Enhancing Resilience to Wildfire Smoke in Alaska: Evaluating and Communicating the Use of Air Quality Data for Health Protection

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Abstract

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In recent decades, Alaska has experienced unprecedented wildfire seasons,[1] increasing the public's exposure to harmful particulate matter from wildfire smoke. To track this air pollution for the entire state, there are only six federal regulatory air monitoring stations that continuously monitor fine particulate matter ($PM_{2.5}$). Moreover, these monitoring sites are all located within the population centers of Anchorage, Fairbanks, and Juneau[2]. This leaves significant gaps in real-time exposure assessment and trend tracking of wildfire smoke for rural and Alaska Native communities far from air monitoring sites, limiting their ability to make informed exposure-reduction decisions in a timely manner. As a result, strategies such as the use of low-cost air quality sensor networks and web-based tools that share air quality data from multiple sources, are needed to supply air quality information to rural communities. Low-cost air quality sensor networks have been used to provide individuals with real-time, personalized exposure data for air pollution,[3] that help inform exposure assessment efforts.[4] While there is some understanding of benefits and challenges involved with using low-cost sensor networks for air pollution planning and response efforts,[4–8] most studies have examined networks located in urban areas, and few have examined them in the context of wildfire smoke.[8] Further, limited evaluations have been conducted on the usability of low-cost sensors[9,10] and how it influences their effectiveness as an intervention for wildfire smoke resilience. Additionally, a new state-wide tool–the Alaska Wildfire Explorer–was recently developed by researchers at the University of Alaska Fairbanks to provide geographically-relevant fire and air quality information in an accessible web-based format that incorporates data from low-cost sensors[11].

Still, there is a need for tailored guidance on interpreting and applying data from this tool to inform exposure-reduction strategies during wildfire smoke events at both the community and individual levels. This study aims to (1) describe the barriers and facilitators to the implementation and use of low-cost air quality sensors in Alaska and to (2) co-create story-based user guides that communicate the utility and functionality of the Alaska Wildfire Explorer tool. For aim 1, we applied the Consolidated Framework for Implementation Research (CFIR)[12] and Proctor et al.'s Implementation Outcomes[13] as a conceptual framework to identify key factors that influenced implementation processes and innovation outcomes. We employed semi-structured interviews and a survey tool to investigate perspectives of implementation leads, innovation deliverers, and innovation recipients of low-cost sensor networks in Alaska. We found that although low-cost air quality sensors are not perceived as challenging to install and maintain, Alaska's extreme winter weather, variable internet infrastructure, and limited resources within the work infrastructure allocated to low-cost monitoring posed barriers to the sustainability of this innovation. This evaluation also revealed that although some surveyed communities use air quality data to inform risk communication messages and local initiatives to reduce exposure to air pollution, the vast majority would like to. Additionally, most sensor hosts are not currently using data from their sensors to make wildfire smoke-related evacuation decisions. These findings indicate that investments in community infrastructure to support sensor durability and Wi-Fi connectivity, as well as providing additional training for sensor hosts on accessing and interpreting air quality data, can help improve the sustainability of low-cost air quality sensor networks in Alaska for access to real-time air quality data. For aim 2, we used a co-production process and a storytelling approach rooted in scientific and environmental communications to create five story-based user guides communicating the utility of the Alaska Wildfire Explorer tool to help promote personal and community health resilience during wildfire smoke events. Reflections on co-creation aspects that influenced the final public health communication products and recommendations for future co-production efforts are described.

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Abbreviations and Acronyms

95% CI: 95% confidence interval

ADEC: Alaska Department of Environmental Conservation

API: Application programming interfaces

AQI: Air Quality Index

AWE: Alaska Wildfire Explorer

CAA: Clean Air Act

CFIR: Consolidated Framework for Implementation Research

CO: Carbon monoxide

CONUS: Contiguous United States

COPD: Chronic obstructive pulmonary disease

EPA: Environmental Protection Agency

FEM: Federal Equivalent Method

FRM: Federal Reference Method

HEPA: High Efficiency Particulate Air

JUSTICE-HIA: JUst Solutions To Impacts of Climate Exposures for Health In Alaska

KAB: Knowledge, Attitudes, and Behavior

KAP: Knowledge, Attitudes, and Practice

NAAQS: National Ambient Air Quality Standards

NO_2: Nitrogen Dioxide

O_3: Ozone

OR: Odds ratio

PAHs: Polycyclic Aromatic Hydrocarbons

PM: Particulate Matter

PM_{10}: Particulate Matter less than 10 microns in diameter

$PM_{2.5}$: Particulate Matter less than 2.5 microns in diameter

REDCap: Research Electronic Data Capture

RIRC: Retell, Identify, Remember and Contextualize

RVAT: Rapid Vulnerability & Adaptation Tool

SD: Secure digital

SLAMS: State and Local Air Monitoring Stations

SPM: Special Purpose Monitoring Site

U.S.: United States

UAF: University of Alaska Fairbanks

VOCs: Volatile organic compounds

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Introduction

Globally, wildfire-favorable weather conditions have increased in frequency and severity over the last fifty years as a result of anthropogenic climate change.[14] These favorable conditions are defined by a combination of warmer temperatures, dry summers, reduced precipitation during winter months, and earlier spring snowmelt.[15] While fires play an important role in the health of many ecosystems, unprecedented increases in fire activity due to warming climates are threatening their health.[16] Specifically, in the western United States (U.S.), climate change has been attributed to doubling the cumulative area that would have otherwise burned from natural climate activity alone.[17] Additionally, a projected 50% increase in lightning strikes–the prominent wildfire ignition source–over the contiguous U.S. (CONUS) throughout the 21st century, poses conditions for more wildfires to start.[18] Coupled with factors affecting vegetation flammability such as topography, land management, and vegetation change and productivity, the intensity, size, and frequency of fires are also set to be affected.[19]

Environmental exposure to wildfire smoke is harmful to human health both near and far from a fire site, posing major public health consequences. Through epidemiological evidence, wildfire smoke exposure has been repeatedly associated with health outcomes including exacerbation of asthma and chronic obstructive pulmonary disease, and increases in respiratory emergency department visits and hospitalizations.[20] While there is mixed evidence on the relationship between wildfire smoke and cardiovascular morbidities,[20] specific air pollutants present in wildfire smoke have been linked to various cardiovascular health outcomes. Wildfire smoke contains air pollutants including particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), volatile organic compounds (VOCs), ozone (O_3), and polycyclic aromatic hydrocarbons (PAHs).[21] Most notable is fine particulate matter ($PM_{2.5}$) which includes particles from combustion, organic compounds, or metals that are less than 2.5 microns in diameter[22] that are small enough to travel deep into the lungs and bloodstream.[22,23] $PM_{2.5}$ is especially of concern as both short and long-term exposure to $PM_{2.5}$ has been causally associated with cardiovascular health effects and all-cause mortality.[22] These health burdens are projected to worsen, with one study estimating an additional 178 (95% CI: 6.2, 361) respiratory hospital admissions per day in 2046 compared to 2004-2009 for the Western US due to increased frequency of intense wildfire smoke days.[24]

Since 1970, the US Environmental Protection Agency's (EPA) Clean Air Act (CAA) has set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, to combat and prevent air pollution issues that threaten public health and welfare.[25] In 2024, as a result of overwhelming evidence on the adverse health effects from $PM_{2.5}$ exposure, the EPA strengthened the primary standard for annual $PM_{2.5}$ to 9.0 micrograms per cubic meter–a further reduction from the 2012 revision from 15 to 12 micrograms per cubic meter.[26] In order for regions to meet these compliance requirements, agencies at the state, local, and Tribal levels use a network of monitoring sites with "gold standard" air quality equipment designated as federal reference method (FRM) or federal equivalent method (FEM) monitors to track air pollution trends.[27]

These regulatory monitoring sites are located to monitor air pollution in areas with large populations and high-emitting sources such as coal-fired power plants or traffic-related air pollution.[28] Consequently, these regulatory air monitoring sites are concentrated in urban areas, the western and eastern coasts, and are not equally distributed across the country.[28] In Alaska, only six federal-grade $PM_{2.5}$ monitoring stations actively collect air quality data for the entire state, and these sites are all located within the major population centers of Anchorage and Fairbanks metropolitan areas (>50,000 people) or Juneau's micropolitan area (10,000-50,000 people).[2,29] This gap in the current monitoring infrastructure prevents real-time assessments of air pollution exposure during wildfire smoke events and trend tracking of $PM_{2.5}$ for rural Alaska.

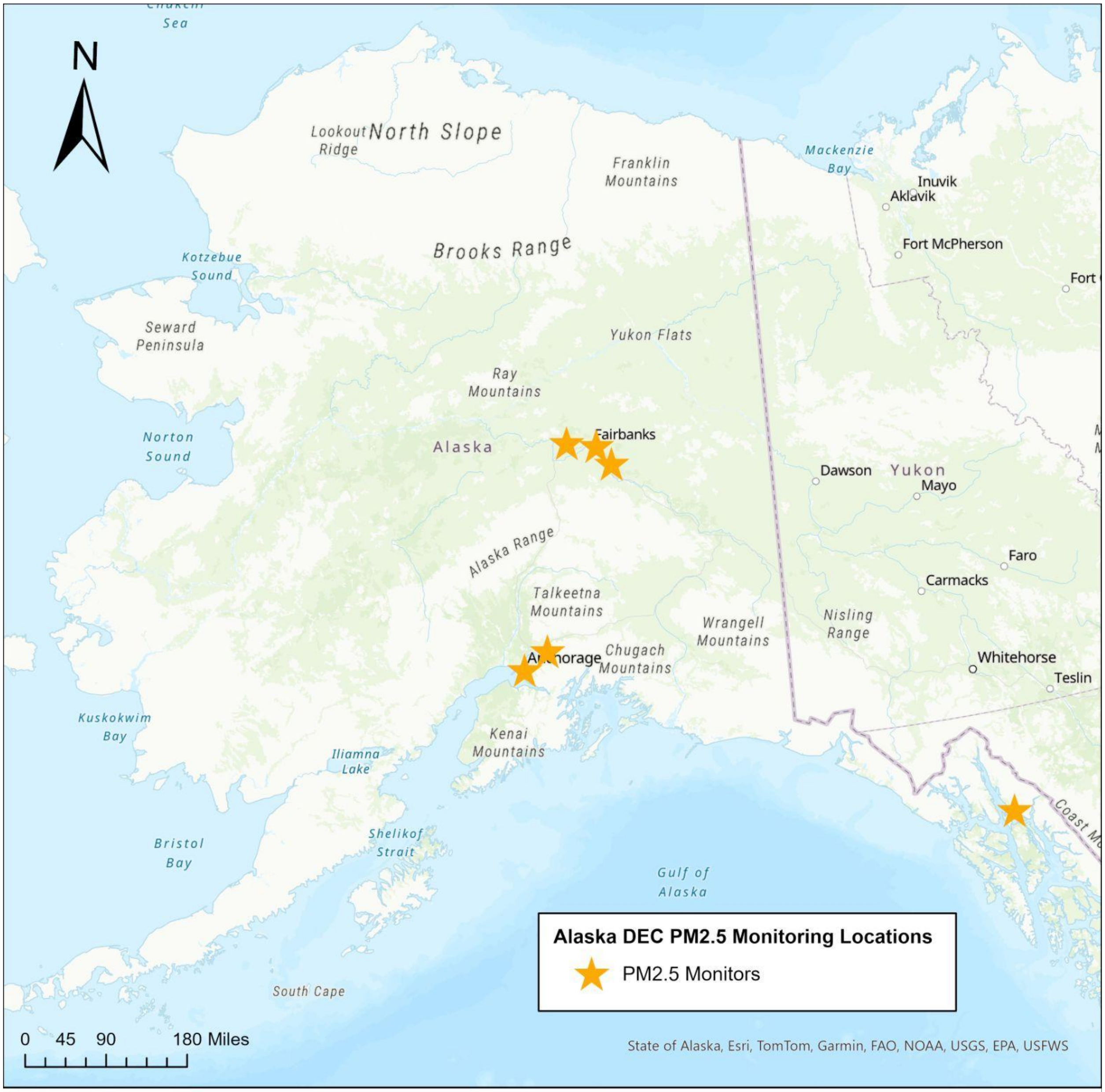
Table 1: State of Alaska $PM_{2.5}$ Regulatory Air Monitoring Sites

Site Name	Location	$PM_{2.5}$ Monitor Type (FEM/FRM)	$PM_{2.5}$ Monitoring Objectives
NCORE site	Fairbanks	FRM ● Continuous $PM_{2.5}$ and PM_{10}* Met One *BAMs with particle size selective inlets ● $PM_{2.5}$ and PM10 filter-based Thermo Scientific Partisols (two-2000is and one-2025i)	To gather data on typical background concentrations of $PM_{2.5}$
A Street site	Fairbanks	FRM ● One $PM_{2.5}$ filter-based Thermo Scientific Sequential Partisol 2025i ● One continuous $PM_{2.5}$ Met One BAM.	To gather data on the highest concentrations of $PM_{2.5}$ pollutants expected in an area and the impact of significant sources. Designations: SLAMS*, SPM*
Plant Material Center site	Butte	FEM ● Continuous $PM_{2.5}$ and PM_{10} Met One BAM, with particle size selective inlets	To gather data on highest concentrations of $PM_{2.5}$ and PM_{10} pollutants expected in an area and impact of significant sources. Designations: SLAMS for $PM_{2.5}$
Hurst Road site	North Pole	FRM ● Two $PM_{2.5}$> Thermo Scientific Sequential Partisols ● One $PM_{2.5}$ Met One BAM	To gather data on the highest concentrations of $PM_{2.5}$ pollutants expected in an area and impact of significant sources. Designations: SPM site for $PM_{2.5}$
Garden site	Anchorage	FEM ● Continuous $PM_{2.5}$ and PM_{10} Met One BAM with particle size selective inlets,	To gather data on typical background concentrations of $PM_{2.5}$

		• Two filter-based Thermo Scientific 2000i Partisols	
Floyd Dryden site	Juneau	FRM • $PM_{2.5}$ filter-based Thermo Scientific Partisol • Teledyne T640x that measures both $PM_{2.5}$ and PM_{10} pollutants	To gather data on typical background concentrations of $PM_{2.5}$ and PM_{10} pollutants. Site designations: SLAMS, SPM

*BAMs: Beta Attenuation Monitors, PM_{10}: Particulate matter less than 10 microns in diameter, SLAMS: State and Local Air Monitoring Stations, SPM: Special Purpose Monitoring
Sources: Alaska DEC monitoring sites,[2] EPA AirData Air Quality Monitors,[29] List of Designated Reference and Equivalent Methods.[27]

Figure 1: Map of Alaska $PM_{2.5}$ Regulatory Air Monitoring Sites



$PM_{2.5}$ monitoring locations sourced from Alaska Department of Environmental Conservation (ADEC) monitoring sites[2] and EPA AirData Air Quality Monitors.[29]

The Alaska region faces climate and environmental changes that threaten health, economies, and important cultural resources that depend on healthy ecosystems. All regions in Alaska have been getting warmer. Over the past 50 years, Alaska's North Slope and Western coast have experienced an increase in average annual temperatures of 6.1 and 4.5 degrees Fahrenheit, respectively.[30] Other regions have seen increases between 2.2 to 4.3 degrees Fahrenheit, with the greatest observed change occurring in winter months.[30] These changing temperatures are contributing to wildfire weather, through shortened snow seasons and increased and earlier snow melt, and more lightning strikes.[23,30] Lightning is especially of concern as this ignition source burns more acres than ignition from human activity in Alaska.[23,30] Specifically, lightning strikes per year have more than doubled between 2014-2023 in the western Interior region, and has replaced the eastern Interior region as the area where lightning is most common in Alaska.[30] These fire-friendly conditions and fuel availability have contributed to increased frequency and size of wildfires in Alaska's tundra and boreal forest regions.[1,31] The last decade has seen the greatest impact from wildfires on record, burning approximately 14 million acres in 2015-2024.[23] The second-most significant decade was from 1995-2004 where 2004 had the largest fire year on record with 6.59 million acres burned.[23]

With increased fire activity comes increased smoke and associated public health impacts. The city of Fairbanks has only experienced two smoke-free summers since 2000, where prior to then, it was common to see a summer without smoke.[23] Most recently between 2022 and 2024, three consecutive summers were characterized by more than 100 hours with moderate or worse air quality. When smoke is severe enough it can limit visibility to six miles or less,[23] disrupting air travel that disproportionately affects rural areas only accessible by plane.[31] This leaves individuals such as Alaska Native Elders, other older adults, and those with respiratory conditions living in rural areas without the ability to evacuate during such events.[31] Alaska Native peoples–who make up large portions of rural Alaska's populations ranging from 23% to 95% of the population in the Southwest, Interior, and Far North regions[32]–already face higher rates of respiratory and cardiovascular diseases[33] that can be further exacerbated by exposure to wildfire smoke.

Underlying factors that are thought to increase this risk include higher rates of chronic disease including respiratory and cardiovascular diseases, and limited access to healthcare, or exposure-reduction resources such as air filters.[33] It is reported that communities living further away from healthcare facilities may be less likely to seek medical attention for acute cardiovascular morbidity due to travel time,[33] highlighting a unique risk determinant for rural communities during wildfire smoke events. Still, there is a limited understanding of how climate change is affecting health in Alaska. This is partially due to the lack of readily available clinical records for the state, rendering reduced statistical robustness for quantitative assessments.[34] These factors exemplify the need for the expansion and resilience of air quality monitoring infrastructure to facilitate and inform early wildfire smoke response decisions, as well as long-term air pollution exposure assessments for resilience efforts in rural and Alaska Native communities.

One low-barrier method to improving access to air quality data is the use of low-cost air quality monitors, or low-cost sensors. These sensors are relatively inexpensive (generally <$400, though there is no official definition of "low-cost") and simple devices that target consumers and citizen scientists, providing them with real-time, local exposure data for air pollution.[35] They are generally accessible devices as they do not require special training or knowledge to install or use.[35] Their accessibility has given rise to their popularity in the last decade, and have contributed to many community-based monitoring efforts[8,9,35–39] and studies aimed at assessing their performance, especially in urban settings.[40,41] Among the low-cost sensor types used in community-based monitoring efforts, many have opted to utilize outdoor PA-II sensors from the company PurpleAir, which uses PM sensors manufactured by Plantower.[42] Not only does PurpleAir provide customers with real-time air quality data from their purchased sensor, but also data for all sensors that are publicly-viewable on their web-based PurpleAir Map.[43] This robust data access feature has fueled their global popularity and contributed to their integration into the US EPA's AirNow Fire and Smoke Map to inform individuals on protecting their health from wildfire smoke.[44]

Researchers posit that by providing the public with accurate and timely air quality information, it could help reduce wildfire smoke-related health impacts by alerting people to take protective actions.[45] This motivated University of Alaska Fairbanks researchers to establish a low-cost sensor network using PurpleAir PA-II monitors throughout the state during the spring and summer months of 2019, which was characterized by especially unusual wildfire activity in the Southcentral region.[46] Researchers partnered with 27 rural and Tribal communities throughout the state to install one monitor in each community. The goal of this network was to track exposure to wildfire smoke and empower community members with locally-relevant, real-time information they could use to make decisions about their exposure to air pollution. However, while the network aimed to provide actionable air quality information, questions remain about how this network is being used and whether community members can easily access and apply data from these sensors. Limited evaluations have been conducted on the usability of low-cost sensors[8,10] and how it influences their effectiveness as an intervention for wildfire smoke resilience. However, it remains crucial to assess this and other public health evidence-based interventions to gain a clearer understanding of both their intended and unintended outcomes, as well as their cost-effectiveness.[13,47] Such evaluations can provide valuable insights into the potential success of future interventions and help persuade funders to support them.[48]

Another way researchers have tried to support communities during wildfire events is by creating web-based tools with real-time information. For example, the Alaska Wildfire Explorer (AWE) was created by the University of Alaska Fairbanks Scenarios Network for Alaska and Arctic Planning to provide real-time geospatial information on locations and sizes of active wildfires as well as historical and projected fire-related variables throughout Alaska.[11] A recent EPA-funded project (Award #84047901 Hahn, Busch-Isaksen, Errett, Fresco) aimed to support Alaska communities as they respond to and prepare for wildfire and smoke.[49] Project components included designing wildfire and health tools, holding community conversations about Indigenous Health Indicators, evaluating low-cost air quality sensor implementation, and co-creating story-based user guides to communicate the use of wildfire and health tools, all to improve access to climate and health information to support decision-making in Alaska. The project, referred to as the JUst Solutions To Impacts of Climate Exposures for Health in Alaska (JUSTICE-HIA) project, brought together researchers at the University of Alaska Anchorage Institute for Circumpolar Health Studies, the University of Washington Center for Disaster Resilient Communities, and various state and community partners in Alaska, alongside developers of the AWE. Through a co-production process, the team identified a need for improved wildfire smoke information across the state and therefore sought to add real-time and forecast air quality information to the AWE. The JUSTICE-HIA team supported integration of ground-based, real-time air quality information from all sensor networks including the Alaska Department of Environmental Conservation (ADEC) and PurpleAir sensors, and satellite-based information on current and forecasted smoke plumes into the tool.[11,49]

While the AWE facilitates access and interpretation of these environmental data, the lay user may require additional guidance on how to apply such information for health-protection efforts. One method for communicating a data tool's functionality is through a story-based user guide. A user guide is a type of user manual that communicates the functionality and utility of a product.[50] S*tory-based* user guides incorporate storytelling to frame a specific use-case that tailors the guidance or messaging being communicated. A story-based format creates an accessible mode of communication that can more effectively speak to the user's unique concerns and priorities, supporting increased understanding and interest in the scientific information presented.[51] Story-based user guides can be presented in many formats including illustrations, concise narrative descriptions, or verbal role-play. Moreover, co-creating story-based user guides can tailor guidance by involving end-users, resulting in culturally specific messaging.[51]

Study Aims

Alaska communities are experiencing wildfire events that are increasing in size and frequency, exposing residents to greater amounts of harmful wildfire smoke.[23,30,31,33] In order to effectively implement appropriate adaptation efforts, an understanding of exposure to wildfire smoke is necessary. Currently, there are a limited number of air quality $PM_{2.5}$ monitors for the state, limiting access to air quality information for communities seeking to make exposure-reduction decisions.[2,52] The use of low-cost air sensors has improved access to greater spatiotemporal $PM_{2.5}$ data, yet their implementation and use for community resilience to wildfire smoke has not been evaluated. Additionally, there is a need for guidance on the interpretation and application of environmental data for the general public's use to help inform exposure-reduction efforts to wildfire smoke. We aimed to describe the barriers and facilitators associated with installing, maintaining, and using low-cost air quality sensors in rural and Alaska Native communities as a public health intervention for wildfire smoke exposure assessment and response decisions. We interviewed and surveyed individuals at various levels of the implementation process, guided by the Consolidated Framework for Implementation Research (CFIR) and Proctor et al.'s Eight Implementation Outcomes.[12,13] Additionally, we aimed to co-create story-based user guides to communicate the utility and facilitate the dissemination of a wildfire and air quality data tool for diverse audiences, to promote personal and community health resilience during wildfire smoke events.

Aim 1: Describe the barriers and facilitators to the implementation and use of low-cost air quality sensors in Alaska.

1.1 Investigate the barriers and facilitators to implementation experienced by implementers of low-cost sensor networks in Alaska.

1.2 Investigate the barriers and facilitators experienced by low-cost sensor hosts while installing, maintaining, and using low-cost sensors.

Aim 2: Co-create story-based user guides that communicate the utility and functionality of the Alaska Wildfire Explorer tool.

1.1 Identify audiences and tool use-cases relevant to the project communities and state liaisons, framed through wildfire smoke events.

1.3 Develop story elements for each use-case story.

1.4 Facilitate the co-creation process with project communities and contracted artists to visualize the story-based user guides.

Aim 1: Describe the barriers and facilitators to the implementation and use of low-cost air quality sensors.

An Evaluation on the Implementation and Usability of Low-Cost Air Quality Sensors in Rural and Alaska Native Communities

Abstract

Higher temperatures and reduced precipitation from climatic changes and land management practices have contributed to an increase in area burned by wildland fires in North America, increasing exposure to harmful wildfire smoke.[14,19] Wildfire smoke exposure is associated with exacerbation of asthma, chronic obstructive pulmonary disease, and increased respiratory hospitalizations.[21] Fine particulate matter ($PM_{2.5}$) is the primary pollutant of concern which has been causally associated with cardiovascular health effects and all-cause mortality.[22] While federal reference/equivalent methods (FRM/FEM) air quality monitors are the gold standard for quantifying ambient concentrations of $PM_{2.5}$, they can be limited in their spatial distribution, posing substantial gaps in exposure assessment and trend tracking of wildfire smoke. This is the case for much of Alaska, as only six federal reference/equivalent monitoring stations continuously capture $PM_{2.5}$ concentrations, and are all located within the population centers of Anchorage, Fairbanks, and Juneau.[2] In recent decades, Alaska communities have experienced unprecedented wildfire seasons[1]. As wildfire smoke exposure becomes more common, rural Alaskans need better access to real-time, proximal air quality data for exposure-reduction decisions. Rural Alaska is home to a large proportion of Alaska Native people who face disproportionate rates of respiratory and cardiovascular diseases[33]. Further exacerbation of these morbidities from exposure to poor air quality poses significant public health risks.[1,53]

The use of low-cost outdoor air quality sensors is a method to provide individuals with real-time, local exposure data for air pollution.[35] They help promote public health awareness of poor air quality and allow for behavior changes centered around exposure assessment efforts and exposure-reduction interventions.[4] While there is some understanding of the public health benefits and challenges involved with using low-cost sensor networks for public health planning and response efforts,[4–8] most studies have examined networks located in urban areas, and few have examined them in the context of wildfire smoke[8]. Lastly, limited evaluations have been conducted on the usability of low-cost sensors[8,10] and how it influences their effectiveness as an intervention for wildfire smoke resilience.

