Use of Low-Cost Sensors in Community-Engaged Research on Wood Smoke in the Lower Yakima Valley

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Abstract

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Rural lower Yakima Valley, Washington is home to communities including Latinx farmworker families, the Confederated Tribes and Bands of the Yakama Nation, and Native Americans of other tribes. Episodic poor air quality impacts this region, reflecting sources of particulate matter with a diameter of less than 2.5 micrometers (PM2.5) that include residential wood smoke and agricultural biomass burning. University of Washington (UW) partnered with the Yakama Nation Environmental Management Program and local institutions, Heritage University and White Swan High School, to develop community-engaged research on wood smoke. Both a strong partnership and reliable methods are necessary for community-engaged research. The overall aim of this thesis was to address the feasibility of forming a community-academic partnership and using low-cost sensors to examine wood smoke emissions. This study assessed the following: (1) what are community-academic partnership perspectives on trust, equitable and culturally informed processes, and community involvement in research? and (2) can the low-cost sensor be easily calibrated, and can low-cost sensor particulate matter size distributions be used to predict wood smoke emissions? Aim (1) used semi-structured interviews with each member of the UW team (n=6) and most of the community partners (n=6). Responses were coded and analyzed using a grounded theory approach. Funding, Dialogue, and Formal roles and processes were structural components that provided foundations for the following themes as practices: Community partner capacity building, Academic presence in community, Recognition of community strengths, Understanding the significance of historical and current community dynamics and culture, and Transparency in the research process. Each of the practices contributed to research question outcomes: trust, equitable and culturally informed processes, and community involvement in research. Based on these findings, recommendations were developed for rural, multicultural community-academic partnerships involved in air quality research. Aim (2) used data collected at a tribal air monitoring site in Winter 2018 with a laser based, low-cost, 5-bin particle counter and a 5-wavelength aethalometer (MA200 Aethlabs). Delta-C, the absorbance difference at 375nm-880nm, was used as an indicator of biomass burning. Low-cost sensor PM2.5 calibration used regression parameters from an 8-day co-location with a tribal beta-attenuation monitor. The 80th percentile of the hourly Delta-C:PM2.5 ratio was used to signify wood smoke-enriched hours. The low-cost sensor particle size distributions during these wood smoke-enriched hours were compared to those below 50th percentile of the hourly Delta-C:PM2.5 ratio. Hourly PM2.5 mean was 6.7 μg/m3 (standard deviation 6.7 μg/m3, range 1.3-31.8 μg/m3). Measured particle size distribution did not differ between wood smoke-enriched and low wood smoke hours. The correlation between Delta-C and PM2.5 was higher during wood smoke-enriched hours (0.84) vs. low wood smoke hours (0.75). This suggests that while the low-cost sensor captures wood smoke emissions, further analysis exploring application of low-cost methods to isolate wood smoke episodes are needed. Through evaluation of community engagement and assessment of the performance of low-cost sensors, this thesis contributes to knowledge of best practices in conducting community-engaged research on air quality and provides information on the potential use of low-cost sensors in identifying wood smoke in a rural US setting. These results may facilitate future studies of rural air quality in multicultural communities historically underserved in air quality research.

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Introduction

Rural lower Yakima Valley, located in south-central Washington, is home to communities including Latinx farmworker families, the Confederated Tribes and Bands of the Yakama Nation, and Native Americans of other tribes. Episodic poor air quality impacts this region, reflecting sources of particulate matter that include residential wood smoke and agricultural biomass burning. University of Washington (UW) partnered with the Yakama Nation Environmental Management Program and local institutions, Heritage University and White Swan High School, to develop community-engaged research (CEnR) on wood smoke, called Next Generation Sensors and Scientists (NextGenSS). NextGenSS involves training and mentoring Heritage University students to mentor White Swan High School students to design and implement their own research projects regarding air quality using UW low-cost sensors. The NextGenSS team works with a Project Advisory Committee (PAC) consisting of community partners.

This study aimed to promote CEnR on wood smoke and provide information on the use of low-cost sensors in identifying wood smoke in a non-urban, agricultural US setting. Most air quality studies have focused on urban air pollution. Poor air quality in urban settings has been associated with cardiopulmonary disease, including asthma (McConnell et al, 2010). Previously, it was assumed that asthma prevalence and morbidity were worse in urban areas than rural areas (Estrada and Ownby, 2017). Over the last several years, rural asthma has received more attention (Estrada and Ownby, 2017). Little is known about the relative importance of different rural environmental factors; wood smoke is suspected to be a contributor to asthma morbidity (Singleton et al, 2017). In Washington state, Native American and Alaska Native populations have a higher prevalence of asthma compared to other groups (WA DOH, 2012).

Air pollution related (including wood smoke related) research in rural communities can be challenging due to low population density, disparate access to health services, sparse regulatory monitoring, and distance from academic research centers. One approach to this challenge is to adhere to the principles of CEnR. Low-cost sensors may play a role in CEnR because they facilitate citizen science type implementations (Kaufman et al, 2017). CEnR on wood smoke in rural, multicultural communities is supported through strengthening both community-academic partnerships and methods of studying wood smoke. Successful research relies on sound internal team processes and reliable methods. This study assessed (1) perspectives on trust, equitable and culturally informed processes, and community involvement in research for the project's new community-academic partnership, and (2) whether the low-cost sensor can easily be calibrated and the particulate matter size distributions used to predict wood smoke emissions.

Part 1: Perspectives on the Community-Academic Partnership

Background

Ahmed and Palermo define CEnR as: *"a process of inclusive participation that supports mutual respect of values, strategies, and actions for authentic partnership of people affiliated with or self-identified by geographic proximity, special interest, or similar situations to address issues affecting the well-being of the community of focus"* (2010). CEnR methods have been linked to more effective health interventions and better recruitment and retention in health research (Minkler and Wallerstein, 2008). CEnR methods were highlighted for their role specifically in advancing environmental health (O'Fallon and Dearry, 2002). Research centered on CEnR principles in rural areas has been successful in engaging communities to explore health-related topics (Downey et al, 2010; Baquet et al, 2013). Some residents in rural areas such as the Yakima Valley burn wood as their sole heat source and/or for ceremonial purposes. The impact of wood smoke on local air quality is a delicate subject due to the personal nature of burning wood. An advantage to CEnR is effective uptake of healthy community-level behavior changes during the action phase of the research process. Behavior such as burning dry and seasoned wood and maintaining stoves is essential in reducing wood smoke emissions (Ward et al, 2015; Ward and Noonan, 2008). CEnR may lead to greater uptake of these behaviors that benefit individual and community health. CEnR has been shown to be especially effective among Native American and Alaska Native communities (Jernigan et al, 2015) including by increasing research capacity among tribes (Elliott et al, 2015) and community partners (Jernigan et al, 2015).

Perspectives on trust, equitable and culturally informed processes, and community involvement in research for this CEnR partnership were gathered and analyzed. The interviewer is a white, non-Native, non-Latinx student, who is part of the UW research team and supports the project's programmatic and research objectives. The UW team is comprised of multicultural faculty, staff, and students. UW partners with faculty from Heritage University, a rural Hispanic Serving Institution located on the Yakama

Reservation, and the PAC. The PAC is comprised of community leaders and agency representatives from the Yakama Nation, a local Spanish language radio station, Indian Health Service, a tribal health focused non-profit, and the Mt. Adams school district. The project is located on the Yakama Reservation in south-central Washington state, and involves undergraduate students and high school students conducting student-directed research projects about air quality and wood smoke. Major communities in the area include tribal communities (Yakama Nation and Native Americans of other tribes) and immigrant Latinx agricultural communities. While the academic team has a history of research engagement with the Latinx agricultural community, this project developed new connections between UW and the Yakama Nation, and the interviewer joined at the beginning of this new engagement.

Three overarching research question groups guided this inquiry:

1. What are some ways that the research processes and roles on the research team can build or erode trust among team members, particularly between the research team and PAC partners? Are there examples of ways trust has already been built or eroded on this team? What are some ways trust could be built or eroded?
2. What are some ways that the research processes and roles on the research team can combat inequities arising from differences in power and privilege between researchers from UW and local researchers and community members?

    2a. What are some ways that the research processes can be informed by Yakama Nation, Native American, and immigrant Latinx cultures?

3. What are some ways that the research processes and roles on the research team can facilitate the involvement of the community partners in the research?

    3a. What are some ways that the team can facilitate the involvement of community members in using the results of the research for public health actions or benefits?

Theoretical Frameworks

Trust, equitable and culturally informed processes, and community involvement in the research are all foundational elements for a sustainable partnership and relevant and successful research. Theoretical frameworks for each are described below.

Trust

This research used the definition of Critical Reflective Trust from Lucero: *"Trust is at the place where mistakes and other issues resulting from differences can be talked about and resolved"* (2013). Open dialogue and communication are essential to building and sustaining trust (Butterfoss, 2007). Formalized decision-making and formal roles build trust in the research team (Butterfoss, 2007) along with clear expectations and transparent intentions (Christopher et al, 2008). Additionally, it builds trust when academic partners recognize community histories and the historical context of research, including research abuses (Christopher et al, 2008). Minkler notes that in community-academic partnerships, academics carry with them the history of their own institution as well as the history of other researchers (2004). Trust is built and eroded in the context of historical and institutional dynamics, outside of just interpersonal relationships (Minkler, 2004). Part of recognizing community and institutional histories is acknowledging and addressing racism and privilege, especially white privilege (Chavez et al, 2008). Not doing so leads to unjust power dynamics, which obstruct trust (Chavez et al, 2008).

Practices that support trust include recognition of each party's contributions and expertise (Christopher et al, 2008) and having a shared goal for the project (Butterfoss, 2007), as well as academics being present in the community (Christopher et al, 2008). Additional practices include following through with commitments, showing care for other people's interests, acknowledging fault, talking openly about trust, and regularly revisiting shared ideals and intentions of the project (Butterfoss, 2007). The quality of trust in the partnership impacts the success of the work (Butterfoss, 2007).

Equitable and Culturally Informed Processes

Research is more likely to be successful if the team demonstrates respect for community cultural and social institutions (Gibbs, 2001) and works in partnership with the community to plan the project (Christopher et al, 2008). Christopher et al discuss the notion of cultural sensitivity: *"respect for each other's specific cultural beliefs and practices"* as vital to health interventions (2008). Israel et al examine the concept of cultural safety, which requires professionals (in this context the academics) to create a space where the community partners feel comfortable expressing if they feel safe or not and then responding through behavior change as indicated (2013). Practices that support cultural safety include reflection by academics on how culture and privilege impact their perspectives on the research issue and being open to other views (Israel et al, 2013).

Promoting equity not only involves self-reflection but also reflection on the origins and values associated with conventional research, particularly its connections to colonization and imperialism (Tuhiwai Smith, 1999). This is particularly salient for partnerships with indigenous peoples. Equity is also supported through clear and formal agreements surrounding knowledge sharing and data use (Gibbs, 2001). Addressing power dynamics and academic privilege is essential to just community engagement (Muhammad et al, 2015).

Community Involvement

Community involvement in research is supported by greater and more diverse opportunities for interaction (Butterfoss et al, 1996), providing time for socializing (Wolff, 2001), and consistent, regular contact (Kumpfer et al, 1993). Community members are more likely to want to be involved if the partnership demonstrates a desire to treat community members as equals, and acknowledgement of the community's perspectives rooted in culture and history (Butterfoss, 2007).

Forms of community involvement include, but are not limited to, issue identification and implementation of health interventions (Butterfoss, 2007). Involvement during the planning phase is particularly important for sustaining involvement throughout the project (Roussos and Fawcett, 2000). Formal agreements, roles, and specific tasks promote collaboration with community members (Butterfoss, 2007; Winer and Ray, 1994).

Figure 1 summarizes the major theoretical frameworks for how trust, equitable and culturally informed processes, and community involvement in research impact a community-engaged partnership.

