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Sources and Perceptions of Indoor and Ambient Air Pollution in Rural Alaska

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Abstract

Even though Alaska is the largest state in the United States, much of the population resides in rural and underserved areas with documented disparities in respiratory health. This is especially true in the Yukon-Kuskokwim (southwest) and Ahtna (southcentral) Regions of Alaska. In working with community members, the goal of this study was to identify the air pollution issues (both indoors and outdoors) of concern within these two regions. Over a two-year period, 328 air quality surveys were disseminated within seven communities in rural Alaska. The surveys focused on understanding the demographics, home heating practices, indoor activities, community/outdoor activities, and air quality perceptions within each community. Results from these surveys showed that there is elevated potential for PM₁₀/PM_{2.5} exposures in rural Alaska communities. Top indoor air quality concerns included mold, lack of ventilation or fresh air, and dust. Top outdoor air pollution concerns identified were open burning/smoke, road dust, and vehicle exhaust (e.g., snow machines, ATVs, etc.). These data can now be used to seek additional funding for interventions, implementing long-term, sustainable solutions to the identified problems. Further research is needed to assess exposures to PM₁₀/PM_{2.5} and the associated impacts on respiratory health, particularly among susceptible populations such as young children.

Keywords

Indoor air quality; ambient air quality; Alaska Native communities; particulate matter; respiratory health

Introduction

When the Indian Health Service began collecting health information on Alaska Native people in the 1950s, the average life expectancy at birth was only 47 years, 46% of all deaths were due to infections, and more than one in ten babies died at birth [1, 2].

Advancements in overall health have been achieved over the last five decades, but Alaska Native people still suffer dramatic health disparities when compared to the general US population. Among such disparities, respiratory disease poses a particular challenge. For

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example, in the Yukon-Kuskokwim region of Alaska, nearly one in four Alaska Native infants are hospitalized each year for acute respiratory infection [3]. Asthma and other chronic respiratory conditions are also common among Alaska Native people. Of 466 Alaska Native children interviewed in 1997, 7.4% reported a diagnosis of asthma from a physician, while another 11.4% reported asthma-like symptoms [4, 5].

A major contributor to these respiratory health problems is likely air pollution – both in indoor and ambient environments. This indoor component is especially important as most people spend the majority of their time indoors [6, 7]. In rural and remote Alaska communities, long, cold and harsh winters may facilitate the amount of time spent indoors. In addition, homes in colder climates can be built tighter for energy efficiency purposes, allowing for less ventilation of indoor spaces.

As part of the 2009 American Recovery and Reinvestment Act (ARRA), The University of Montana received funding from the National Institute of Environmental Health Sciences (NIEHS) to implement a project titled “Air Pollution Outreach, Education, and Research Capacity Building in Alaska Native Villages.” Through air quality surveys, one of the aims of this project was to identify community-specific air pollution issues (both indoors and outdoors) of interest, while working directly with community members with the long-term goal of designing future partnership studies to address the identified problems through research and intervention. In this manuscript, we present the results of these surveys.

Methods

During the winter of 2011/2012 and spring of 2012, surveys were disseminated within seven communities in rural Alaska. Demographics, household characteristics, and information related to air quality were collected through interviews using community-based household questionnaires. These questionnaires focused primarily on summarizing household and community activities, and potential sources of PM_{2.5} (i.e., particulate matter 2.5 microns in aerodynamic diameter or less) in both the indoor and ambient environment.

Survey Locations

Region 1 - Yukon-Kuskokwim (YK) Delta—The YK Delta (see Figure 1) is located in the southwest region of Alaska and covers an area of approximately 75,000 square miles, primarily dominated by subarctic tundra and wetlands [8]. In 2004, approximately 23,000 Yup'ik people inhabited the YK region and nearly 50% of the population was under the age of 20 [9]. With virtually no roads, travel is limited to small bush planes, boats in the summer, and snow machines or vehicles in the winter via ice roads. In addition to transportation barriers, weather can be extreme in the YK region, with temperatures dropping to below –30 °F in the winter [10, 11].