This study endeavors to address gaps in the literature by identifying the barriers and facilitators associated with installing, maintaining, and using low-cost sensors in rural and Alaska Native communities as a public health intervention for wildfire smoke exposure assessment and response decisions. We employ a mixed-methods approach through formative key informant interviews and an online survey to assess barriers and facilitators experienced by low-cost sensor organizers and sensor hosts, respectively. We applied the Consolidated Framework for Implementation Research (CFIR)[54] and Proctor et al.'s Implementation Outcomes[13] as a conceptual framework to identify key factors that influenced innovation and implementation outcomes. The survey asked about participant risk perception of various environmental exposures, aspects of sensor installation, maintenance, data accessibility, interpretation, and air quality information needs. Sixteen survey responses were collected. We found that most participants represented small communities with less than 1,000 people and that installation and ongoing general maintenance are not challenging. Top maintenance concerns include replacing the sensor when needed, its ability to withstand environmental conditions, and finding an alternative host to take over maintenance. We also found that the work infrastructure across Alaska communities–such as high turnover for sensor host positions and lack of time and resources to maintain low-cost sensors–create conditions that may not be conducive to the sustainability of a low-cost sensor network. This evaluation also revealed that although some surveyed communities use air quality data to inform risk communication messages and local initiatives to reduce exposure to air pollution, the vast majority would like to. Additionally, most sensor hosts are not currently using data from their sensors to make wildfire smoke-related evacuation decisions. These findings indicate that investments in community infrastructure to support sensor durability and Wi-Fi connectivity, as well as providing additional training for sensor hosts on accessing and interpreting air quality data, can help improve the sustainability of low-cost air quality sensor networks in Alaska for access to real-time air quality data.

Background

As a result of climatic changes, higher temperatures and reduced precipitation have contributed to an increase in area burned by wildland fires in North America[15,17]. Additionally, factors such as vegetation change and productivity, topography, and land management affect vegetation flammability that in turn affect the intensity, size, and frequency of fires.[19] It is projected that longer fire seasons, long-term warming, and increased lightning frequency will result in more wildfire activity in future decades[45].

One consequential byproduct of wildland fire is the release of smoke containing air pollutants that are harmful to health, including carbon monoxide (CO), nitrogen oxides (NOx), and most notably, fine particulate matter ($PM_{2.5}$). $PM_{2.5}$ includes particles from combustion, organic compounds, or metals sized 2.5 microns or less in diameter that are small enough to travel deep into the lungs and bloodstream[22,23]. $PM_{2.5}$ is especially of concern in wildfire smoke as both short and long-term exposure to $PM_{2.5}$ alone has been causally associated with cardiovascular health effects and all-cause mortality.[22] While there is mixed evidence for associations between wildfire smoke exposure and cardiovascular effects,[55] it has been strongly associated with respiratory health effects including exacerbation of asthma and chronic obstructive pulmonary disease (COPD).[1,55]

In order to better understand exposure to ambient air pollution, the U.S. Environmental Protection Agency (EPA) uses the most reliable monitors available, classified as federal reference method (FRM) and federal equivalent methods (FEM), to measure concentrations of six criteria air pollutants including particulate matter, carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, and lead, as outlined in the Clean Air Act[25]. While these monitors have great temporal resolution, they can be limited in their spatial distribution, limiting exposure assessment efforts for areas far from monitoring sites.

This is the case for much of Alaska, as only six federal grade $PM_{2.5}$ monitoring stations are actively collecting air quality data for the entire state, and are all located within the major population centers of Anchorage and Fairbanks metropolitan areas (>50,000 people) or Juneau's micropolitan area (10,000-50,000 people).[2,29] In recent decades, Alaska has experienced an unprecedented number of million-acre wildfire seasons.[1] Within the past two decades the two most populated cities in the state, Anchorage and Fairbanks, recorded an increase in frequency and length of smoky days due to wildfires, with 2019 being the smokiest summer in recorded history for Anchorage[1].

However, outside of major population centers, reliable air quality data is limited, which hinders accurate exposure assessments for air pollutants like wildfire smoke. Additionally, remote locations in Alaska are home to large proportions of American Indian and Alaska Native peoples–ranging from 23% to 95% of the population in the Southwest, Interior, and Far North regions,[32] who face disproportionate rates of respiratory and cardiovascular diseases.[56] These health conditions can be further exacerbated by exposure to poor air quality. The only epidemiological study on the health effects of exposure to wildfire smoke focused on Alaskan populations reported an increased odds of asthma (OR: 1.16, 95% CI = 1.09, 1.23) and heart failure-related (Lag Day 5 OR = 1.13, 95% CI = 1.02, 1.25) emergency department visits for Alaska Native peoples from exposure to elevated wildfire smoke $PM_{2.5}$ concentrations.[56] Additionally, it is reported that remote community members far from healthcare facilities may be less likely to seek medical attention for acute cardiovascular morbidity due to travel time,[56] highlighting a unique risk determinant for rural communities during wildfire smoke events. These factors exemplify the need for the expansion and resilience of air quality monitoring infrastructure to facilitate and inform early wildfire smoke response decisions, as well as long-term air pollution exposure reduction planning efforts for rural and Alaska Native communities.

Supplemental air quality monitoring through the use of low-cost air quality sensors (also referred to as low-cost sensors) has become a popular method to understand exposure to, and increase public health awareness of, poor air quality. The increase in availability and affordability of these consumer-targeted air sensors coupled with rising concerns over health effects from poor air quality, has resulted in the establishment of many low-cost sensor networks throughout the world. This type of citizen science-based intervention engages individuals at the community level in monitoring local air quality, raising environmental literacy, promoting partnerships, and increasing political advocacy.[5] Among the low-cost sensor types used in community-based monitoring efforts, many have opted to utilize outdoor PA-II sensors from the company PurpleAir. Not only does PurpleAir provide customers with real-time air quality data from their purchased sensor, but also data for all sensors that are publicly-viewable on their web-based PurpleAir Map.[43] This robust data access feature has fueled their global popularity and contributed to their integration into the US EPA's AirNow Fire and Smoke Map to inform individuals on protecting their health from wildfire smoke.[44] Though, questions remain about the reliability of data captured using low-cost sensors,[57] and whether they have been successful as a public health intervention at the community level, for reducing air pollution exposure.

In 2019, the University of Alaska Fairbanks (UAF) researchers established a low-cost sensor network using PurpleAir PA-II monitors throughout 27 rural and Tribal communities. They successfully deployed one monitor in each community with the goal of tracking exposure to wildfire smoke and to provide these communities with access to local real-time air quality data. The sensors were located in communities throughout the eastern half of the state for the following boroughs: Lake and Peninsula, Kenai Peninsula, Matanuska-Susitna, Chugach, Copper River, Southeast Fairbanks, Denali, Fairbanks North Star, Yukon-Koyukuk, and North Slope. All of these boroughs have high population proportions of American Indian or Alaska Native peoples (ranging from 2.8% to 66.4% of their populations).[32] The following summer, the researchers checked PurpleAir's online map to record whether or not each sensor was still online, though no further evaluation was conducted to understand the adoption of this intervention.

Evaluations currently exist on the performance of various low-cost sensor models in comparison to regulatory air monitors.[37,41,57] Though, few studies have focused on performance for particulate matter (PM) from wildfire smoke,[58] and even fewer have focused their evaluations at the user perspective for effective deployment and use.[4] While there is some understanding of the challenges and benefits of using low-cost sensor networks for public health planning and response efforts,[3–8] the vast majority of studies have examined networks located in urban areas and only one has studied them in the context of wildfire smoke response[8]. Lastly, no studies have focused on the end-user perspective of these sensor networks among Indigenous communities and how they can inform their public health emergency planning and response efforts.

As part of the JUSTICE-HIA project, this study endeavors to answer gaps in the literature by identifying the barriers and facilitators associated with installing, maintaining, and using low-cost sensors in rural and Alaska Native communities as a public health intervention for wildfire smoke exposure assessment and response decisions. Through examining sensor host perspectives, insight into the implementation and adoption of low-cost sensors in Alaska's unique environments will better inform wildfire smoke exposure reduction efforts for these remote populations.

Methods

I. Study Design

Our mixed-methods study used key-informant interviews and a survey tool to capture various perspectives of individuals involved at different stages of the implementation of low-cost sensors: implementation leads, innovation deliverers, and recipients. To structure this evaluation, we applied the Consolidated Framework for Implementation Research[12] (CFIR) as a conceptual framework to identify key factors that influenced innovation outcomes, along with six of Proctor et al.'s Eight Implementation Outcomes[13] (adoption, appropriateness, cost, feasibility, penetration, and sustainability) to then identify implementation and innovation outcomes. All of the main CFIR domains (Innovation, Outer Setting, Inner Setting, Individuals, and Implementation Process) were included in the analysis, though only the constructs within each domain that best fit the context and research aims of this study were selected for inclusion. Table 2 presents study-specific definitions of each CFIR domain, tailored construct definitions, and tailored definitions of Proctor et al.'s implementation outcome taxonomy.

In this study, the *Innovation* domain was defined as the use of a low-cost air quality sensor and its data within a community to characterize exposure to $PM_{2.5}$. The *Outer Setting* domain was defined as the entities, organizations, policies, programs, and conditions within Alaska. The *Inner Setting* domain was defined as the individual Alaska communities that received a low-cost sensor. The *Individuals* domain included individuals who were involved with implementing, delivering, and/or receiving low-cost sensors. Lastly, the *Implementation Process* domain encompassed the activities and strategies used to recruit sensor hosts and deploy and install the low-cost sensors within communities. The key informant interviews served to identify characteristics of the *Outer Setting* from the perspective of implementation leads and deliverers. Meanwhile, the survey tool was designed to gather information primarily about the *Inner Setting* from implementation recipients–individuals who acted as community representatives, participated in sensor maintenance, accessed and interpreted data, and helped relay this information to their communities. For these reasons, they were considered both recipients and deliverers of the innovation , and were therefore included in the evaluation as such.[59] Often, innovation recipients are not included in implementation science research, as they rarely hold key decision-making or delivery roles that influence outcomes; however the CFIR emphasizes the importance of their inclusion if they are involved with delivering the innovation in some way.[59] Lastly, we adapted Proctor et al.'s definition of *implementation outcomes* to the context of this study as the effects of deliberate and purposive actions to implement low-cost air quality sensors within rural and Alaska Native communities.

Table 2: CFIR Project Definitions

Domain	Construct	Definition
Intervention		The use of a low-cost air quality sensor and its data within a community to characterize exposure to $PM_{2.5}$.
	A. Relative advantage	The low-cost sensor of interest is better (or worse) than other sensors or instruments to collect air quality data. Also includes information about cost.
	B. Complexity	The innovation is complicated (or not), which may be reflected by its scope and/or the nature and number of connections and steps.
	C. Adaptability	The low-cost sensor can (or can't be) modified, tailored, or refined to fit local context or needs.
Outer Setting		Entities, organizations, policies, programs, and conditions within Alaska.
	A. Local attitudes	Sociocultural values (e.g., shared responsibility in helping recipients) and beliefs (e.g., convictions about the worthiness of recipients) encourage (or do not encourage) the Outer Setting to support implementation and/or delivery of low-cost sensors and their data.
	B. Local conditions	Local environmental, political, and/or economic conditions enable (or disable) the Outer Setting from supporting implementation and/or delivery of low-cost sensors and their data.
	C. Financing	Funding from external entities (e.g., grants, reimbursement) is available (or unavailable) to implement and/or deliver low-cost sensors and their data.
	D. Partnerships & Connections	Communities are networked with external entities (or not), including referral networks, academic affiliations, and professional organization networks. Additionally this domain captures the relationship between the Inner and Outer setting.

Domain	Construct	Definition
	E. Policies and Laws	Legislation, regulations, professional group guidelines and recommendations, or accreditation standards support (or do not support) implementation and/or delivery of low-cost sensors and their data.
Inner Setting		The individual Alaska communities that received a low-cost sensor
	A. Structural Characteristics	Infrastructure components support (or do not support) functional performance of the Inner Setting.
	1. Physical infrastructure	Layout and configuration of space and other tangible material features support (or don't support) functional performance of the Inner Setting with regards to the use of low-cost sensors and their data.
	2. Information Technology infrastructure	Technological systems for tele-communication, electronic documentation, and data storage, management, reporting, and analysis support (or do not support) functional performance of the Inner Setting with regards to the use of low-cost sensors and their data.
	3. Work infrastructure	Organization of tasks and responsibilities within and between individuals and teams, and general staffing levels, support (or do not support) functional performance of the Inner Setting
	B. Culture	There are (or are not) shared values, beliefs, and norms across the Inner Setting.
	C. Learning-centeredness	There are (or are not) shared values, beliefs, and norms around psychological safety, continual improvement, and using data to inform practice.
	D. Relative Priority	Implementing and delivering low-cost sensors and their data is (or is not) important compared to other initiatives.
	E. Mission	Implementing and delivering low-cost sensors and their data is (or

Domain	Construct	Definition
	Alignment	is not) in line with the overarching commitment, purpose, or goals in the Inner Setting.
	F. Access to knowledge & information	Guidance and/or training is (or is not) accessible to implement and deliver low-cost sensors and the use of their data.
Individuals		Individuals who were involved with implementing, delivering, and/or receiving low-cost sensors.
	A. Roles and Characteristics	Roles and characteristics of individuals involved with implementing, delivering, and/or receiving low-cost sensors.
	1. Implementation leads	Previous, current, or prospective organizers of low-cost air quality sensor networks in Alaska.
	2. Innovation deliverers	Those who were involved in delivering low-cost sensors and their data to communities, including sensor hosts.
	3. Innovation recipients	The people within communities who have a low-cost sensor, including sensor hosts.
Implementation Process		The activities and strategies used to recruit sensor hosts, and deploy and install the low-cost sensors within communities.
	A. Assessing Context	Information to identify and appraise barriers and facilitators to implementation and delivery of the low-cost sensors.
	B. Tailoring Strategies	Choices made to operationalize implementation strategies to address barriers, leverage facilitators, and fit context.
	C. Engaging	Attract and encourage participation for hosting and using low-cost sensors.
	D. Assessing	Information about the priorities, preferences, and needs of sensor

Domain	Construct	Definition
	Needs	hosts and their communities to guide implementation and delivery of low-cost sensors and their data.
Proctor et al.'s Implementation Outcomes		The effects of deliberate and purposive actions to implement low-cost air quality sensors within rural and Alaska Native communities.
	A. Adoption	The intention, initial decision, or action to try or employ the use of low-cost sensors.
	B. Appropriateness	The perceived fit, relevance, or compatibility of using low-cost sensors in rural and Alaska Native communities; and/or perceived fit of low-cost sensor data to address wildfire smoke exposure.
	C. Cost	The incremental or implementation cost impact of establishing and maintaining low-cost sensors in rural and Alaska Native communities.
	D. Feasibility	The extent to which low-cost sensors can be successfully used in rural and Alaska Native communities.
	E. Penetration	The integration of low-cost sensor use within community wildfire smoke planning and response efforts.
	F. Sustainability	The extent to which low-cost sensors are maintained or institutionalized within a community and their operations.

II. Key Informant Interviews

We conducted semi-structured key-informant interviews to understand the strengths, challenges, and lessons learned by implementation leads including five previous, current, and prospective organizers of low-cost air quality sensor networks in Alaska. Their perspectives on the deployment and installation process were vital for understanding the implementation process and innovation itself. Key informants were identified and recruited through pre-existing collaborations with the EPA JUSTICE-HIA Project or Principal Investigator. We created an interview guide to collect details of the key informant's low-cost sensor network program and the strengths and barriers to implementation. We hypothesized that the main barriers to sensor use will be attributed to extreme weather and lack of Wi-Fi access in the study area, and facilitating factors will focus on ease of use and affordability.

Participants included two researchers from the University of Alaska Fairbanks who established a sensor network in 2019 using PurpleAir sensors, two individuals from ADEC with a statewide low-cost sensor network using AQMesh sensors, and one Tribal non-profit representative looking to establish a sensor network using PurpleAir sensors. Participants were contacted via email, and sixty-minute virtual interviews were conducted and detailed notes were taken by two or three investigators. One interview session included two key informants, for a total of four interviews.

We consolidated and analyzed the interview notes via a rapid qualitative analysis technique[60] using the CFIR constructs explored through the interview as a guiding framework. In brief, we categorized excerpts from each interview into the framework constructs, then created summaries that captured common themes across all four interviews, organized by respective domains and constructs. Results from this rapid analysis are summarized and presented in Appendix A2. The matrix presents both the analysis summaries and the questions asked during the key informant interviews, along with the resulting survey questions developed through post-interview analysis. Table 3 presents the overarching themes, listed by facilitators and barriers.

Table 3: Facilitators and Barriers Perceived by Low-Cost Sensor Network Organizers

Domain	Facilitators	Barriers
Innovation	Sensors were perceived as relatively inexpensive, requiring little energy, user-friendly. With improved Wi-Fi infrastructure in Alaska, sensors were perceived to be a good option for air monitoring.	There was a lack of confidence around data accuracy reported by the sensors. They need periodic calibration, they degrade over time and have poorer performance during the winter.
Outer Setting	Interviewees were motivated to provide support via hosting regular data reviews and webinars for technical guidance. Funding from state and/or federal grants was used for sustainability of programs. Relationships and trust with participating communities were established by contacting local Tribal environmental professionals, and holding in-person information sessions about the sensor network.	Interviewees reported feelings of suspicion among communities due to perceived government monitoring if they were to use the sensors.
Inner Setting	Sensor hosts were described as individuals with great familiarity with their community's technological infrastructure necessary for innovation implementation and sustainability. They relayed concern from Tribal communities over having to rely on visibility as a measure of air quality and interest in measuring air pollution from dust points to their motivation and mission alignment with the innovation. Network	Winter weather, power outages, and brown outages prevented sensor installation and service. Limited electrical outlets, extension cords, or access to specialized equipment disrupted sensor installation. Issues with access to Wi-Fi and electricity impacted sensor data access. Fast turnaround times among some sensor host roles, coupled with lack of available time, resources, or requirements to participate in low-cost air quality monitoring, prevented

Domain	Facilitators	Barriers
	organizers provided (or planned to) support via air quality advisory services and guidance documents.	communication with sensor network organizers. Interviewees reported community concerns over how much Wi-Fi and electricity a sensor uses, resulting in unplugging them, prioritizing other electricity needs.
Implementation Process	Engagement with community representatives with environment-focused roles was described as beneficial to the implementation. To improve the implementation process, network organizers discussed purchasing more sensors specifically for replacing those in need of maintenance, using strategies to increase sensor tolerance to extreme weather variance and snowfall, and having access to a designated representative from the sensor company at the time of install.	Cost of travel expenses to install sensors in rural communities was cited as a prominent use of funds, with ~$1000 per community visit.
Implementation Outcomes	None identified	It was unknown whether communities were using their sensors after installation. Interviewees identified a need for education among communities on wildfire smoke, air quality, and their impacts on health.

Key informants had not previously investigated the innovation's impacts and were unable to provide insights on implementation outcomes. While we considered key informants as individuals of the *Outer Setting*, they provided valuable perspectives about the *Innovation* and *Inner Setting* domains. These formative interviews provided the necessary context to design a survey tool targeted to sensor hosts.

III. Survey

We designed the survey tool using CFIR constructs aligned with our key informant interviews and incorporated the aforementioned six of Proctor et al.'s Eight Implementation Outcomes[13] to systematically collect data on implementation outcomes and sensor host perspectives. We wrote survey questions based on the emergent themes from the rapid analysis of key informant interviews, and asked questions on information pertaining to sensor host role, installation motives, challenges faced during installation, maintenance concerns, relative priority of various environmental hazards, air quality information of interest to participants and their community, how they have accessed air quality data from their low-cost sensor, risk perception of wildfire smoke and dust, feasibility of accessing and interpreting air quality data in their community, use of their sensor's data, and sensor installation and operation status. We designed the survey tool to automatically end after the first set of risk perception questions if a participant indicated that they have never hosted a low-cost sensor. The full survey tool is presented in Appendix A. We asked a total of 59 questions including primary and branching questions. Fourteen questions asked about risk perception of poor air quality, wildfire smoke, dust, and other environmental hazards. Nineteen questions asked participants about their role as a sensor host, their community's characteristics, and installation of their sensor. Ten questions asked about sensor maintenance. Seven questions asked about their use of low-cost sensor data, and nine questions asked about information or education needs for themselves and their community.

We designed and administered the survey using the secure web application for online surveys, Research Electronic Data Capture (REDCap).[61] This application facilitated question/answer format, distribution, and the tracking and collection of survey response data. Members of the JUSTICE-HIA project team who currently host a low-cost sensor were invited to pilot the survey. Four project partners completed the survey and were included in the analysis. We conducted participant outreach targeting previous and current low-cost sensor hosts within the 27-community network established by UAF researchers and any other current or previous low-cost sensor host in Alaska. Sensor hosts from the UAF network were sent survey invitations via REDCap, and a public survey URL was shared with other low-cost sensor network organizers in Alaska for dissemination. To complete the survey, participants had to acknowledge that they were over the age of 18 and consent to the use of the data collected for this study. They were also asked to provide their name and mailing address, and were sent a $25 gift card via mail as compensation. Lastly, they were invited to participate in a follow-up conversation to learn more about their experience hosting a sensor in their community.

Survey responses were tracked and stored using REDCap. After the survey period, participant responses were de-identified and exported from REDCap for analysis. Descriptive statistics were calculated. Categorical ordinal answers (such as Likert scales) were analyzed by calculating the average response within a five-point scale. Values of 1 through 5 were assigned to each response category: Strongly disagree/Very challenging to Strongly agree/Very easy respectively, and average response values for each question was calculated. Responses labeled as "I don't know" were excluded from these calculations. This assisted in determining the highest ranked barriers, facilitators, priorities, and concerns for the study population. Both quantitative and qualitative responses were inductively organized into the framework constructs to help identify barriers or facilitators to installation, maintenance, and use of low-cost sensors and their data.

IV. Follow-up Focus Group

Following the completion of the survey period, we invited four participants who expressed interest in providing additional details about their experience hosting a low-cost sensor to an optional follow-up focus group session. Three attempts were made to contact each individual and no responses were received. This aspect of the evaluation was therefore omitted.

Results

I. Inner Setting

A. Characteristics

In total, 17 survey responses–including one incomplete–were captured and included in the analysis. The incomplete response only captured the first survey section on risk perception before the participant exited the survey. It is believed that this individual was a member of an Alaska community as only specific email addresses associated with community members or workers in Alaska received a survey invitation, and therefore the response was still included. We received 16 complete responses, which on average took participants about 27 minutes, with a median time of about 14 minutes, to complete the survey. Sixteen communities were represented, with 11 participants each representing a unique community, two participants representing the same community as someone else, and three participants representing two communities.

Small communities with populations under 250 people accounted for 43.8% (n=16) of participants, followed by communities of 250-1,000 people (31.3%, n=16) and those with 1,000-10,000 residents (25%, n=16). Communities were located in either the Southcentral, Interior or Far North regions of Alaska. Figure 2 displays the communities with low-cost sensors where at least one sensor host submitted a response to our survey.

Of the 16 complete survey responses, over half of participants (56.3%, n=16) had roles related to environmental stewardship. This included environmental program officers, natural resource directors, and air quality specialists. The second-most common role represented was "community member" (37.5%, n=16). Other roles represented included Tribal contacts, library directors, and city IT directors. Most participants (93.8%, n=16) were previous or current hosts of a low-cost sensor, with 31.25% (n=16) hosting more than one sensor. One individual was not a sensor host but indicated that they knew the current host for their community's sensor.

We asked sensor hosts about their motivations for installing a low-cost sensor in their community. Most participants reported being motivated to measure wildfire smoke impacts on air quality (62.5%) and dust impacts on air quality (31.3%). Participants were also looking to inform community interventions or actions aimed at reducing exposure to poor air quality (31.3%). One individual expressed that they were motivated to install a sensor because UAF supplied their community with one.

Figure 2: Map of Low-Cost Sensor Communities Surveyed in Alaska

B. Relative Priorities & Risk Perception

Overall, participants expressed strong agreement that exposure to both wildfire smoke (94.1%, n=17) and dust (76.4%, n=17) may be harmful to the health of their community members, though participants' concern was higher for wildfire smoke than for dust (Figure 3). Less participants (64.7%, n=17) agreed or strongly agreed that there is evidence that using low-cost sensors to monitor air quality during air pollution events protects health. Some participants (29.4%, n=17) reported lack of knowledge about related evidence, pointing to a potential need for information around the use of low-cost sensors and how they could inform local air quality and promote behavior change to protect health. While most participants (70.6%, n=17) agreed or strongly agreed that monitoring air quality for their community and/or home is a top priority, with some disagreeing, felt neutral, or did not know (29.4%, n=17).