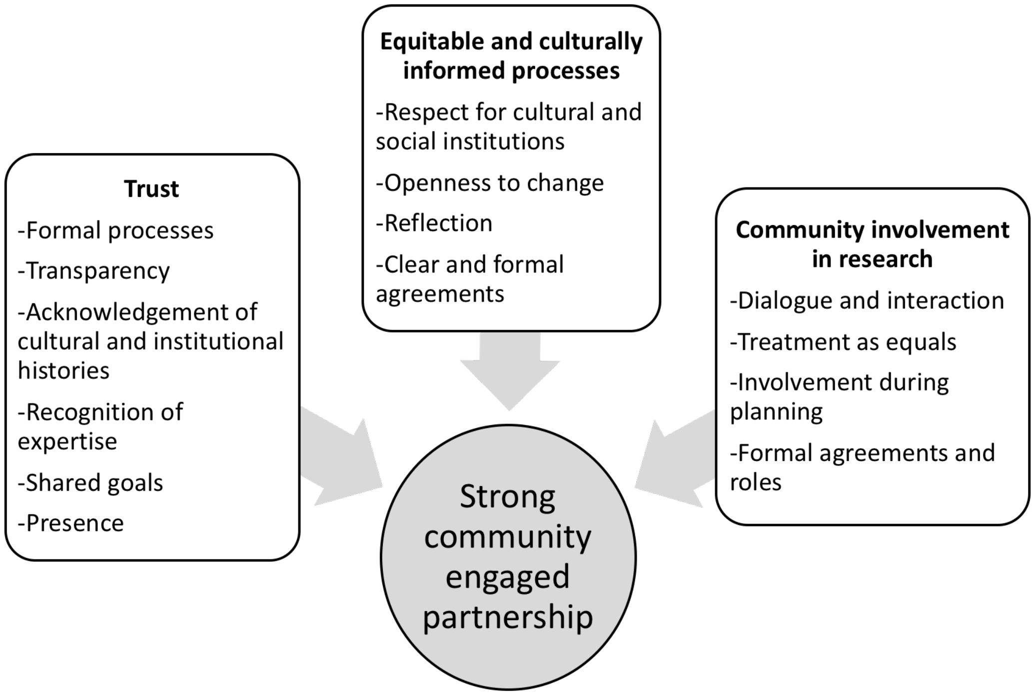

Figure 1: Summarized conceptual framework about elements of trust, equitable and culturally informed processes, and community involvement in research for a strong community-engaged partnership.

Methods

Interview questions were formulated from a literature review examining the relationships between trust, cultural relevance, and community involvement in research with partnership processes, roles, and strengths. Each interview question fits into one of the three overarching research question groups listed above, pertaining to trust, equitable and culturally informed processes, and community involvement in research. Interview questions are included in Appendix A.

Twelve semi-structured interviews were conducted with individuals from the community-academic partnership: 5 PAC members (out of 7), 6 UW research team members (out of 6), and 1 academic partner from Heritage University (out of 2). Because Heritage University is small and has strong ties in the surrounding rural Yakima Valley community, for the purposes of this analysis this academic partner was categorized as a community partner. Interviews lasted from 22 to 90 minutes, were either in-person or over the phone, and were recorded with participants' permission. All interviews occurred between September and December 2017. Prior to any interviews, this study was submitted to the UW IRB and US EPA Human Subjects Regulations review and was determined by both to be exempt.

Each interview was transcribed using a combination of audio-to-text and typing using Wreally

Studios' Transcribe software. After transcribing all of the interviews, major themes that emerged were noted, which guided the selection of 31 codes, described in Appendix B. These codes each related to different aspects of relationship building, research processes, and community qualities. Dedoose software was used to apply codes to interview excerpts (Dedoose, 2018). Following the coding of 3 interviews, another team member coded 2-page selections from each of the 3 interviews. These codes were in agreement about 30% of the time. 62% of the discrepancies came from differing perspectives on the scope of "Trust Built" and "Trust Eroded." It was agreed that an additional code related to communication was also needed. In response to this, 3 codes were added, described in Appendix B. This raised agreement in coding to 73%.

Once the code selections were complete, a close reading of each interview was performed and codes were applied as themes appeared. Within each code, excerpts were grouped thematically and emerging patterns were noted. For analysis, a grounded-theory approach was used, which is based on open-mindedness (Charmaz, 2014) and the lack of preconceived notions (Patton, 2014). This approach does not test hypotheses; it instead generates theories from the data to explain patterns that have emerged (Patton, 2014). Grounded theory is flexible and encourages exploration of the data through all stages of analysis, documented through memo-writing (Charmaz, 2014).

Grounded theory was useful in this research because the research questions were open-ended, seeking ideas for how to improve the research partnership, processes, and project. This was not meant to be merely an assessment of how the partnership is currently operating. This investigation was open to perspectives outside of existing theoretical frameworks and sought to understand patterns of perspectives from the various partners about the partnership.

Findings

Eight salient themes emerged from the analysis: Funding, Dialogue, Formality (formal roles and processes), Community partner capacity building, Academic presence in community, Recognition of community strengths, Understanding the significance of historical and current community dynamics and culture (which is referred to as "community context"), and Transparency in the research process. Each of these themes is described below, including select supporting quotations. To respect confidentiality and privacy of respondents, each person is referred to as either a community partner or an academic partner, as categorized in the methods section. Each respondent approved of the use of their quotations.

Funding

Issues with funding were related to rigidity surrounding conventional research, including the limited time-frame of grants, the scope of research issues relevant to funding agencies, and budgetary restrictions. Academic partners pointed out that the grant, while community focused, does not fund relationship building despite its centrality to project success.

Both academic and community partners expressed that for community partners, participation in the project was only potentially useful, and UW's resources were an important prospective benefit. An academic partner suggested that perhaps for community partners: *"it's still probably a little bit of a gamble for them in a daily way when they've got so many other things in a resource poor environment to deal with. Is it really worth squeezing to deal with this stuff that maybe will pay off, but they don't really know yet?"* In this project, community partners expressed that they were pleased with how funding was allotted. One community partner said: *"I think it's really good for the students to get appropriately compensated. I feel I am. There was money to buy some supplies at the end because we had extra so that was really good."* At the same time, an academic partner noted: *"We have the fiscal oversight and responsibility and we asked [organization] what they wanted for a budget, but at the end of the day, we've got control of the budget and so I think that's a power thing within the context of this project."* Academic and community partners voiced differing perspectives on what constitutes a lot of money; an academic partner mentioned that *"there just isn't very much money on this project"* while a community partner stated: *"It's a great support. Having students that are supporting this project is huge. That's huge. So that's incredibly beneficial to have that…. We were able to outfit ourselves with some things we can use for the students like the laptops, that's huge for us, so again that's definitely a benefit."*

Both academic and community partners discussed the short time-frame of research grants. A community partner explained: *"These grants do have a lifetime and an end, but we'll still be here and we'll still be working with these kids and we'll still be continuing on [the program]…. For us we will have to continue this work because we can't stop, because there's an expectation that no matter what we don't just leave, we stay…. Funded or not we find a way to keep going. For us, whenever we take on a commitment like this, it's a much longer commitment than people realize."*

Academic partners discussed that UW drove issue identification. At the same time, community partners shared that the issue identified was indeed important and relevant to them and their community. Academic partners shared their perspectives on issue identification for future projects and suggested that those could be more community driven and academically relevant, rather than the other way around. Speaking of a future project, one academic partner suggested: *"the next one could really be driven more from the community…that we could somehow foster or assist with."*

Dialogue

Academic and community partners noted that early communication, before decisions have been made, is highly important so that community partners can bring their strengths to the table. In general, community and academic partners felt positive about relationship building, and felt that dialogue supported transparency and openness within the UW team, within community partners, between UW and community partners, and between UW and community members. Speaking about sharing information about the project, one community partner said: *"I think this group is doing a pretty good job. I do. We reached out repeatedly to various tribal members, to Hispanic members, to community members, to the relevant departments… I think this group has done a lot to really make the effort."*

Academic and community partners both discussed goals for building community partner capacity, but they had slightly different focuses. Academic partners expressed desires to build community capacity to *"identify some resources that are beneficial," "write a grant…drive their own interests,"* and do *"outreach and engagement."* Community partners discussed *"technical expertise," "roles of research and investigations,"* and *"public health."* An academic partner also voiced that without dialogue, community partners may not even know what is available to them through the project. This partner suggested: *"We can just ask them what are some other things that you need, what would you like, maybe there's some other things we can provide to you. Just having an open conversation acknowledging the fact that we might be able to provide you more than what you're asking for."* Academic and community partners described tension about the balance between requesting more of community partners and providing opportunities to build capacity.

Academic and community partners conveyed many opportunities for dialogue, such as through check-ins with community partners about how the project is progressing and what adjustments are needed. Sharing project feedback with the community and raising awareness about the research issue were also mentioned, along with updating the team more regularly. Partners emphasized the importance of mutual, multidirectional dialogue as opposed to one party simply providing information to the other. One community partner said: *“I think that we all are lifetime learners and so I think that there's a lot that myself and my staff can learn from University of Washington, but I also think that UW folks can learn a lot from us…living the life and traditions that we live, and help you gain an understanding of our tribe and our culture. I think we have a lot to share between each other.”*

<u>Formality</u>

Two community partners suggested formal processes around dialogue, for example having a debrief at the beginning of meetings where partners can discuss updates and needs, or providing time for community partners at the beginning of meetings to discuss amongst themselves, without the other partners present. Academic and community partners expressed that formal processes may help provide structure for more direct dialogue around issues including tribal sovereignty, past experiences with research, community strengths, and capacity building needs. One community partner specifically raised the idea of a formative assessment: *“One way that's done is the concept of a formative assessment like before you even plan on preparing a grant application…we don't want to make any assumptions about what your needs or interests are…can we ask you a series of questions to better understand…who you are and your priorities and needs.”* Through this structure, academic partners could learn from community partners about community context, strengths, and priorities in a formalized way early in the project process, ideally before planning on preparing a grant.

Academic and community partners suggested formal processes that may have been helpful in starting the project, such as a formal *“kick-off”* and *“one-on-one meetings”*. Two academic partners suggested that formal roles could increase accountability. One academic partner noted that formality can support transparency about project expectations: *“Having very defined roles, especially with respect to how long we're going to be there and what exactly we're going to give back and what the timeline is, is probably critical.”*

Academic and community partners noted several caveats to the benefits of formalizing processes and roles. One community partner emphasized that establishing formal roles should ideally be followed with funding, and that it would be ideal *“if formal roles were genuine and built capacity.”* Academic partners mentioned that the establishment of roles should be iterative, revisited frequently, and flexible.

Community Partner Capacity Building

Community partners expressed appreciation for academics’ assistance in data interpretation and also just general support and patience while community partners navigated their work. One community partner in particular raised the idea that the team trusts each other because it is necessary in order to do the work, and they trust that the academic partners will continue to be supportive. This partner said: *“There's a lot of trust. It can be frustrating at times, but there has to be a lot of trust because we're conducting it. The fact that we're still working together is an acknowledgement of that.”*

An important note voiced by a community partner was that building community partner capacity must be genuine. This community partner noted that research money often goes to academic institutions working with community partners. This partner said: “*I don't want to call it token, but there's a certain degree of ‘the more we have you involved the more likely we are to get this grant’ which is great but it's sort of holding the community's capacity in as a feature vs. as the driving component.”* Community partners expressed that genuinely building community partner capacity may more lead to more equitable benefits from the research between the two groups.