Region 2 - Ahtna (Copper River Basin) Region—The Ahtna Region (see Figure 1) is located on the road system approximately 200 miles northeast of Anchorage, AK and is home to eight Alaska Native communities [12]. The majority of the Ahtna Region is situated within the Copper River Basin, and embodies an area greater than 18 million acres [13]. Health care is primarily provided to the region by the Copper River Native Association, while travel is required to an urban center such as Anchorage for major medical services [13]. The climate of the Ahtna region consists of warm summers and long, cold winters with extreme temperatures reaching below –60 °F [11, 13].

Participants and Study Design

Air quality surveys were developed by The University of Montana in conjunction with input from our partners at The University of New Mexico (Community Environmental Health Program), The University of Alaska Fairbanks (Center for Alaska Native Health Research), and community members. Prior to dissemination, The University of Montana's Institutional Review Board (IRB), the Alaska Area IRB, and the Yukon-Kuskokwim Health Corporation's Executive Board of Directors approved the survey instruments and research protocols. Tribal council approval was also received from each participating community prior to conducting activities related to this study.

Air quality surveys were conducted within two regionally and culturally distinct areas of rural Alaska between September 2011 and March 2012. Household representatives were eligible for participation if they were: 1) a current household member, 2) over 18 years old, and 3) resided in the community for at least eight out of the previous 12 months. An effort was made to recruit all community households to participate in the study, with both males and females encouraged to participate. Each survey participant (one per household) was informed of the research and provided signed consent prior to participating in the study. Within the Region 1 communities, a summary of the project was first announced over the VHF radio and flyers were distributed around the community (e.g., in stores, Tribal offices, etc.). For both Region 1 and 2 communities, personal phone calls and/or visits were also made to households to describe the study and solicit participation.

Questionnaire Dissemination

To assist with the distribution of the air quality surveys, Community Coordinators were hired within each of the seven communities. These individuals were invaluable as they provided feedback on survey instruments, assisted with data collection, ensured cultural appropriateness, and served as a liaison between the community and the research team. As Yup'ik is the native language in the Region 1 communities, household questionnaires were developed in English prior to being translated by a native Yup'ik speaker. Participants in Region 1 had the choice to complete the survey in English or Yup'ik. In Region 2, English versions of the survey were exclusively used. Surveys were then disseminated within the communities using several methods. Door-to-door visits were most commonly employed, while central community locations such as a local bingo hall and a community center were also used.

Results

The air quality questionnaire was broken down into six sections, including: 1) demographics, 2) home heating practices, 3) indoor activities, 4) community/outdoor activities, 5) air quality perceptions, and 6) public health activities (i.e., what would you change to make the air better within your home and community?). A total of 241 households from three Yup'ik communities in Region 1 and 87 households from four Ahtna Athabascan communities in Region 2 participated in this study. Although the majority of households participated in the survey process within each community, a small percentage of non-participation was observed. Reasons for non-participation included not being home/out of town, declining participation, or inability to establish contact.

In Region 1, community populations ranged from approximately 350 to 700 people, and more than 93 percent of the population in each community was Alaska Native [11]. Based on the 2010 Census, air quality data was captured for approximately 70% of all households in the Region 1 study locations – 76% in Community 1, 59% in Community 2, and 85% in Community 3.

In Region 2, our surveys targeted tribal members living within four Alaska Native communities. According to the 2010 Census, the communities in this region were between 100 and 300 people, with 20 to 80 percent of residents being of Alaska Native decent. However, as census data for communities in Region 2 also include non-tribal members that live in the defined census area, it was not possible to use these data to accurately estimate the percentage of tribal homes. Nonetheless, we estimate that more than 70% of all tribal households participated in the study within this region.

Demographics

In the demographics section of the survey, participants were asked how many people lived in the household and their approximate ages, the number of bedrooms in the household, and the approximate age of the house. Table 1 summarizes this information. In Region 1, the number of occupied households in each community ranged from approximately 80 to 160 [11]. On average, households had 2.6 bedrooms and 4.8 occupants, while the maximum number of occupants in a single household was 11 people. The average number of household occupants in each community was similar, ranging from 4.6 to 5.1 people. Among all households, 76.8% had children less than 18 years of age living in the home, and children (<18 years) represented approximately 41.0% of the household populations.