Figure 3: Participant Risk Perception on Air Pollution and Monitoring

Please rate your level of agreement with each of the following statements:	**Responses (n=17)**	**Mean (of 5)**
Exposure to poor air quality from **dust** may be harmful to community members' health.		4.71
Exposure to poor air quality from **wildfire smoke** may be harmful to community members' health.		4.94
There is evidence that the use of low-cost sensors to monitor air quality during air pollution events protects health.		4.76
Monitoring air quality for my community and/or home is a top priority.		4.18

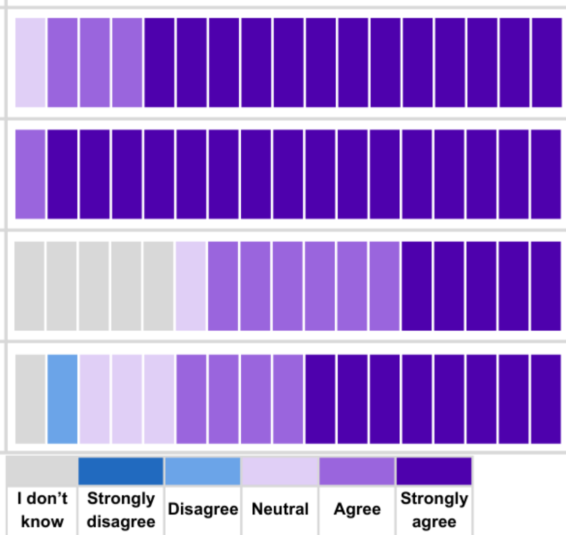
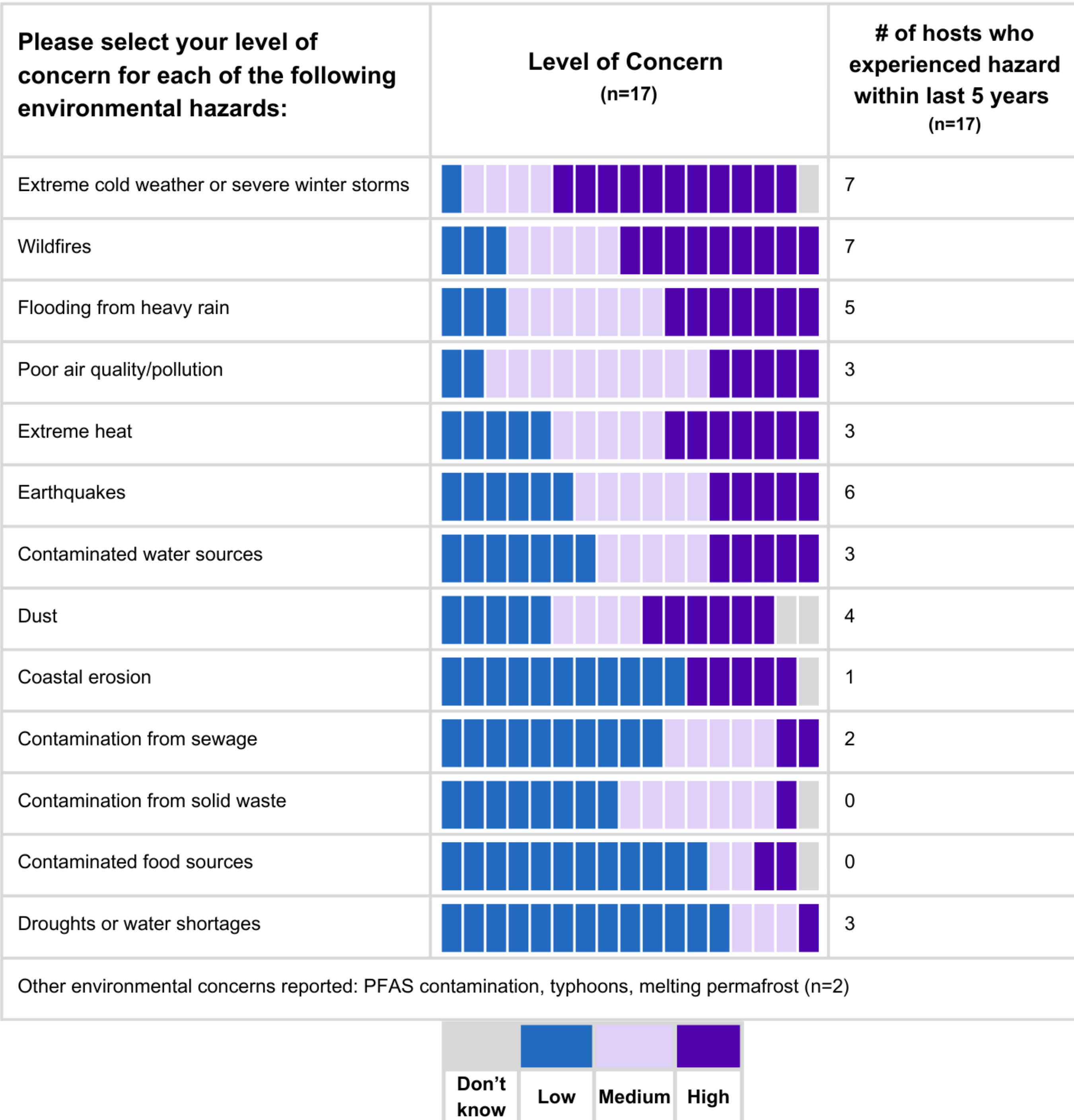


Figure 4 continues to reflect mixed priorities about wildfire smoke and dust air quality, showing how participants ranked their concern levels for different environmental hazards. The top three environmental hazards participants were most concerned about were (1) extreme cold weather or severe winter storms, (2) wildfires, and (3) flooding from heavy rain. These three were also reported as frequently experienced within the last five years. Two participants listed other environmental concerns including PFAS contamination, typhoons, and melting permafrost. Poor air quality and dust exposure were the fourth and sixth most cited concerns, respectively. This indicates that concern over air pollution within this study population may likely be episodic in nature.

Figure 4: Participant Risk Perception on Environmental Hazards



When comparing perceptions of health and community impacts between wildfire smoke and dust, participants agreed or strongly agreed that wildfire smoke, more so than dust, has negatively impacted the physical and mental health of people living in their community, as well as their quality of life (Figure 5). Overall, participants expressed that both pollutants–wildfire smoke and dust–negatively impact physical health, quality of life, and mental health of people in their community, in that order. However, participant perspectives about whether either pollutant has negatively impacted their community's culture or economic vitality varied, though more participants felt neutral toward the effect dust has on these aspects compared to wildfire smoke.

Figure 5: Participant Risk Perception on Wildfire Smoke and Dust

Please rate your level of agreement with the following statements: [Pollutant] has negatively impacted...	**Wildfire Smoke** (n=17)	**Mean** (of 5)	**Dust** (n=17)	**Mean** (of 5)
the physical health of people living in my community.		4.25		3.94
the mental health of people living in my community.		4.00		3.44
the quality of life of people living in my community.		4.19		3.56
my community's culture.		3.25		3.07
my community's economic vitality.		3.00		2.69

I don't know	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

II. Innovation

A. Characteristics of installation

Most participants reported using PurpleAir sensors (81.3%, n=16) in their community, with one using a QuantAQ Modulair sensor. More than half of participants (62.5%, n=16) expressed that sensor installation was "Easy" or "Very easy. Others either did not know or felt neutral about the difficulty of installation, indicating that they may have not installed the sensor themselves. Over half (56.3%, n=16) of participants indicated that their sensor was located at a government or Tribal building. Other locations included residential homes, churches, public restrooms, and libraries.

Half of participants knew when their sensor was installed, with four indicating that their sensor was installed in the summer months of 2019, and the rest reporting installment between 2015 and 2023. Seven of ten participants knew that their sensor was still installed, and five of these individuals knew that their sensor was still operating. These participants who indicated that they host a sensor that is no longer operating expressed reasons why, for example:

"Sensor was fried during a cold spell"
"Loss of internet connectivity and power at that location"
"At the time the Tribe did not have high speed internet"

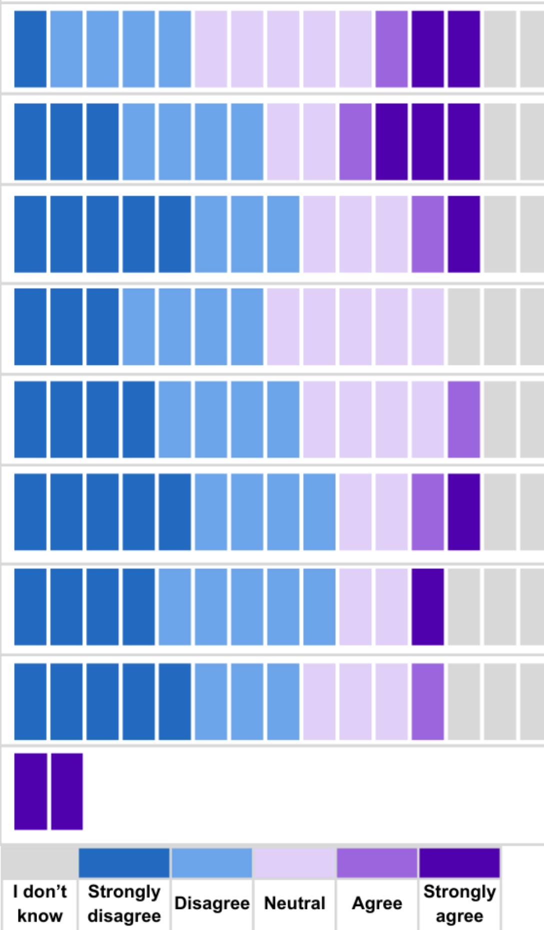
The third testimonial highlights a common barrier to installation and maintenance that was noted by both key informants and survey participants: lack of high-speed internet in their community.

B. Maintenance Factors

In general, participants expressed little concern over sensor upkeep. Most participants (81.25%) expressed that maintaining their low-cost sensor was easy or very easy. Figure 6 presents the level of agreement over various potential maintenance concerns. Overall, there was greater disagreement than agreement related to concern about the maintenance aspects presented. Still, participants expressed most concern over replacing the sensor when needed and concern over the sensor's ability to withstand environmental conditions. Other concerns expressed included: access to cellular service to download air quality data and extreme cold damaging or weakening cords providing power to the sensor. The lowest average level of concern reported by participants was related to the sensor's general maintenance, the amount of electricity required by their sensor, and the Wi-Fi bandwidth required to transmit data from the sensor.

Figure 6: Sensor Host Maintenance Concerns

Please rate your level of agreement with each of the following statements: I am concerned about...	Responses (n=15*)	Mean (of 5)
replacing the sensor, when needed.		2.92
the sensor's ability to withstand environmental conditions.		2.77
finding an alternative community/staff member to take over hosting/maintaining the sensor.		2.23
the cost associated with repairing or replacing the sensor.		2.16
repairing/servicing the sensor.		2.15
the Wi-Fi bandwidth required to transmit data from the sensor.		2.15
the amount of electricity used by the sensor		2.08
the sensor's general maintenance		2.00
Other: cell service for data download, extreme cold causes brittle cord (n=2)		



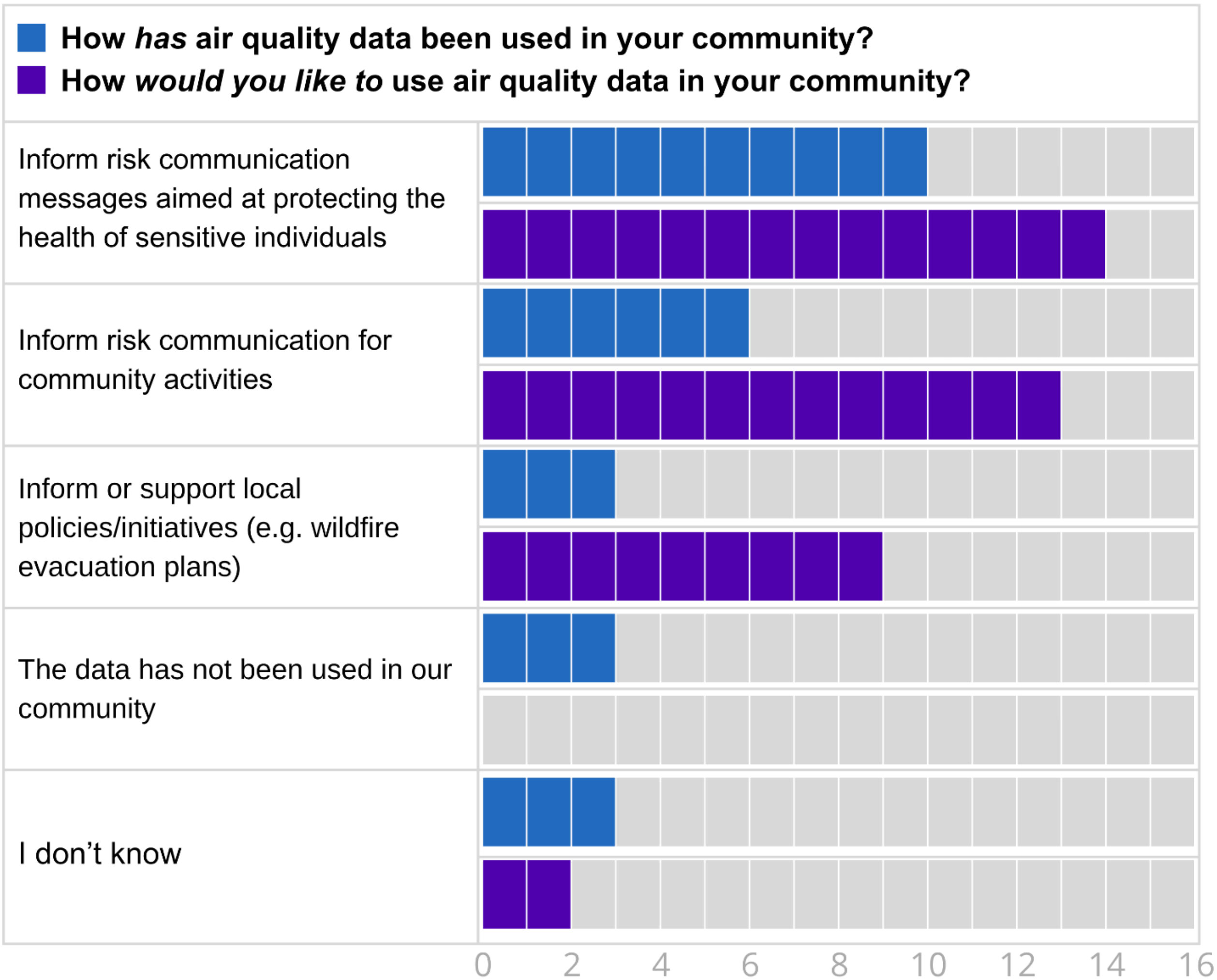
*One response removed due to missingness (NA: respondent who knows the host)

III. Implementation Outcomes

A. Data Access & Use

Most participants reported accessing data from their low-cost sensor through the PurpleAir website or EPA's AirNow website. Only three participants indicated that someone on their team knows how to use application programming interfaces (APIs) to request air quality data. These participants indicated using Microsoft Excel and R programming to analyze their data. Only two participants expressed that their community uses local air quality information to make smoke-related evacuation decisions, with one indicating that "*[their] community evacuates those vulnerable to smoke*". The rest of participants reported that their community did not use information in this way, or that they didn't know. As presented in Figure 7, the vast majority of participants indicated that they would like to use air quality data to inform risk communication for protecting the health of sensitive individuals (including elders, children, and individuals with pre-existing conditions), though only about half already do so. The same is true for using air quality data to inform risk communication for community activities (such as hunting and school field trips), though even less are already doing so. Lastly, only three participants have used air quality data to inform or support local policies or initiatives such as wildfire evacuation plans or dust suppression policies, though over half would like to do so. One respondent expressed using PurpleAir data from their sensor on a weekly basis to "fill in the gaps" for aerosol sampling.

Figure 7: Past and Prospective Uses of Air Quality Data Within Respondent Community



B. Information Needs

Most participants expressed agreement or strong agreement over concerns that their communities don't know how to access air quality data. The same was true over whether they perceived their community knows how to interpret air quality data, though with a slightly lower level of concern. Additionally, there was a lack of consensus among participants on their level of concern over Wi-Fi bandwidth or cellular connectivity limiting their community's access to local air quality data.

Types of air quality information that are of most interest to these sensor hosts include: (1) poor air quality forecasts for their region, (2) health impacts associated with wildfire smoke and dust, and (3) examples of household and community interventions/actions known to reduce exposure to poor air quality.

As for the information made available from using low-cost sensors, the most important time periods for the participants included: immediate data, recent trends, and long-term historical trends, in that order. Additionally, the most popular broader areas of interest for air quality information were watersheds and Alaska Fire Management Units. Alaska Native Corporation geographic boundaries and Alaska Game Management Units were tied as the third most popular areas of interest.

Types of information that participants reported to be of most interest to their community include: (1) health impacts associated with wildfire smoke and dust, (2) poor air quality forecasts for their region, (3) examples of household and community interventions/actions known to reduce exposure to poor air quality, and (4) instructions for how to access real time air quality data.

Participants believed that they would prefer to receive this information via a website or email, and that their communities would prefer to receive this information via (1) a website, (2) a social media campaign, (3) physical postings via a community message board, and (4) a brochure or newsletter/factsheet.

Discussion

I. Barriers

This study revealed that among hosts of low-cost air quality sensors in rural and Alaska Native communities, installation and general maintenance of these sensors were not perceived as challenging, though there are still perceived barriers to sustaining their use. The most prominent barriers were attributed to environmental conditions (extreme weather) and information technology infrastructure (electricity availability and Wi-Fi access). A similar study that assessed barriers and challenges with using low-cost sensors in Washington state found that participants were also concerned with lack of data capture if their sensor were to lose electricity or Wi-Fi access.[10] With regards to extreme weather, most of the communities surveyed in this study historically experience an average of 29 days (Southeast interior) to 47 days (Northeast Interior) below -22 degrees fahrenheit.[62] As the majority of the low-cost air sensors used by this group were outdoor PurpleAir PA-II sensors, these extreme winter temperatures pose conditions that exceed their 14 degree Fahrenheit operating temperature minimum,[63] creating potential for damage to the sensors or their power supply cords, resulting in need for earlier replacement. Short lifespans of low-cost sensors have been cited as a challenge in other assessments of low-cost sensors, as many are indicated to last anywhere from six months to a few years.[3] Coupled with extreme weather conditions, this increases the labor and costs needed to maintain or replace them. A prominent maintenance factor in other low-cost monitoring efforts is the need for frequent calibration to improve data accuracy as the sensor ages.[4] This study did not explicitly ask sensor hosts about calibration as part of maintaining their sensor, but one key-informant brought up during their interview how the sensor's need for periodic calibration as a barrier to keeping sensors online.

PurpleAir sensors also require a W-Fi connection to record and upload sensor data to their real-time air quality map.[42] While sensor network organizers indicated Wi-Fi access as a large barrier to installation, sensor hosts expressed little concern for this in regards to sensor maintenance, indicating this may be more of a challenge during installation. Sensor hosts' mixed perspectives on Wi-Fi as a barrier to use may be attributed to the varying level of Wi-Fi access across rural Alaska. Broadband internet access for most of Alaska's interior regions outside of Fairbanks North Star is limited, whereas the Southeast and parts of the Far North regions have more access.[64] Other low-cost air quality monitoring efforts have used sensors equipped with secure digital (SD) cards that do not require internet access to collect data,[65] which may be beneficial to monitoring efforts in Alaska. However, this data may be more valuable for retrospective versus real-time exposure assessments, given that data must be downloaded to assess exposure.

Other barriers influencing program implementation were around staffing, staff time, and resources, echoing other program evaluations using the CFIR.[66] Environmental program officer positions, the most common sensor host profession in this study, tend to experience staffing turnover that, coupled with lack of available time, resources, or requirements to participate in low-cost air quality monitoring, prevent maintenance efforts or the use of sensor data. Still, they are considered key individuals with great knowledge of their community's technological infrastructure, which is crucial for the innovation's implementation and sustainability.

II. Facilitators

Factors that facilitated sensor implementation included establishing relationships with local environmental health-focused individuals within target communities, such as environmental program officers. Partnering with these established professionals helped improve delivery and sustainability of the low-cost sensors within communities. Involving individuals from the community who have relevant training, knowledge, or experience with the particular health issue being addressed has been shown to promote cultural sensitivity and appeal of an intervention.[67] One such example is the involvement of community health workers in health disparities research, which has been shown to positively impact planning and delivery of community-based participatory research interventions.[67]

Sensor hosts expressing their motivation to measure impacts from wildfire smoke at the community level was also seen as a facilitator to implementation. Participant interest in immediate and recent air quality data and poor air quality forecasts for watersheds and Alaska Fire Management Units signify continued concern over wildfires and their environmental impacts. In a similar low-cost sensor network that recruited citizen scientists in a rural community of Washington State, researchers found that individuals involved were also motivated to participate in hosting a low-cost sensor partially because of their interest in air quality or environmental science, as well as their concern about health effects from wildfire smoke, especially for those most susceptible.[10] The presence of shared goals within the research-practice partnership has been identified as an important aspect of the community-engagement process that helps determine the success of evidence-based interventions.[68]

III. Implementation Outcomes

A major finding from this study is that sensor hosts are not currently using data from these sensors to make wildfire smoke-related evacuation decisions, though the majority are interested in using air quality data to inform risk communication messages and local policies or initiatives in their communities. This may be due to the aforementioned barriers, especially staffing considerations and lack of knowledge among low-cost sensor hosts on how to use APIs to request sensor data necessary for data analysis. This is one area in which sensor network organizers have the opportunity to influence implementation outcomes, by providing consistent educative support to sensor hosts that can allow them to gain the skills necessary for utilizing and interpreting their sensor's data. In the aforementioned Washington State low-cost sensor network study, sensor hosts reported using sensor data to inform individual-level actions to protect their health or the health of their family[10] rather than community-level actions. This may suggest that the use of low-cost sensors to inform exposure-reduction efforts are more actionable at the individual or family level, rather than at the community level.

This study also identified a need for education through web-based resources or social media campaigns around health impacts from wildfire smoke and dust, and examples of how to reduce exposure to poor air quality, such as seeking and using air quality data. Providing this education and emphasizing the importance of accessing local air quality data can help establish a receptive audience to promote innovation sustainability, as observed in other program evaluations.[69]

IV. Recommendations

The findings of this study support investments in both new and existing community resources to address the barriers to successful, sustainable low-cost sensor networks in Alaska. To combat weathering of low-cost sensors, sensor hosts can consider uninstalling their sensor prior to the winter months and then reinstalling once seasonal temperatures are within the sensor's operating range. Although this prevents year-round air quality data collection, it could improve the lifespan of the sensor, delaying the purchase of a replacement sensor. Alternatively, network organizers can consider utilizing sensors with alternative data collection methods that do not require an internet connection for underserved areas, such as sensors which use SD cards, though this impedes access to real-time air quality data.

Investments in workforce development could significantly improve the ability of the low-cost sensor network to drive public health outcomes. For example, providing additional training for sensor hosts on accessing, interpreting, and using data collected from their low-cost sensor could support their ability to utilize the data to trigger protective actions or a local alert program. Development of program instructions or standard operating procedures amongst network organizers and sensor hosts can improve the likelihood that sensors are maintained even during staffing changes. This can include a systematic record-keeping system that tracks sensor host information, sensor location, history, and maintenance, to inform subsequent hosts of the program and whether the sensor is due for necessary repairs or replacement. Additionally, examining the experiences of more recently established low-cost sensor hosts in Alaska could offer new insights into participant perspectives. In 2024, ADEC initiated their community-based air monitoring project using QuantAQ MODULAIR™ low-cost sensors, that provides supplementary real-time air quality data to their Air Quality Index dashboard.[70] Lastly, improving broadband internet infrastructure can support low-cost sensor functionality to report real-time air quality data, especially for areas in Alaska that do not have reliable internet.

V. Limitations

There were a number of limitations that affect the generalizability to other settings. The first, and likely most significant limitation, was the amount of time that passed between initial sensor network implementation and this study's evaluation. While the UAF network was established in 2019, this evaluation took place in late 2023 and early 2024. Staffing changes during the multi-year gap between the sensor network's deployment and its evaluation altered the participation of the original sensor hosts in our study. For example, it was difficult to contact the original sensor hosts as well as individuals who took on their roles after staffing changes. As a result, of the 27 communities that participated in the UAF program, 14 communities were not represented via a survey response. While these factors did not affect survey participation by other low-cost sensor hosts outside the UAF network, limited contact information still resulted in underrepresentation from other sensor networks.

Aim 2: Co-create story-based user guides to communicate the utility of a wildfire and air quality data tool

Co-Creation of Story-Based User Guides for a Climate Resilience Tool: A case study in Alaska for wildfire smoke exposure-reduction

Abstract

Alaska faces a wide range of climate-related hazards including increasing exposure to wildfire smoke, threatening public health across the state. Wildfire smoke exposure is especially of concern for the vast number of small, remote communities in Alaska who have limited availability of local air quality data. To address this, an EPA-funded co-production project involving researchers, and state and community representatives, aimed to improve access to climate and health information to support decision-making in Alaska. The team further developed an existing web-based wildfire information tool–the Alaska Wildfire Explorer (AWE)–to integrate real-time air quality data and current and forecasted smoke plumes. While this tool presents complex, wildfire and smoke data in an accessible manner, there is a need for tailored guidance on interpreting and applying this data to conduct vulnerability assessments and develop responsive adaptation strategies at the community and individual levels. In addition to enhancing the AWE with air quality information, the project designed story-based user guides to communicate examples of how to mobilize information presented in the tool to improve health during wildfire smoke events. We applied co-creation principles and a storytelling approach grounded in scientific and environmental communications, to develop communication products that are relevant and useful to various audiences most vulnerable to wildfire smoke in Alaska. We created five story-based user guides that showcase tailored strategies, framing each guide around a specific wildfire smoke-related use-case. Reflections on co-creation aspects that influenced the final public health communication products and recommendations for future co-production efforts are described.

Background

Alaska faces a wide range of climate-related hazards that threaten health, especially for its vast number of small, remote communities. The majority of these communities are far from the major population centers of Anchorage, Fairbanks, and Juneau, and are only accessible via boat or plane, making life-saving healthcare services difficult to access.[56] These communities are also home to large proportions of American Indian and Alaska Native peoples, ranging from 23% to 95% of the population in the Southwest, Interior, and Far North regions,[32] who face disproportionate rates of respiratory and cardiovascular diseases.[56] These health conditions can be further exacerbated by exposure to poor air quality, particularly during wildfire smoke events. The 2015-2024 decade has been defined by the greatest area burned on record in Alaska, with approximately 14 million acres burned.[23] As a result, Fairbanks has experienced more smoky days over this time period.[23] The city of Fairbanks has only experienced two smoke-free summers since 2000, where prior to then, it was common to see a summer without smoke.[23] Most recently between 2022 and 2024, three consecutive summers were characterized by more than 100 hours with moderate or worse air quality.[23]

Harmful particulate matter released in wildfire smoke is associated with exacerbation of asthma and increased hospitalizations due to respiratory effects when exposed.[20] Fine particulate matter ($PM_{2.5}$) is the primary pollutant of concern in woodland fire and is one of the six criteria air pollutants monitored under the US Environmental Protection Agency's (US EPA) Clean Air Act (CAA).[25] Agencies at the state, local, and Tribal levels use the highest-grade air quality monitors designated as federal reference method (FRM) or federal equivalent method (FEM) to monitor ambient $PM_{2.5}$ concentrations.[25] These regulatory air monitors are concentrated in urban areas and are not equally distributed across the U.S.[28] This disparity is seen even more prominently in Alaska, as only six federal-grade $PM_{2.5}$ monitoring stations actively collect air quality data for the entire state, and are all located in the three major population centers.[2,29] This leaves remote communities with little-to-no information on their level of exposure to air pollution, which is crucial to making public health decisions on community interventions such as health-risk messaging, establishing a clean air center, or evacuating individuals most at risk.

The JUSTICE-HIA project aimed to improve access to climate and health information to support decision-making in Alaska. Through a co-production process with state and community partners, the team identified a need for improved wildfire smoke information across the state. As a result, the team decided to pursue this goal by expanding on an existing statewide, web-based tool called the Alaska Wildfire Explorer (AWE). This tool, developed by the University of

Alaska Fairbanks Scenarios for Alaska + Arctic Planning team, originally provided geospatial information on locations and sizes of active wildfires and historical and projected fire-related variables throughout Alaska.[11] The JUSTICE-HIA team supported integration of ground-based, real-time air quality information from all sensor networks including the ADEC and PurpleAir sensors, and satellite-based information on current and forecasted smoke plumes into the tool.