Academic Presence in the Community

Academic and community partners expressed that academic presence and shared experience provide opportunities for the two groups to get to know each other as people, and that it provides an opportunity for the community to educate academics, including about their strengths. Additionally, presence in the community sends a stronger signal that the academics are invested in the community, especially if their presence is at an event unrelated to the research project. One community partner noted: *“I think that it helps if it is not necessarily project driven…. I think taking it out of the context of project driven interaction and presence could be valuable.”*

One community partner said about the high school students: “*So these kids, it's kind of the same thing where the university comes in - not all white obviously but the perception is that - and they can get really intimidated. And it's nothing you're doing - it is based on the color of your skin. And that's a reality. But it doesn't take long for them to get to know you, and then you become not the color of your skin, but*

[UW team member]. Sort of like [the project principal investigator], who's worked in the Hispanic community here for so long, who has a lot of trust, who's not seen as a white lady from - she's seen as Dr. [_____] who's here a lot, who's here regularly, over many years. That's kind of the same."

Partners noted that academic presence is necessary for mutual, two-way learning between academic and community partners. One community partner stated: "*There's no book you can pick up, there's no movie you can watch, there's no way to get our experience other than from us. And making the time to be out here with us and learn from us is probably the best way."* This partner described the benefits of attending a cultural event and how it would support academics understanding community context: *"To come out and actually witness that and see that for yourself is very strong, and it helps you to get an understanding of why we fight so hard and why we protect our foods and our resources so heavily."*

<u>Recognition of Community Strengths</u>

Several community partners commented on a perceived lack of strengths recognition in the context of trust erosion. One community partner reflected: "*It was a very classic scenario where someone from the University of Washington was not sufficiently aware of the work of the Yakama Nation or their air quality program. Being unfamiliar, they didn't recognize the tribal nation as a fully functioning air quality agency with all of the capacity and resources of a regional or state agency, if not more. Nor did they grasp the extent of tribal knowledge and expense around air quality and natural resource management.*" Similarly, academic partners expressed that they felt that the partnership would benefit from learning more about community strengths.

Despite initial tension surrounding strengths recognition, all but two interviewees (one academic and one community partner) discussed that they felt listened to and heard, without being prompted on this topic during the interview. Looking forward, one community partner commented: *"I would like to think that what happens from this point on is that that relationship can be repaired… I think that if the group is beginning to understand and see what we are capable of, what we have done, and what we have to offer, I think that that relationship will continue to build."* Community and academic partners noted that community partner strengths may be especially valuable in air quality program implementation, community engagement, and curriculum development. Further, they noted that focusing on strengths is necessary to support a genuine relationship. As this project does rely on community partners and community strengths for implementation, a shift in power was recognized by an academic partner: *"Sometimes I feel like I have less power over this thing, because it's really kind of up to a lot of these other people to be involved and do things to make it all happen."*

Community Context

Partners discussed many factors outside of this project and partnership that contribute to general trust erosion and discomfort between community and academic partners. These fell generally into three categories: the history of the Yakama Nation and Native Americans post-contact with white settlers, being a close tight-knit community, and experiences with researchers and outsiders causing harm (including when well-intentioned). Academic and community partners raised concerns about general and/or previous community experiences with research where the benefits were inequitable. One community partner stated: "*It's kind of the thought that here are these outsiders that come in here, and they come into the community, and they do their research, they write up their papers, they get published, pad their resumes and stuff like that, but what does the tribe or the community get from that research? How do they benefit? They don't. And in a lot of these research projects there's a level of vulnerability on behalf of the community that shared - and what's the benefit to them?"* Academic and community partners also raised concerns about UW's reputation in this area and how that might impact community-level trust and involvement.

Several partners alluded to the idea that trust could be supported through academics learning more about community history and culture and appreciating it. This included reflecting on the Yakama Nation Treaty of 1855 and how it reveals the forethought of the Nation's elders in reserving rights and land, and that natural resource conservation is vital to the life of the Yakama people. This also included appreciating cultural differences between academic and community partners and how those impact perspectives on the environment. Partners also discussed the importance of understanding current relationships and dynamics between organizations and agencies in the region to avoid eroding trust.

Academic and community partners emphasized that a high level of trust exists between some community partners, namely Heritage University and White Swan High School, which supports the project. Partners recognized the importance of having advocates within the community and the support of

Tribal Council. One community partner noted: *"In the case of designing a research project, if you have teams together that involve the academic researchers but also community members, other stakeholders that have the context of our community and our way of life, then I think that ultimately the trust will be higher, you'll get more buy in because there's more of a feeling of transparency, and it eliminates surprises."* This community partner also discussed how community context should inform how research is done: *"That context - even though that might not be at the center of our conversation, but understanding those kinds of things gives us clues about how we would approach well intended research today - in 2017 - almost 18. How do we approach families to collect data, for example if we're trying to get data from families? What kinds of questions are appropriate, and who should be asking the questions? Where should we be asking those questions? All of those kinds of little details could be different from place to place or community to community."*

Academic and community partners noted that the community is diverse, and it is important to have representation on the project from different parts of the community, especially including both Latinx and Native community members. Additionally, partners raised concerns that most of the people involved in the project are representing organizations or agencies, but it is important to also have people involved who are just interested individuals. This would facilitate more robust community involvement.

One aspect of community context that several community partners raised is the desire to translate air quality research and awareness into practical actions that individual community members can take. This would make the project more culturally relevant. One community partner noted: *"It would be more relevant if the curriculum includes practical things to do at home. That would be more relevant to the community and create more impact…we know there are certain things we can do in the broader picture but how the community can make little changes in their lives, and they're practical and they're not too expensive to do, it will create more impact and it'll be more relevant to the community."*

<u>Transparency in the Research Process</u>

Community and academic partners expressed that their own and others' roles in the project were unclear, which was a source of tension. Some also voiced a lack of knowledge about each other's goals and motivations in participating in the project, although in reality partners had similar and sometimes overlapping goals, shown in Figure 2. Both community and academic partners cared about building relationships with each other, supporting the project, and learning.

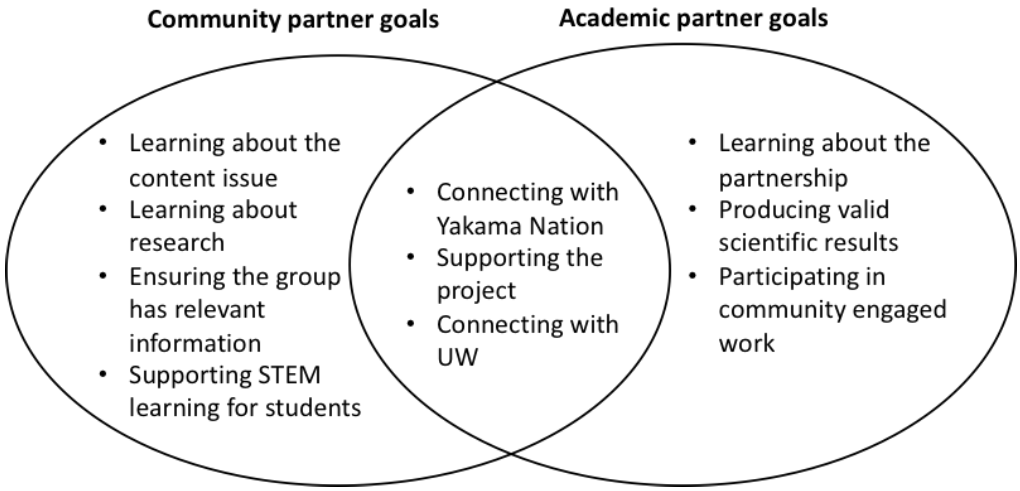

Figure 2: Partner goals for participating in the project and partnership.

Throughout the interviews, nearly everyone mentioned that one thing they liked most about the project was that it involved youth. An academic partner stated: *"It isn't just about technology and how to use technology but how kids learn about problems within their community and how they can play a role in helping to solve some of those problems. So I think that could be an important public health lesson - how do we get our young people involved in environmental health problems."*

Community partners connected this perceived lack of transparency around roles and motivations to community involvement and trust. They noted that people may be hesitant to participate if the intention and asks are unclear, and that making project goals and motivations more explicit might support trust building in the community. One community partner noted: *"Transparency is one of the biggest pieces to trust"* and that *"a big project can definitely lift off with the right people in the room and the intent is put out there and people have a better understanding of what's going on and why, and they can really jump on and say yeah let's get behind this."*

Community partners also made the connection between transparency and equity in the partnership. They shared that transparency about academic intentions and assumptions about community partners enables conversations where community partners are able to voice their agreement or opposition and help shape the project and partnership to better meet their needs. Transparency also facilitates understanding and knowledge of the project, which better allows partners to participate as equals.

Discussion

While these themes were interrelated, in general, Funding, Dialogue, and Formality were structural components that provided foundations for the other themes as practices. Each of the practices, in turn, contributed to outcomes of two or three of the overarching research questions. In some cases, structural components impacted each other and outcomes directly. These relationships are depicted in Figure 3:

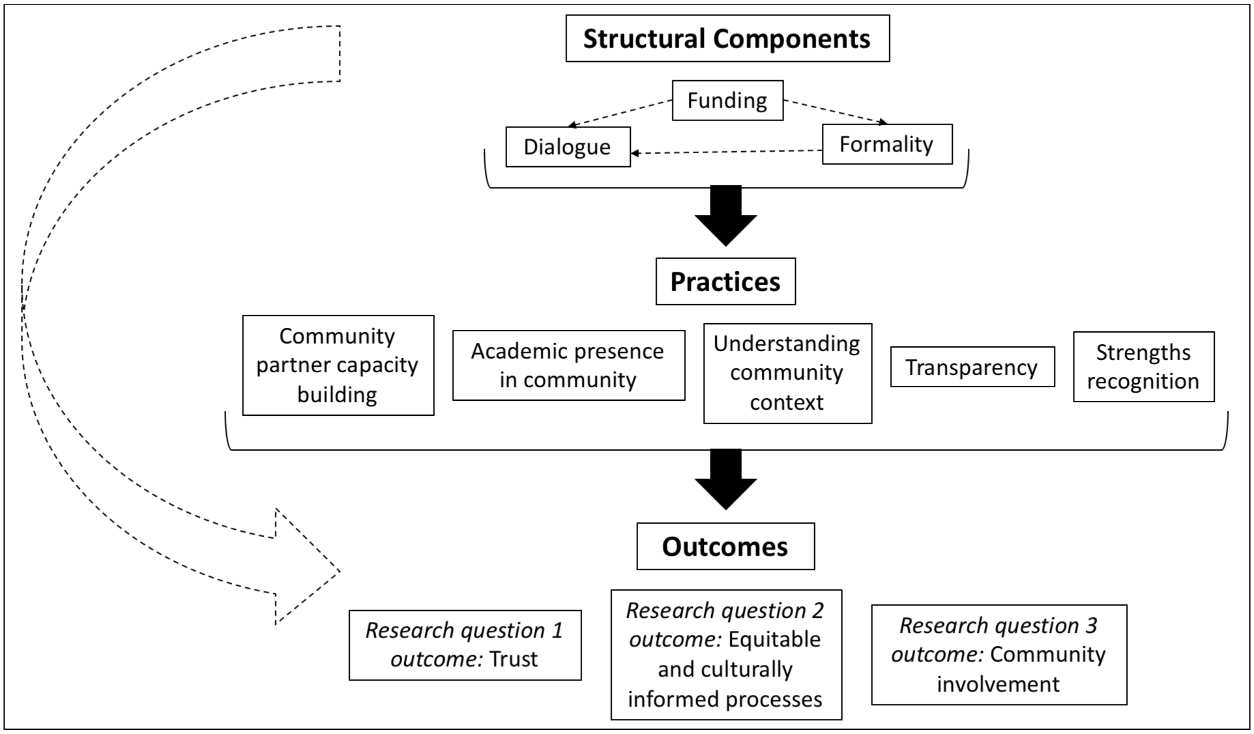

Figure 3: Conceptual model of the relationships between major themes and research questions.

Building relationships is an essential part of the CEnR process, particularly with Native American communities (Harala et al, 2005). If community partners are not being compensated for their time spent relationship building, their participation is risky in the sense that their time and energy investment may not result in a benefit to them or their community. A power dynamic emerges from community partners not being compensated for their time in relationship building and only potentially standing to benefit from the relationship.

