AIR QUALITY COMMUNITY ACTION NETWORK

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ABSTRACT

In Denver, 11% of public school children have asthma and some schools have asthma rates as high as 29%, leading to increased school absenteeism. Denver's high levels of air pollution exacerbate the problem. To address this inequity, Denver, in partnership with Denver Public Schools (DPS), is creating a citywide air quality monitoring network to provide real-time air quality data – utilizing low-cost cutting-edge air pollution sensor technology, redeveloped with solar, battery storage, and data connectivity to make it useful for widescale deployment and replicable in any municipality. To date, no US municipality has a city-led, community-based air-monitoring program. While the air sensors are foundational to the project, the heart of the solution is the collaborative, culturally-appropriate and scientifically-validated approach to programming. Each participating school (with asthma rates above the median) will receive a sensor, air quality dashboard and programming. Programming options are appropriate for elementary, middle or high school and include STEM curriculum, anti-idling campaign, event plan for extremely high air pollution days (e.g., wildfires), built environment safety study to change traffic patterns near schools, and school-based challenges to incentivize new ideas for driving behaviour change and reducing pollution. The dashboard will display real time data and suggested behaviour changes, while the backend data platform will create insights for air quality patterns near each school – leading to policy and institutional changes for the City and DPS – as well as generate automated alerts for stakeholders.

Keywords: sensors, PM, schools, community, innovation, dashboard, human centred design.

1 INTRODUCTION

As one of the fastest-growing US cities, Denver experiences significant construction and traffic congestion, worsening the air quality – the 14th worst among major US cities [1]. Only 53% of residents realize the impacts of poor air quality [2], including that children are more susceptible to its effects, such as decreased lung function and missed school days. While multiple factors influence exposure to air pollution, schools are an ideal intervention point for sensor deployment, education and empowerment. Denver will provide real-time, hyper-local air quality data measured at Denver schools, supported by evidence-based, culturally responsive programming to empower communities to limit exposure and reduce pollution.

A winner of the 2018 US Bloomberg Mayor Challenge, Denver's idea has received $1,000,000 to implement the program at scale in Denver Public Schools (DPS), the city's primary public school district with 207 schools and 92,331 students [3]. Working closely with DPS, the City and County of Denver will scale the project from its 3 pilot schools in 2018, to 40 over the next three years.

2 US AIR QUALITY REGULATORY STRUCTURE

Within the United States, air quality regulatory structure is defined by the Clean Air Act (CAA) of 1970. The CAA is a United States federal law designed to control air pollution on a national level [4]. It was first established in 1970 and has continued to evolve with its most recent major amendment in 1990. The CAA authorised the development of comprehensive federal and state regulations limiting emissions from stationary as well as mobile sources. It led to the creation the National Ambient Air Quality Standards (NAAQS), which sets limits

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for six major pollutants: sulphur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead.

Under the CAA the federal agency responsible for implementation and oversight is the United States Environmental Protection Agency (USEPA). The USEPA sets national limits on pollutants and approves state, tribal and local agency plans for reducing pollution from sources to meet those limits. Individual state, tribal, and local agencies may have stricter regulations but not more lenient. State, tribal, and local agencies take the lead on developing solutions to meet pollution limits as they have a better understanding of conditions such as local industry, geography, housing, and travel patterns, as well as other influencing factors. They also take the lead on monitoring air quality in their respective jurisdictions.

Specifics can vary from state to state in terms of the number of local and tribal agencies, as well as which local agencies are responsible for which facilities. Additionally, it is common for state and local agencies to work cooperatively to oversee facilities and other sources in a specific region. In Denver Colorado, the local agency, the Denver Department of Public Health and Environment (DDPHE) does some local inspection and monitoring. DDPHE is overseen by the state agency, the Colorado Department of Public Health and Environment (CDPHE) which is overseen by the federal agency, the USEPA. There is also an additional agency which is the lead on regional planning, the Regional Air Quality Council (RAQC) (Fig. 1).