In 2010, the number of occupied households in the Region 2 communities varied from approximately 40 to 100 [11]. Average reported households had 3.0 bedrooms with 2.7 people per home. The average household size ranged from 2.6 to 3.6 occupants and the maximum number of household occupants was ten people. Among all households, 46.0% had children less than 18 years of age living in the home, and children represented one-third (33.3%) of the household populations.

Home heating practices

Survey participants were asked about home heating practices within their households, with Table 2 presenting the results of this question. Fuel oil stoves (e.g., Toyostove or Monitor heaters) were most commonly used as a source of home heating in Region 1, while wood stoves and fuel oil furnaces were most commonly used in Region 2. In Region 1, 78% of households used a fuel oil stove for home heating, while 56% of households used a wood stove as either a primary or secondary source of heat. Electric heat was reported by 14% of respondents in Region 1. Wood stoves and fuel oil furnaces were each used by 45% of households for home heating in Region 2, while 21% used a fuel oil stove.

Compared to Region 1, wood stoves in Region 2 were reported to be slightly newer and in better condition. Among households that used a wood stove for home heating, the average age of wood stoves was 17 years old in Region 1 and 13 years old in Region 2. Twenty-five percent of wood stoves in Region 1 and 11% in Region 2 were reported to be in bad or poor condition. The types of wood burned in wood stoves varied by community and region. In Region 1, driftwood and willow were the most common types of fuel used, while spruce was the most frequently used fuel reported in Region 2. In addition to burning wood inside the home, households in Region 1 reported burning paper and/or cardboard (90.4%), trash (6.7%), old clothes (5.9%) and Duraflames (4.4%). In Region 2, 61.5% of respondents reported burning paper and/or cardboard to start a fire, while 5.1% reported burning trash. Wood seasoning times were similar among the two regions, with the majority of households reporting burning wood a few days after it was collected. Cutting standing dead trees (Regions 1 and 2) or having firewood delivered (Region 2 only) was commonly reported.

Indoor household activities and sources of air pollution

In an effort to determine sources of indoor air pollution, survey participants were asked to identify if any of the following activities occurred within the home: 1) burning scented candles or incense, 2) use of kerosene/oil lamps, 3) burning pic (mosquito repellent), 4) sweeping and 5) mopping. The results from this question are presented in Table 3.

Inside the home, 52.3% of households in Region 1 and 58.6% of Region 2 households reported burning candles and/or incense, but the majority said they were rarely used. Power outages can occur frequently in many rural Alaska communities, particularly during the winter months. Eight percent (8.3%) of households in Region 1 and 9.2% of households in Region 2 reported using kerosene or oil lamps primarily for emergencies or during times without power. Pic or mosquito repellent use was reported in both regions, and primarily burned seasonally in an attached arctic entry way or outside the home. Pic was used by 58.9% of households in Region 1, while 52.9% used it in Region 2.

Outdoor community activities and sources of air pollution

In an effort to identify sources of outdoor air pollution, survey participants were asked if any of the following activities or sources of air pollution occurred within their community: 1) use of burn barrels, 2) open burning at the dump, 3) use of diesel generators, 4) road dust, 5) emissions from ATVs/snow machines, and 6) use of steam baths. The results from this section are also presented in Table 3.

In Region 1, the occurrence of outdoor activities varied among communities. For example, open burning at the dump was noted by the majority of respondents as a common activity in communities 1 and 2, while the use of burn barrels was more common in community 3. Road dust was reported in all Region 1 communities, with over 90% of respondents from two communities noting it as a common occurrence. Snow machine/ATV exhaust and steam bath use were also common in all Region 1 communities, with 80–95% of respondents reporting their occurrence.

