three Mesa, though the participants from First Mesa were more likely to be employed outside the home, have higher levels of education, and were less likely to speak Hopi in their households.

When asked about how the environment on Hopi might be affecting human health, two main themes emerged across from the six focus groups: arsenic in drinking water and respiratory disease associated with exposure to air pollution. Follow-up questions on how the environment might be changing on Hopi generated discussion not just on perceptions of specific environmental health risks, but also on broader social changes that threaten cultural traditions and values on Hopi. In the older focus groups concerns with changing youth behaviors and expectations were strongly interwoven with observations of health and environmental trends. Here, we present findings from the focus groups organized around the two primary themes of environmental health concerns, arsenic and air pollution, followed by findings on how these risk perceptions are linked to broader concerns of changing social values on Hopi.

Table 1 Focus group demographics

Characteristics	Age group 18–40 (<i>n</i> = 17) (%)	Age group 40+ (<i>n</i> = 24) (%)
Mesa		
First	46.2	53.8
Second	42.9	57.1
Third	35.7	64.3
Gender		
Female	23.5	70.8
Mean age (s.d.)	46 (16.7)	42.7 (14.9)
Hopi language spoken at home	5.9	41.7
Employment status		
Self-employed	35.3	12.5
Employed full or part time	17.7	41.7
Unemployed/retired	35.3	45.8
Education		
< High school	17.6	0
High school degree	41.2	8.3
Some college	35.3	75.0
BA or BS	5.9	16.7

Arsenic in Drinking Water

Arsenic is a naturally occurring element that is regularly found in soil and water. In the American Southwest, arsenic is commonly found in aquifers that supply drinking water due to favorable geologic and climate conditions where groundwater is in contact with rock and sediment containing arsenic-bearing materials. A study conducted by the US Geological Survey found that approximately 42% of all aquifers in the Southwest were at or exceeded the Environmental Protection Agency's (EPA) drinking water standard of 10 µg/L or 10 ppb [23].

Many Hopis lack running water and instead haul water from a variety of sources including village cisterns, rural wells, or commercial suppliers. Public water on Hopi draws from the Navajo aquifer, which was first tapped for drinking water in the 1980s and the source of all pumped water on Hopi. Virtually all water pumped from the Navajo aquifer fails to meet health and safety thresholds [24]. Since, assessments by the US Geological Survey have found repeated violations of the drinking water standard, frequently ranging from double to quadruple the federal limits [25].

With safe drinking water hard to come by on Hopi, it is unsurprising that concerns with arsenic in water was the dominant theme to emerge from our focus group data. Participants' concerns with the arsenic focused on cancer risks of consuming the contaminated water:

Again, with cancer – when I was young and listening to my mothers and others that were older, they said that there seemed to be no one that had cancer or was dying of cancer. Over the years, we've had an increase in people with kidney cancer and renal failure – because of all the chemicals in the water. *3rd Mesa 40+ group*

Participants often referred to personal or familial experiences with health problems attributed to arsenic exposure. Here, participants observed health trends in their own daily lives and attributed them to the much-discussed elevated levels of arsenic:

Since the water and the arsenic has gotten bad, my son and grandson are getting sick a lot and missing a lot of school. They constantly have stomach pains, nausea, and diarrhea. It's just getting worse and worse. It hasn't gotten better. My neighbor, she passed from cancer too. It's all due to the water out here. *Second Mesa, 40+ group*

Participants also reported frustration with the tribal government's struggle to find an immediate and effective solution. Many participants were unsure about whether the water in their homes or wells exceeded the federal standard and the

implications for the health, as well as the validity of any such safety standard:

We do have arsenic in our water, but they call it at what are safe levels. What's acceptable but who determines those standards? Is it [Hopi] Environmental Health? Is it federal guidelines that set the standards of what's safe and not safe? Are we borderline safe, or are we just above that? Or are we below that? *Third Mesa, 40+ group*

Attributions of blame for the high levels of arsenic were regularly directed towards the Peabody Western Coal Company (Peabody), which extracts coal from the Black Mesa region jointly owned by Hopi and the Navajo Nation. In 2006, Peabody's controversial Black Mesa mine was shut down due to resolutions passed by the Navajo and Hopi Tribal Councils prohibiting pumping of groundwater from the Navajo Aquifer to transport coal through an unconventional slurry system. Although Peabody is no longer allowed to draw such vast amounts of water from the aquifer, many believe that the damage to Hopi's primary source of groundwater continues to plague them:

I think we were saying that because of the pumping of water at the Peabody Coal Mine, it's affected us here. It was not believed at the time, but I think I know there's a connection being made because of the pumping. Our pristine water out here, our wells, our springs, are being affected by it. Maybe it'll get better once they shut that mine down, but we don't know if it will affect the arsenic level in the wells. *First Mesa, 40+ group*

Peabody Coal and the impact of coal mining on several health and environmental issues were complicated topics of discussion for most of the focus group participants. Royalties from its extraction generate approximately 75% of the Hopi Tribe's annual revenue and provides the financing for nearly all tribal programs. Threats of closing the mine also threaten the livelihood of hundreds of Hopi workers and raise questions about a very uncertain future.