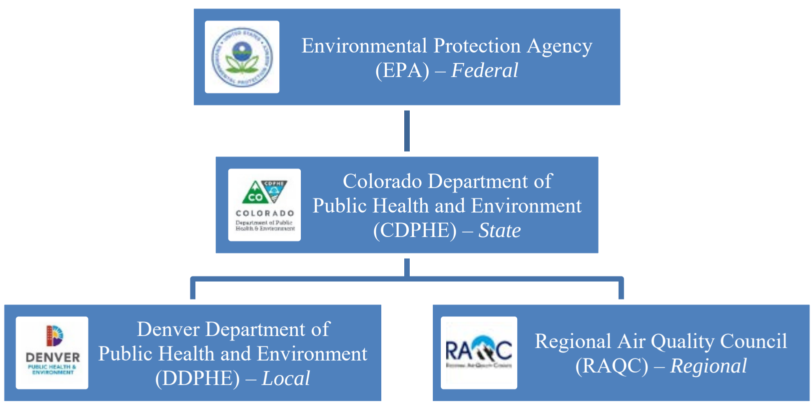

Figure 1: Organizational chart of federal, state, and local air agencies in Denver, Colorado.

3 THE MAYORS CHALLENGE

On 26 June 2017, Bloomberg Philanthropies announced the US Mayor Challenge. The fourth iteration of the challenge, the second of which was focused in the United States, the Mayors Challenge is an ideas competition, challenging cities to find innovative solutions to solving urgent problems within their municipalities [5]. The 2018 Mayors Challenge was open to US cities larger than 30,000. 324 cities applied for the challenge and on 20 February 2018, 35 cities, including Denver, were selected as Champion Cities. These cities received $100,000 each, with a timeline of 6 months to pilot their idea and show that they could deliver on their projects. At the end of the pilot, the 35 cities then submitted a second application. On 20 October 2018, nine cities were then selected as winners, each receiving $1,000,000 to implement their projects at scale in their cities. Selection criteria for winning cities included: vision, impact, implementation, and transferability. In addition to the funding, each city in the pilot phase were assigned an innovation coach and an implementation coach. These coaches helped the cities refine their ideas and provided guidance and training in new and innovative methods such as human centred design. The participation and collaboration with the implementation coaches will continue through the three-year project assisting through in-person work sessions, regular project conference calls, and replication events.

4 PILOT TESTING

During the six-month pilot phase, Denver tested key components of the idea with three pilot schools. The methodology incorporated iterative testing with key stakeholders while co-creating solutions using a human centred design approach. Components tested included: stakeholder identification and buy-in, influencing behaviour change, dashboard/information sharing, and sensor/data platform technology.

4.1 Stakeholder identification and buy-in

This was a key component in the project because of the fact that in the Denver Public School system each individual school is given the freedom to select programs and projects in which it participates. The City and County of Denver had already been collaborating with the school district on the idea, but it was necessary to received buy-in and approval from principals on a school by school basis.

Tested at three public schools, the initial approach was direct outreach to school principals through phone calls and email introductions. The team provided an overview of programs and asked principals if the phone call or email approach was effective and received feedback on how it could be more effective. The Denver team refined their approach and developed a strategy for future school initial engagement.

This strategy involved approaching engaged nurses and science teacher at events they would regularly participate as part of their specific roles. The team attended workshops and built relationships with nurses working in the schools. Those individuals would then champion the idea to the principal of their schools leading to in-person meetings and approval of participation.

4.2 Influencing behaviour change

Behavioural change experiments were conducted with parents to test various idling reduction methods at three schools. Volunteers from the city as well as community members and parents monitored idling at pilot schools during morning drop-off and afternoon pick-up. Vehicle counts as well as idling duration were recorded. One week of baseline, as well as one week for each intervention methodology were tracked. The first method tested was anti-idling signage. This method differed from signage previously present at schools in that the signage was facing the direction of oncoming traffic as well as near eye level with drivers (Fig. 2). The second test was an anti-idling pledge sent home with students in weekly folders. The third intervention was intended to use a district media platform to relay messages daily to the school communities. This last intervention was not tested as there were some hurdles in allowing testing though the district portal that the team was not able to overcome before school let out for summer.

Many lessons were learned through this testing. Manually tracking idling at a school of 300+ students is very difficult with only 3–4 volunteers per school. The detail of notes varied from volunteer to volunteer which resulted in inconsistent data sets. During the period of sending pledges home, it was found there was often a disconnect with the person who picked

Figure 2: Dashboard mock-ups created in parent focus group.

up the student from school and the person who went through the weekly folder and received the pledge. While the Denver team did not see expected results through this test, they found the experience to be very insightful. Being present on the ground at schools, gave a more detailed understanding of the situation during pick-up and drop-off times. It was shown that each school is unique. There are some basic strategies that can be implemented to help ease some of the challenges, however, a customized plan developed with each school will have the biggest impact.