In Region 2, a regional landfill is centrally located, and refuse collection services are available within the communities. As no communities had a landfill, no responses were recorded for open burning at the dump in this region. In Region 2, the use of burn barrels was the only outdoor activity noted by the majority of respondents (72.4%) as a common outdoor activity. Road dust, ATV/snow machine exhaust, and steam baths were each additionally reported by approximately 40% of respondents.

Air Quality Perceptions - Indoor

In addition to the household activities described above, participants described concerns they had with indoor and ambient air quality (perceptions), as well as changes they would make to improve air quality in their indoor and outdoor environments. In Table 4, we summarize the top indoor concerns per region. In Region 1, mold/moisture (27.8%), lack of ventilation/fresh air (5.4%), and dust (5.0%) were the most common concerns reported for inside the home. Other concerns included cold draft/gaps in house, exhaust fumes from the stove backing up in the house, and wood smoke from outside (infiltration). In Region 1, increased/improved ventilation (13.3%), air purification and filtration (11.6%), and addressing mold problems (10.0%) were most frequently described to improve indoor air quality. Other desired changes described included dust control, “a new home”, using a dehumidifier, and “a better or new wood stove”.

In Region 2, the top concerns noted for indoor air quality included the “air was too dry” (13.8%), lack of ventilation /fresh air (9.2%), and dust (9.2%). Other concerns described

included mold, cold draft/gaps in the house, and allergens in the air. Air purification and filtration (27.6%), increased/improved ventilation (17.2%), and using a humidifier (6.9%) were most commonly noted as desired changes to improve indoor air quality. Fewer concerns with indoor air quality were noted in this region with 57.5% of respondents reporting they did not have any concerns, compared to 53.9% in Region 1.

Air Quality Perceptions - Outdoors

Table 4 presents the air quality perceptions for outdoor air. Among other concerns in Region 1, smoke (21.2%) and road dust (6.6%) in the ambient environment were the most frequently reported air quality concerns. Similar to indoor perceptions, fewer respondents from Region 2 reported concerns with ambient air quality (23.0% compared to 33.6%). In addition, respondents proposed fewer changes they would make to improve ambient air quality compared to Region 1. The top responses for outdoor concerns in Region 2 included open burning/smoke (11.5%), dust (6.9%), and vehicles/ATVs/snow machines (4.6%).

In Region 1, the most frequently described changes to improve ambient air quality included addressing road dust (20.3%) and outdoor smoke issues (19.9%), including steam bath smoke, burning trash, wood stove smoke, and the burning of treated wood, oils, and rubber. Less snow machines/ATVs, “making the community cleaner” (e.g., picking up trash), running water/sewer, and community education were additionally described as potential ways for improving air quality. The most frequently desired change among Region 2 communities was to stop or decrease the burning of trash close to homes (11.5%). Some respondents also noted paving or improving the road, less pollution from vehicles, and trash management improvement as desired changes to improve outdoor air quality.

Results Dissemination

Following the completion of the air quality surveys, a detailed report summarizing the results from the surveys was delivered to each community. Through multiple community events, the findings were also discussed with the respective communities through informational sessions. These meetings brought together members from the community as well as Tribal Administrators and Tribal Council members.

Discussion

This study was unique in that we worked directly with residents in rural Alaska communities to identify community-specific concerns with indoor and ambient air quality through the dissemination of household questionnaires. Many differences existed between the two regions included in this study, such as access to services, household size, home heating practices, and the occurrence of specific community activities (e.g., use of burn barrels). Despite the uniqueness of these two regions, similar concerns were noted for both indoor and ambient air quality. Although the order of the top concerns differed, the same issues existed for both regions. Among the top indoor air quality concerns described, 1) mold, 2) lack of ventilation or fresh air, and 3) dust were each described in both Regions 1 and 2. This was additionally true for outdoor concerns, as 1) open burning/smoke, 2) road dust/dust outside, and 3) mobile exhaust (e.g., snow machines, ATVs, and vehicles) were the top three concerns noted in both regions.