Often, scientific data resources are tailored to other experts or researchers rather than practitioners, creating barriers for the translation of such information to non-scientific audiences. Without accessible evidence-based information, efforts to develop climate change vulnerability assessments or enact adaptation strategies at the local level can be difficult. The Alaska Wildfire Explorer tool improves the accessibility of complex environmental data through data visualizations and useful location-based stratification that allows community planners, health professionals, and even individual families to more easily access and interpret such data.

Still, there is a translational gap that limits the use of this data for adaptation interventions, especially at the community level. There is a need amongst various Alaska populations including the general public, public health practitioners, and Tribal health officers for tailored guidance on interpreting and applying the presented information from this data tool for community wildfire and smoke exposure assessments, and the development of responsive exposure-reduction strategies. These include decision-making at the community level, allocating resources, or eliciting change in behaviors, that can reduce exposure to wildfire smoke. By showcasing specific examples of how scientific evidence can be applied to enact such interventions, practitioners and lay users can better engage with and apply scientific data tools.[71]

A method that can be applied to both inform users of a climate and health tool and also relay tailored public health messaging is the use of story-based user guides. A user guide is a type of user manual that communicates the usability of a product, in order for the audience to perceive its utility (Fries, 2000). S*tory-based* user guides incorporate storytelling to frame a specific use-case that can more effectively tailor the guidance or messaging being communicated. A story-based format creates an accessible mode of communication that can more effectively speak to a user's unique concerns and priorities, supporting increased understanding and interest in scientific information presented.[51] Story-based user guides can be presented in many formats including illustrations, concise narrative descriptions, or verbal role-play.

Moreover, developing user guides through a co-creation process that actively involves end-users can ensure that guidance is tailored with culturally relevant messaging. Engaging in co-creation for public health research not only improves the effectiveness of outcomes but also enhances their cultural sensitivity.[72] We applied co-creation principles and a storytelling approach grounded in scientific and environmental communications, to develop story-based user guides that communicate how to use the Alaska Wildfire Explorer tool to inform strategies for reducing wildfire smoke exposure before and during smoke events. These guides showcase tailored examples of strategies for specific audiences in Alaska most vulnerable to wildfire smoke.

Methods

The primary aim of the JUSTICE-HIA project was to create locally-relevant and practical climate and health data tools for rural and Tribal communities through a co-development process that involved representatives from these communities as integral contributors. Central to the project were key aspects of co-creation including (1) bringing diverse people together as active and equal partners, (2) valuing all types of knowledge, (3) using creative approaches, and (4) applying iterative techniques.[71] Arguably the most important of these aspects when conducting community-engaged research, is facilitating a community-academic partnership that is guided by the health priorities identified by the specific communities involved.[73] The JUSTICE-HIA project aimed to prioritize this by involving key individuals who have deep, trusted relationships with their community, and are concerned about the health impacts from wildfire smoke. These partnerships, alongside the involvement of other Alaska state and local practitioners engaged in either wildfire management, air quality and/or public health planning, were essential to achieving our co-creation goals.

I. Project Team Characteristics

The JUSTICE-HIA Project Team is composed of climate and environmental health researchers (including developers of the Alaska Wildfire Explorer tool), state, local and Tribal public health practitioners, fire managers, an environmental social scientist, and liaisons from three Tribal communities and a regional Tribal organization in Alaska. Three of the environmental health researchers on the project led the team in co-creating the story-based user guides. All members of the Project Team were invited to participate in all steps in the story design process. Lastly, two comic artists were invited to visualize the user guides and help craft the narrative elements.

II. Group Commitments

During the initial meetings of the JUSTICE-HIA project, the Project Team developed group commitments that steered collaboration efforts at all subsequent work sessions. These commitments were group-sourced and included: agreeing to create inclusive meetings, setting clear expectations, collaborating with respect, and having clear communication. Inclusive meetings meant that we would prioritize conversation-based activities, create opportunities for diverse communication styles, accommodate meeting schedules, and incorporate opportunities to build relationships on a personal level. To set clear expectations, the group agreed to measure and share progress towards goals, designate clear roles, and outline objectives at each work session. In order to collaborate with respect in mind, the group also agreed to listen to all perspectives and adequately incorporate those perspectives into solutions, credit the team over individuals, and follow through with deliverables or communicating with others when a deadline could not be met. Lastly, we emphasized clear communication and transparency during email correspondence and in-person workshops.

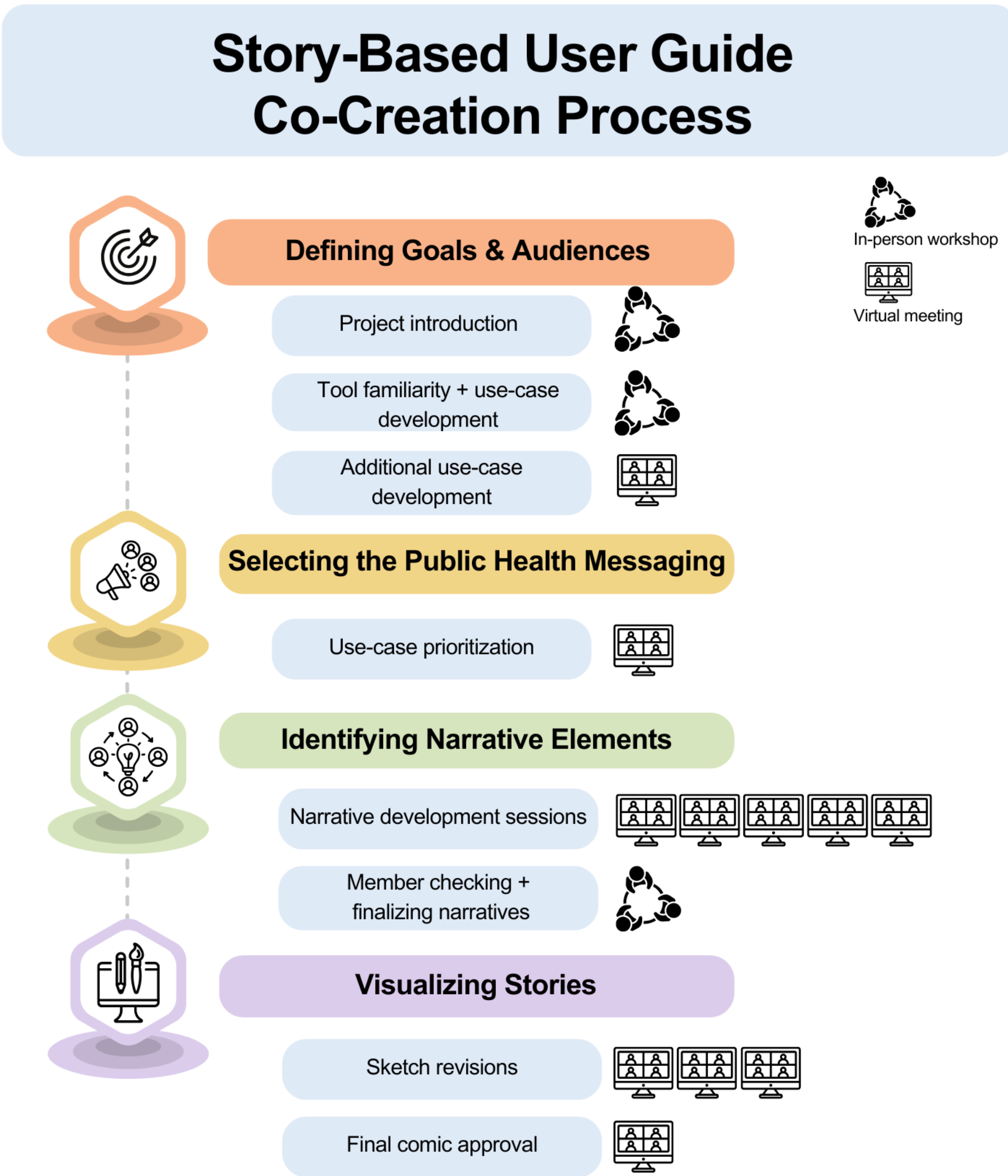
III. Collaborative Sessions

While the JUSTICE-HIA project involved semiannual in-person workshops and frequent ongoing virtual work meetings, the collaborative meetings focused on developing the story-based user guide took place across 15 months, including three in-person all-day workshops and eleven hour-long virtual meetings. At each of these meetings, we sought to establish a collaborative environment where everyone came to the table with a shared understanding of our group commitments and an acknowledgement of the group's diverse experiences and knowledge.

IV. Storytelling & Iterative Design Approach

We adapted a visual storytelling approach grounded in scientific and environmental communication outlined in Cortes Arevalo et al.[51] This framework highlights essential steps in designing science communication that enhance the likelihood of effective communication. Arevalo et al. argue that systematically designing effective science communication can help researchers support practitioners in better understanding new research outputs.[51] Here we applied the framework and its recommended practices to develop the stories for the user guides. The approach involves A) defining the audience goal, B) selecting the scientific content, C) identifying the story parts or narrative elements, and D) story visualization and presentation.[51] These steps were adapted to fit the context of this project, and are outlined in Figure 8, along with a description of activities conducted at each step.

Figure 8: Story-Based User Guide Co-Creation Process



A. Defining the Goals and Audiences

At an initial in-person workshop, we began by introducing the group to the concept of story-based user guides and presented examples to establish understanding of the communication method. We presented an outline of the overarching development process along with how and when members of the project team would participate. At this workshop, both the goal and target audience definitions were kept broad, yet were rooted in communicating the usability of the Alaska Wildfire Explorer tool for protecting health during wildfire smoke events in Alaska.

At a subsequent in-person workshop, the Project Team met to discuss tool updates and further establish familiarity with its functionality. Two developers of the tool conducted a demonstration of its various features and how to navigate it. Project Team members had the opportunity to ask about the tool's functionality, justifications for data organization and visualization, and to provide their feedback on tool usability. We then conducted an activity to brainstorm potential use-cases and users of the tool, alongside their possible health needs in the context of wildfire smoke events. This activity involved group discussions driven by questions developed using a community and resilience adaptation framework for climate-informed community planning, called the Rapid Vulnerability & Adaptation Tool (RVAT).[74] It outlines a four-step process for evaluating climate change vulnerabilities at the community level and identifying potential adaptation strategies.[74] Table 4 outlines the various questions the group discussed, organized by each step in the RVAT.

Table 4: Discussion Activity Questions by Rapid Vulnerability & Adaptation Tool Steps

RVAT Step	Discussion Questions
Project Scoping	● What are some public health issues/Indigenous health indicators that are a priority for your agency/community and are being or will be impacted by wildfire smoke? ● What aspects of the tool could help you identify adaptive capacity for your selected topic?
Vulnerability Assessment	● How could you use the AWE tool to assess how wildfire smoke is currently affecting or will affect your selected topic? ● How could you use the tool to identify the likelihood of wildfire smoke impacting your selected topic? ● How could you use the tool to determine the degree of consequence that would result from wildfire smoke on your selected topic?
Adaptation Strategies	● How could you use the tool to identify possible adaptation strategies to mitigate effects from wildfire smoke on your selected topic (in the near-future or long-term future)?
Adaptation Implementation	● How could you use the tool to determine how and when you would implement an adaptation strategy to reduce the impact of wildfire smoke on your selected topic?

From these conversations, the group identified use-cases related to various populations and settings in Alaska aiming to protect their own health or that of their family members or communities. The Alaska Wildfire Explorer tool is intended for use by anyone in Alaska, so it was important to frame the story-based user guides via use-cases that would be accessible and understandable to a diverse range of audiences. These use-cases were based on the diverse lived and learned experiences of those within the group. Due to limited time allotted for this activity, we held an additional discussion via a virtual meeting after the workshop to ensure that all Project Team members had the opportunity to contribute use-cases tailored to their priorities. Following these sessions, we summarized the list of potential use-cases and presented them back to the group at another virtual meeting for further refinement, validation, and prioritization. The group identified 10 unique tool use-cases and are summarized in Table 5 by its respective RVAT step.

Table 5. Brainstormed List of Use-Cases by Vulnerability & Adaptation Tool Step

RVAT Step	Tool Use-Cases
Project Scoping	• Identifying locations for future low-cost air quality sensors. • Informing occupational health and safety during smoke events. • Protecting susceptible populations including children, older adults, pregnant people, and those immunocompromised during smoke events.
Vulnerability Assessment	• Assessing the impact of wildfire and smoke on caribou migration using long-term flammability models. • Assessing snow cover for access to salmonberries. • Assessing the impact of wildfire and smoke on customary and traditional foods.
Adaptation Strategies/ Implementation	• Mitigating effects of wildfire smoke on community events using air quality forecasts to inform decisions around rescheduling an event or disseminating public health messaging. • Using flammability models to inform efforts in advocating for moving or extending hunting season due to wildfire and smoke impacts. • Normalizing tool use for air quality information similar to how weather forecasts are used to prepare for potential smoke conditions, showcasing caretakers of sensitive individuals. • Applying wildfire projections to inform grant applications for developing clean air centers or purchasing air filters for elderly community members.

B. Selecting the Public Health Messaging

Next, the Project Team reconvened over a virtual meeting to prioritize and refine the use-cases according to three group-defined criteria relevant to the context of health protection during wildfire smoke events. These prioritization criteria included: (1) targeting vulnerable populations, (2) highlighting key tool features, and (3) illustrating various exposure-reduction strategies. Additionally, use-cases that did not center around wildfire and smoke were omitted. This resulted in a list of five refined use-cases that were used to begin the narrative development process.

<u>Prioritized Use-Case List</u>

1. Community event planners or health officers using the near-future air quality forecasts to inform safety of community events that may be impacted by wildfire smoke.
2. Caretakers of susceptible populations using the real-time and forecasted air quality index (AQI) information to plan outings or outdoor activities and avoid poor air quality. Activities can include recreation, camping, gardening, etc.
3. Individuals using the active fires information and air quality forecasts alongside knowledge of the land to make decisions about where to harvest wild berries during an active fire.
4. Individuals from an urban setting using real-time and forecasted air quality information alongside local knowledge of the land to inform decisions on where to fish, to protect fisher's respiratory health.
5. Employers of outdoor workers using the real-time and forecasted AQI and active fire information to navigate occupational health and safety and provide employees with pertinent air quality and health information.

C. Identifying the Narrative Elements

Once the use-cases were identified and prioritized, the Project Team worked to define the narrative elements that would later help turn each use-case into a story. Team members were invited to participate in at least one of the five narrative development sessions, which took place via hour-long virtual meetings. During each session, the group brainstormed elements central to story development: defining the setting, the main character, the story's communication goal, acts or events that occur, the conflict, and the means to solve the conflict.[51,75] To fit the context of individuals experiencing a wildfire smoke event in Alaska, the group defined the overarching communication goal, the setting, the subjects, the outdoor activity, concerns and motivations during a wildfire smoke event, tool interaction, health-protection measures, and the explicit public health messaging to be relayed. Figure 9 presents a sample worksheet used during the pre-workshop narrative development meetings.

Figure 9: Narrative Development Session Worksheet

User Case:
Decision making for Wild Berry Harvesting

Overarching communication goal: Making decisions about where to harvest wild berries during an active WFS event using the active fires map and the 48 hour smoke projections in addition to local knowledge of the land.

Audience: General audience, families with sensitive individuals, rural residents

Setting/Scene
What is the outdoor event? Where is it? Who will attend? Possible smoke conditions?

- Boating to a specific berry location
- Late june/early July in the YK region for cloudberry harvesting (ripen late July early August)
- Snowpack could potentially be low, cloudberry conditions might not be optimal, plays into sense of urgency

Subject
Who will use the WFE tool to make decisions for this event?

- A family in a rural community OR IGAP officer informing the community?
- Adult informs their elder parent on health effects OR teenage grandchild prompts the WFE tool to their family
- Then the grandchild expresses their concern for their grandparents health, which convinces the elder to decide for themselves that they want to stay at home instead

Objective
What is their conflict or concern due to the wildfire smoke event?

Physical/emotional health concern:
- Health effects from wildfire smoke

Other concerns:
- Which day of the week might have less smoke exposure
- Type of berry might have a shorter harvesting window (cloudberries become too soft at some point)

Objective(s):
- Keeping family members safe during their harvesting trip

Plan
What tool feature might they use and how/when? What information do they learn?

Tool features: AQI, AQ forecast, active fire data, lightning strikes, fire danger ratings, hotspots, projected flammability
- Day of: Checking the real-time AQI value in the area they will harvest berries
- Day of: Checking if there are any active wildfires near them/their harvesting location
- Longer-term planning: learning whether the area where they have historically harvested berries has a higher projected flammability
- Picking a window using the smoke projection, picking a different location along the river, deciding to go later
- Wind conditions, could be that wind might pick up in the afternoon, so decide to go in the morning

Resolution
Specific messaging to audience. How does the subject use information from the tools to help them achieve their objectives?

- E.g. highlight different options:
  - Educate their family members on health risks from WFS
  - Decide to wear PPE as a family
  - Shorten the time they spend outside harvesting?
  - Having a conversation about different berry harvesting locations that they could go to
- A "go" checklist or to-do list
  - Baskets, inhalers, N95s, data sources, emergency backpack, WF/WFS plan (with coordinates of location)
- Make decision of who should go - final panel can show family boating off with fire in the distance

During the narrative development meetings, the group combined some use-cases and shifted the contexts of others. This was done in order to further iterate on the aforementioned prioritization criteria. Among these changes, the group sought to connect the diverse characters and storylines presented in the five use-cases, to create a holistic communication product. This resulted in adapting one of the more general use-cases into an introduction story that connected prominent characters from the other use-cases. This introduction also provided an opportunity to include a knowledgeable character who presents the tool, its features, and communicates to other characters, and subsequently the reader, important public health messaging aimed at reducing exposure to wildfire smoke.

To accommodate for these changes when summarizing the final narrative elements, we adjusted the target audiences, tool features, or exposure-reduction strategies to better fit the context of the updated use-cases. These story summaries delineated important story elements, including the setting, subjects, objectives, and resolution, as well as elements of the public health messaging, including the focused audience, vulnerable populations being addressed, tool features highlighted and how the subjects interact with them, the level of air quality pollution, and the demonstrated exposure-reduction measures. Table 6 presents a sample summary of the story elements, and Table 7 presents a sample of the public health messaging elements for the same story.

Table 6: Sample Narrative Elements Summarized

Story	Cloudberry harvesting during a wildfire smoke event
Setting	Rural: A Yukon-Kuskokwim community near a river.
Subjects	A tribal family including a teen, a parent, and an elder.
Objectives	The family plans to boat along the river to get to their cloudberry harvesting location. They want to go harvesting but also consider the grandparent's health due to the wildfire smoke.
Events + Tool Interaction	Early morning of event: *Teenager remembers learning about the Alaska Wildfire Explorer and pulls up the tool on their phone.* They see that the AQI level for the area they will be harvesting in is currently in the moderate category, however when they check the air quality forecast they see that the next day when they plan to go harvesting, the air quality is forecasted to be worse. The teenager mentions this around the breakfast table and a discussion ensues with initially those not concerned for the next day's air quality. The teenager expresses concern that the worsening poor air quality may be bad for the elder's health and convinces the family that it is important to consider. Because it is peak cloudberry season, they still plan to go, but they reschedule their day to leave and return earlier - before the air quality is projected to worsen. They prepare to leave by referencing their "go" checklist: baskets/containers, N95s, emergency backpack, wildfire/smoke plan, coordinates of their harvesting location, etc.
Resolution	The family returns with full containers of cloud berries just as the air quality begins to worsen. End scene of the elder and teen preparing a dish with cloudberries in a room with their HEPA air cleaner.

Table 7: Sample Public Health Messaging Elements

Focused Audience	General, tribal communities, sensitive populations, rural
Specific Sensitive Populations	Elders
Tool Features	Real-time AQI and air quality forecasts
AQI Level	Real-time: Moderate Forecasted: Unhealthy for Sensitive Individuals
Exposure-Reduction Measures	Deciding when to leave for and return from harvesting area according to the Alaska Wildfire Explorer to avoid poor air quality

At a third in-person workshop, we conducted a member checking process where the story summaries were presented back to the Project Team to further refine and reach full group consensus on all story elements. Member checking is a technique used in qualitative research that involves participants in confirming the accuracy of qualitative data, as well as its analysis or interpretation.[76] This process ensured that the stories reflected accurate portrayals of people, settings, and cultures in Alaska, especially those of rural and Tribal communities. At this meeting, the comic artists were invited to participate in story development and facilitate the transition from narratives to visual stories. The group spent one hour discussing and iterating on each of the five stories. We started each session by reviewing the proposed story. We then invited feedback and discussed specific elements that had not yet been agreed upon by the whole group, and brainstormed visual elements that would later help the artists adapt the stories into illustrations. Each hour-long session involved small and large group discussions led by one or two researchers, who helped synthesize ideas to reach group consensus on all story elements. Following this workshop, the story elements were updated based on these discussions and were again summarized, and delivered to the artists for adaptation. Table 8 presents a sample of the final story elements for the Berry Harvesting story.

Table 8: Final Narrative Elements - Berry Harvesting Story

Story	Cloudberry harvesting during a wildfire smoke event
Setting	A rural setting such as in the Yukon-Kuskokwim region near a river. A family's home. Hazy conditions in the distance.
Subjects	A tribal family including a teen, a parent, and an elder.
Objectives	The family plans to boat along the river to get to their cloudberry harvesting location. They want to go harvesting but also consider the grandparent's health due to the wildfire smoke.
Events + Tool Interaction	• Early morning of event, the teenager remembers conversation about the Alaska Wildfire Explorer at the solstice event and pulls up the tool on their phone. • The elder and teen review the tool together, and see that the AQI level for the area they will be harvesting is currently unhealthy for sensitive individuals, however the AQ forecast says it's predicting better air quality in the evening. • The elder makes the decision that the family should go later in the day to avoid the poor air quality. It is peak berry season so they prioritize going. • They prepare to leave by referencing their "go" checklist: baskets/containers, N95s, emergency backpack, communication device, telling their contact where they're going, bear spray, gun, life jackets on the boat. • Family boats to location wearing life jackets.
Resolution	The family is seen picking berries and collecting them in plastic buckets along the river. Visual components depict a collaborative effort with lots of hands seen picking berries. If picking on a hillside, elders are down below, youth higher up, and the Elder has the most berries in their bucket. If extra space: visual of making jam with the berries.

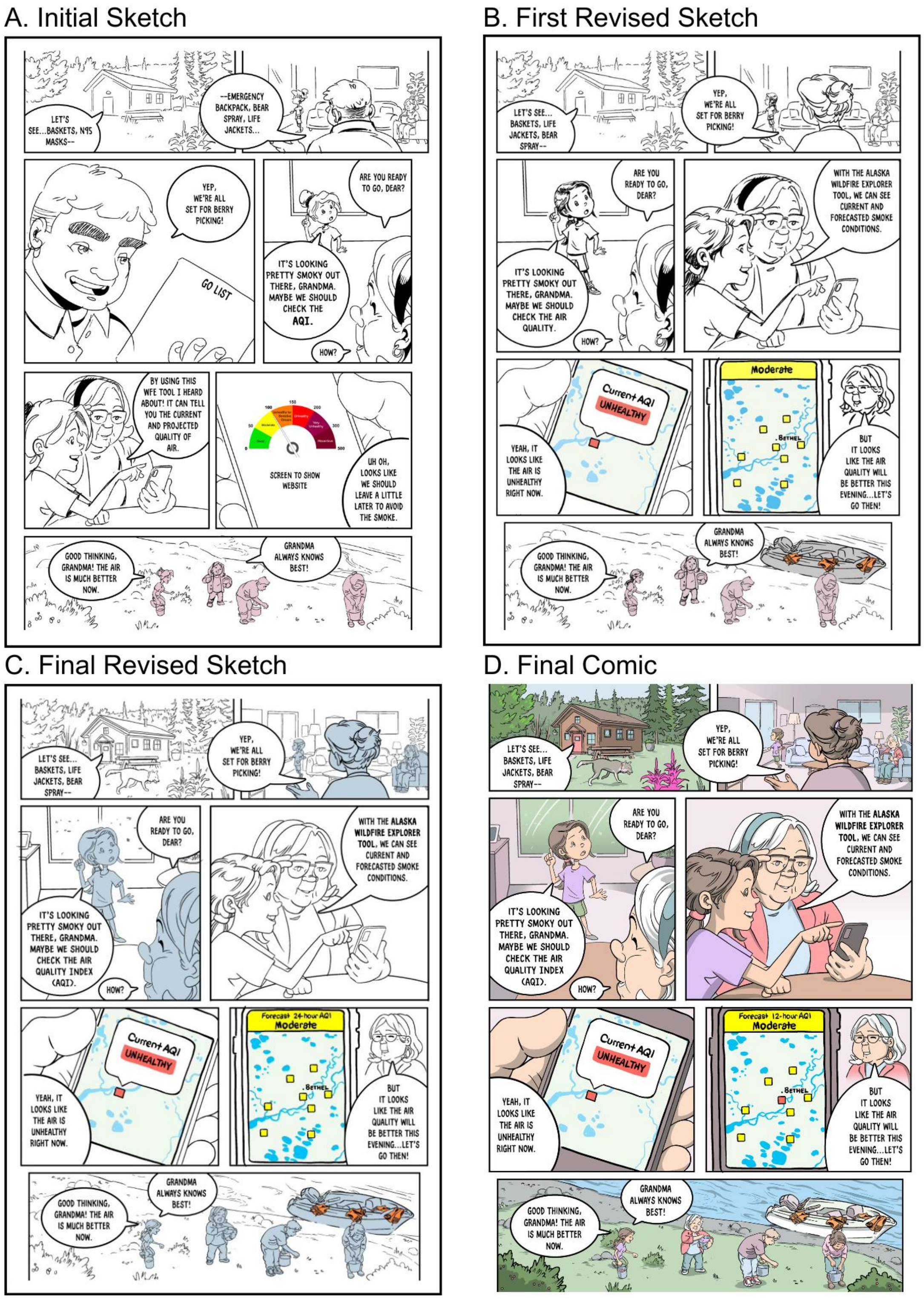
D. Story Visualization and Presentation

During the second workshop, the group had discussed potential formats that would be most accessible for a story-based user guide about the AWE tool, with options including: video, video series, infographics, comics, physical pamphlets, and audio/podcasts. The group agreed that a user guide presented as a physical pamphlet would be best received by most individuals and could be easily handed out at health fairs or clinics to those who were looking for information about wildfire smoke and guidance on how to protect one's health. The group sought a format that could be easily printed by anyone, with the flexibility to present the story guides individually to ensure relevance for specific audiences. The group decided that we would develop the story-based user guides into a short comic book format, as well as stand-alone comic strips featuring each of the stories.