While appropriate compensation for community partners is essential, it does not eliminate this power dynamic because decision-making power about money still lies with the academic partners. An equitable partnership may involve finding ways to compensate community partners for their time spent relationship building, and having an open and transparent dialogue about how money is spent and how much money is meaningful to different partners.

Short research time-frames contribute to the occurrence of "helicopter research," where academics merely collect data from a community and fail to report results or otherwise involve in the community in any meaningful way (Harala et al, 2005; Christopher et al, 2008). This style of research can cause communities to rightfully be wary of research and make it more difficult to involve community partners (Harala et al, 2005; Christopher et al, 2008). Limited time on research grants also creates barriers to having an equitable partnership, because community partners often need to continue the work no matter what, while academics typically only work on a project within the grant time-frame. This places extra pressure on the community partners. A research process and partnership that has a plan for longevity and sustainable impacts would be a culturally informed research process.

Communication is essential to successful community-academic partnerships (Koné et al, 2000). Dialogue is important in framing how to pursue community partner capacity building aims, and plays a role in addressing the balance between community partner time and resources and capacity building opportunities. Without open dialogue, community partners may not even know what is available to them from academic partners. Academic partners need to be clear about what they might be able to offer, even if community partners do not ask. This kind of conversation helps move the partnership away from negotiation or transaction style interactions and towards a mutually supportive and equitable collaboration. When community partner capacity building priorities inform how research is done and what roles community partners have, there may be more equal distributions of research benefits between academic and community partners. When roles are based on existing strengths and capacity building priorities, and have power, the partnership is strengthened by avoiding tokenizing community partners (Butterfoss, 2007).

Formal processes such as a formative assessment help ensure that dialogue around community context, strengths, and other considerations is explicit and comprehensive (Butterfoss, 2007). Formality may reduce some of the hesitation of community partners in voicing their priorities and concerns because it sends a signal that academic partners are seeking feedback and creates a clear pathway for doing so. Duran et al note that for the best chance at success, community partner involvement in research should be formalized from the very beginning (2013). Establishing clear agreements and protocols early in the partnership sets the stage for expectations throughout the process. It is necessary for the partnership to be able to effectively summarize community priorities, needs, assets, perspectives on explanations of the health issue, and culturally centered interventions (Duran et al, 2013).

Academic research pressures, particularly from funding agencies, contribute to researchers focusing on scientific questions that would contribute new information to the field and are appropriate for the funding and time length of the project. These questions may not match up well with community partner needs and interests. This may limit how useful the work is to community partners, and also contributes to a power dynamic where the academic partners' needs are weighted more than the community partners' needs. Community driven issue identification helps demonstrate academic commitment to the community and makes the project more relevant (Minkler and Wallerstein, 2008). In order for CEnR with academic institutions to thrive, the issue must be academically relevant. However, it does not need to be academically driven. The project may be more successful in the long run if it is community driven because that makes the project more relevant to the community (Harala et al, 2005).

One of the focal points of trust erosion in this partnership stemmed from academic partners not recognizing and acknowledging community strengths. Acknowledging community strengths moving forward may help build trust. Duran et al describe several key elements in establishing and nurturing community partnerships (2013). These include emphasizing the community's assets, and conducting a strengths assessment in addition to a needs assessment (Duran et al, 2013). Academic due diligence plays a role in recognizing strengths in general, because community strengths cannot be recognized well if academics do not know about them.

Community strengths related to implementation may help the project be more beneficial to the community, and also may make it more sustainable. These strengths should inform how the research is conducted. Asking community partners for their help upfront is a form of strengths recognition because it makes it more likely that the project will lean on community partner strengths. Genuinely relying on the capabilities and wisdom of community partners shifts the power dynamic, which may also help build trust from the community side. Sharing power and recognizing what the community has to offer are vital to CEnR (Koné et al, 2000). When academic partners express that the community partners are experts in their fields and in their community, community partners are more likely to participate (Christopher et al, 2008).

Academic presence in the community is thought to support trust building in community-academic partnerships (Christopher et al, 2008) including showing up for things that are important to the community, even if they are not closely related to the research topic (Duran et al, 2013). Academics being present in the community facilitates getting to know each other as individuals, demonstrates investment in the community, and gives the community a chance to educate the academics.

CEnR is partly based on the idea that community members are not just research subjects, and when community members help drive the research they are more humanized. However, even when community members have more power, they may still be viewed primarily as research subjects by academics. To have a more genuinely equal partnership, both sides need to share with and humanize each other. Being present in the community facilitates academic perceptions of community members as people first and research partners and/or subjects second.

Academic presence outside of the scope of the research project may carry extra weight and demonstrate more investment to the community because academic partners are not typically compensated for taking the time to be present outside of the scope of the research. This might make their presence more meaningful and reduce the power dynamic implicated when community partners are uncompensated for time spent on the project. Christopher et al describe an example where the academic partner's presence in the community is noticed by community members and communicated broadly (2008).

Recognizing the historical context of research and community histories builds trust, and demonstrating respect for community cultural and social institutions may lead to more successful research (Christopher et al, 2008). Butterfoss emphasizes that understanding the community is essential for an effective partnership and understanding decision making structures and authority in the community is key (2007). When working with tribes, an understanding of tribal sovereignty is vital (Christopher et al, 2008). In this partnership, by spending time in the community and with community partners, academic partners learned about the nuances of different relationships between groups present in the community that informed who needed to be part of this project.

Trust erosion on a broad, systemic level occurring outside of the partnership shapes attitudes toward this research project. This suggests that the partnership may, or even should, start out with a trust deficit (term from Lucero, 2013) due to the larger context of trust erosion. Proxy trust, trusting a person/organization/program because of their connection to a person or entity that one already trusts (Lucero, 2013), also plays a role in community trust building. Proxy trust may build community trust because community members expect that the program or entity is informed about the community context, and that people they trust are involved and know about the project plans.

Understanding the significance of community context is different from understanding community context. While academic partners should strive to be culturally competent through learning about community context, the emphasis should be on cultural humility. Cultural humility involves continual self-reflection and the recognition that one cannot ever fully know another's situation or community context (Tervalon and Murray-Garcia, 1998). Harala et al note that recognizing that community and academic partners have different worldviews, including on research, builds trust (2005).

Duran et al caution that academic researchers need to be cognizant of the fact that a single community entity contains a multitude of perspectives and opinions (2013). Smaller groups within the community may have different stances on an issue (Duran et al, 2013). Israel et al found that when partnerships had a history of successful relationships and the involvement of key community members, the partnerships were more likely to be successful (1998). In this partnership, being intentional about having members from both Latinx and Native communities is an example of a culturally informed research partnership process. Community representation is important not only in getting information from the community, but also getting information back to the community. It is important to be intentional about who is involved in the research so that the partnership is learning about strengths and concerns from different parts of the community and also so that community members from different parts of the community will be reached.

Community representation is also complicated by organizational vs. individual perspectives. All of the PAC members represent both themselves and their organizations when they participate in this partnership. No one in the PAC solely represents themselves. A culturally informed process might be to intentionally include community partners who do not represent an organization in the partnership. It is important to have formal leaders, informal leaders, and regular people involved in the project (Minkler and Wallerstein, 2008).

Lack of clarity around roles and goals has implications for trust, because in any kind of relationship, knowing each other's motivations and intentions is foundational. In Lucero's assessment of trust, the two lowest levels of trust are described as: *"--Trust deficit (suspicion). Partnership members do not trust each other. --Neutral. Partners are still getting to know each other; there is neither trust nor mistrust*" (2013). It seems unlikely that it would be possible to get past these two levels of trust without having a sound understanding of each other's motivations. If the community does not understand the project goals, then the partnership is not ready to act (Butterfoss, 2007). Israel et al found that when community and academic partners together established operating norms and procedures, the project was more likely to be successful (1998). Clear expectations build trust in the research team (Butterfoss, 2007). Formal processes are helpful in stating expectations (Christopher et al, 2008).

Unknown motivations support a power imbalance between community and academic partners. Not knowing each other's intentions creates a situation where community partners may feel forced to guess and attempt to comply with what they think the academics' goals are. Being explicit about agendas and goals may be a culturally relevant research process because it takes into account historical and present adverse experiences with research among the communities at the center of this project. Clarity about intentions, asks, and the project in general facilitates community involvement because people understand more about the project so may better know how to participate or benefit from it. The intention behind the project needs to be transparent in order to gain community trust and support.

Implications

Based on the relationships between themes described in the discussion, there are several recommendations for building community-academic partnerships to promote trust, equitable and culturally informed processes, and community involvement.

1. Fund relationship building and dialogue, including compensating community partners' time. Have an open dialogue about money, including what amounts are reasonable from each party's perspective within the context of the grant. Keep fiscal oversight transparent.
2. Be mindful of the implications of the project for community partners after the grant is over. Discuss

the sustainability of the project at the beginning and make a plan for the end of the grant. Explore grant mechanisms that provide more opportunities for project sustainability.

3. Have open and explicit dialogue about community partner capacity building priorities. Ensure that community partners know what might be available to them, and be mindful of the balance between burdening community partners and providing opportunities. Community capacity building priorities should drive community partners' formal roles.
4. Conduct a formative assessment at the beginning of the relationship to learn about community context, priorities, strengths, and ways they would be interested in participating in the project.
5. Choose an issue that is community driven and academically relevant.
6. Learn about community strengths, and acknowledge and appreciate them. Recognize community partners as equals. Genuinely rely on community partners for project success.
7. Find opportunities for academic partners to be present in the community, including at events unrelated to the research issue.
8. Take the time to understand and appreciate the significance of community context. This could be done through a formative assessment, dialogue, and academic presence in the community. Learn about relationships and dynamics to be aware of, the community's previous experiences with researchers and outsiders, and what community partners and community members want to share about their cultures. With tribal partnerships, ensure that academics and non-tribal community partners understand the implications of tribal sovereignty for the project and partnership.
9. Include people in the project who represent the diversity of the community, including involving interested individuals in addition to people who represent relevant organizations.
10. Be transparent about roles, goals, motivations, asks of community partners and community members, project design, data, analysis, and connections to scientific/programmatic/policy implications.

Limitations

There are several important limitations in this study. An overarching limitation is that the interviewer is part of the research team, and their views are not unbiased. Using grounded theory helped mitigate bias through its emphasis on abandoning preconceived notions and requiring self-reflection from the interviewer. The interviewer strove to remain aware of their positionality as a white, urban student and member of the UW team. At the same time, conducting interview coding and analysis manually introduced more potential for bias. Comparing coding with another coder helped reduce this bias, though the high number of codes (31) contributed to poor initial validity. With the addition of new codes, validity increased.

Another important limitation is that community partner interviewees may not have felt comfortable sharing openly with an academic partner. This may impact how well the interview results reflected partners' ideas. This limitation may have been mitigated by the open-ended, neutral nature of the interview questions, and the relatively low power attributed to students compared to other academic partners. Nearly all partners freely shared vulnerabilities and concerns, which suggests some level of comfort during the interviews.

Conclusion

This study is an example of a successful analysis of perspectives on a community-academic partnership. Nearly all members of the partnership participated and shared their views. While community and academic partners had some similar views, for example about goals for the project, there were also important examples of differing views, such as those about community partner capacity building. This analysis showed that there are actionable ways to build trust, promote equitable and culturally informed processes, and facilitate community involvement in the community-academic partnership.

This partnership is unique in that it is multicultural and includes both a large, urban, public university and a small, rural, community-based university. At the same time, these recommendations may be relevant to other community-academic partnerships, particularly multicultural partnerships in rural areas. This analysis and recommendations help inform ways to establish successful community-academic partnerships, fostering more effective research and interventions. Next steps include gathering additional insight on the findings and recommendations from the partners, and making plans for implementing recommendations.