Particulate Matter Air Pollution

One unique finding from these surveys is that even though these communities are rural in nature, there were many sources of airborne particulate matter (PM) identified from both the indoor and ambient environments. PM is one of six criteria air pollutants currently regulated by the Environmental Protection Agency, with ambient air quality standards for both PM_{2.5}

and PM₁₀ (i.e., particulate matter with aerodynamic diameters of <2.5 and <10 micrometers, respectively). No standards currently exist for indoor environments. Along with ground-level ozone, PM is considered to be the most dangerous of the criteria pollutants in terms of public health impacts, and a growing body of literature has linked both PM₁₀ and PM_{2.5} to a variety of respiratory and cardiovascular health outcomes including increased incidence of respiratory symptoms and infections, decreased lung function, respiratory hospital admissions, and respiratory and cardiovascular mortality [14–23].

Among children, PM_{2.5} has been linked to a greater than three-fold increased risk of acute respiratory tract infections and increased asthma morbidity [24–27]. When compared to the general US population, American Indian and Alaska Native (AI/AN) children experience greater respiratory morbidity due to lower respiratory tract infections [28–30]. Although there are many factors that may contribute to these disparities, environmental conditions such as house crowding, use of wood stoves, and exposure to air pollution have been shown to increase the risk of these infections in children [4, 28, 31–32].

Interventions

As identified by the surveys, potential sources of indoor PM₁₀/PM_{2.5} included wood stoves, fuel oil stoves, dust, and various sources of infiltration from the ambient environment. Outdoor sources of PM₁₀/PM_{2.5} included open burning/smoke (e.g., the use of wood stoves in homes and in steam baths, burning at the dump, and use of burn barrels), road dust, and ATV/vehicle emissions. There are several interventions that could help reduce exposures of PM in the indoor environment (where people spend the most time). Some examples include outreach/education programs, wood stove change outs (replacing old stoves with new efficient stoves), air purification and filtration, and improved ventilation. For the outdoor environment, watering or paving the roads, speed limits, and community campaigns highlighting best burn practices could be used. One major limitation of some of the proposed interventions is that the costs associated with these strategies are likely elevated compared to more urban areas. Therefore, a cost-impact analysis needs to be conducted before implementing these interventions, ensuring the most appropriate, cost-effective strategy. Finally, our team believes that targeted outreach/education (both in schools and within the community) could be a highly effective intervention strategy in the future, and one that we will continue to pursue in an effort to improve overall community health.

Conclusion

The long-term, overall mission of these air quality surveys is to reduce health disparities of Alaska Native people living in rural communities by raising awareness of indoor air quality issues affecting respiratory health. Results from the air quality surveys identified what the major indoor and ambient air pollution problems were within each of the seven communities that participated in this study. In addition, community members provided suggestions on things they would like to see implemented (i.e., interventions) to improve air quality within their homes and community. The results of the air quality surveys will now be used to seek additional funding for implementation of interventions within these communities, with the goal of improving air quality and overall respiratory health in these underserved areas. Specifically, interventions will focus directly on the suggestions provided by community members. Further research is additionally needed to assess exposures to PM₁₀/PM_{2.5} and the associated impacts on respiratory health, particularly among susceptible populations such as young children.

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Figure 1.
Map of Alaska Study Areas

Table 1
Summary of selected demographics and household characteristics for Region 1 and Region 2 communities

Household Characteristics per Community*	Region 1		Region 2				
	1 (n=64)	2 (n=97)	3 (n=80)	4 (n=21)	5 (n=23)	6 (n=15)	7 (n=28)
Residents per household	4.6 ± 2.6	4.8 ± 2.1	5.1 ± 2.2	3.6 ± 2.2	2.7 ± 1.4	3.3 ± 1.9	2.6 ± 1.5
Max residents per household	11	9	11	10	6	7	6
Max age, yrs.	55.3 ± 15.7	51.3 ± 15.8	51.7 ± 15.6	55.1 ± 19.0	50.9 ± 20.1	52.0 ± 15.7	52.4 ± 21.1
Min age, yrs.	16.4 ± 22.1	13.6 ± 18.4	10.6 ± 15.5	18.4 ± 21.0	29.3 ± 25.3	25.5 ± 19.6	34.3 ± 27.7
<18 years, %	41.3	39.8	42.3	38.7	31.1	34.7	28.8
No. of household bedrooms	2.4 ± 1.1	2.5 ± 0.99	2.8 ± 0.90	2.9 ± 0.91	2.2 ± 0.80	3.2 ± 1.1	2.6 ± 0.92
Home age, yrs.	32.1 ± 15.5	28.6 ± 17.8	20.3 ± 13.9	18.6 ± 9.5	21.1 ± 20.9	15.4 ± 12.6	23.6 ± 16.4