The creation of the user guide visuals was done in four stages, with rounds of member checking in between: Initial sketches, revised sketches, final sketches, then final illustrations. First, the artists adapted the five stories into initial sketches formatted via one or two-page comic strips and wrote accompanying dialogue. These sketches were first reviewed by the lead design team to verify that the illustrations and dialogue accurately reflected the intended public health messaging. The artists incorporated these changes to produce revised sketches, which were then shared with the rest of the Project Team. Three hour-long virtual meetings were scheduled to conduct a member-checking process with Project Team members.

The Project Team suggested revisions to improve public health communication, cultural accuracy and representation, and verify that the proposed storylines made sense in comic format. Additional member checking allowed for feedback on the potential interpretation of the user guides, and gauging elements of understanding, clarity, and presentation. We then sent the suggested changes from this process to the artists, who incorporated them to render the final sketches before fully illustrating the comics in full color.

Figure 10: Iterations of the Berry Harvesting Story Comic



Product

The final story-based user guide comic book depicts five stories of various populations interacting with the Alaska Wildfire Explorer tool to protect health during a wildfire smoke event. The first story depicts an outdoor community event where a knowledgeable fox character informs a group about active wildfires and how they can protect their health when there is poor air quality due to wildfire smoke. The fox character introduces the concept of the air quality index (AQI) and who is most at-risk of adverse health effects when air quality worsens. They then learn about the AWE tool as a resource for locating active wildfires, and with real-time and forecasted air quality information presented geographically. The comic then includes actions that one can take to reduce exposure to wildfire smoke, and characters from this first story take their new knowledge into their own situations that unfold after learning about the wildfire smoke event and the AWE tool.

Figure 11: Introduction Story Comic Strip 1

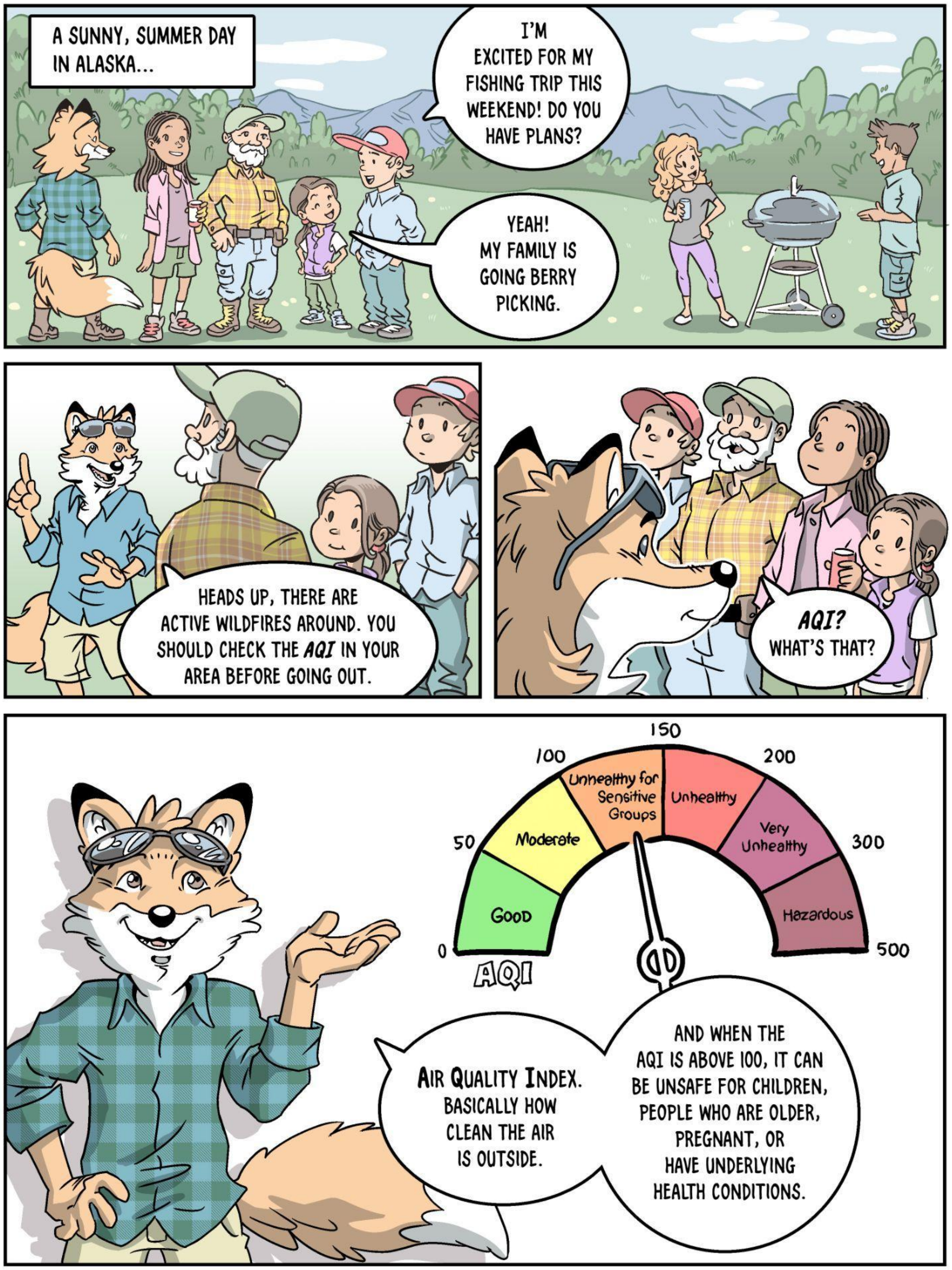
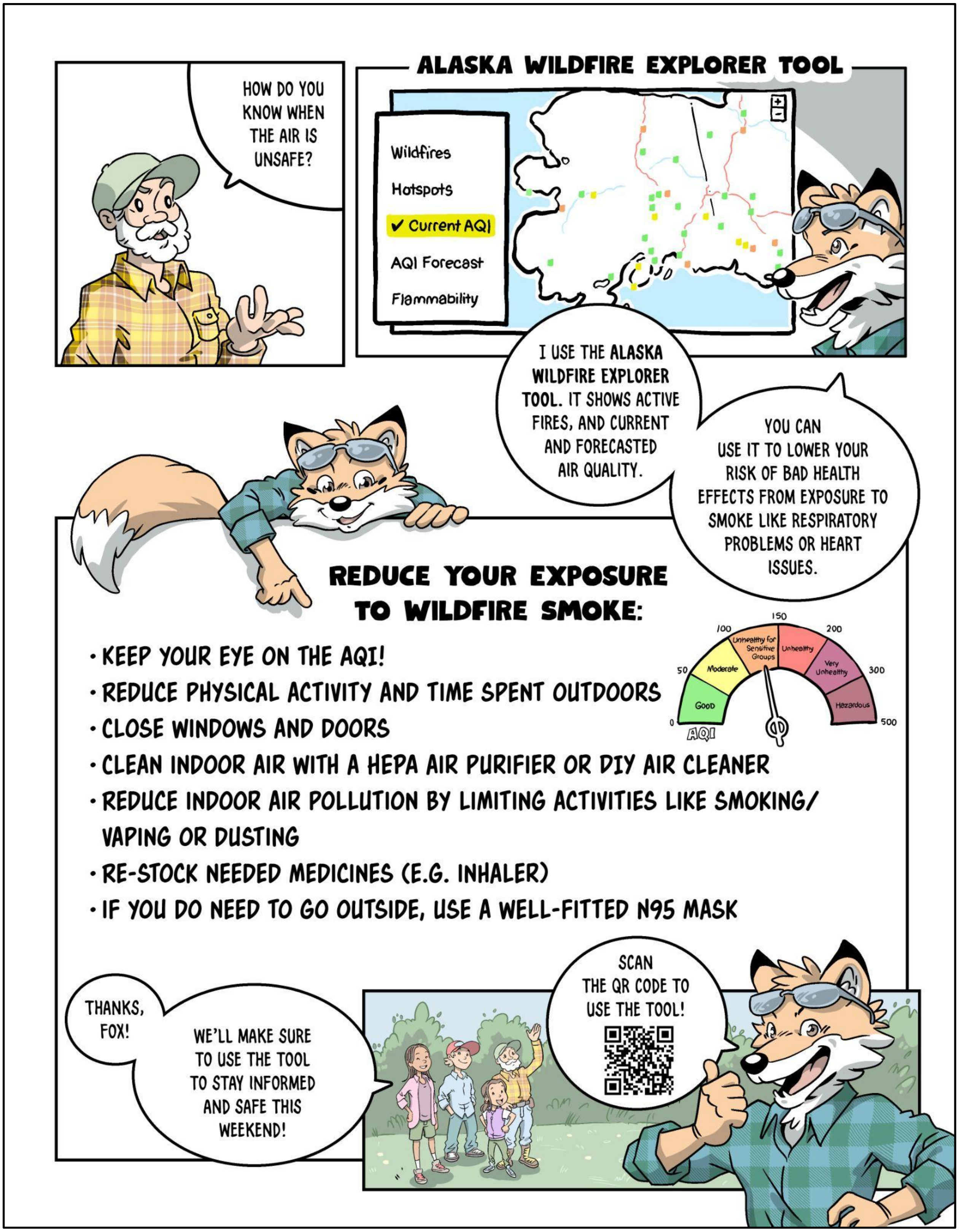
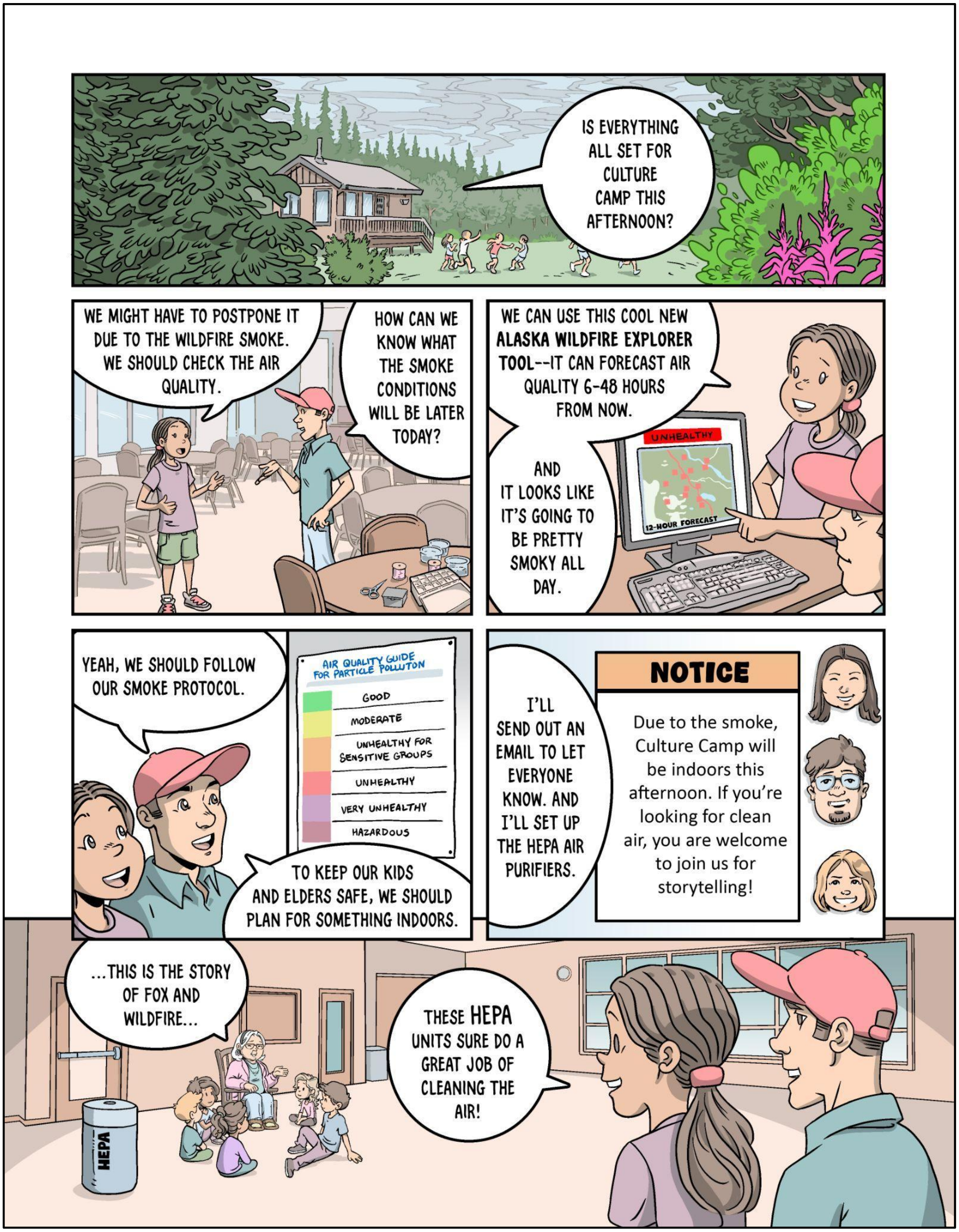


Figure 12: Introduction Story Comic Strip 2



The Culture Camp story depicts counselors of a summer culture day camp making decisions about adjusting their planned outdoor activities to protect the health of the children and elders at the camp. They are shown using information from the air quality forecast on the Alaska Wildfire Explorer tool along with their smoke protocol to decide to move activities indoors. They also send out notices to their community members about this decision and invite them to their clean air space if needed. The final panel features an elder leading a storytelling activity and a high-efficiency particulate air (HEPA) unit to filter out any smoke that may have entered the building, portraying what a clean air space may look like for this community.

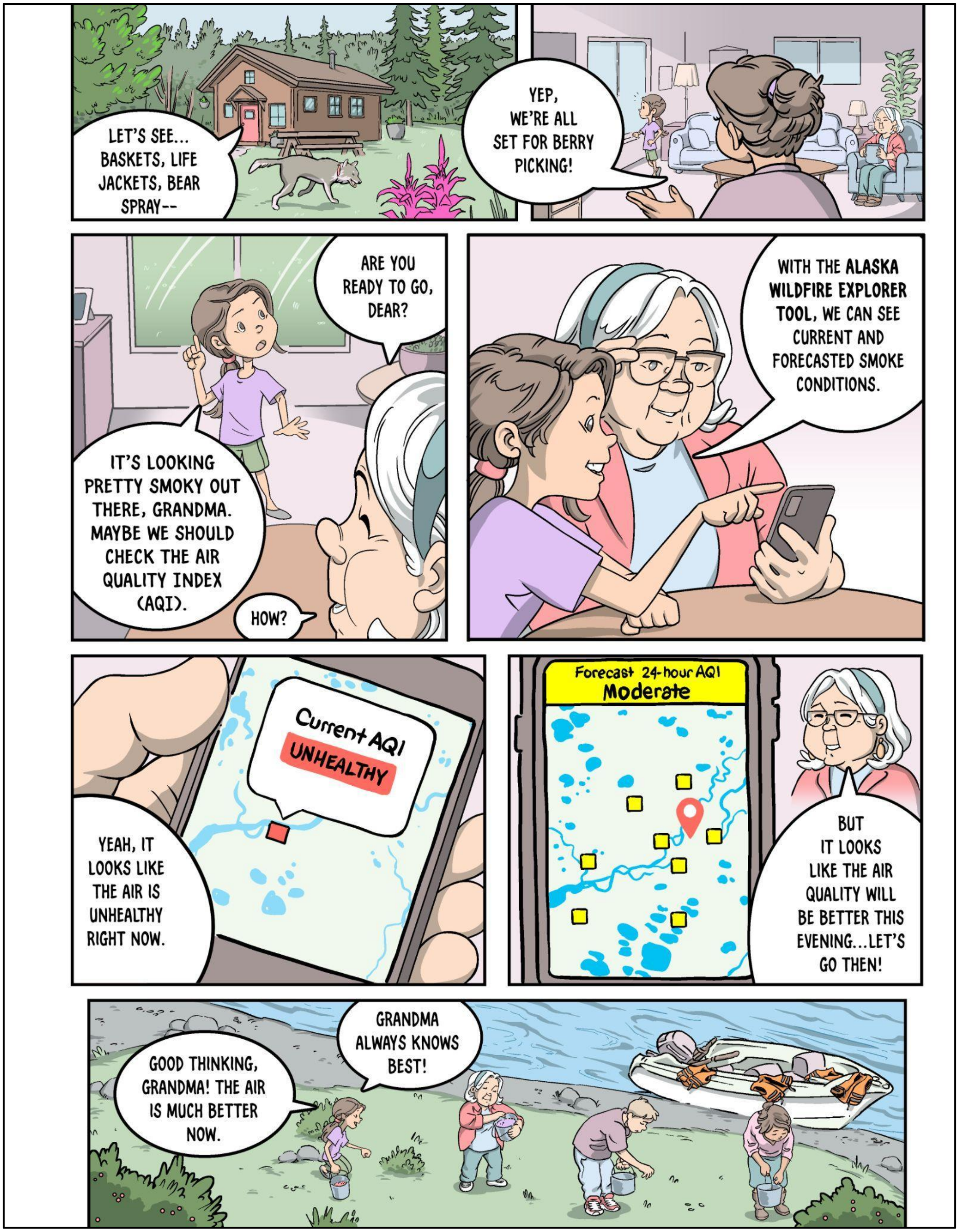
Figure 13: Culture Camp Story Comic Strip



The berry picking story evolved from showcasing only the forecasted air quality feature on the AWE, to then also showcasing the current AQI feature, to more clearly communicate how these two features can be used in conjunction to inform when it may be safer to spend time outdoors during a smoke event. This led to the omission of depicting the family's "go-list" originally intended to communicate various important safety considerations when conducting an activity outdoors during a smoke event. Due to the limited number of panels available to tell this story, the group decided to instead include one panel to showcase the AWE's current AQI feature that helped the family make their health-protecting decision. Additionally, visual features were added throughout the comic that more realistically portrayed a rural home in Alaska, including a chimney on the house, a dog playing in the yard, wildflowers outside. Additionally, a boat with four life jackets–one for each member of the family–was included in the concluding panel to highlight how many rural communities frequently travel via rivers, as well as the importance of water safety when doing so.

The final berry picking story depicts a family in their home preparing to go boat along the river to their berry picking location, when one of the children notices the wildfire smoke outside. From recently learning about the AQI from the fox character in the introduction story, the child teaches their elder about the AWE tool to check the AQI. They learn together that the air quality is set to improve later that evening. This prompts the elder to make a decision about changing the time at which they go on their berry picking excursion, to avoid the poor air quality. This story reflects actions taken by both young children and older adults to protect their family's health, while still prioritizing food traditions important to their culture.

Figure 14: Berry Picking Story Comic Strip



The dipnetting trip story follows a group of young friends planning for a road trip to a location to fish for salmon, when one group member expresses their concern about the effect of the wildfire smoke on their asthma condition. Another friend introduces the AWE tool and how they can use the forecasted air quality feature to pick a new location that might have better air quality, so that the friend with asthma can still go on the trip without being exposed to as much smoke. This story highlights not only important considerations for individuals with respiratory conditions during a wildfire smoke event, but also showcases how others around this individual can support them using information on the AWE.

Figure 15: Dipnetting Story Comic Strip

The work party story portrays a group of brush clearing volunteers in a wooded area using the AWE tool to check the air quality forecast. They are depicted to be in good health, with no overtly susceptible individuals. They learn that the air quality for later in the day is forecasted to be unhealthy for all, but they decide to continue their work due to other factors that they want to prioritize. Their group lead also expresses the availability of N95 respirators that they could use to reduce their exposure to the smoke if necessary. As time goes on, the group starts to experience physical symptoms from smoke exposure, prompting their decision to end their work early. This story showcases how the Alaska Wildfire Explorer tool can help inform decision-making, but also communicates the importance of paying attention to one's own physical symptoms as an indicator to adjust your activity, environment, or personal protection for reducing exposure to wildfire smoke.

Figure 16: Work Party Story Comic Strip

Discussion

The final story-based user guides communicate five stories of how various audiences can apply air quality data and smoke forecasts from the Alaska Wildfire Explorer tool during a wildfire smoke event to protect health. The stories depict at-risk individuals including younger children, older adults, those with respiratory conditions, as well as generally healthy individuals, to communicate how people of all ages and health statuses can be affected by wildfire smoke depending on the severity. The final product was heavily influenced by an iterative co-production process, rooted in an understanding of group dynamics, the use of flexible discussion-based in-person collaboration sessions, and the iterative user needs-based narrative creation process that helped tailor the final communication goals.

I. Co-Production Process

Before beginning the user guide development process, the co-production team had already established a working relationship through their collaboration on related projects within the larger JUSTICE-HIA Project. This helped promote a shared understanding of the needs of everyone at the table, which allowed for tailoring the production process to accommodate for the group's dynamic, experience, knowledge, priorities, and communication styles. For example, previous collaboration sessions involving this group found success through flexible semi-structured discussions, which influenced the use of a similar structure for the narrative development sessions. This style of group interaction worked especially well during the in-person workshops, as it provided ample opportunity for discussion, brainstorming, and exploration in a physical space. It facilitated the group to establish the overarching communication goals, provided an environment where everyone was given a voice, and the opportunity for all to develop a sense of ownership of the work. Moreover, by using a creative and discussion-based approach anchored by our group commitments, we were able to develop trust and confidence that everyone's contributions were met with openness and would help drive exploration. This was most poignant during the iterative parts of the narrative development phase.

Moreover, by initially keeping the overarching communication goal for the user guides broad, we enabled the goal-defining process to be grounded in co-production. This approach allowed information needs expressed by community liaisons and state and local government representatives part of the project to directly inform and shape the specific communication goals. Specifically, using the RVAT framework helped the group identify an initial set of needs and circumstances relevant to individuals in the Project Team, as well as the communities they serve, during a wildfire smoke event. However, in subsequent work sessions where we prioritized the use-cases and conducted member checking, additional or related information needs emerged, which further shaped the communication goals. While this evolution of the communication goals helped ensure that the final product had tailored messaging, it also prevented the group from starting off with a complete conceptual idea of the final product. It is a tradeoff that is important to be aware of when conducting co-production efforts, dependent on the type of style or project.

II. Recommendations for Future Story-Base User Guides

While these user guides showcase potential use cases of the AWE tool that were brainstormed by this Project Team, future design efforts for story-based user guides can also consider showcasing real examples of users applying the tool. By doing so, audiences may feel more encouraged to use the tool in a similar way to protect their health, based on seeing positive outcomes experienced by a real person. Showcasing real examples can be facilitated by setting the right conditions for tool engagement. For example, the Alaska Wildfire Explorer tool is a time-varying data tool that is only active during spring and summer months when wildfires are most common. Therefore by prompting intended users to apply the tool under specific conditions, in this case during wildfire season, they can be better equipped to speak on how they have interacted with the tool, to inform story development. This was unfortunately not feasible for this project due to project timeline constraints, and made use-case development, and in turn, story development, reliant on the perspectives and assumptions of the project team.

III. Future Evaluation Efforts

While the JUSTICE-HIA Project incorporated an evaluation of the overall co-production processes, it did not plan for an assessment of the intended (or unintended) outcomes that may result from the story-based user guides. Evaluating the effectiveness and impact of public health interventions is critical for determining whether they achieve their intended objectives to optimize future efforts.[13] We recommend that future studies assess the degree to which these story-based user guides effectively communicate or promote behavior change to protect health during wildfire smoke events among the target populations in Alaska.

A method that could be used to conduct this evaluation is a framework based in Participatory Health Research (PHR) that details principles and recommendations for evaluating a co-created public health intervention.[77] It expands beyond PHR methods to include methods to formally test the effectiveness of co-created interventions developed at a local level.[77]

It proposes that researchers first develop a logic model that outlines how the potential mechanism of the intervention might lead to positive health outcomes, then test the intervention's effectiveness at both the local and population levels using a formal positivist research framework such as a randomized controlled trial, where the co-created intervention is compared to a similar intervention that did not use co-created methods (i.e. top-down approach).[77]

Another potential approach to evaluation is through the use of a Knowledge, Attitudes, and Practice (or Behavior) (KAP or KAB) study.[78] A KAP study is a widely accepted method for investigating health-related behaviors where participants are surveyed about what is known, believed, and done with regards to a topic of interest.[78] Participants can be surveyed prior to being exposed to specific public health messaging and then again after being exposed, to measure changes in their knowledge, attitudes, and behaviors. Relevant KAB studies have looked at factors that influence adoption of air pollution protective measures, and found that the likelihood of enacting health protective measures to reduce their exposure to air pollution is influenced by perceived barriers and knowledge of air pollution.[79]

Additionally, the story-based user guides can be evaluated through a science communication lens using the Retell, Identify, Remember and Contextualize (RIRC) framework that uses memory to assess learning.[80] It measures a subject's ability to retell, identify, remember and contextualize information that can be used to evaluate how memorable the user guides are, increasing the likelihood of adoption or of mimicking health protection behavior.[80]

Conclusion

The main goals of these studies were to (1) describe the barriers and facilitators to the implementation and use of low-cost air quality sensors and (2) develop story-based user guides for wildfire risk communication through a co-production process based in Alaska. We found that although low-cost air quality sensors were not perceived as challenging to install and maintain, Alaska's extreme winter weather, internet infrastructure, and limited staffing capacity allocated to low-cost monitoring posed barriers to the sustainable use of the sensors. Still, the process of implementing low-cost sensor networks in Alaska was facilitated by partnering with local environmental health-focused community members due to their robust knowledge of their community's infrastructure and their shared motivations to assess health impacts from wildfire smoke. This evaluation also revealed that although some surveyed communities use air quality data to inform risk communication messages and local initiatives to reduce exposure to air pollution, the vast majority would like to. Additionally, most sensor hosts are not currently using data from their sensors to make wildfire smoke-related evacuation decisions. In addition to the expressed need for information on air quality forecasts and health impacts of wildfire smoke, this highlights an opportunity to offer further education on these topics to communities and low-cost sensor hosts in Alaska. This finding directly influenced Aim 2. Further, this study provides evidence to support investments in both new and existing technological and workforce infrastructure to address the barriers for a more resilient air quality monitoring system in Alaska.

The final story-based user guides communicated five stories of how various audiences can apply air quality data and smoke forecasts from the Alaska Wildfire Explorer tool during a wildfire smoke event to protect health. The final product was heavily influenced by elements of the co-production process, rooted in an understanding of group dynamics, the use of flexible discussion-based in-person collaboration sessions, and the iterative user needs-based narrative creation process that helped tailor the final communication goals. We suggest future evaluations be conducted on the effectiveness of this story-based user guide comic in promoting and eliciting behavior change among target audiences in Alaska. By highlighting the value of co-creation principles and story-based user guide development methods, this study may help shape future public health communication strategies.