Part 2: Assessment of Low-Cost Sensors in Monitoring Wood Smoke

Background

Residents of the Yakima Valley are disproportionately exposed to poor air quality compared to the rest of Washington state, including high levels of particulate matter with a diameter of less than 2.5

micrometers (PM2.5). In 2015, Yakima was listed as one of just two major communities in Washington in danger of exceeding the 24-hour standard for PM2.5 (Washington Dept. Ecology, 2015). In 2015 and 2016, Yakima County had the greatest percentage of monitored days per year over 35 µg/m3, compared to all other monitored counties in Washington (Washington Tracking Network). A major contributor to PM2.5 emissions in the region is residential wood burning (Pruitt, 2014). In Yakima city, residential wood combustion was found to be responsible for 55% of the black carbon in the air, an important component of particulate matter (VanderSchelden et al, 2017). Additionally, wood smoke was estimated to be responsible for 73% of the city’s formaldehyde emissions, 69% of the acetaldehyde emissions, and nearly all of the ultrafine particulate matter (VanderSchelden et al, 2017).

The Yakama Nation Reservation is almost completely contained in Yakima County. High exposure to wood smoke is associated with respiratory issues, including asthma and lower respiratory tract infections (Noonan and Balmes, 2010). Factors influencing pediatric asthma and lower respiratory tract infections in rural settings are under-studied (Estrada and Ownby, 2017). Wood smoke is of even greater concern during the fall and winter months when weather inversions are common, trapping air pollution in the valley. Due to stagnant atmospheric conditions common in the wintertime in the Yakima Valley, the county (for its jurisdiction) and the EPA (for the Yakama Reservation) issue bans on burning.

It remains a research challenge to understand PM2.5 in rural settings given the sparseness of regulatory monitoring. There is a need to distinguish residential wood smoke from other types of emissions. Delta-C, the difference in measurement of particles absorbing light at ultraviolet and infrared wavelengths, has been found in some cases to be an inaccurate representation of wood smoke, and a reliable indicator of wood smoke in others. Delta-C was found to be impacted by traffic emissions (Su et al, 2015), industrial emissions (Cheng et al, 2014), coal combustion (Kirchstetter et al, 2004; Olson et al, 2015), and other aerosols (Kirchstetter et al, 2004; Zhang et al, 2017; Olson et al, 2015). Wood smoke may also increase absorption at ultraviolet and infrared wavelengths at the same rate, thus not impacting Delta-C (Su et al, 2015). Harrison et al found that Delta-C did not capture wood smoke as well as other markers (2013).

On the other hand, Delta-C was found to reflect diurnal and seasonal patterns expected from residential wood burning (Wang et al, 2011a; Wang et al, 2012a; Sandradewi et al, 2008; Zhang et al, 2017; Sofowote et al, 2014; Crilley et al, 2015), be sensitive to smoke from forest fires (Wang et al, 2011a; Wang et al, 2010; Landis et al, 2017; Kimbrough et al, 2015), be sensitive to other biomass burning and fireworks (Wang et al, 2011b; Kirchstetter et al, 2004), and not be associated with vehicle exhaust (Wang et al, 2011a; Kirchstetter et al, 2004; Wang et al, 2012b). Delta-C was also found to correlate with other wood smoke markers – levoglucosan and potassium (Wang et al, 2011a; Harrison et al, 2012; Kimbrough et al, 2015; Crilley et al, 2015), and to correlate with PM2.5 in wood smoke dominated environments (Zhang et al, 2017). In one study, Wang et al attributed more than 72% of Delta-C to a wood combustion factor (2012a).

Because Delta-C is sensitive to many types of biomass burning, it cannot be used to distinguish residential wood smoke from other biomass burning. Zhang et al caution that Delta-C is only semi-quantitative and in general cannot be used to signify a particular amount of a compound (2017). At the same time, the ratio of Delta-C to PM2.5 may indicate the relative contribution of biomass burning to total PM2.5 (Wang et al, 2011a) which implies that a higher Delta-C to PM2.5 ratio is expected during instances of greater biomass burning.

While Delta-C measurements generally require a higher cost instrument, it may be possible to identify particle size distributions or relationships that are more likely to occur when Delta-C is higher. Urban black carbon particles trend smaller than particles from biomass burning (Schwarz et al, 2008). Within the ultrafine range, Wang et al found that, compared to other seasons, wintertime Delta-C more strongly correlated with particle sizes of 100-500nm than 50-100nm (2011a). In another study, Wang et al found that wintertime particles were greater in the range below 120nm compared to summertime, especially in the range of 30-50nm (2012c). Krecl et al suggested that wood smoke emissions are dominated by particles sized 25-606nm, PM10, and PM1 (2008). Kimbrough et al found that biomass burning was associated with an increase in particles greater than 100nm and a decrease in particles 20-100nm (2015). Lin et al found that Delta-C episodes had increased particles at 56-320nm, while non-episodes increased 32-180nm (2016). Liu et al found that solid fuel emissions increased particles at sizes up to 360nm, particularly around 167nm (2014). In general, these various findings suggest that particles from biomass burning trend larger than urban emissions, but these differences are within the ultrafine range. Nevertheless, particle size distributions or relationships may be measured using a lower cost instrument.

This study evaluated how well a low-cost air sensor estimated PM2.5 compared to a tribal beta-attenuation monitor (BAM). Such validation work may provide a foundation for more extensive monitoring in this rural community. This study also assessed the relationships between particle size distributions as measured by the low-cost sensor with wood smoke and biomass burning levels estimated by a higher cost instrument.

Methods

Data was collected at a tribal air monitoring site in Toppenish, Washington from 1/29/18-3/10/18 using two different instruments. The Toppenish site is located near Toppenish High School, at the end of a residential area and near agricultural fields, an industrial area, and a major roadway (Highway 97). This air monitoring site is owned by the Yakama Nation Environmental Management Program and operated jointly with the Washington Department of Ecology and contains a BAM which measures an hourly average of PM2.5 concentration.

The UW low-cost air sensor uses 2 Plantowers, laser-based particle sensors, to measure particle counts with the following size cut-points: 0.3, 0.5, 1, 2.5, 5, and 10 micrometers. Particle counts are measured every two to three minutes and the units are number of particles per 0.1 liters of air sampled. Additionally, the mass is estimated for PM1, PM2.5, and PM10. The monitor also includes four gaseous sensors that measure carbon monoxide, nitrogen oxide, nitrogen dioxide, and ozone, and has humidity and temperature sensors. This monitor is not commercially available but is estimated to cost around $1,500-$2,000 to assemble. The gaseous sensors were not calibrated for the study area so this data was not used in this analysis.

The other sensor utilized was a 5-wavelength aethalometer: the microAeth® MA200, by AethLabs. This instrument measures the mass of particles in a sample of air that absorb light at the following wavelengths: 880, 625, 528, 470, and 375 nanometers. The mass of particles that absorb light at 880 nm is considered to be a measurement of black carbon and is referred to as the infrared wavelength (IR). The mass of particles that absorb light at 375 nm is considered to be a measurement of particles emitted by biomass burning including wood smoke, tobacco, and agricultural burning, and is referred to as the ultraviolet wavelength (UV). The aethalometer collects particles on a filter, where the instrument analyzes their absorption of light at different wavelengths. The filter automatically advances when it is saturated. This is a higher cost instrument than the UW low-cost sensors.

For the low-cost sensor, to determine which Plantower sensor measurements to use, PM2.5 estimates were plotted against each other and the correlation was calculated. The average of the two Plantower PM2.5 values was used to calibrate the low-cost sensor against the co-located tribal BAM. Linear regression parameters from an 8-day period from 1/29/18 to 2/5/18 were used to quantify the relationship between the low-cost sensor and BAM PM2.5 values, and inverted to establish a calibrated low-cost sensor PM2.5 value. The calibration was examined using Bland Altman plots (Bland and Altman, 1986) and the concordance correlation coefficients, which measure proximity of the relationship to the 45-degree line through the origin (Watson and Petrie, 2010). A value closer to 1 indicates a relationship between the two values that is linear along the 45-degree line through the origin (Watson and Petrie, 2010).

For the aethalometer, the flow set point was 100 ml/min. The first 30 minutes of measurements after a filter cartridge change were removed to mitigate estimates influenced by the instrument warming up. Delta-C, the absorbance difference at 375nm-880nm, was used as a biomass burning indicator. Data was averaged by hour. The bottom 2% of Delta-C values were removed to remove negative Delta-C artifacts. This corresponded to keeping Delta-C values >-0.1 µg/m3, for a sample size of 947 hours. Diurnal patterns of Delta-C, UV, and IR were assessed, and hourly boxplots of Delta-C were used to establish groups of hours to compare.

BAM PM2.5 measurements were used to create a Delta-C:PM2.5 ratio. PM2.5<4 µg/m3 were excluded to avoid small values that are more prone to error (removed 43% for a sample size of 543 hours) and days of less concern for potential health effects. Two groups of hours were created to compare: the 80th percentile of the Delta-C:PM2.5 ratio (wood smoke-enriched, n=109) and those same hours on 7, 8, 9, and 10 days later and/or earlier that were <50th percentile of the Delta-C:PM2.5 ratio (low wood smoke, n=109). The same hours were used in the low wood smoke group to attempt to elucidate differences in particle size that might be a stronger predictor of Delta-C than hour of day.

The following comparisons were made between the two groups: Pearson correlations between Delta-C and low-cost sensor PM2.5; Pearson correlations between Delta-C and BAM PM2.5; mean proportions of particle count for size bins of 0.3 to 0.5μm, 0.5 to 1μm, 1 to 2.5μm, 2.5 to 5μm, and 5 to 10μm; and means of temperature, Delta-C:PM2.5, Delta-C, the mass absorbed at UV, the mass absorbed at IR, and low-cost PM2.5. Additionally, regional mean PM2.5 measurements were compared from Yakima (about 20 miles north of Toppenish), White Swan (about 20 miles west of Toppenish), and Sunnyside (about 20 miles east of Toppenish). The 80th percentile of BAM PM2.5 (high PM2.5, n=175) was also analyzed for the same information listed for the groups based on Delta-C:PM2.5.

Results

The correlation between the two Plantower PM2.5 estimates was 0.99 and ranges were similar, so for the rest of the analysis we used the average of the two PM2.5 estimates. The relationship between the low-cost sensor PM2.5 (y) and BAM PM2.5 (x) was found to be:

$$y = x * 1.61 – 2.05$$

Therefore, the calibrated low-cost sensor PM2.5 value, z = (y + 2.05)/1.61.

The mean and standard deviations (SD) derived from the tribal BAM PM2.5, low-cost sensor PM2.5, and calibrated low-cost sensor PM2.5 values are shown in Table 1:

Table 1: Means and SDs of the BAM PM2.5, low-cost sensor PM2.5, and calibrated low-cost sensor PM2.5.

PM2.5 (μg/m3)	**Mean**	**SD**
BAM	7.4	7.0
Low-cost sensor before calibration	9.0	11.1
Calibrated low-cost sensor	6.9	6.9

The concordance correlation coefficient between the calibrated low-cost sensor PM2.5 and the BAM PM2.5 was 0.91 (95% confidence interval (CI): 0.90-0.92). A plot of the calibrated low-cost sensor PM2.5 vs. the BAM PM2.5 for the time period after the calibration period (2/6/18-3/10/18) is shown in Figure 4:

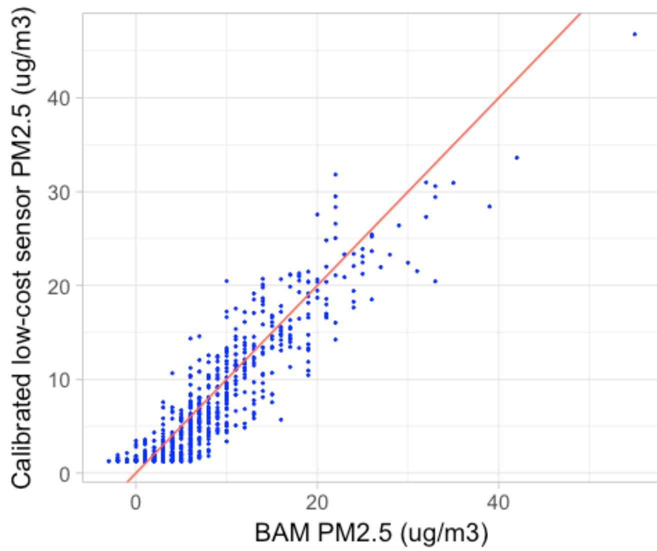

Figure 4: The calibrated low-cost sensor PM2.5 vs. the BAM PM2.5, with a 45 degree line through the origin, for the time period after the calibration period (2/6/18-3/10/18).