Indoor Air Quality and Respiratory Health

The Hopi have a strong heritage of the home and the community, placing great value on family cohesion, stability, generosity, and valuing and honoring the needs of the entire community. Hopi homes are commonly heated during the winter months by coal-burning stoves. Though an increasing number of homes on the Hopi reservation are connected to the electrical power grid, Hopi households receive a fixed amount of free coal from the nearby Kayenta Mine during the winter months.

Burning coal and wood indoors yields high amounts of ultrafine particulate matter (PM_{2.5}) and is associated with

significant health problems such as respiratory and cardiovascular mortality and morbidity [26]. Hopi's rural isolation and lack of economic development has significantly limited the availability of alternative energy sources, forcing most Hopi homes to choose coal as an energy source. Consequently, both indoor and outdoor air pollution are major areas of concern for the tribe. Maintaining aging stoves and ventilation systems is an ongoing challenge for many Hopi households and older, inefficient stoves produce higher levels of PM_{2.5}.

Our younger participant groups spent more time discussing the respiratory health risks associated with burning coal indoors than arsenic in drinking water than the 40+ groups. Indoor air pollution was viewed a much more tangible environmental health hazard and discussed as one of the core challenges to maintaining a clean and healthy home:

One thing that we're battling at our house right now is the stove. It's pretty old and sometimes they leak, so there's soot and ash everywhere. We're trying to keep it clean, but it just won't stop. We're turning black, slowly! *Second Mesa, 18–40 group*

The residual soot and ash from coal burning stoves, along with the acrid smoke often trapped indoors, creates a tangible environmental health treat and many of the focus group participants discussed the challenge of cleaning the dust from their homes during the heating season:

I always go with what my grandfather taught me... He was really all about trying to keep us healthy and trying to keep us cleaning the right way. 'For cleaner the air, polish the coal.' He wouldn't burn dirty coal because of the carbon monoxide. He would try and do the best he could to eliminate all the contamination. It's bad enough out there. It doesn't blow away; it stays in one little area. One big old circle. *Third Mesa, 18–40 group*

Much like the discussion of the association between arsenic and cancer, many of our focus group participants shared personal narratives of experiencing respiratory disease that they associated with exposure to air pollution. In particular, many respondents reported personally witnessing a substantial increase in the number of cases of asthma on Hopi:

A lot of the kids are beginning to have asthma. My nieces and nephews had it when they were young. They got over it thankfully. It's still out here. My son has asthma and I believe it has a lot to do with what's floating around in the air. *First Mesa, 18–40 group*

However, not every participant attributed the rise in respiratory diseases like asthma directly to burning coal. A small minority of participants attributed increases in cases of asthma to a drier and dustier environment brought about by

climate change. Nonetheless, coal mining was consistently identified as a problem for human health.

The Loss of Traditional Values and Environmental Health

Focus group participants were asked how the environment on Hopi had changed since they were children, which was intended to prompt discussions on observable differences in climate, air and water quality. For the 18–40 groups, discussions tended to conform to our expectations; conversations in these groups focused on the presence of litter and garbage, climatic challenges to traditional farming practices, and changes in the weather. For the three 40+ groups, discussions about environmental changes on Hopi tended to shift towards social and cultural changes perceived as detrimental to Hopi traditions. These responses, while not specifically about environmental risk, provide important context for understanding how the concerns with arsenic and air pollution are shaped by social and cultural influences.

Although Peabody Coal's mining operations emerged as a central topic of concern regarding arsenic, most of the discussion of broader environmental change attributed blame directly on the changing values and practices of the Hopi people. Observing a loss of traditional values and practices particularly among younger generations, many of the focus groups in the older age groups viewed the intrusion of Western society as the main cause of environmental change:

I think a lot of the influence of Western society has had a lot to do with it because of the TV, just how people are outside. It's starting to infiltrate in. Everybody nowadays just doesn't seem to care about a lot of things anymore. We take a lot of these things for granted, like the land. We just throw stuff out the window. We don't really care. *First Mesa, 40+ group*

For multiple participants, blame for the negative environmental changes on Hopi was directed particularly at *Pahana*. Hopi prophecy holds that the True White Brother, *Pahana*, will return to Hopi and be recognized by the people, ushering in a new phase in the cycle of life—the Fifth World. Until then, though other white-skinned men were prophesied to come, but would not act like as a brother. On Hopi today, the term *Pahana* is also associated with the imperial whites that have taken land that does not belong to them. *Pahana* was often referenced as intentionally degrading Hopi traditional values:

Here, we're talking about protecting water, the program for protecting the environment. That's part of it, but *Pahana* is greedy. Sorry to say, *Pahana* is greedy. He has a lot of things against our Hopi way of life, which we've had to adapt to. We're talking about all

of that, and that's why the environment has changed.