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Appendix A. Aim 1

Appendix A1. Key-Informant Interview Questions by Framework Domains and Constructs

Domain	**Construct**	**Key-Informant Interview Questions**
Intervention		
	A. Relative advantage	Why was this particular type of air quality monitoring instrument selected?
	B. Complexity	How complicated do you perceive this low-cost air quality sensor to be?
	C. Adaptability	[No specific question asked]
Outer Setting		
	A. Local attitudes	What kind of policies, regulations, guidelines, or other factors influenced the decision to implement this low-cost air quality monitoring system?
	B. Local conditions	What kinds of changes or alterations do you think would make the low-cost air quality monitor(s) work more effectively in your setting?
	C. Financing	Can you provide an overview of your community-based air monitoring pilot project?
	D. Partnerships & Connections	Who are the key influential individuals you need/needed to get on board with this implementation?
	E. Policies and Laws	What kind of policies, regulations, guidelines, or other factors influenced the decision to implement this low-cost air quality monitoring system?
Inner Setting		
	A. Structural	

	Characteristics	
	1. Physical infrastructure	Can you provide an overview of your community-based air monitoring pilot project? What do you think the primary challenges will be that your organization will face when implementing this community-based air quality monitoring network?
	2. Information Technology infrastructure	Can you provide an overview of your community-based air monitoring pilot project? What do you think the primary challenges will be that your organization will face when implementing this community-based air quality monitoring network?
	3. Work infrastructure	Can you provide an overview of your community-based air monitoring pilot project? What do you think the primary challenges will be that your organization will face when implementing this community-based air quality monitoring network?
	B. Culture	What kind of policies, regulations, guidelines, or other factors influenced the decision to implement this low-cost air quality monitoring system? Who are the key influential individuals you need/needed to get on board with this implementation? What do you think the primary challenges will be that your organization will face when implementing this community-based air quality monitoring network?

	C. Learning-centeredness	[No specific question asked]
	D. Relative Priority	[No specific question asked]
	E. Mission Alignment	[No specific question asked]
	F. Access to knowledge & information	Do you already meet with the people who will be hosting sensors regularly or do you expect to? Or will this be 1:1 meeting style?
Individuals		
Roles and Characteristics	A. Roles and Characteristics	
	1. Implementation leads	[No specific question asked]
	2. Innovation deliverers	[No specific question asked]
	3. Innovation recipients	[No specific question asked]
Implementation Process		
	A. Assessing Context	Can you describe how your organization evaluates its low-cost air quality monitoring efforts? Can you describe any lessons learned from implementing low-cost air quality sensors in Alaska, and if and how your organization is planning to incorporate these lessons into future iterations of air quality monitoring implementation? Was the air monitoring network implemented according to plan?

		What are the primary challenges your organization faces when implementing this low-cost air quality monitoring network?
	B. Tailoring Strategies	What kinds of changes or alterations do you think would make the low-cost air quality monitor(s) work more effectively in your setting?
	C. Engaging	What have you done or plan to do around community engagement or evaluation of your existing communities/sites?
	D. Assessing Needs	What questions should we ask community members and sensor hosts about their sensors/experiences hosting a sensor?
Proctor's Implementation Outcomes		
	A. Adoption	[No specific question asked]
	B. Appropriateness	How well do you think this low-cost air quality monitoring network meets the needs of the individuals served by your organization?
	C. Cost	[No specific question asked]
	D. Feasibility	[No specific question asked]
	E. Penetration	What are those individuals saying about the air quality monitoring system now?
	F. Sustainability	[No specific question asked]

Appendix A2. Key-Informant Interview Rapid Qualitative Analysis Summaries by Framework Domains and Constructs

Domain	Construct	Key-Informant Interview Questions
Intervention		
	A. Relative advantage	The use of low-cost air quality sensors was seen as an inexpensive and low-energy use method to capture air quality data in rural areas. PurpleAir sensors were specifically credited with being "the best tool" to measure particulate matter due to their user-friendly design and ease of use, including their web-based map for accessing air quality data. With the improvement of wifi infrastructure throughout Alaska, PurpleAir sensors were seen as a good option for the state. Still, there was a lack of confidence around the quality and accuracy of data reported by low-cost sensors.
	B. Complexity	Calibration and/or colocation were reported as necessary aspects of using low-cost sensors--due to degradation over time--which was reported to disrupt/diminish the longevity of the intervention. The modems used in AQMesh sensors required replacements to function with newly available 5G networks, rendering a months-long disruption to the intervention. PurpleAir sensors were reported to perform better during the summer than in winter in Fairbanks, AK, due to the varying temperatures and humidity levels.
	C. Adaptability	AQMesh sensors should not be exposed to extreme temperature variations, therefore lack easy adaptability to winter weather in Alaska. Additionally, AQMesh sensors use sim cards that were not compatible with Alaskan phone carrier GCI, which made the intervention difficult for newer or more rural communities with only GCI service.
Outer Setting		

	A. Local attitudes	The outer setting expressed motivations to support the implementation including providing regular data reviews to fulfill communities' requests for baseline air quality data, intentions to provide regular webinars for technical guidance, and by expressing an understanding of the differing health priorities within rural communities.
	B. Local conditions	Winter weather, power outages, and brown outages are the main environmental and technological conditions that prevent sensor installation and sensor service. Winter weather conditions also prevent travel to a sensor's intended or current location, disrupting troubleshooting or maintenance. Challenges were cited when attempting to set up PurpleAir sensors to wifi, though reports of increased broadband internet infrastructure throughout Alaska are seen as beneficial for the intervention. Lastly, political conditions included reports that communities felt suspicion towards the potential use of low-cost sensors for government monitoring.
	C. Financing	All of the low-cost sensor network programs receive funding through state and/or federal grants, though supplementary funding was used or needed. The DEC program was supplemented by funding from Indian General Assistance Program (IGAP), and UAF expressed that the intervention requires funding from a federal agency to support the labor necessary to maintain this work.
	D. Partnerships & Connections	UAF was able to establish relationships with local Tribal residents through the Institute for Tribal Environmental Professionals to recruit sensor hosts. Once implementers were invited to a community, efforts to garner trust among residents involved offering foods less commonly found in the area to initiate conversations about the intervention.
	E. Policies and Laws	Expressed that low-cost sensors could also be used to make sure AQ standards are being followed at mine sites or similar industry locations, especially for dust. Regulations and/or permitting

		requirements may influence decisions to implement sensors.
Inner Setting		
	A. Structural Characteristics	
	1. Physical infrastructure	The physical infrastructure of the inner setting was characterized by a lack of electrical outlets or extension cords, disrupting sensor installation. Additionally, there is limited access at times to specialized equipment for reaching and troubleshooting sensors.
	2. Information Technology infrastructure	Sensor data access was impacted by issues with wifi and electricity access.
	3. Work infrastructure	Work infrastructure characteristics that did not support the intervention included hosts' general disinterest or relocation, more individuals than anticipated being needed to help maintain the sensors, hosts may have multiple roles unrelated to the intervention which reduced available time to communicate with the outer setting about it. Environmental program officers were not obligated to participate in the intervention and these roles have fast turnaround times, reducing uptake and sustainability of the intervention. Despite this, they were cited as individuals with great familiarity with a community's technological infrastructure (i.e. wifi, power outlets, etc) to facilitate implementation.
	B. Culture	Culture within the Inner setting is exemplified through key informants' awareness of the impact of wildfire smoke events on summer subsistence activities and those with respiratory issues. Additionally, permission from Tribal administrators was often required before implementing the intervention. There were accounts from individuals in the Inner setting about having less interest in understanding the level of air contamination during a wildfire smoke event, due to its enjoyable smell.

	C. Learning-centeredness	
	D. Relative Priority	Concerns over how much wifi and electricity a sensor was using and unplugging sensors to use electrical outlets for other purposes indicated other activities were prioritized over the intervention. Additionally, it was presumed that most individuals do not evacuate during a wildfire smoke event to protect their health due to them coinciding with subsistence work.
	E. Mission Alignment	Tribal communities expressed concern over having to rely on visibility as a measure of outdoor air quality, indicating their need for the intervention. Though, communities expressed greater health concerns over high dust contamination during dry spring seasons. Alaskans are used to dealing with poor air quality from winter emissions and wildfire smoke, therefore communities were interested in low-cost sensors to better understand impacts from dust.
	F. Access to knowledge & information	For the two ongoing sensor network programs, one provides air quality advisory services available to anyone every summer, and the other program had plans to provide sensor hosts with guidance documents and quality assurance templates. Additionally, there were plans to increase education on air quality within communities through collaborative efforts.
Individuals		
Roles and Characteristics	A. Roles and Characteristics	All key informants were considered Innovation Deliverers ("individuals who are directly or indirectly delivering the innovation") and all but one were considered implementation leads (those "who lead efforts to implement the innovation"), with the other being an implementation team member (those "who collaborate with and support the Implementation Leads to implement the innovation").

	1. Implementation leads	Four of the five interviewees can be considered implementation leads
	2. Innovation deliverers	One of the five interviewees can be considered an innovation deliverer.
	3. Innovation recipients	N/A
Implementation Process		
	A. Assessing Context	Cost of travel expenses to install sensors in rural communities was cited as a prominent use of funds, with ~$1000 per community visit. Good Wi-fi connection and electricity were crucial for sensor maintenance, and reported as the main barrier. Delays in sensor installation or troubleshooting were caused by the company's different timezone (AKT vs. BST for AQMesh sensors). Quality assurance paperwork requirements by the EPA were cited as a barrier to sensor deployment.
	B. Tailoring Strategies	Strategies that were employed or would be employed upon reflecting on the barriers and facilitators of implementation include purchasing more LCSs than needed for a particular network, to serve as replacement sensors when deployed sensors need calibrating or co-location. Strategies to address sensor tolerance to extreme weather included incremental temperature acclimation to prevent cold shock, and protection from intense snowfall through installation of additional sensor coverings. For troubleshooting during sensor installation, a designated individual from the sensor company or a person with equivalent knowledge was seen as a potential facilitator.
	C. Engaging	All key informants discussed engaging with individuals with environment-focused roles within Tribes to recruit as new sensor

		hosts. This engagement was done by contacting environmental program officers, or soliciting individuals that were personally affected by poor air quality.
	D. Assessing Needs	One key informant perceives that there is a need from the recipient communities for education on wildfire smoke, air quality measurements (i.e. AQI), and their impacts on health.
Proctor's Implementation Outcomes		
	A. Adoption	There was a lack of knowledge about whether communities were using their sensors after installation.
	B. Appropriateness	While the key informants felt optimistic about interest in the intervention, funding opportunities, and its utility within the target communities, there was uncertainty in how sensor hosts were using the data collected, if at all.
	C. Cost	N/A
	D. Feasibility	N/A
	E. Penetration	One sensor network did not receive communications from sensor hosts after installation, and attributes this to a lack of reliable internet access. At the time, Wifi was often exclusively accessed via public networks in buildings such as Tribal offices or schools.
	F. Sustainability	N/A

Appendix A3. Survey Questions by Framework Domains and Constructs

Domain	**Construct**	**Key-Informant Interview Questions**
Intervention		
	A. Relative advantage	[No specific question asked]
	B. Complexity	On a scale of 1 to 5, how challenging was it to install the sensor(s)? • 1 = Very challenging • 2 = challenging • 3 = neither challenging nor easy • 4 = Easy • 5 = very easy • Not applicable • Don't know Skip Logic: If 1 or 2, What were the factors that made installation challenging?
	C. Adaptability	[No specific question asked]
Outer Setting		
	A. Local attitudes	[No specific question asked]
	B. Local conditions	Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): • I am concerned about .... • the sensor's general maintenance • repairing/servicing the sensor • replacing the sensor, when needed • finding an alternative community/staff member to take over hosting/maintaining the sensor • the cost associated with repairing or replacing the sensor • **the sensor's ability to withstand environmental**

		conditions ● **the wifi bandwidth required to transmit data from the sensor** ● **the amount of electricity used by the sensor** ● other (please describe): _______
	C. Financing	Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): I am concerned about .... ● the sensor's general maintenance ● repairing/servicing the sensor ● replacing the sensor, when needed ● finding an alternative community/staff member to take over hosting/maintaining the sensor ● **the cost associated with repairing or replacing the sensor** ● the sensor's ability to withstand environmental conditions ● the wifi bandwidth required to transmit data from the sensor ● the amount of electricity used by the sensor ● other (please describe): _______
	D. Partnerships & Connections	Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): ● I am concerned about .... ● the sensor's general maintenance ● repairing/servicing the sensor ● replacing the sensor, when needed ● **finding an alternative community/staff member to take over hosting/maintaining the sensor** ● the cost associated with repairing or replacing the sensor ● the sensor's ability to withstand environmental conditions ● the wifi bandwidth required to transmit data from the sensor ● the amount of electricity used by the sensor ● other (please describe): _______

	E. Policies and Laws	[No specific question asked]
Inner Setting		
	A. Structural Characteristics	
	1. Physical infrastructure	What community is the low-cost sensor located in? (fill in the blank) What is the community's population? ● Less than 250 ● 250-1,000 ● 1,000-10,000 ● More than 50,000 ● I don't know Where is the sensor installed? ● Clinic ● Library Government building ● School ● Residential home ● Other Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): I am concerned about .... ● the sensor's general maintenance ● repairing/servicing the sensor ● replacing the sensor, when needed ● finding an alternative community/staff member to take over hosting/maintaining the sensor ● the cost associated with repairing or replacing the sensor ● **the sensor's ability to withstand environmental conditions**

		• the wifi bandwidth required to transmit data from the sensor • the amount of electricity used by the sensor • other (please describe): _______
	2. Information Technology infrastructure	What kind of sensor was installed? • PurpleAir • AQMesh • DustTrack (portable handheld unit) • QuantAQ Modulair • Don't know • Other Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): I am concerned about .... • the sensor's general maintenance • repairing/servicing the sensor • replacing the sensor, when needed • finding an alternative community/staff member to take over hosting/maintaining the sensor • the cost associated with repairing or replacing the sensor • the sensor's ability to withstand environmental conditions • **the wifi bandwidth required to transmit data from the sensor** • **the amount of electricity used by the sensor** • other (please describe)
	3. Work infrastructure	Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): I am concerned about .... • **the sensor's general maintenance** • **repairing/servicing the sensor**

		● **replacing the sensor, when needed** ● **finding an alternative community/staff member to take over hosting/maintaining the sensor** ● the cost associated with repairing or replacing the sensor ● the sensor's ability to withstand environmental conditions ● the wifi bandwidth required to transmit data from the sensor ● the amount of electricity used by the sensor ● other (please describe): _______
	B. Culture	[No specific question asked]
	C. Learning-centeredness	What was the motivation for installing an air quality sensor in your community? (Check all that apply) ● Local air quality information was requested by community members ● Inform community interventions/action aimed at reducing exposure to poor air quality ● inform government interventions/action aimed at reducing poor air quality ● Inform government policy (state or federal) / rule making over dust generating sources ● Supplement regulatory monitoring station information ● Collect data to inform future grant applications ● To measure dust impacts to air quality ● To measure wildfire smoke impacts to air quality ● Don't know ● Other (please specify) What time periods are important to you when using air quality data? (Check all that apply) ● Long-term historical trends (over years or decades) ● Recent trends (over weeks, days, or hours) ● Immediate data (what is happening right now) ● Near future predictions (next few days)

		• Long term future predictions (next few years) • Other Are you interested in air quality information for these areas? (Check all that apply) • Watersheds • Alaska Native Corporation geographic boundaries • Alaska Fire Management Units • Ethnolinguistic regions of Alaska • Alaska Game Management Units (GMUs), e.g. GMU19a, etc. • Statewide • Other
	D. Relative Priority	Please select your level of concern (Low, Medium, High, Don't Know) for each of the following environmental hazards. Please also indicate whether your community has experienced any of these hazards within the last 5 years. Contaminated food sources • Droughts or water shortages • Dust • Earthquakes • Extreme cold weather or severe winter storms • Extreme heat • Flooding from heavy rain and/or sea level rise • Poor air quality / pollution • Sewage • Solid Waste • Wildfires • Other
	E. Mission Alignment	Please select your level of concern (Low, Medium, High, Don't Know) for each of the following environmental hazards. Please also indicate whether your community has experienced any of these hazards within the

		last 5 years. Contaminated food sources • Droughts or water shortages • Dust • Earthquakes • Extreme cold weather or severe winter storms • Extreme heat • Flooding from heavy rain and/or sea level rise • Poor air quality / pollution • Sewage • Solid Waste • Wildfires • Other _____
	F. Access to knowledge & information	What information is of interest to YOU? (check all that apply) • Poor air quality forecasts for your region • Health impacts associated with wildfire smoke • Health impacts associated with dust • Examples of household and community interventions/actions known to reduce exposure to poor air quality • Instruction on how to access real time air quality data for my community • Instruction on how to download and use local, historical air quality data for decision/policy making in my community • Basic installation, maintenance, and troubleshooting for our community air quality sensor(s) • Other _____ What platform would be best for YOU to receive this information? (check all that apply) • Website • Webinar • Brochure or newsletter / factsheet

		• Social media • Radio • Email • Direct outreach from community member • Physical postings via a community message board • Other _______________ What air quality information do you think YOUR COMMUNITY needs? (check all that apply) • Poor air quality forecasts • Health impacts associated with wildfire smoke • Health impacts associated with dust • Interventions/actions known to reduce exposure to poor air quality • Instruction on how to access real time air quality data • Instruction on how to download and use local, historical air quality data for decision/policy making • Basic installation, maintenance, and troubleshooting for sensors • Other ____________________ What type of platform would be best for YOUR COMMUNITY MEMBERS to receive this information? (check all that apply) • Website • Webinar • Brochure or newsletter / factsheet • Social media campaign • Radio • Direct outreach from community member • Physical postings via a community message board • Other ____________________
Individuals		
Roles and	A. Roles and	What is your role in the community where the sensor is/was located

Characteristics	Characteristics	(select all that apply)? ● Environmental program officer (e.g. IGAP coordinator) ● Public health or healthcare provider ● Air quality specialist ● Community Member ● Other ______________ Do you currently host/maintain a low-cost air quality sensor in your community (e.g. PurpleAir sensor, AQMesh sensor, DustTrack, QuantAQ Modulair, etc)? ● Yes ● No ● No, but I hosted a sensor in the past ● No, but I know of someone else who hosts/maintains a low-cost sensor in my community Do you host more than one low-cost sensor for your community? ● Yes ● No
	1. Implementation leads	[No specific question asked]
	2. Innovation deliverers	[No specific question asked]
	3. Innovation recipients	[No specific question asked]
Implementation Process		
	A. Assessing Context	On a scale of 1 to 5, how challenging was it to install the sensor(s)? ● 1 = Very challenging

		• 2 = challenging • 3 = neither challenging nor easy • 4 = Easy • 5 = very easy • Not applicable • Don't know Skip Logic: If 1 or 2, What were the factors that made installation challenging?
	B. Tailoring Strategies	[No specific question asked]
	C. Engaging	[No specific question asked]
	D. Assessing Needs	What information is of interest to YOU? (check all that apply) • Poor air quality forecasts for your region • Health impacts associated with wildfire smoke • Health impacts associated with dust • Examples of household and community interventions/actions known to reduce exposure to poor air quality • Instruction on how to access real time air quality data for my community • Instruction on how to download and use local, historical air quality data for decision/policy making in my community • Basic installation, maintenance, and troubleshooting for our community air quality sensor(s) • Other ___________________ What platform would be best for YOU to receive this information? (check all that apply) • Website • Webinar • Brochure or newsletter / factsheet • Social media

		• Radio • Email • Direct outreach from community member • Physical postings via a community message board • Other _______________ What air quality information do you think YOUR COMMUNITY needs? (check all that apply) • Poor air quality forecasts • Health impacts associated with wildfire smoke • Health impacts associated with dust • Interventions/actions known to reduce exposure to poor air quality • Instruction on how to access real time air quality data • Instruction on how to download and use local, historical air quality data for decision/policy making • Basic installation, maintenance, and troubleshooting for sensors • Other ____________________ What type of platform would be best for YOUR COMMUNITY MEMBERS to receive this information? (check all that apply) • Website • Webinar • Brochure or newsletter / factsheet • Social media campaign • Radio • Direct outreach from community member • Physical postings via a community message board • Other ____________________
Proctor's Implementation Outcomes		

	A. Adoption	How have you accessed air quality data from your low-cost sensor (select all that apply)? ● Purple Air website ● Cellular applications (e.g. EPA AirNow that incorporate low-cost sensor data) ● Downloaded data from sensor's SD card ● Department of Environmental Conservation (DEC) website ● I have not accessed the data ● Other ________________________ Have you utilized any of these tools to analyze your data? ● Excel ● R ● Python ● Other
	B. Appropriateness	Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree) ● Exposure to poor air quality from dust may be harmful to community members' health ● Exposure to poor air quality from wildfire smoke may be harmful to community members' health ● There is evidence that the use of low-cost sensors to monitor air quality during air pollution events, protects health. ● Monitoring air quality for my community and/or home is a top priority. Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): Wildfire smoke has negatively impacted... ● The physical health of people living in my community. ● The mental health of people living in my community. ● The quality of life of people living in my community. ● my community's culture.

		● my community's economic vitality. Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): Dust has negatively impacted... ● The physical health of people living in my community. ● The mental health of people living in my community. ● The quality of life of people living in my community. ● my community's culture. ● my community's economic vitality.
	C. Cost	Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): I am concerned about .... ● the sensor's general maintenance ● repairing/servicing the sensor ● replacing the sensor, when needed ● finding an alternative community/staff member to take over hosting/maintaining the sensor ● **the cost associated with repairing or replacing the sensor** ● the sensor's ability to withstand environmental conditions ● the wifi bandwidth required to transmit data from the sensor ● the amount of electricity used by the sensor ● other (please describe): _______
	D. Feasibility	Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): ● I am concerned that community members ● don't know how to access local air quality data ● don't know how to interpret air quality data ● are limited by wifi bandwidth required to access local air quality data ● are limited by cellular connectivity required to access local air quality data

		• other (please describe): _______ Is there someone on your team who knows how to use APIs to request data? • Yes • No • Don't know (SKIP LOGIC from data access question under Adoption) If You Have Not Accessed Data.... What prevents you from accessing your community's sensor data? (Check all that apply) • I don't know how to access the data • It's too complicated to access data • My access to wifi is a limiting factor • My cellular coverage is a limiting factor • I am not interested in the data • Other ___________________
	E. Penetration	Does your community use local air quality information to make wildfire smoke-related evacuation decisions? • Yes • No • I don't know How has air quality data been utilized in your community? (Check all that apply) • Inform risk communication messages aimed at protecting the health of sensitive individuals (elders, children, individuals with pre-existing conditions, etc) • Inform risk communication for community activities (ie. hunting season, school field trips, etc) • Inform/support local policies initiatives (e.g. wildfire evacuation plans / dust suppression policies, etc.)

		• The data has not been used in our community. • Don't know • Other (please specify) Skip logic (if "The data has not been used in our community"): Do you have ideas as to why the data has not been used? (text box)
	F. Sustainability	Is the sensor still installed? • Yes • No • Don't know Is the sensor still operating? • Yes • No • Don't know Skip logic, if "No": Why is the sensor no longer operating? ____________ On a scale of 1 to 5, how challenging is/was it to maintain the sensor? • 1 = very challenging • 2 = challenging • 3 = neither challenging nor easy • 4 = easy • 5 = very easy • Not applicable • Don't know Skip Logic: If 1 or 2, What are the factors that make maintenance challenging? Please rate your level of agreement with each of the following statements (1= strongly disagree, 5= strongly agree): I am concerned about ....

		• the sensor's general maintenance • repairing/servicing the sensor • replacing the sensor, when needed • finding an alternative community/staff member to take over hosting/maintaining the sensor • the cost associated with repairing or replacing the sensor • the sensor's ability to withstand environmental conditions • the wifi bandwidth required to transmit data from the sensor • the amount of electricity used by the sensor • other (please describe): _______

Appendix A4. Low-Cost Air Quality Sensor Survey Tool

Low-Cost Air Quality Sensor Survey

Study Information: We are part of a team of researchers at the University of Washington, University of Alaska Anchorage, and University of Alaska Fairbanks inviting you to participate in a study on low-cost air quality sensors across Alaska. We are reaching out to you because you have hosted/maintained a low-cost sensor in your community either currently or in the past. The goal of this study is to understand the strengths and challenges in implementing, maintaining, and using low-cost air quality sensors in the state. This data will ultimately be used to inform the development of a sustainable air quality sensor system in Alaska.

This survey will take approximately 10-15 minutes. Your participation is completely voluntary, and you may discontinue the survey at any time without any adverse consequences. There are minimal risks to participating in this study. Your responses to the questions will be kept confidential, and data you provide will be de-identified. De-identified data may be placed in a data repository for use in future research or to answer alternative research questions. Your name and contact information will not be associated with any data that is shared in such a repository or with other researchers. We will not attribute your data or comments to you or your organization in any publicly facing study documents or reports without your explicit permission.

Additionally, this survey study has a Certificate of Confidentiality from the U.S. federal Environmental Protection Agency (EPA) which allows us to keep your identifiable research information confidential from legal proceedings or in response to a legal request unless you give us permission to release it. You can share information about yourself or your part in this research if you wish. There are some limits to this protection, including reporting things like child or elder abuse, monitoring by the agencies conducting the research, and others as listed elsewhere in this consent form. The Certificate expires when the US EPA funding for this study ends. Currently this is August 2025. Any data collected after their expiration is not protected as described above. Data collected prior to expiration will continue to be protected. Findings from this project will be shared in a report and/or manuscript(s) developed for publication in the peer-reviewed literature. We will also share the results directly with study participants. You will receive a $25 gift card as compensation for completing this survey. At the end of the survey, you will be asked to provide a mailing address to receive the gift card.By continuing with this survey, you are acknowledging that you are over the age of 18 and are consenting to the use of this data in our study.

If you have any questions about this research, please contact Dr. Tania Busch Isaksen at tania@uw.edu.

Risk Perception

Please rate your level of agreement with each of the following statements (1 = strongly disagree, 5 = strongly agree):

	1 = Strongly disagree	2	3	4	5 = Strongly agree	I don't know
Exposure to poor air quality from dust may be harmful to community members' health.	○	○	○	○	○	○
Exposure to poor air quality from wildfire smoke may be harmful to community members' health.	○	○	○	○	○	○
There is evidence that the use of low-cost sensors to monitor air quality during air pollution events protects health.	○	○	○	○	○	○

Monitoring air quality for my community and/or home is a top priority.	○	○	○	○	○	○

Please rate your level of agreement with each of the following statements (1 = strongly disagree, 5 = strongly agree): WILDFIRE SMOKE has negatively impacted...