Bland Altman plots comparing the BAM PM2.5 with the low-cost PM2.5 non-calibrated and calibrated values from 1/29/18-3/10/18 are shown in Figures 5 and 6:

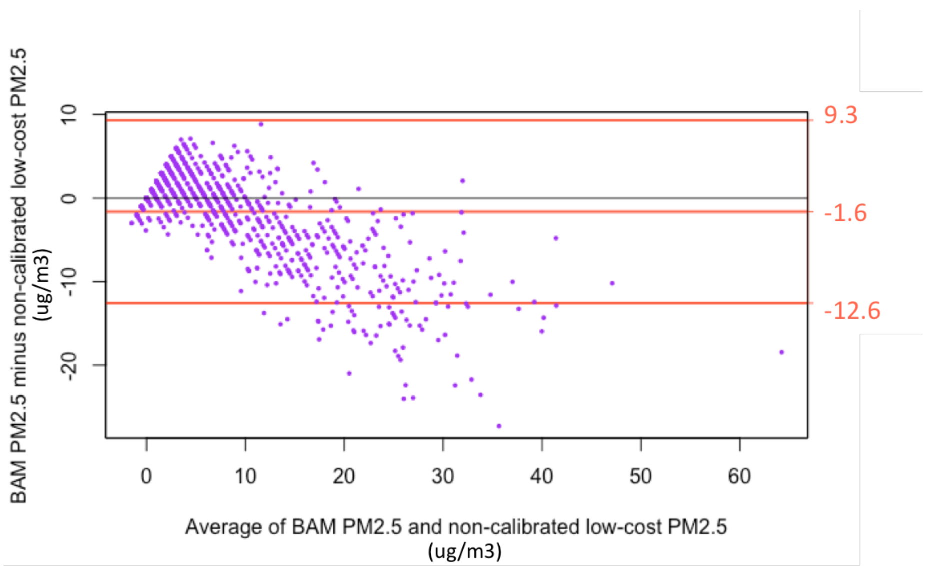

Figure 5: Bland Altman plot comparing the BAM PM2.5 with the low-cost PM2.5 non-calibrated values.

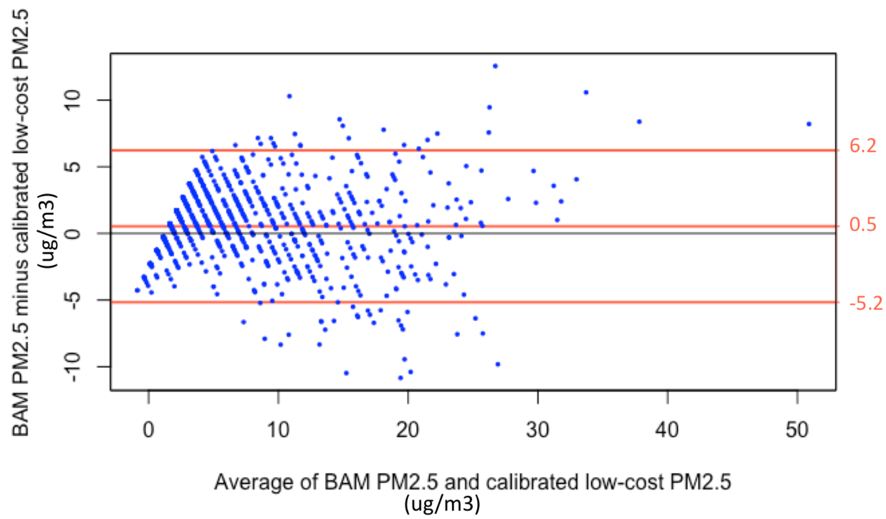

Figure 6: Bland Altman plot comparing the BAM PM2.5 with the low-cost PM2.5 calibrated values.

The observed mean difference in Figure 5 (non-calibrated) is -1.6 and in Figure 6 (calibrated) is 0.5. The standard deviation of the differences (s_d) for the non-calibrated values is 5.5 and for the calibrated values is 2.8. The maximum likely difference between the BAM and non-calibrated low-cost estimates can be found by multiplying the 95% CI z-score by the s_d: 1.96*5.5=10.8 µg/m3. The maximum likely difference between the BAM and calibrated low-cost estimates was 1.96*2.8=5.5 µg/m3. Figure 5 (non-calibrated) shows an irregular shape where the mean difference for low values is more often >0 and the mean difference for higher values is more often <0. Higher values show a wider range of disagreement. Figure 6 (calibrated) shows a more regular shape across low and high values. Higher values show a wider range of disagreement.

A summary of aethalometer and low-cost sensor observations averaged hourly over the study time period are shown in Table 2 (Delta-C<-0.1 µg/m3 was excluded).

Table 2: Summary of aethalometer, calibrated low-cost sensor, and regional hourly observations from 1/29/18-3/10/18 (n=947 unless noted).

	Mean	**SD**	**Min**	**Max**
UV (µg/m3)	0.7	0.8	-0.1	6.2
IR (µg/m3)	0.4	0.5	-0.0	6.0
Delta-C (µg/m3)	0.3	0.4	-0.1	2.9
PM1 (µg/m3)	6.2	7.4	0.0	33.5
PM10 (µg/m3)	10.7	13.4	0.0	73.9
PM2.5 calibrated low-cost sensor (µg/m3)	6.7	6.7	1.3	31.8
PM2.5 BAM (µg/m3)	7.2	6.7	-3.0	39.0
0.3 to 0.5µm (proportion of total particle count)	0.7	0.0	0.7	0.9
0.5 to 1µm (proportion of total particle count)	0.3	0.0	0.2	0.3

1 to 2.5µm (proportion of total particle count)	0.0	0.0	0.0	0.1
2.5 to 5µm (proportion of total particle count)	0.0	0.0	0.0	0.0
5 to 10µm (proportion of total particle count)	0.0	0.0	0.0	0.0
PM1 (proportion of mass) (n=942)	0.5	0.3	0.0	1.0
PM1 to 2.5 (proportion of mass) (n=942)	0.2	0.1	0.0	1.0
PM2.5 to 10 (proportion of mass) (n=942)	0.3	0.3	0.0	1.0
Delta-C:PM2.5 ratio (n=543)	0.0	0.0	-0.0	0.1
Temperature (degrees F)	39.9	10.0	14.7	67.0
Yakima PM2.5 (µg/m3) (n=943)	7.1	7.0	-4.0	47.0
Sunnyside PM2.5 (µg/m3) (n=944)	5.7	4.4	0.2	29.1
White Swan PM2.5 (µg/m3) (n=942)	1.8	1.3	0.3	8.5

Figures 7 and 8 show Delta-C, calibrated low-cost PM2.5, and BAM PM2.5 over time during the week of 3/2/18-3/8/18. This week includes two Delta-C peaks.

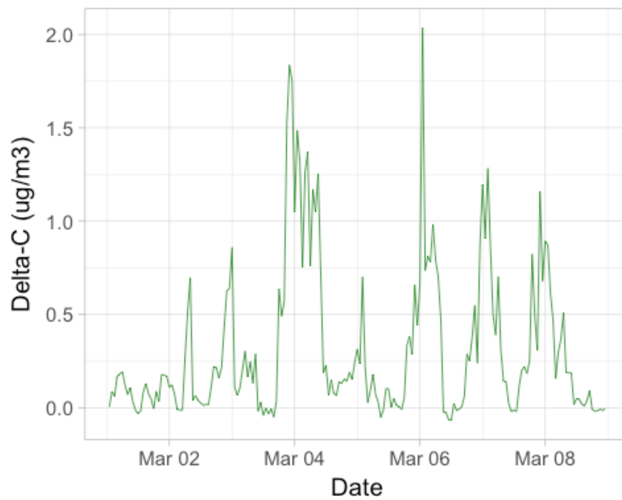

Figure 7: Delta-C over the week of 3/2/18-3/8/18.

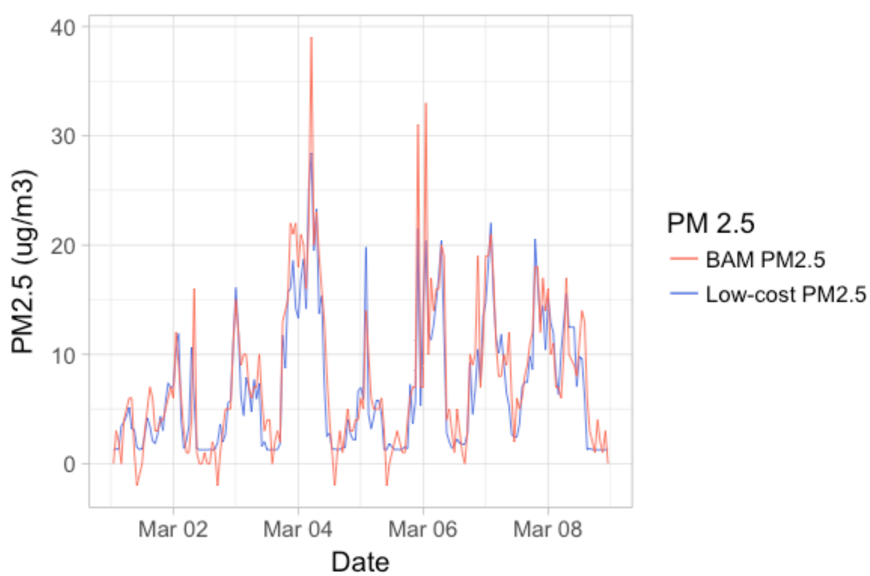

Figure 8: Low-cost PM2.5 and BAM PM2.5 over the week of 3/2/18-3/8/18.

Figure 9 shows a plot of the BAM PM2.5 and calibrated low-cost PM2.5 vs. Delta-C over the entire study period (1/29/18-3/10/18).

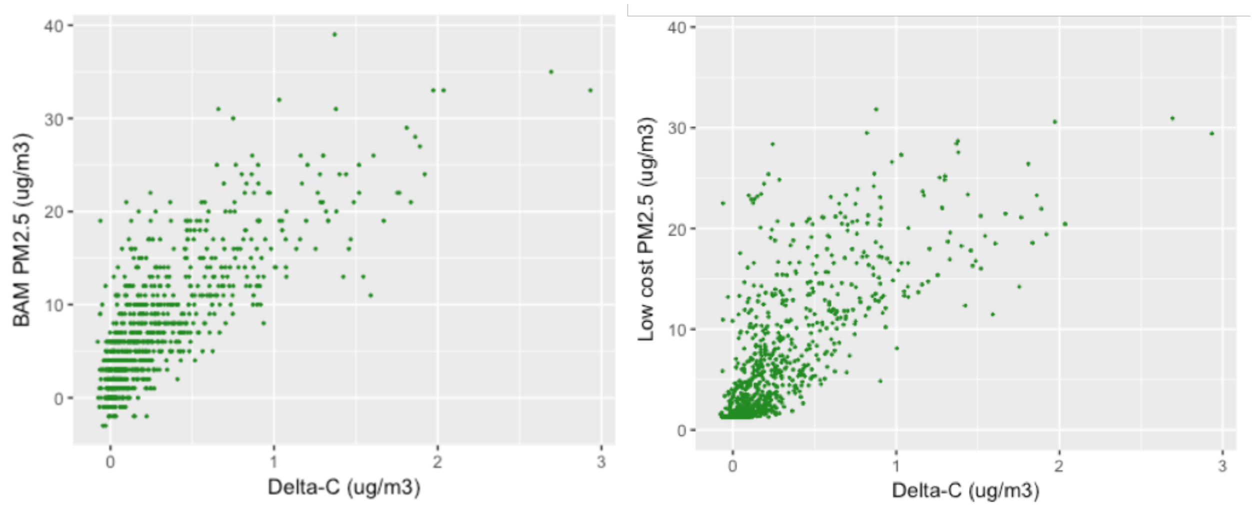

Figure 9: BAM PM2.5 and calibrated low-cost PM2.5 vs. Delta-C over the study period.