Second Mesa, 40+ group

Although there was debate regarding the cause of these cultural shifts, each focus group contained some discussion about the problems associated with moving away from tradition. Even in the younger focus groups, reflection on the loss these tradition traditional values was present:

It's how we're living. Can any of us honestly say we'd be able to give this up, give that water up, give this electricity up, give that tap water up, the gas in our car? No. We have become so dependent on this way of life that it is completely alien for us to think that our ancestors will walk miles to haul water home... No car to put gas into, to go up there to make a life simpler, easier. Easier is the thing that we've become so used to that we can't pull our mouth off that breast anymore.

First Mesa, 18–40 group

These narratives articulate a general fear of assimilation into mainstream Western culture and the loss of traditional values and practices associated with a balance with the natural environment.

Discussion

The environmental risk perceptions identified by the participants in our focus groups were grounded in their personal experiences and observations of changes around Hopi, but also through their history and cultural practices associated with the Hopi Way. Participants identified arsenic in drinking water and indoor air pollution as significant changes in their environment. Arsenic was framed as a likely cause of increased cancer rates, brought about by external factors and necessitating immediate intervention by the tribal and federal governments. By contrast, indoor air pollution was associated with increases in asthma but lacked any discussion of eliminating the use of coal for heating Hopi homes.

For focus group participants over the age of 40, these environmental health risks were strongly associated with the perceived loss of traditional Hopi values and practices. The three 40+ focus groups all included discussions of changing values brought about by the increased exposure to Western influences and modern conveniences. Participants linked perceptions of fundamental social change with changes in the natural and built environment seen as leading to increases in environmental health hazards. These narratives provide important context in understanding how tribal members perceive environmental health risks, suggesting that future efforts to improve tribal health need to address both social and environmental dimensions.

The discussions of arsenic and air pollution diverged around attributions of blame and insistence on remediation. For arsenic in drinking water, almost every discussion involved complaints over delays and barriers in efforts to filter drinking water. Participants also commonly directed blame for the reported increase in arsenic levels to mining activities, poor management, and the lack of infrastructure. Unlike the discussions about arsenic in drinking water, there was a lack of immediacy in the responses focused on the link between coal and air pollution. Participants presented conflicted opinions about the health effects of coal as a heating fuel, reflecting its integration in traditional Hopi culture and practices. For example, no participant made a case for the immediate removal of coal from Hopi homes. Instead, the majority of participants emphasized secondary approaches to intervention such as improving home maintenance and cleaning behaviors.

The risk perception literature suggests that threats that are seen as controllable and familiar tend to evoke less fear and dread than unfamiliar threats outside of one's immediate sphere of influence [14]. Our focus group findings strongly reflect this pattern, where the risks associated with coal tended to be downplayed in comparison to arsenic and understood more through a lens of behavioral modification regarding proper home cleanliness and maintenance. Perceived risks that generate such uncertainty and dread tend to also generate conflicts between lay people on experts on defining and acting on risks that can delay timely remediation. Our findings suggest that while the presence of arsenic in drinking water on Hopi was generally understood, participants were uncertain as to whether government officials would prioritize any remediation efforts that would benefit them directly. These lingering feelings of uncertainty and a generalized lack of trust in experts and officials' ability to address the issue amplify the perceived health risks associated with exposure to arsenic.

Limitations of this study include the lack of a comparison group, which may limit its generalizability to other AI/AN populations. Another limitation is the small sample size, which limits our ability to make broad generalizations about the risk perceptions of the entire Hopi Tribe. Differences within our sample, where the participants from First Mesa reported higher socioeconomic status than other participants, may also limit the generalizability to the entire Hopi Tribe. Lacking comparable studies of environmental risk perceptions in similar tribal populations however, our findings do offer several important insights into how ongoing health threats are perceived by a representative sample of Hopi members.

Our findings suggest that the perception of environmental health risks on Hopi are linked to the cultural context in which individuals are making decisions about their health-related behaviors. This cultural context is undergoing

significant change on Hopi, with younger generations adhering less to traditional ways and older generations associating these cultural and social shifts with an increase in environmental health risks. Attitudes about the potential health risks of arsenic and indoor air pollution, and their potential solutions, diverged substantially due to their meaning and value within Hopi culture. And although each indigenous tribe is unique, there are common challenges in the valuing of traditional practices while addressing the problems of today. On Hopi, finding a balanced approach that protects human health in a changing social and environmental context requires understanding not only threats such as arsenic and indoor air pollution, but also how shared risk perceptions shape individuals' attitudes and actions for addressing them.

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Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflicts of interest.

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