* Means ± standard deviations are presented above unless otherwise noted.

Table 2

Home heating practices: primary and secondary sources of heat reported in Region 1 and Region 2 communities

Home Heating Source per Community	Region 1			Region 2			
	1	2	3	4	5	6	7
Heat source, %							
Fuel oil stove	75.0	83.5	75.0	9.5	39.1	6.7	21.4
Wood stove	37.5	60.8	65.0	28.6	47.8	40.0	57.1
Electric	4.7	--	11.3	--	--	--	3.6
Furnace	23.4	8.2	12.5	87.5	4.3	93.3	28.6
Oil stove	10.9	2.1	1.3	4.8	--	--	3.6
Fuel oil boiler	9.4	3.1	2.6	9.5	39.1	--	35.8
Secondary source of heat, %	59.4	58.8	66.3	33.3	39.1	53.3	60.7
Wood stove characteristics *							
Average age, yr.	1995	1992	1999	2001	1997	2003	1997
Bad/poor condition, %	27.3	29.3	19.6	--	27.3	--	6.3
Good/decent condition, %	63.6	69.0	70.6	80.0	45.5	100.0	87.5

* Reported for homes with a primary or secondary wood stove heat source.

Table 3

Indoor household/outdoor community activities and sources of air pollution

Indoor Activity/Source per Community, %	Region 1			Region 2		
	1	2	3	4	5	6
Burning incense/candles	35.9	54.6	62.5	57.1	73.9	53.3
Use of kerosene/oil lamps	10.9	1.0	15.0	9.5	4.3	13.3
Burning pic/mosquito repellent	21.9	64.9	81.3	61.9	56.5	46.7
Sweeping	100.0	99.0	100.0	100.0	100.0	100.0
Mopping	93.8	99.0	100.0	100.0	95.7	100.0
Outdoor Activity/Source per Community, %	1	2	3	4	5	6
Use of burn barrels	25.8	7.2	67.5	66.7	73.9	66.7
Open burning at the dump	85.7	93.8	20.0	n/a	n/a	n/a
Use of diesel generators	16.1	61.9	27.5	--	13.0	--
Road dust	92.2	96.9	53.8	76.2	56.5	6.7
Snow machine/ATV exhaust	85.9	94.8	80.0	23.8	39.1	6.7
Steam baths	93.8	92.8	98.8	66.7	73.9	--

Table 4

Community perceptions: top indoor and ambient air quality concerns by region

Region 1 – Indoor Concerns		Region 2 – Indoor Concerns	
1	Mold/moisture	1	Air is too dry
2	Lack of ventilation/fresh air	2	Lack of ventilation/fresh air
3	Dust	3	Dust
4	Cold draft/gaps in house	4	Mold
5	Exhaust fumes from stove	5	Cold drafts/gaps in house
6	Air is too dry	6	Allergens in air
7	Smoke from outside	7	Need new wood stove/smoke
8	When sewage system freezes	8	Carbon monoxide
9	Need new wood stove/ smoke	9	“Feels sick”/“makes me sick”
10	Carbon monoxide	10	Old carpet/flooring

Region 1 – Outdoor Concerns		Region 2 – Outdoor Concerns	
1	Open burning/smoke	1	Road dust/dust outside
2	Road dust/dust outside	2	Open burning/smoke
3	ATVs/snow machines	3	ATVs/snow machines/vehicles
4	Sewage smells	4	“Dirty air”/“unknown haze”
5	Trash/pollution	5	Forest fires