Diurnal patterns of UV, IR, Delta-C, and calibrated low-cost PM2.5 over the study period are shown in Table 3. Hour groups were chosen based on a boxplot of Delta-C by hour, shown in Figure 10.

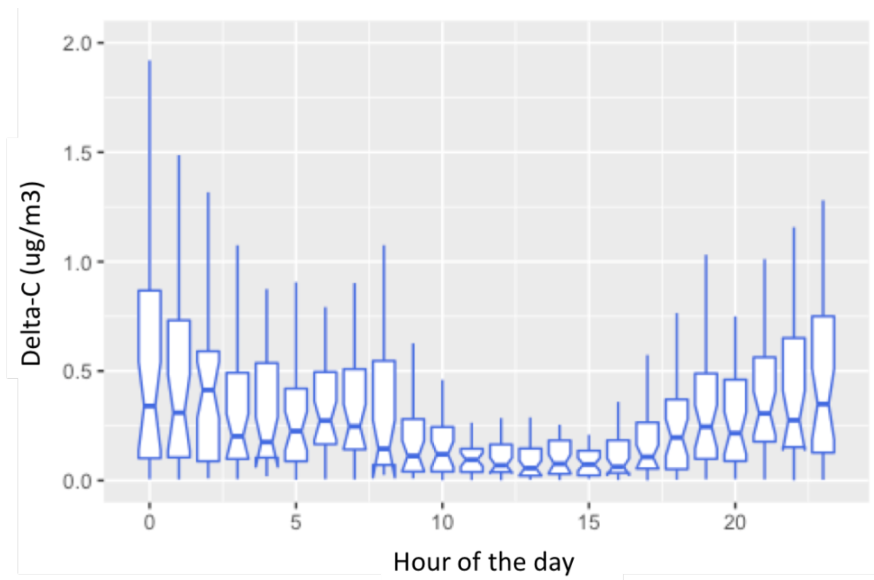

Figure 10: Delta-C by hour of the day.

A boxplot of the calibrated low-cost PM2.5 by hour of the day is shown in Figure 11.

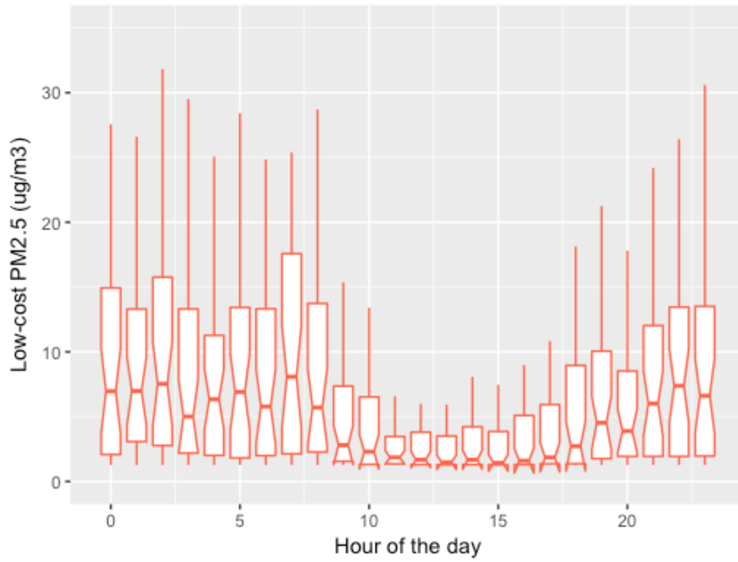

Figure 11: Low-cost PM2.5 by hour of the day.

Table 3: Diurnal patterns of UV, IR, Delta-C, and low-cost PM2.5.

Means (µg/m3)	UV	IR	Delta-C	Calibrated low-cost PM2.5
Early morning (3am-8am) n=233	0.9	0.6	0.3	8.6
Day (9am-4pm) n=314	0.4	0.3	0.1	4.0
Early evening (5pm-8pm) n=160	0.6	0.4	0.3	5.8
Night (9pm-2am) n=240	1.0	0.5	0.5	8.9

Table 4 shows the distribution of hours and days for the wood smoke-enriched group compared to the expected distribution if Delta-C did not have diurnal or weekday vs. weekend patterns.

Table 4: Number of hours during different times of day, weekends, and weekdays for the wood smoke-enriched group, compared to the expected number based a regular proportion.

Number of hours	Wood smoke-enriched (n=109)	Expected number
Early morning (3am-8am)	26	27
Day (9am-4pm)	7	36
Early evening (5pm-8pm)	15	18
Night (9pm-2am)	61	27
Weekends	24	31
Weekdays	85	77

Tables 5 and 6 describe comparisons between wood smoke-enriched hours and low wood smoke hours.

Table 5: Pearson correlations between Delta-C and PM2.5 during wood smoke-enriched and low wood smoke hours.

Pearson correlation and 95% CI	Wood smoke-enriched (n=109)	Low wood smoke (n=109)
Delta-C and calibrated low-cost PM2.5	0.84 (0.78 - 0.89)	0.75 (0.66 - 0.82)
Delta-C and BAM PM2.5	0.93 (0.90 - 0.95)	0.88 (0.83 -0.92)

Table 6: Means of particle size bin proportions, Delta-C, UV, IR, temperature, and regional PM2.5 during wood smoke-enriched and low wood smoke hours.

Means	**Wood smoke-enriched (n=109)**	**Low wood smoke (n=109)**
0.3 to 0.5µm (proportion of total particle count)	0.7	0.7
0.5 to 1µm (proportion of total particle count)	0.3	0.3
1 to 2.5µm (proportion of total particle count)	0.0	0.0
2.5 to 5µm (proportion of total particle count)	0.0	0.0
5 to 10µm (proportion of total particle count)	0.0	0.0
PM1 (proportion of mass)	0.6	0.6
PM1 to 2.5 (proportion of mass)	0.2	0.2
PM2.5 to 10 (proportion of mass)	0.2	0.2
Delta-C (µg/m3)	1.0	0.2
Delta-C:PM2.5 ratio	0.1	0.0
IR (µg/m3)	0.8	0.6
UV (µg/m3)	1.8	0.8
Temperature (degrees F)	36.2	32.7
Calibrated low-cost sensor PM2.5 (µg/m3)	13.1	9.3
BAM PM2.5 (µg/m3)	13.4	10.7
Yakima PM2.5 (µg/m3)	12.6	10.0
Sunnyside PM2.5 (µg/m3)	7.4	6.9
White Swan PM2.5 (µg/m3)	1.9	2.3

Table 7 shows the distribution of hours and days for the high PM2.5 hours, compared to the expected numbers given a regular distribution.

Table 7: Number of hours during different times of day, weekends, and weekdays for the high PM2.5 hours, compared to the expected number based a regular proportion.

Number of hours	**High PM2.5 (n=175)**	**Expected number**
Early morning (3am-8am)	63	44
Day (9am-4pm)	24	58
Early evening (5pm-8pm)	20	29
Night (9pm-2am)	68	44
Weekends	31	50
Weekdays	144	125

Tables 8 and 9 describe high PM2.5 hours.

Table 8: Pearson correlations between Delta-C and PM2.5 during high PM2.5 hours.

Pearson correlation and 95% CI	**High PM2.5 (n=175)**
Delta-C and calibrated low-cost PM2.5	0.34 (0.20 - 0.47)
Delta-C and BAM PM2.5	0.58 (0.48 – 0.67)

Table 9: Means of particle size bin proportions, Delta-C, UV, IR, temperature, and regional PM2.5 during high PM2.5 hours.

High PM2.5 (n=175)	**Mean**	**SD**
0.3 to 0.5µm (proportion of total particle count)	0.7	0.0
0.5 to 1µm (proportion of total particle count)	0.3	0.0
1 to 2.5µm (proportion of total particle count)	0.0	0.0
2.5 to 5µm (proportion of total particle count)	0.0	0.0
5 to 10µm (proportion of total particle count)	0.0	0.0
PM1 (proportion of mass)	0.6	0.1
PM1 to 2.5 (proportion of mass)	0.3	0.0

PM2.5 to 10 (proportion of mass)	0.2	0.1
Delta-C (µg/m3)	0.8	0.5
Delta-C:PM2.5 ratio	0.0	0.0
IR (µg/m3)	1.1	0.7
UV (µg/m3)	1.9	0.9
Temperature (degrees F)	34.4	8.7
Calibrated low-cost sensor PM2.5 (µg/m3)	17.8	5.5
BAM PM2.5 (µg/m3)	18.7	5.1
Yakima PM2.5 (µg/m3)	15.0	8.1
Sunnyside PM2.5 (µg/m3)	10.0	5.1
White Swan PM2.5 (µg/m3)	2.4	1.5

Discussion

PM and Delta-C data were collected from 1/29/18-3/10/18 in Toppenish. The average temperature was 39.9 degrees F. Mean PM2.5 was 6.7 µg/m3, while the mean PM2.5 in Yakima was 7.1 µg/m3, in Sunnyside was 5.7 µg/m3, and in White Swan was 1.8 µg/m3. Regional variability should be interpreted with caution because different instruments were used, but it does suggest that use of low-cost sensors and citizen science would be useful to address spatial variation in this area (Zikova et al, 2017; Wang et al, 2012c). Mean Delta-C was 0.27 µg/m3, which is within the range of other reported wintertime mean Delta-C values: 0.26 (Wang et al, 2011b), 0.19 (Wang et al, 2012c), 0.10 (Croft et al, 2017), 0.50 (Malashock, 2012), 0.2 (Evans et al, 2017), 0.2 (Huang et al, 2011), 0.34 (Rich et al, 2018), and 0.31 µg/m3 (Rich et al, 2018). Reported means of Delta-C during other seasons or year-round were variable, most lower than 0.27 µg/m3: 0.15 (Wang et al, 2011b), -0.4 (Wang et al, 2012c), 0.11 (Wang et al, 2012a), 1.82 (Malashock, 2012), 0.35 (Malashock, 2012), 0.67 (Malashock, 2012), 0.07 (Evans et al, 2017), and 0.09 µg/m3 (Huang et al, 2011). Maximum hourly Delta-C in this study was 2.9 µg/m3. Reported Delta-C means during wildfire episodes were 20 and 8.0 µg/m3 (Landis et al, 2017).

The two Plantower sensors contained in the low-cost sensor performed similarly. The non-calibrated average value on average was higher than the BAM PM2.5, demonstrated by the negative mean difference value in Figure 5 (Bland and Altman, 1986). For average PM2.5 values less than around 10 the variation between the two estimates was lower, and the BAM estimates were higher than the low-cost sensor estimates. For average PM2.5 values greater than around 10 the variation between the two estimates was greater, and the BAM estimates were lower than the low-cost sensor estimates. This suggests that the low-cost sensor is more reliable at lower PM2.5 values, underestimates at lower values, and overestimates at higher values. The maximum likely difference between the BAM and low-cost estimates of 11 μg/m3 is probably an unacceptable difference as it is greater than the BAM SD and approximately equal to the low-cost SD (see Table 1).