	1 = Strongly disagree	2	3	4	5 = Strongly agree	I don't know
the physical health of people living in my community.	○	○	○	○	○	○
the mental health of people living in my community.	○	○	○	○	○	○
the quality of life of people living in my community.	○	○	○	○	○	○
my community's culture.	○	○	○	○	○	○
my community's economic vitality.	○	○	○	○	○	○

Please rate your level of agreement with each of the following statements (1 = strongly disagree, 5 = strongly agree): DUST has negatively impacted...

	1 = Strongly disagree	2	3	4	5 = Strongly agree	I don't know
the physical health of people living in my community.	○	○	○	○	○	○
the mental health of people living in my community.	○	○	○	○	○	○
the quality of life of people living in my community.	○	○	○	○	○	○
my community's culture.	○	○	○	○	○	○
my community's economic vitality.	○	○	○	○	○	○

Please select your level of concern (Low, Medium, High, Don't Know) for each of the following environmental hazards. Please also indicate whether your community has experienced any of these hazards within the last 5 years.

	Low	Medium	High	I don't know	Experienced
Coastal erosion	☐	☐	☐	☐	☐
Contaminated food sources	☐	☐	☐	☐	☐
Contaminated water sources	☐	☐	☐	☐	☐
Contamination from sewage	☐	☐	☐	☐	☐
Contamination from solid waste	☐	☐	☐	☐	☐

Droughts or water shortages	☐	☐	☐	☐	☐
Dust	☐	☐	☐	☐	☐
Earthquakes	☐	☐	☐	☐	☐
Extreme cold weather or severe winter storms	☐	☐	☐	☐	☐
Extreme heat	☐	☐	☐	☐	☐
Flooding from heavy rain	☐	☐	☐	☐	☐
Poor air quality/pollution	☐	☐	☐	☐	☐
Wildfires	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐

Other (please describe): __________________________________

Please complete the following questions about the installation of your community's low-cost air quality sensor.

Do you currently host/maintain a low-cost air quality sensor in your community (e.g. PurpleAir sensor, AQMesh sensor, DustTrack, QuantAQ Modulair, etc)?
- ◯ Yes
- ◯ No
- ◯ No, but I hosted a sensor in the past
- ◯ No, but I know of someone else who hosts/maintains a low-cost sensor in my community

Why are you no longer hosting a low-cost sensor? __________________________________

Do you have their contact information?
- ◯ Yes
- ◯ No

Please input their email here so we may send them a personal link to this survey. __________________________________

What community is the low-cost sensor located in? __________________________________

What is the community's population?
- ◯ Less than 250
- ◯ 250 - 1,000
- ◯ 1,000 - 10,000
- ◯ 10,000 - 50,000
- ◯ More than 50,000
- ◯ I don't know

What is your role in the community where the sensor is/was located (select all that apply)?
- ☐ Environmental program officer (e.g. IGAP coordinator)
- ☐ Public health or healthcare provider
- ☐ Air quality specialist
- ☐ Community Member
- ☐ Tribal contact
- ☐ Other

Other (please describe): __________________________________

Do you host more than one low-cost sensor for your community?	◯ Yes ◯ No

Please answer the following questions regarding the sensor that your community relies on for decision-making.

Please note, if you host multiple sensors, we would appreciate scheduling an interview with you to better understand the barriers and facilitators of hosting multiple sensors. At the end of this survey there will be an opportunity to agree to a follow-up interview.

What kind of air quality sensor was installed?	◯ PurpleAir ◯ AQMesh ◯ DustTrack (portable handheld unit) ◯ QuantAQ Modulair ◯ Don't know ◯ Other
Other (please describe):	__________________________________
Do you know approximately when the sensor was installed (MM/YYYY)?	◯ Yes ◯ No
Approximately when was the sensor installed (MM/YYYY)?	__________________________________
Where is the sensor installed?	◯ Clinic ◯ Library ◯ Government building ◯ School ◯ Residential home ◯ Other
Other (please describe):	__________________________________

	1 = Very challenging	2	3	4	5 = Very easy	Not applicable	I don't know
On a scale of 1 to 5, how challenging was it to install the sensor?	◯	◯	◯	◯	◯	◯	◯

What were the factors that made installation challenging?	__________________________________

What was the motivation for installing the sensor in your community? (Check all that apply)	☐ Local air quality information was requested by community members ☐ Inform community interventions/actions aimed at reducing exposure to poor air quality ☐ Inform government interventions/actions aimed at reducing poor air quality ☐ Inform government policy (state or federal) (e.g. rule-making over dust generating sources) ☐ Supplement regulatory monitoring station information ☐ Collect data to inform future grant applications ☐ To measure dust impacts on air quality ☐ To measure wildfire smoke impacts on air quality ☐ Don't know ☐ Other
Other (please describe):	__________________________________
Is the sensor still installed?	◯ Yes ◯ No ◯ Don't know
Why is the sensor no longer installed?	__________________________________
Is the sensor still operating?	◯ Yes ◯ No ◯ Don't know
Why is the sensor no longer operating?	__________________________________

Sensor Maintenance

Please answer the following questions pertaining to the maintenance of your community's low-cost sensor.

	1 = Very challenging	2	3	4	5 = Very easy	Not applicable	Don't know
On a scale of 1 to 5, how challenging is/was it to maintain the sensor?	◯	◯	◯	◯	◯	◯	◯

What are the factors that make/made maintenance challenging?	__________________________________

Please rate your level of agreement with each of the following statements (1 = strongly disagree, 5 = strongly agree):
I am concerned about ....

	1 = Strongly disagree	2	3	4	5 = Strongly agree	I don't know	Not applicable
the sensor's general maintenance.	○	○	○	○	○	○	○
repairing/servicing the sensor.	○	○	○	○	○	○	○
replacing the sensor, when needed.	○	○	○	○	○	○	○
finding an alternative community/staff member to take over hosting/maintaining the sensor.	○	○	○	○	○	○	○
the cost associated with repairing or replacing the sensor.	○	○	○	○	○	○	○
the sensor's ability to withstand environmental conditions.	○	○	○	○	○	○	○
the Wifi bandwidth required to transmit data from the sensor.	○	○	○	○	○	○	○
the amount of electricity used by the sensor.	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○

Other (please describe): __________________________________

Use of Sensor Data

Please answer the following questions pertaining to the use of data from your community sensor.

How have you accessed air quality data from your low-cost sensor? (Check all that apply)

- ☐ Purple Air website
- ☐ Phone app (e.g. EPA AirNow that incorporate low-cost sensor data)
- ☐ Downloaded data from sensor's SD card
- ☐ Department of Environmental Conservation (DEC) website
- ☐ I have not accessed the data
- ☐ Other

Other (please describe): __________________________________

What prevents you from accessing your community sensor's data? (Check all that apply)	☐ I don't know how to access the data ☐ It's too complicated to access data ☐ My access to wifi is a limiting factor ☐ My cellular coverage is a limiting factor ☐ I am not interested in the data ☐ Other
Other (please describe):	__________________________________
Have you utilized any of these tools to analyze your data?	☐ Excel ☐ R ☐ Python ☐ Other
Other (please describe):	__________________________________
How has air quality data been utilized in your community? (Check all that apply)	☐ Inform risk communication messages aimed at protecting the health of sensitive individuals (elders, children, individuals with pre-existing conditions, etc.) ☐ Inform risk communication for community activities (ie. hunting season, school field trips, etc) ☐ Inform/support local policies/initiatives (e.g. wildfire evacuation plans / dust suppression policies, etc.) ☐ The data has not been used in our community ☐ Don't know ☐ Other
Do you have ideas as to why the data has not been used?	__________________________________
Other (please describe):	__________________________________
Does your community use local air quality information to make wildfire smoke-related evacuation decisions?	◯ Yes ◯ No ◯ I don't know
Please describe how you use air quality information to make evacuation decisions:	__________________________________
How would you like to use air quality data in your community? (Check all that apply)	☐ Inform risk communication messages aimed at protecting the health of sensitive individuals (elders, children, individuals with pre-existing conditions, etc) ☐ Inform risk communication for community activities (ie. hunting season, school field trips, etc) ☐ Inform/support local policies/initiatives (e.g. wildfire evacuation plans / dust suppression policies, etc.) ☐ I don't know ☐ Other (please specify)
Other (please describe):	__________________________________

What time periods are important to you when using air quality data? (Check all that apply)	☐ Long-term historical trends (over years or decades) ☐ Recent trends (over weeks, days, or hours) ☐ Immediate data (what is happening right now) ☐ Near future predictions (next few days) ☐ Long term future predictions (next few years) ☐ Other
Other (please describe):	__________________________________
Are you interested in air quality information for these areas? (Check all that apply)	☐ Watersheds ☐ Alaska Native Corporation geographic boundaries ☐ Alaska Fire Management Units ☐ Ethnolinguistic regions of Alaska ☐ Alaska Game Management Units (GMUs), e.g. GMU19a, etc. ☐ Statewide ☐ Other
Other (please describe):	__________________________________

Please rate your level of agreement with each of the following statements (1 = strongly disagree, 5 = strongly agree): I am concerned that community members...

	1 = Strongly disagree	2	3	4	5 = Strongly agree	I don't know	Not applicable
don't know how to access local air quality data.	○	○	○	○	○	○	○
don't know how to interpret air quality data.	○	○	○	○	○	○	○
are limited by wifi bandwidth required to access local air quality data.	○	○	○	○	○	○	○
are limited by cellular connectivity required to access local air quality data.	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○

Other (please describe):	__________________________________
Is there someone on your team who knows how to use APIs to request data?	○ Yes ○ No ○ Don't know

Education & Information Needs

What information is of interest to you and/or to your community? (Check all that apply):

	Myself	My community
Poor air quality forecasts for your region.	☐	☐
Health impacts associated with wildfire smoke.	☐	☐
Health impacts associated with dust.	☐	☐
Examples of household and community interventions/actions known to reduce exposure to poor air quality.	☐	☐
Instruction on how to access real time air quality data for my community.	☐	☐
Instruction on how to download and use local, historical air quality data for decision/policy making in my community.	☐	☐
Basic installation, maintenance, and troubleshooting for our community air quality sensor(s).	☐	☐
Other	☐	☐

Other (for yourself, please describe): __________________________________

Other (for your community, please describe): __________________________________

What platform(s) would be best for you and/or your community members to receive this information? (Check all that apply):

	Myself	My community
Website	☐	☐
Webinar	☐	☐
Brochure or newsletter / factsheet	☐	☐
Social media campaign	☐	☐
Radio	☐	☐
Email	☐	☐

Direct outreach from community member	☐	☐
Physical postings via a community message board	☐	☐
Community meeting	☐	☐
Other	☐	☐

Other (for yourself, please describe): __________________________________

Other (for your community, please describe): __________________________________

Conclusion & Follow-up

We would love an opportunity to learn more about your experience hosting a sensor in your community to inform the development of a community decision-making tool. We would like to invite you to participate in a 30-40 minute interview. Individuals who agree to participate in a follow-up conversation will receive an additional $45 Amazon gift card for their time.

Would you be interested in participating in a follow-up interview?

○ Yes
○ No

If yes, please provide your name: __________________________________

If yes, please provide your email: __________________________________

Would you like to receive a summary of the study results via email?

○ Yes
○ No

If yes, please provide your email: __________________________________

Thank you very much for taking the time to complete this survey. To compensate your time and express our gratitude, we would like to send you a $25 gift card. Please enter your mailing / postal address in the space below. Note that it may take a couple of weeks for the gift card to arrive. We will send an email to notify you when the gift cards have gone into the mail.

Name: __________________________________

Street Address or P.O. Box: __________________________________

City, Town, or Village; __________________________________

Zipcode:

____

Email address:

____

Appendix B: Aim 2

Appendix B1. Narrative Development Session Worksheet - Community Events

User Scenario: **Decision Making for Community Events**	**Communication goal:** An individual uses the real-time AQI values and/or the 6-48 hour air quality forecast in their region to inform the safety of public community events that may be impacted by WFS. This guide will portray this individual making decisions to cancel or reschedule an event, or relay important public health messaging to sensitive populations to aim to reduce harm from wildfire smoke. **Target Audience:** Outdoor community event planners
Setting/Scene What is the outdoor community event? Where? Who will attend? Possible AQI level?	Outdoor community event with an indoor area available (and population): • Summer camp (incorporates elders in rural communities too), weeklong event, but focusing on one day of camp AQI level in their region: • Various AQI levels throughout the day to communicate decision tree, making decisions throughout the day based on AQ conditions • Visual AQI "wheel" and some commentary on the AQI from the organizer with counselors, elders (and kids?)
Subject Who will use the WFE tool to make decisions for this event?	Summer camp director, discussing with other leads and camp counselors • Proactively discussing their WFS event protocol, highlighting decision tree, using WFE tool
Objective What is their conflict or concern due to the wildfire smoke event?	Physical health concern: • Concerns over harmful health effects for participating youth and elders Emotional health concerns: Other type of concern: • If camp is closed, parents may not be able to go to work • Physical space concern: is there an available indoor space that can be used?
Plan What tool feature might they use and how/when? What information do they learn?	• Subject explains the camp's WFS event protocol and how the WFE tool informs the decision tree Tool features: AQI, AQ forecast, active fire data, lightning strikes, fire danger ratings, hotspots, projected flammability • Checking the real-time AQI value the morning of camp and throughout the day • Checking the 6-48 hour air quality forecast, the day before to make a decision each day. Day before and day-of conditions Subject discusses their camp protocol in different AQ conditions (AQI wheel) • Sending out notices to parents on conditions, moving activities indoors if AQI worsens, checking on HEPA units for indoor activities, masks/PPE, education (talking with campers), special indoor activities for sensitive kids,

Resolution
Specific messaging to audience. How does the subject use information from the tools to help them achieve their objectives?
	• E.g. decide whether to inform sensitive populations of
	  ◦ The potential health effects of poor air quality
	  ◦ To consider wearing PPE
	  ◦ To limit time outdoors or lowering intensity of outdoor activities
	• E.g. decide whether to reschedule or cancel activity
	• Showcase options that are available: moving activities indoors (fully, student rec centers), during really bad conditions short-term refuge in nearby building, active air cleaner (HEPA units)
	• Final panel: images of the camp depicting how their decisions ended up looking like - a scene of activity

Appendix B2. Narrative Development Session Worksheet - Fishing Trip

User Scenario: **Decision making for Fishing Trip Location**	**Overarching communication goal:** Depicting the use of data from the WFE to make salmon fishing location decisions during a wildfire smoke event from an urban perspective. Highlighting importance of access to fishing for subsistence. Considering fishers respiratory health and local knowledge of the land and fish. **Audience:** General urban audience, families with sensitive individuals

Setting/Scene
What is the outdoor event? Where? Who will attend? Possible smoke conditions?

- Travelling from urban area to a river to fish for salmon (somewhere in southern Alaska). They plan to camp there for a night or two. On land with no special designations
- Mid-June to early July, mid-july as well (depending on location and salmon species)
- AQ conditions are Hazardous at the location they want to go to, look for alternative salmon fishing location using the WFE

Other notes:

- Fishing camps - who they are going to visit, multi generations having discussion together, to decide on where to go, different host and community ties along a river
- Northern region, fishing season is shorter, versus Yukon region = general longer fishing season
- North (Chum salmon), South (plentiful most of season)

Subject
Who will use the WFE tool to make decisions for this event?

- Family with an elder who wants to participate on family fishing trip
    - Or an intergenerational friend group
- BLM land vs private land, etc difficult to showcase (land use), general public programs vs tribal program
- With a fishing license with Fish & Game
    - Gakona area river, or south regions, Chitina (north of Anc) / Kenai (south of Anc) (as the two options)
    - Look at what salmon are in season

Conflict/Objective
What is their conflict or concern due to the wildfire smoke event? What is their workaround?

Objective: to safely go fishing with their family and to replenish their freezer with salmon. Both recreational and food source motivated. They is also a sense of urgency due to the salmon season.

- Physical/emotional health concern:
- Health effects from wildfire smoke

Plan
What tool feature might they use and how/when? What information do they learn?

Tool features: Current AQI, AQ forecast, active fire data, lightning strikes, fire danger ratings, hotspots, projected flammability

- Use the real-time AQ conditions to consider relocating their fishing location
- Camping on the beach - another motivator to change locations
- Plan to bring masks? For elder/sensitive individuals. (depict that this is only one option, masks not always perfect) Highlight
    - Consider if wearing a mask is a good option for the particular individuals/activities (does it make sense?)

Resolution
Specific messaging to audience. How does the subject use information from the tools to help them achieve their objectives?

- Example options:
    - Educate their family members on health risks from WFS
    - Fisher decides to wear PPE
    - Shorten the time they spend outside fishing
    - Postpone fishing trip

Appendix B3. Narrative Development Session Worksheet - Outdoor Workers

User Scenario: **Decision making for outdoor workers/volunteers**	**Initial communication goal:** Navigating occupational safety, during or in anticipation of smoky days. How and when to get information about current air conditions across a region, to provide their workers with information ahead of time such as short and long-term health effects from smoke exposure, options to reduce exposure, training, etc. Point to guidance from Alaska-based entities **Highlight best practices tailored to employers (for health protection of employees)** **Audience:** Groups with outdoor workers

Setting/Scene
What is the outdoor event? Where? Who will attend? Possible smoke conditions?
	Ex: Volunteer trails maintenance crew
	• Workers and volunteers trail maintenance - decisions are administratively done, removing risk (rescheduling)
	  ○ Could work on a different trail not have as much smoke, postpone by 24 hrs, change activity,
	• Crew is already out in the field when they start to smell smoke
	• Crew about to head out to work area check the WFE tool to prepare for conditions
	  ○ Decide to take N95s - NIOSH page for
	• Narrator could be recalling a scenario when they were in a work setting during a WFS event (out in the field).
	• Pre-planning for possibility of getting stuck in smoke. Use smoke projections. Forestry (revegetation, surveying after burns, maintaining remote stations (BLM)), four person crew, fly into location, weeklong

Subject Who will use the WFE tool to make decisions for this event?	• Narrator (employee) discussing with co-workers on making sure to keep an N95 on them, discuss proper mask fitting, etc. • The volunteer/group lead • Maintenance crews, electric crews, construction, community gardens, NPS volunteers • Have satellite phone if out in remote area
Objective What is their conflict or concern due to the wildfire smoke event? What is their workaround?	Objective(s): • Keeping their volunteers safe during the smoke event • Employee prioritizing their health during an unexpected wildfire smoke event Physical/emotional health concern: • Health effects from wildfire smoke
Plan What tool feature might they use and how/when? What information do they learn?	Tool features: AQI, AQ forecast, active fire data, lightning strikes, fire danger ratings, hotspots, projected flammability A crew could be planning to go out to do field work, the AQ projections in work area look Unhealthy for all, group lead makes decision to prepare crew (administrative decisions), crew decides to wear proper-fitting N95s

Resolution
Specific messaging to audience. How does the subject use information from the tools to help them achieve their objectives?
	• Safety measures
	  ○ Being aware of other employees,
	  ○ **Pre- planning** for a possible WFS event causing employee to be stranded. Being aware of where you are going ahead of time and if you will be able to get back home - projected AQ conditions?
	• Exposure reduction efforts (CDC):
	  ○ Taking additional breaks
	  ○ Relocating or rescheduling work to less-smoky areas or times of day
	  ○ Moving work indoors
	• Communication - brief with leadership about conditions and health status of individuals - ask about WFE tool information

Appendix B4. Final Story Summaries

Intro Story (~12 panels)

Context considerations:

- **Focused audience**: General
- **Specific sensitive populations**: Older adults, youth, people with underlying health conditions
- **Tool feature:** Introduce wildfire explorer tool
- **Exposure reduction measures:** See story below

Story:

- **Setting:** Summer solstice bbq
- **Subjects:**
    - Main narrator is a fox
    - Four individuals from stories:
        - A teenage camp counselor from the culture day camp
        - A ~10 year-old child from the Tribal family going berry picking
        - A 20ish year old from the fishing trip group
        - A 40ish year old volunteer from outdoor work party
- **Objectives:** Back and forth conversation between fox and 4 individuals around:
    - An active wildfire in the state and the potential for poor air quality this weekend
    - Health effects from poor air quality
        - Upper respiratory (eyes/nose); lower respiratory (asthma, COPD); cardiovascular & cerebrovascular impacts
    - Populations who are most at risk
        - Old, young, pregnant, people with underlying health conditions
    - Exposure reduction solutions (envision a checklist of the risk reduction activities)
        - Be informed!
        - Re-stock needed medicines (e.g. inhaler)
        - Change behaviors (move indoors or limit outdoor activities)
        - Reduce indoor air pollutant generation (limit cleaning and burning of candles)
        - Close doors and windows
        - Actively clean indoor air with HEPA filters
        - Use PPE (e.g. properly fitted N95) when outdoors
        - Reduce time spent outdoors
- **Tool interaction:** The fox narrator mentions the wildfire explorer tool as a way to stay informed and aware of the air quality in your area.
- **Resolution:** They encourage their friends to inform their outdoor activities using the various tool features this weekend to protect their health and the health of their friends and family

Culture Day Camp (~6 panels)

Context considerations:

- **Focused audience**: General; Community leads; parents; caretakers of sensitive populations
- **Specific sensitive populations**: Young; 65+ yrs
- **Tool feature:** Forecasted and current AQI
- **AQI level:** Unhealthy for sensitive groups, unhealthy for all

- **Exposure reduction measures**: Use their camp's wildfire smoke event protocol; move activities indoors; actively clean air with HEPA filters

Story:
- **Setting:** An outdoor culture camp, at a tribal/community building. Environment: boreal forest, near mountains, with spruce/birch trees, and hazy conditions.
- **Subject(s):** The camp organizer, camp counselors (older youth), an elder participant, and youth campers (a variety of ages)
- **Objective(s):**
    - Morning of camp: The teen camp counselor from the intro story brings up the wildfire smoke event and the WFE tool with camp lead and other counselors
    - The camp organizer discusses enacting the camp's wildfire smoke event protocol (could be depicted as a poster inside their building) with the other counselors (this poster can be similar to this, a table with the different AQI colors and a "description" of their protocol - this text can be scribbles)
- **Tool Interaction:**
    - They look at the WFE's 6-hour AQ forecast on their computer prior to the start of camp which says the air quality will be Unhealthy for sensitive individuals.
    - Per their wildfire smoke event protocol, they send notices to parents about these expected air quality conditions and information about the potential health effects.
    - They prepare to use their tribal/community building as their clean air space by closing windows and checking availability of HEPA units.
    - Once the camp day starts, the real-time AQ is Unhealthy.
- **Resolution:** They decide to move camp indoors and announce it to the campers. Doors/windows are closed and air is actively being cleaned with HEPA units. The elder is depicted starting camp with a prayer or story, as the campers sit around the elder.

Berry Harvesting (~6 panels)

Context considerations:
- **Focused audience:** General; Tribal community members; sensitive populations
- **Specific sensitive populations**: Older adults
- **Tool features**: Current AQI & 12-48 hr projected
- **AQI level**: Unhealthy for sensitive groupsl, afternoon changes to Moderate
- **Exposure reduction measures highlighted**: Change of activity timing

Story:
- **Setting:** Rural setting: A Yukon-Kuskokwim community near a river. A family's home. Hazy conditions in the distance.
- **Subject(s):** A tribal family (with a teen, a parent, and an elder)
- **Objective(s):** They plan to boat along the river to get to their berry harvesting location. They want to go harvesting but also consider the grandparent's health
- **Tool Interaction:**
    - Early Morning of event: *Teenager remembers convo at the solstice event and pulls up the tool on their phone.*
    - The elder and teen review the WFE tool together, and see that the AQI level for the area they will be harvesting is currently unhealthy for sensitive individuals, however the AQ forecast says it's predicting better air quality in the evening.
    - The elder makes the decision that the family should go later in the day to avoid the poor air quality. It is peak berry season so they prioritize going.
    - They prepare to leave by referencing their "go" checklist: baskets/containers, N95s, emergency backpack, communication device (optional), telling their

contact where they're going, bear spray, gun, life jackets on the boat
    - Family boats to location (wearing life jackets)
- **Resolution:** The family is seen picking berries and collecting them in plastic buckets
    - Collaborative, team effort — lots of hands are seen picking berries
    - If picking on hillside, elders down below, youth higher up, and the Elder has the most berries in their bucket
    - If extra space: visual of making jam with the berries

Fishing Trip (~6 panels)

Context considerations:

- **Focused audience:** General; those with underlying health conditions (UHC)
- **Specific sensitive populations**: UHC / Respiratory condition
- **Tool features**: 6-48 hr projections
- **AQI level**: Unhealthy for sensitive groups
- **Exposure reduction measures highlighted**: Change of activity location

Story:

- **Setting:** A friend group planning to roadtrip from the Anchorage area to a beach on the peninsula to dip net for salmon. They plan to camp on the beach. Conversation takes place in their group chat.
- **Subject(s):** A group of 4 friends (4 adults in their 20s) who live in Anchorage (one has asthma)
- **Objective(s):** To go on the friend group's annual weekend fishing trip to fish for salmon to fill their freezers (depict an empty freezer potentially)
- **Tool Interaction:**
    - One of the friends (the one from the intro story) looks at the WFE tool the day before their trip and sees that the 12 and 24 hour air quality forecast for the beach they plan to go to projects Unhealthy for sensitive individuals AQI conditions.
    - They prompt a conversation in their group chat about the projected air quality and one of the friends remembers that someone in the group has asthma. They suggest they move their trip to a different beach on the peninsula where the tool is projecting a lower 12 and 24 hour AQI (Good).
    - The group agrees and the person with asthma mentions they will check that their medications are refilled and that they bring their rescue inhaler along
- **Resolution:** The group is then depicted on their road trip the next morning, hazy conditions in the distance (driving away from smoke), different types of fishing equipment (dip nets, rod & reel) on roof of car, driving past a burn ban sign.
    - If space: depiction of the group dip netting at the beach for salmon (camping tent, cooler, etc)

Outdoor Work Party (~6 panels)

Context considerations:

- **Focused audience**: General; work leads; volunteer coordinators; outdoor workers
- **Specific sensitive populations**: Outdoor workers
- **Tool features:** Current AQI, 6 hour forecast
- **AQI level:** Unhealthy for sensitive groups to unhealthy for all
- **Exposure reduction measures highlighted:** Reducing physical activity (stopping brush clearing), wearing properly fitted masks
- **Note:** This story is intended to highlight the limitations of the app; folks' experience on the ground is most important – people should monitor their symptoms and the air

quality conditions (e.g., using visual cues) in order to make decisions, not just rely on the app

Story:

- **Setting:** At a forested area, worksite for work party
- **Subject(s):** A brush clearing volunteer maintenance crew (4-5 40ish year olds)
- **Objective(s):** The group needs to go conduct essential brush clearing to help reduce/prevent wildfires
- **Tool Interaction:**
    - The individual from the intro story checks the WFE's real-time AQI on their phone at the trailhead. They see **unhealthy for sensitive individuals AQI,** with forecasts showing worse air quality headed their way, and shows the group. They mention their N95s that they brought with them just in case the smoke gets worse (they had learned about the wildfire from the intro story).
    - The group expresses little concern for the air quality, and begins working (could express the importance of their work, that they've taken time off their day jobs, and/or have rented equipment for the brush clearing)
    - As they work through the trail, mile markers are depicted to show their progress as they move away from the trailhead (depict them using brush-clearing tools)
    - A landmark (e.g., mountain) gets progressively hazy to communicate worsening air quality
    - Multiple individuals in the group start to experience physical symptoms (coughing, eyes watering, shortness of breath)
- **Resolution:**
    - The group acknowledges their symptoms (and the smokier conditions) and decide it's probably time to stop their work and turn around.
    - As they head back, the individual from the intro story passes out N95 masks for the walk back and explains, "when properly fitted, N95 masks can help reduce our exposure to particulates in the air from wildfire smoke".
    - To close out story: maybe some final resolution comments from the group

Appendix B5. Revisions of Initial Comic Sketches

Intro Story Page 1	
- Suggestion for first panel: - Fox is a part of the conversation with the four main characters and the dialogue stays within the group. - The two individuals on the right are standing at a BBQ to indicate to the reader that this is a community event - AQI dial: - Add label to the AQI dial that says AQI or Air Quality Index - Arrow for AQI can point to the center of unhealthy for sensitive groups (between 100 and 150) - Fox: - Consider changing fox's outfit (conversation with project team)	
Script Revisions	
Original	*Edits*
A sunny, summer day in Alaska...	A sunny, summer day in Alaska...
Yeah, classes have been tough–but thankfully I've got a fishing trip planned for this weekend.	I'm excited for my fishing trip this weekend! Do you have plans?
–Totally, this weekend will be great!	Yeah! My family is going berry picking
You guys should check the AQI before going out. There's an active wildfire in the area	Heads up, there are active wildfires around. You should check the AQI in your area before going out
AQI? What's that?	AQI? What's that? **Older man says this**
Air Quality Index. Basically how clean the air is outside.	Air Quality Index. Basically how clean the air is outside.
And this weekend looks like it might be unsafe for people old, young, pregnant or with underlying health conditions.	And when the AQI is above 100, it can be unsafe for people who are old, young, pregnant, or have underlying health conditions.

