BEST PRACTICES FOR VISUALIZING AND COMMUNICATING AIR QUALITY DATA

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Disclaimer

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This project was conducted under the mentorship of Metro Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Metro Vancouver or the University of British Columbia.

Territorial Acknowledgement

The author acknowledges that the work for this project took place on the unceded ancestral lands of the xwməθkwəy̓əm (Musqueam) Nations and Syilx (Okanagan) Peoples.

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Cover photo by Davi de Ferreyro Monticelli

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Executive Summary

Air quality is ever more important these days. With 99% of world cities suffering from episodes of poor air, governments must find ways to communicate the dangers of air pollution to the public. The challenge, however, is how.

A common strategy is to use air quality indexes that converge the concentration of multiple pollutants and their associated health impacts into a single score. This score, then, can be advertised in local media, text messages, delivered via mobile apps or displayed on trusted websites.

In Canada, the index used is the 'Air Quality Health Index' (AQHI), and for Metro Vancouver residents, a trusted source of information is AirMap.ca. However, this tool was developed many years ago and now needs an update to match (or stay ahead) of its competitors, some of which do not show government verified data and may lead to false information to citizens.

In this report, we provide a glance at the state-of-the-art in air quality communication, knowledge translation, and visualization. Several strategies to update AirMap.ca are presented and discussed.

Introduction

Why air pollution?

Recent numbers from the World Health Organization are not cheerful. In 2019, over 6.7 million people died from a combination of exposure to poor air quality at home and outdoors. Only 1% of the world's cities met the air quality guidelines[1].

When it comes to the air we breathe there are a variety of pollutants of concern. They are often divided by physical state, mainly *particles* or *gases*. Particles correspond to solid and liquid droplets found in air. Gases correspond to chemicals found in the gas state. Particles are further divided by their size range, being those below 10µm (PM_{10}) called *"inhalable particles"*, below 2.5µm ($PM_{2.5}$) *"respirable particles"*, and below 0.1µm ($PM_{0.1}$) *"ultrafine particles"*. The gases are divided between *"inorganic"*, meaning no carbon atoms (C), like NO_2, NO, O_3, SO_2 and *"organic"*, like CO, CO_2 and C_5H_8.

The pollutants most usually measured are called *"criteria air pollutants"*. In Canada, they are sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOCs), particulate matter (PM), carbon monoxide (CO), ammonia (NH_3), and ground-level ozone (O_3)[2]. Each air pollutant has an isolated impact on health as shown by multiple reviews (Brunekreef & Holgate, 2002; Kampa & Castanas, 2008). However, it is their combined effect from the mixture in the air that makes environmental management difficult (Hidy & Pennell, 2010; Mauderly et al., 2010).

Monitoring air quality and indexes

Most air pollutants are monitored by the joint efforts of regulatory agencies, citizen scientists, and non-profit organizations. To improve knowledge translation and communication between parties and promote the association between air pollution and health effects, many countries adopted indexes that compile information on one or multiple pollutants into an easy-to-read scale (Tan et al., 2021). In Canada, the index used is the 'Air Quality Health Index' (AQHI), a scale from 1 to 10+ that links the concentration of three pollutants, NO_2, O_3, and $PM_{2.5}$ into a health advisory. The AQHI has been the subject of much debate. One of the positive aspects of the AQHI is that, in the majority of cases, it influences parents towards wildfire smoke worry, willingness to take actions and reduce exposure to wildfire smoke, and support policies to mitigate wildfire

[1] WHO Air Pollution Data Portal: Access it here

[2] Government of Canada, Common air contaminants: Access it here

smoke exposure compared to the US AQI – in Moderate and High Risk Levels and during Short and Long Exposure scenarios (Slavik et al., 2024). However the equation used to estimate the index may not provide the best recommendation for specific groups (e.g. people with asthma) during episodes of intense emissions from residential woodsmoke or wildfires (To et al., 2013; Trieu et al., 2020; Yao, Stieb, et al., 2020). To further comprehend this index's advantages and shortcomings we suggest using the online tool created by the scholar (illustrated in **Figure 1**, to access it click here).