The calibrated PM2.5 mean and SD were closer to the BAM PM2.5 mean and SD than the non-calibrated mean. The calibrated average value on average was lower than the BAM PM2.5, demonstrated by the positive mean difference value in Figure 6 (Bland and Altman, 1986). The mean difference value was closer to zero for the calibrated estimate than the non-calibrated estimate, demonstrating that the calibrated estimate was more reliable. For average PM2.5 values less than around 10 the variation between the two estimates was lower, and for average PM2.5 values greater than around 10 the variation between the two estimates was greater. This suggests that the calibrated estimate is more reliable at low PM2.5 values. The maximum likely difference between the BAM and the calibrated estimates of 5.6 μg/m3 is probably acceptable as it is lower than both the BAM and calibrated low-cost SD (see Table 1).

The low-cost sensor PM2.5 measurement was straightforward to calibrate, suggesting that it may be feasible for citizen scientists and community members to perform a similar calibration, given access to a validated co-located sampler such as a regulatory monitor. While the aethalometer demonstrated a signal associated with biomass burning, the aethalometer data is complex and likely difficult to interpret for community members without expertise in air pollution research.

The Delta-C peaks shown in Figure 7 each lasted a few hours, and were about 6 times greater than the weekly average. Delta-C followed expected diurnal patterns; it was lowest during the day, higher during early morning and early evening, and highest overnight. UV followed a similar pattern, but early morning was much higher than early evening. For IR, early morning was highest and similar to overnight, and early evening was similar to daytime. The PM2.5 pattern most closely followed the UV pattern. While these patterns are expected due to diurnal changes in the boundary layer and increased residential heating needs overnight, agricultural biomass burning and agriculture-related combustion may also follow diurnal patterns. Within the wood smoke-enriched group, nighttime hours were overrepresented, and weekends were slightly underrepresented. This suggests that recreational residential wood burning may not be an important factor in this area. Similarly, within high PM2.5 hours, nighttime hours are overrepresented, and weekends are underrepresented. The temperature did not differ between the wood smoke-enriched, low wood smoke, and high PM2.5 groups, suggesting that combustion unrelated to heating needs may be an important factor in this area.

Based on a period of high residential wood combustion during a winter inversion, Wang et al identified a Delta-C:PM2.5 ratio indicative of high contribution of wood smoke to PM2.5 of 1:7.5= 0.133 (2011a). The mean Delta-C:PM2.5 ratio in this study was 0.04, with a maximum close to the ratio identified by Wang et al (2011a) at 0.14. It is possible that a higher ratio would be observed with a longer sampling period that included the coldest months. This study's sampling period was 43 days, covering the end of January to the beginning of March. Future studies could capture more of the residential wood burning season by sampling November-March.

The correlation between Delta-C and low-cost PM2.5 was greatest during wood smoke-enriched hours, suggesting that the low-cost sensor is capturing emissions associated with Delta-C. Interestingly, even though the Delta-C value and Delta-C:PM2.5 value are larger in the high PM2.5 hours compared to the low wood smoke hours, the correlation between Delta-C and PM2.5 was lower during the high PM2.5 hours than the low wood smoke hours. This suggests that during periods of high PM2.5, the low-cost sensor may be less sensitive to wood smoke due to other pollutants. Also, during periods when other pollutants are present, Delta-C may be a less accurate indicator of biomass burning (Su et al, 2015; Cheng et al, 2014; Crilley et al, 2015; Harrison et al, 2013). Delta-C measurements are also influenced by weather (Wang et al, 2011a; Wang et al, 2011b), which was not accounted for in this analysis.

Particle size distributions were invariable on wood smoke-enriched vs. low wood smoke hours, suggesting that emissions associated with Delta-C are not necessarily dominated by a particular particle size distribution. This consistency of particle size distributions may reflect a low performance of the low-cost sensor in accurately binning particles by size, especially among the smaller bin sizes. Low-cost sensor mass estimates may be unaffected because count error within the smallest bins does not have a meaningful impact on mass estimates. Particle size distributions could also be affected by variable combustion conditions, as air supply (Hueglin et al, 1997) and temperature (Rau, 1989) were found to impact particle size distributions. Sandradewi et al found no difference in particle size distribution between winter and summer in an area impacted by wintertime residential wood combustion (2008). Another issue is that most of the particle size distribution differences identified in the introduction are limited to particles smaller than 500-600nm, and many pertained to particles smaller than 300nm. The smallest cut-point of the low-cost sensor is 300nm, so these size distribution distinctions would be difficult to capture with this sensor.

Future analyses could consider a more complex approach to assessing particle size distribution, which may provide a method for the low-cost sensors to be more useful in addressing wood smoke. Others investigating biomass burning using aethalometers have calculated angstrom coefficients and analyzed spectral dependence of their samples (Sandradewi et al, 2008; Kirchstetter et al, 2004; Segura et al, 2016). Future analyses could also consider using more than just 2 of the wavelengths in this 5-wavelength aethalometer. Other studies suggested that differences between channels besides UV-IR may be more strongly associated with biomass burning (Sandradewi et al, 2008; Kirchstetter et al, 2004; Zhang et al, 2017). For example, instead of using Delta-C, perhaps UV-Red or UV-Green may better characterize biomass burning emissions in this region.

If gaseous sensors in the low-cost sensor could be calibrated for this region, they may also be useful in discerning biomass burning episodes. Carbon monoxide and nitrogen oxides were found to follow wintertime diurnal trends expected of wood smoke (Sandradewi et al, 2008).

Conclusion

The UW low-cost sensors can be used to investigate PM impacts in areas where residential wood smoke and biomass burning are important factors, and regulatory monitoring is sparse. Further analysis is needed to identify ways to isolate wood smoke and biomass burning using these or other low-cost sensors. At the same time, calibration of the sensor PM2.5 measurements is straightforward, and the sensor captures biomass burning emissions as represented by Delta-C.

Overall Conclusion

Both a strong partnership and reliable methods are necessary for successful CEnR. There are actionable ways to promote trust, equitable and community informed processes, and community involvement in research to foster a sound partnership in a multicultural community. The UW low-cost sensor reliably measured PM2.5 in a wood smoke and biomass burning impacted rural community, demonstrating that it can be useful in CEnR on air quality. Further analyses to identify opportunities to use this or other low-cost sensors to isolate wood smoke or biomass burning are needed.

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Appendix A: Interview Questions

RQ1: What are some ways that the research processes and roles on the research team can build or erode trust among team members, particularly between UW and PAC partners? Are there examples of ways trust has already been built or eroded on this team? What are some ways trust could be built or eroded?	RQ2: What are some ways that the research processes and roles on the research team can combat inequities arising from differences in power and privilege between researchers from UW and local researchers and community members? RQ2a: What are some ways that the research processes can be informed by Yakama Nation, Native American, and immigrant Latinx cultures?	RQ3: What are some ways that the research processes and roles on the research team can facilitate the involvement of the community partners in the research? RQ3a: What are some ways that the team can facilitate the involvement of community members in using the results of the research for public health actions or benefits?
What does trust look like to you?	Given differences in resources and power between UW and PAC members, what are some ways you think our team can build equitable and respectful relationships?	What is your goal in participating in this group? *Probe*: Is your participation in this team beneficial to you? *Probe*: What is your vision for the research?
Thinking of trust in the research partnership, what do you think would increase trust? *Probe*: Do you have recommendations for particular partners in the research partnership?	How could our partnership as a whole best gain an understanding of the cultural histories of the communities at the center of this research project?	How do you feel that your voice was heard in defining the issues?
(Ask only if there is extra time) Do you recommend any decision-making processes that may be helpful in building trust among the partners? *Probe*: Do you think that it would be helpful to have a more formalized process in place for addressing conflict when it arises?	How could our partnership as a whole best demonstrate respect for this community's cultural beliefs, practices, and tribal sovereignty? *Probe*: Can you think of any ways to demonstrate this respect as part of the research process?	When research partners are more present in the community, it may help to facilitate community involvement in the research process and in the health actions that follow. What recommendations do you have about partners being more present in the community?
It is thought that more formal roles with explicit expectations and specific tasks can help to build trust among research partners. How do you think this might impact team trust? *Probe*: How do you think this might impact your involvement in the team?	How could this research be better informed by the cultures of the communities we're working with? *Probe*: How could the air pollution curriculum for the students be more culturally relevant?	How do you think that this research will benefit the public health of this community? *Probe*: Any parts of the community in particular?
In other community-engaged research projects, academic and community partners have suggested that for a trusting partnership, academics should reflect on personal and institutional histories, and the	One way to describe traditional knowledge is information passed down through generations based on observation, use, and closeness to an area or ecosystem. Traditional knowledge may be	How can we improve participation in the project by all partners, including meeting attendance and sharing ideas for the project? *Probe*: Would you feel more connected to the group if we

historical context of research and research abuses. How do you think this type of reflection might help build team trust? *Probe*: Do you think this is something we should do altogether, or just the academic partners on their own?	passed down through oral tradition. What roles do you think traditional knowledge has in our research process?	built in time for socializing as part of the meetings? *Probe*: What kind of contact and communication between meetings would help you feel more involved?
How do you feel that your expertise is currently acknowledged by the team? *Probe*: What opportunities would you want to share your expertise?		

Appendix B: Code Definitions

Code type	Code	Meaning
Primary	**Trust Built**	Examples of trust being built in the partnership
Secondary	Being listened to	People expressing that they are being listened to
Secondary	Proxy trust and functional trust	Examples of specifically proxy trust (trust based on connections through another person or entity) and functional trust (trust being forced because of need for project to move forward) in the partnership
Primary	**Trust Eroded**	Examples of trust being eroded in the partnership
Secondary	(Lack of) Academic due diligence	Examples of lack of academic due diligence in choosing community partners, planning the project, etc.
Secondary	Divisions within community	Examples of evidence for divisions within the community, or between community partners
Primary	**Transparency**	References to the idea of transparency in research, including clarity of project roles and motivations, and updates
Primary	**Research**	References to issues related to research needs, grants, timelines
Secondary	Funding	References to funding including issues with grant rigidity
Secondary	Grant time lag	References to the long time period between applying for the grant and starting the project
Primary	**Sustainability**	References to the sustainability of the research – what happens to all of the components of this (including the partnership) after the 3 years of the grant is over?
Primary	**Community context**	Information about the community that is important to inform the way we do this project together, including cultural aspects, socioeconomic situation, relationships, and history.
Secondary	Concern about representation	References to how the project is represented; UW and HU's reputations in the community
Secondary	Multiple perspectives	The community is made up of many different groups and cultures – references to the diversity of perspectives in the community
Secondary	Practical actions	References to the need for information on practical actions individuals in the community can take to better their health
Primary	**Community strengths**	References to community strengths
Secondary	Elders	Potential or actual roles of elders in the community or project
Secondary	Youth	Potential or actual roles of youth in the community or project
Primary	**Community motivations**	Motivations for community members to participate in the partnership (from community partner interviews)
Secondary	Learning	References to community members wanting to learn more (from community partner interviews)
Primary	**Tribal context**	Similar to Community context, but tribal specific.
Primary	**Academics clarity of intent**	Intentions of academics in participating in the partnership (from academic partner interviews)
Secondary	Academics learning	References to academics wanting to learn more (from academic partner interviews)
Secondary	Issue identification	How academics describe issue identification (from academic partner interviews)
Primary	**Community capacity building**	References to community capacity building
Primary	**Academic presence in community**	References to how academics should be present in the community
Primary	**Concrete suggestions/ideas**	This code is to keep track of concrete suggestions or ideas interviewees had for improving the partnership
Primary	**Visions**	This code includes answers to the question "What is your vision

		for this project?"
Primary	**Goals**	This code includes answers to the question "What is your goal in participating this project?"
Primary	**Definition of trust**	This code includes answers to the question "What does trust look like to you?"
Primary	**Formalization**	References to formal roles, processes, and agreements.

Codes added:

Code type	Code	Meaning
Primary	**Trust Built – Potential or General**	Examples of ways that trust has been built within the community or between the community and outsiders in general, or ways that trust could be built
Primary	**Trust Eroded – Potential or General**	Examples of ways that trust has been eroded within the community or between the community and outsiders in general, or ways that trust could be eroded
Primary	**Dialogue**	References to frequency of communication and quality of communication