4.3 Dashboard information sharing

Information sharing with school communities on near-real time air quality can be a challenge. The approach taken was to conduct iterative focus groups with the parents, teachers, and nurses with the aim of developing a dashboard relaying the information that was useful in a way that was understood by the community. The team started with hand drawn low fidelity prototypes, progressing to hand built dashboards mock-ups (Fig. 3), finally to digital dashboards displaying local data from sensors. Different air quality scales, colours, and ranges were also tested in the focus groups.

As in other tests, the team learned a great deal from having the focus groups and hearing directly from stakeholders. The specific outcome was a dashboard design that will be implemented in schools in 2019. The platform which hosts the dashboard allows for continued refinement and customization for each school.

4.4 Sensor and data platform technology

The air quality sensor technology used in this project was co-developed with a local aerospace engineering company for the specific use case of deployment at schools within the project. There were limitations of off the shelf instrumentation, with custom modification

Figure 3: Dashboard mock-ups created in parent focus group.

costly and impractical for scaling up to a city-wide network. By co-designing and developing the units, the Denver team was able to limit the costs while also achieving the level of data resolution and accuracy needed for the project. Testing of the sensors was done through extended collocations at state agency sites equipped with instrumentation that met the standards of the federal agency. Sensors were deployed at three different sites with two different types of instruments and one triplicate collocation for sensor to sensor variability comparison. The results showed very high correlation ($r^2 > 0.9$) of sensors to both types of high quality instruments and extremely high correlations ($r2 > 0.95$) between sensors.

In addition to development of the air quality sensors, the Denver team also worked with a developer to create a platform for management of air quality sensor data. This platform can ingest data from a variety of sensors as well as state run stations. By ingesting both instruments in the same platform it allows for near-real time analytics of the entire network as well as quality assure collocated sensors continuously. Having permanent sensors located at state sites, the platform will have the ability to dynamically generate correction algorithms which would then be pushed to the sensor network allowing for on-going automated calibration. In addition, the platform manages the dashboard interfaces as well as alerting thresholds and automated network reporting, allowing for ease of network management with minimal oversite.

5 MITIGATION METHODOLOGY AND MEASUREMENT

The strategies for mitigating exposure and reducing nearby sources of emission are split into three categories: individual, school community, and city government. The first two categories have exposure reduction as well as pollution reduction sub-categories, while city government is limited to pollution reduction strategies (Table 1). Research was conducted during the pilot phase of the project to identify available programs and strategies for inclusion. While many options existed, we found only limited evaluation of the effectiveness. As the team continues to implement the project at scale, programs will be evaluated to measure the impact and effectiveness of each.

Table 1: Air pollution mitigation strategy categories with examples.

Category	Example
Individual – exposure reduction	Students using air quality information from the dashboard to make decisions about their outdoor activities.
Individual – pollution reduction	Parents choosing to turn off their engines while waiting to pick up their children from school.
School community – exposure reduction	Schools having policies and plans in place for days with pollution above safe levels.
School community – pollution reduction	Schools having reduced emissions events where they swap out fossil fuel generators with electric power banks.
City government – pollution reduction	Prioritizing construction activities near schools to times when schools are not in session.

5.1 Program selection and implementation

The team shared the first iteration of programmatic options with DPS as well as the three pilot schools. It was suggested that the list be developed into a "menu" of options that schools would be able to select from. This would provide schools with flexibility to choose programs that met their needs. Schools with limited time could select simple options such as the installation of anti-idling signs, while other schools would be able to take on bigger projects such as walking school busses or changing recess schedules. By giving schools the ability to opt into programs that suited their needs, they were provided options versus simply implementing a program that may not be well suited for a particular school.

5.2 Measuring impact

As programs are selected by schools, measuring the impact of each will allow the narrowing of options as the project continues to scale. The foundations for measuring this impact are the air quality sensors deployed at schools in addition to health metrics collected at each school. Through a data sharing agreement with the school district, the City of Denver has aggregated baseline asthma indicators including inhaler usage and absenteeism, as well as several others. As programs are implemented, the air quality and health data will be cross analysed to identify which have the most impact on the health of students.

6 CONCLUSION

The Air Quality Community Action Network (AQ-CAN) has evolved since 2017 when first submitted as an idea to the Bloomberg Mayors Challenge. Denver has piloted and evolved the project through direct interaction and feedback from stakeholders. It has continued to learn and will follow the same methodology moving forward. Scaling up to 40 schools will undoubtedly come with additional unforeseen challenges. However, the team is confident in its ability to overcome obstacles and make a positive impact on the respiratory health and air quality of Denver's residents.

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