Intro Story Page 2	
- Panel 2: Sketched screenshot of tool map showing most of Alaska, AQI dots - The fox in the middle of the page: shrink them down a bit, maybe they are peering over the top of the panel, could just be eyes peering over with hands (one finger pointing down), to have more space for exposure reduction solutions/QR code - Exposure Reduction Solutions → Reduce Your Exposure to Wildfire Smoke - Larger QR code	
Script Revisions	
Original	*Edits*
How do you know that?	How do you know when the air is unsafe?
I used the Wildfire Explorer Tool. It's a great way to stay informed about the air quality in your area.	**Screenshot of tool map** I use the Alaska Wildfire Explorer tool. It shows active fires, and current and forecasted air quality.
This helps to avoid bad effects to your health such as upper or lower respiratory problems, or people with heart issues.	You can use it to lower your risk of bad health effects from exposure to smoke like respiratory problems or heart issues.
Exposure Reduction Solutions • Be informed! • Re-stock needed medicines (e.g. inhaler) • Change behaviors (move indoors or limit outdoor activities) • Reduce indoor air pollutant generation (limit cleaning and burning of candles) • Close doors and windows • Actively clean indoor air with HEPA filters • Use PPE (e.g. properly fitted N95) when outdoors • Reduce time spent outdoors	Reduce your Exposure to Wildfire Smoke: • Keep your eye on the AQI! • Reduce physical activity and time spent outdoors • Close windows and doors • Clean indoor air with a HEPA air purifier • Reduce indoor air pollution by limiting activities like smoking/vaping or dusting • Re-stock needed medicines (e.g. inhaler) • If you do need to go outside, use a well-fitted N95 mask
Thanks Fox! We'll make sure to use this wildfire tool to stay safe and informed during our activities	Thanks Fox! We'll make sure to use the tool to stay informed and safe this weekend!

this weekend!	
Scan the QR code to use the tool!	Scan the QR code to use the tool!

Culture Day Camp	
• Panel 1: Depict hazy conditions • Panel 3: Tool on computer screen shows map of AQI forecast, unhealthy • Panel 4: Poster can be sketched version of their wildfire smoke protocol. • Panel 6: Depict one or more HEPA air purifiers to last panel (placed near the group, another on opposite side of room, if space allows) • Add elements to make it more obvious that it's a culture camp? (will discuss with project team)	
Script Revisions	
Original	*Edits*
Is everything all set for the scavenger hunt this afternoon?	Is everything all set for the scavenger hunt this afternoon?
We might have to postpone it due to the active wildfire. We should check the AQI.	We might have to postpone it due to the wildfire smoke. We should check the air quality.
How can we find out if it will be safe or not?	How can we know what the smoke conditions will be later today?
We can use this cool new wildfire explorer tool I learned about which can project air conditions for 6-48 hours.	We can use this cool new Alaska Wildfire Explorer tool – it can forecast air quality 6-48 hours from now.
And it looks like this afternoon is going to be pretty smoky.	And it looks like it's going to be pretty smoky all day. **AQI forecast is Unhealthy (red) over their area**
Ok, well, it seems like young kids and elders will be at the most risk.	Yeah, we should follow our smoke protocol.
According to out smoke protocols, we should plan for something indoors	To keep our kids and elders safe, we should plan for something indoors.
I'll send out an email to let everyone know.	I'll send out an email to let everyone know. And I'll set up the HEPA air purifiers.
	Text for email: NOTICE Hi everyone, Due to the smoke, camp will be indoors this afternoon. If you're looking for clean air, you are

	welcome to join us!
Thanks to the wildfire tool, we can have fun even when it's smoky!	Elder: ...this is the story of fox and wildfire...
And these HEPA filters make this the safest place in town!	These HEPA air purifiers make this the safest place in town!

Berry Picking

• Hazy conditions in the first panel
• Change male-presenting character to female-presenting (panel 2 only)
• Panel 3: eliminate
• Current panels 4, 5, 6 move up (become panels 3, 4, 5)
• Panel 5: Map on phone, current AQI, unhealthy (red)
• New Panel 6
  ○ Map of 12 hour forecast with sparse yellow overlaid
• Panel 7
  ○ Depict a boat on river bank, lifejackets hanging off
• Little girl: more similar features to grandma (to look related). Long dark hair, similar facial features

Script Revisions	
Original	*Edits*
Let's see... baskets, N95 masks...	Panel 1: Let's see... baskets, life jackets, bear spray–
–Emergency backpack, bear spray, life jackets...	Panel 2: Yep, we're all set for berry picking!
Yep, we're all set for berry picking!	Panel 3: Are you ready to go, dear?
Are you ready to go, dear?	Panel 3: It's looking pretty smoky out there, grandma. Maybe we should check the air quality.
It's looking pretty smoky out there, grandma. Maybe we should check the AQI.	Panel 3: How?
How?	New Panel 4: With the Alaska Wildfire Explorer tool, we can see current and forecasted smoke conditions.
By using this WFE tool! It can tell you the current and projected quality of air.	New Panel 5: Yeah, it looks like the air is unhealthy right now. **Map of tool on the phone showing CURRENT AQI, one red dot, unhealthy**
Uh oh, looks like we should leave a little later to avoid the smoke.	New Panel 6: But it looks like the air quality will be better this evening... let's go then! **Map with 12 hour FORECAST with sparse yellow overlaid (layout of phone/hand can be similar to the*

	*panel before this or a front view of the family looking at the phone and the map is shown above them in space)**
Good thinking, grandma! The air is much better now.	Good thinking, grandma! The air is much better now.
Grandma always knows best!	Grandma always knows best!

Dipnetting Trip

- Lighter/muted blue text bubble?
- Panel 4: [screenshot of the tool map]() showing the 24 hour forecast sent as a text

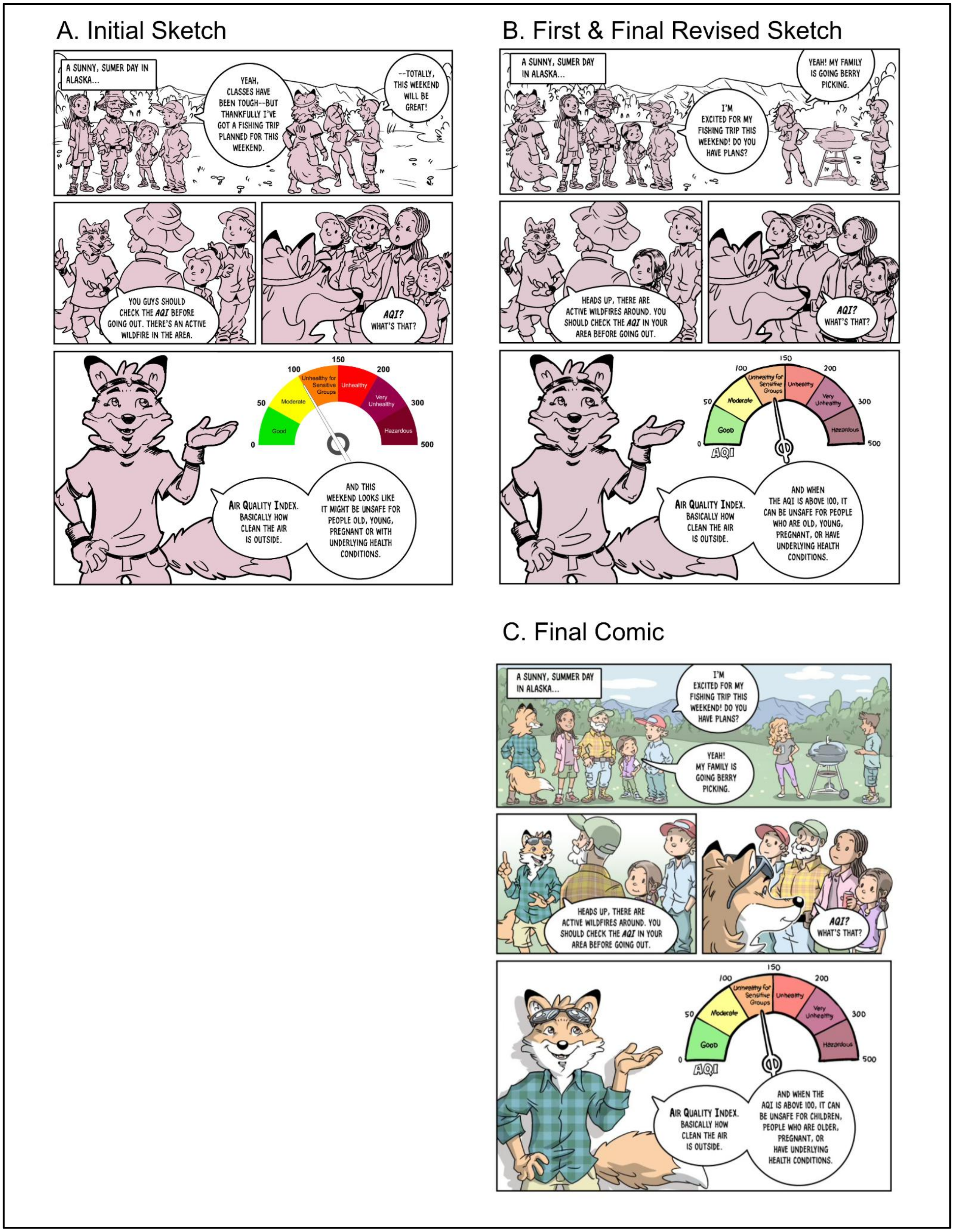
Script Revisions

Original	*Edits*
You guys ready for the fishing trip tomorrow?	You guys ready for the fishing trip tomorrow?
Oh yeah, been ready!	Oh yeah, been ready!
I still have to pack 😓	I still have to pack 😓
I dunno if I'll be able to make it guys, the wildfire smoke has been really tough on my lungs 😦	I dunno if I'll be able to make it guys, the wildfire smoke has been tough for my asthma 😵‍💫
No way dude! We're not gonna let a little thing like asthma get in the way!	No way dude! We're not gonna let that get in the way!
Relax, I got you fam–	Don't worry, I got you fam–
We can use this wildfire protection tool I heard about to find a new spot on the peninsula where the air will be more clean.	We can use the Alaska Wildfire Explorer tool to find a new spot where the air will be better.
It's got realtime and projected AQI–nice!	It looks like the 24-hour smoke forecast looks better over here! **Screenshot of the map sent in the groupchat, 24-hr forecast**
Thanks to the wildfire tool, we can avoid all that nasty smoke!	Bye nasty smoke! Good thing we checked that tool!
The air here is so much cleaner!	The air here is so much cleaner!
Too bad it's not helping you catch any salmon!	Too bad it's not helping you catch any salmon!

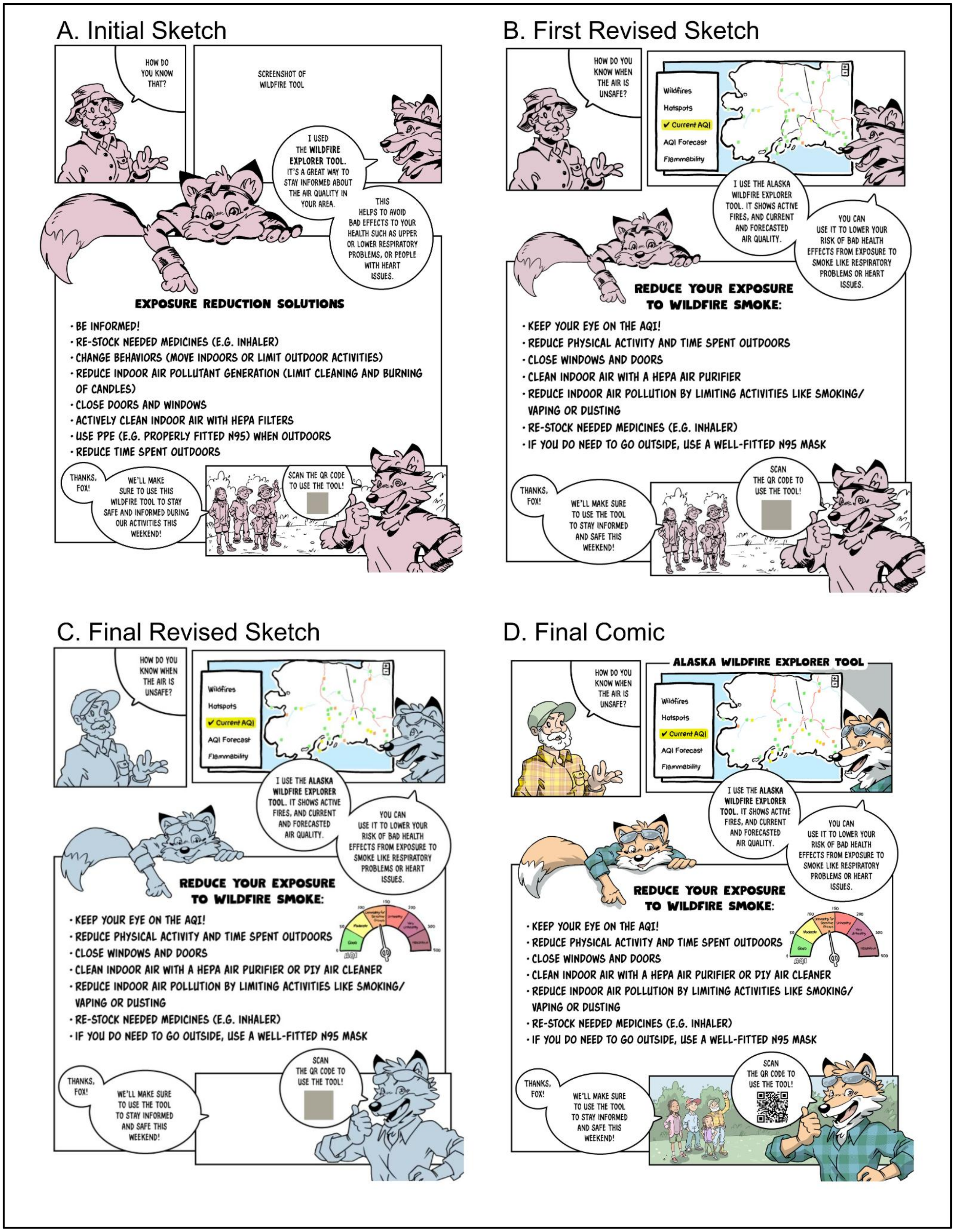
Work Party	
• Panel 1: remove AQI dial, add inset of a phone screen with the tool map of 12 hour forecast, area in red. • Panel 4: dial is at red • Panel 6: Remove AQI dial	
Script Revisions	
Original	*Edits*
Hate to say it guys, but the WFE tool says the AQI isn't looking great for today, we may have to reschedule.	Hate to say it guys, but the Alaska Wildfire Explorer tool says the air quality isn't looking great today, we may have to reschedule our work. *Add an inset of the phone depicting the 12 hour FORECAST, red*
This is the only day I can help clear the brush.	But, this is the only day I can help clear the brush.
Same, besides, we're all healthy, so what's it matter?	Same, besides, we're all healthy, so what's it matter?
And this stuff has to be cleared before there's another fire right?	And this stuff has to be cleared before there's another fire right?
We have the N95s, too... Ok–Let's keep going, but we'll keep an eye on the AQI.	Ok–Let's continue but keep an eye on the air quality. We also have N95 masks if it does get worse.
Later...	Later... *AQI dial is red, labeled CURRENT*
Cough cough–ugh my lungs.	Cough cough–ugh my throat.
Yeah, my eyes are starting to water.	Yeah, my eyes are starting to water.
The smoke is getting too much. AQI is showing bad for everyone. Let's head back.	The smoke is too much and now the air quality is unhealthy for all. Let's head back. *hazier conditions*
Make sure the N95 masks are secure. They can help reduce our exposure to particulates in the air from wildfire smoke.	*Lead person looking back on crew* "Make sure your N95 mask is secure. They can help reduce our exposure to the smoke." *remove AQI dial from this panel*

	person at the front says I guess the tool was right!

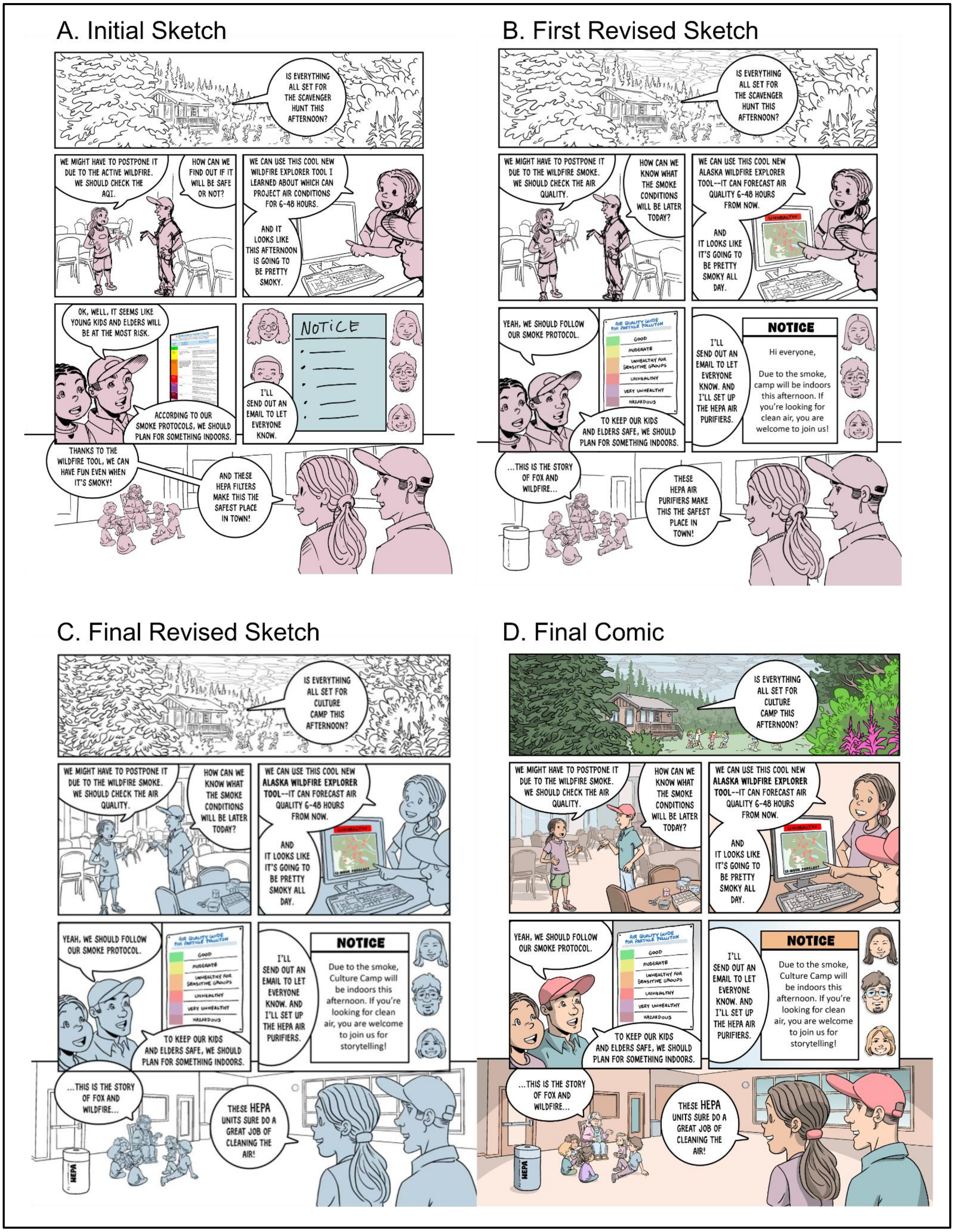
Appendix B6. Iterations of Introduction Story Comic Page 1



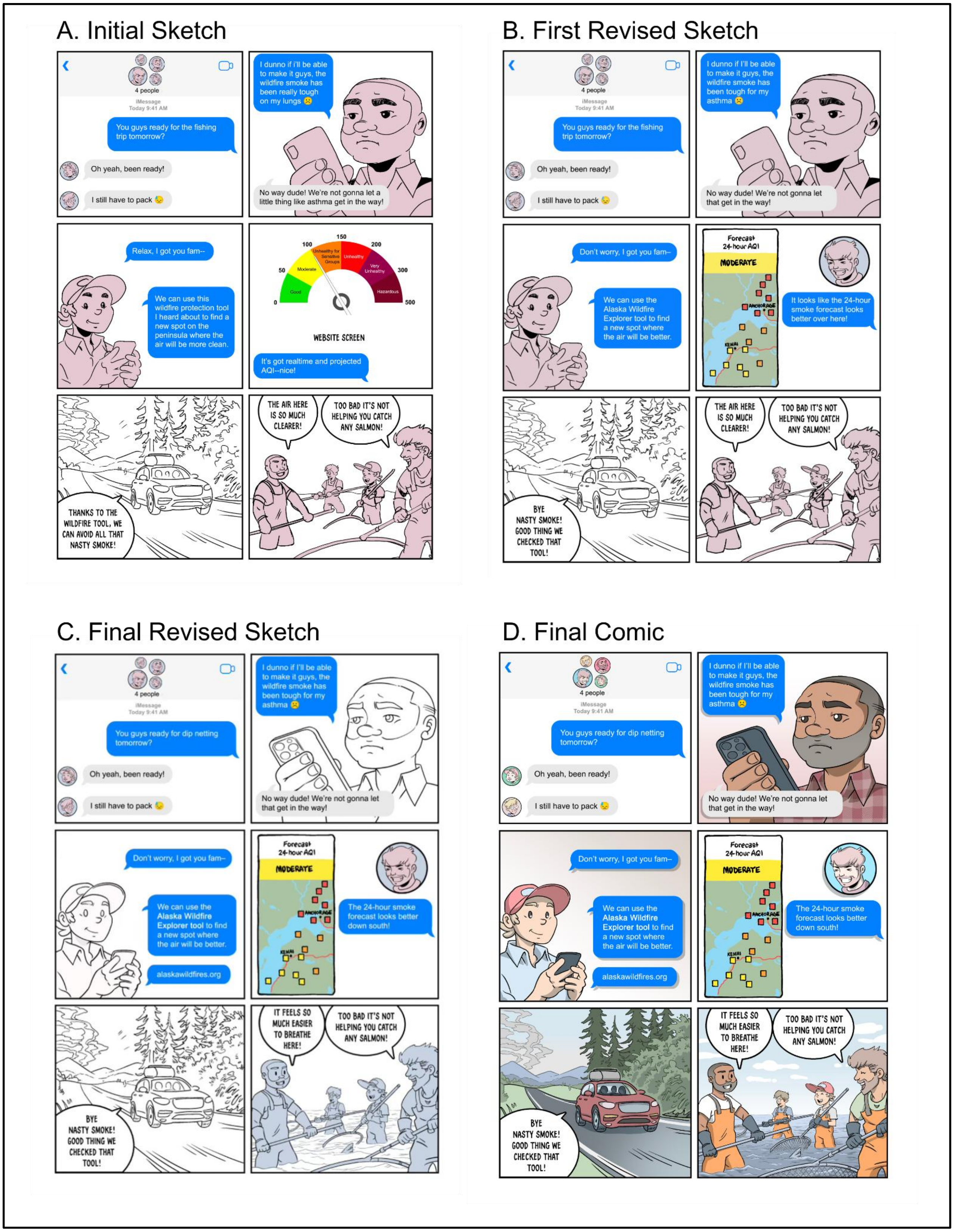
Appendix B7. Iterations of Introduction Story Comic Page 2



Appendix B8. Iterations of Culture Camp Story Comic



Appendix B9. Iterations of Dipnetting Trip Story Comic



Appendix B10. Iterations of Brush Clearing Story Comic