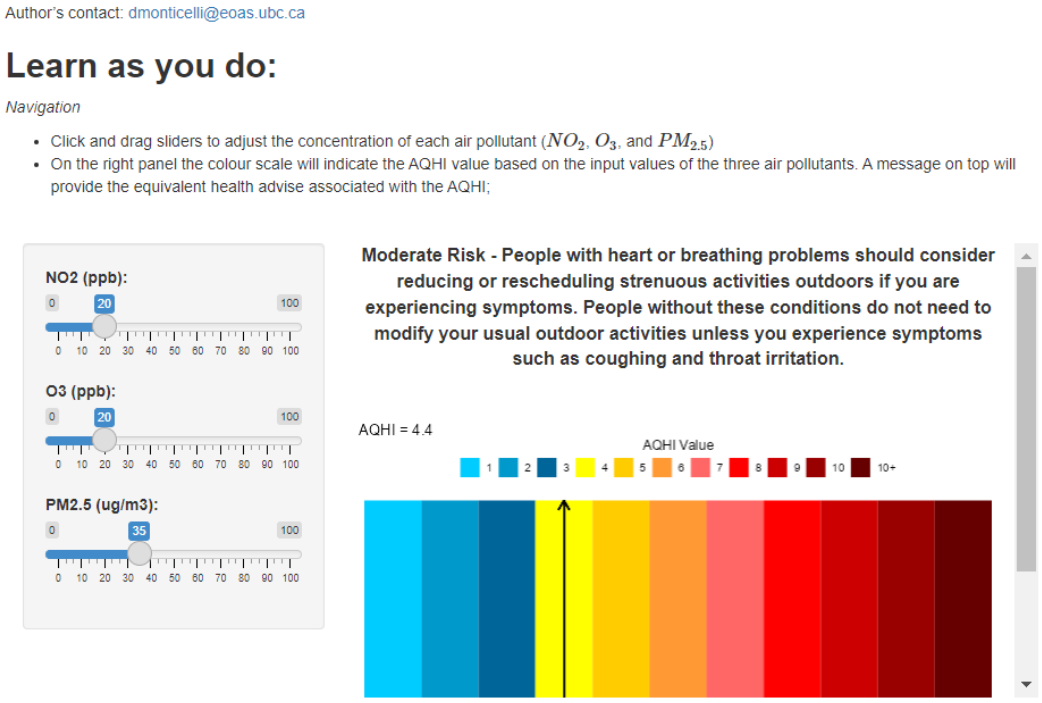


Figure 1. Interactive way of understanding the AQHI, link: here.

Access to information in a time of need

Regional climate projections by Metro Vancouver (2016) indicate that Metro Vancouver region will experience hotter, longer, and drier summers, which can lead to more wildfires and degraded air quality due to smoke impacts and extreme heat events. As our climate changes, the ability to quickly access reliable, timely, and accurate air quality and weather data will become even more essential to protect the health of the region's residents.

This project aligns with the following Metro Vancouver organization management plans:

- *In the Clean Air Plan, action 6.1.12 is "Public Communication," with a direction to "improve online air quality and climate change communication tools".*

• The Board Strategic Plan (2022-2026) includes a priority action to "Protect public and environmental health and fight climate change by continuing to provide world-class air quality and greenhouse gas management services, including monitoring, emissions inventories, and air quality advisories."

Metro Vancouver's AirMap

Metro Vancouver's AirMap.ca webpage displays real-time air quality and weather data from the Lower Fraser Valley air quality monitoring network. It is the most viewed page on Metro Vancouver's website, especially when regional air quality is impacted by wildfire smoke. AirMap.ca also displays the Air Quality Health Index (AQHI), which guides how residents could modify their activities to protect their health when the region experiences poor air quality, and the residential indoor wood burning status to inform residents when they can use their indoor wood burning appliance.

AirMap.ca is an important tool to communicate air quality and weather conditions to Metro Vancouver residents. However, it was developed over 10 years ago, and since then, data visualization tools, air monitoring technology, and online communication strategies have evolved. To ensure AirMap.ca continues to meet the needs of the region's residents, Metro Vancouver is exploring how to modernize and enhance how we communicate and visualize air quality and weather data to the public.

Objectives

- Conduct a literature review to identify best practices for visualizing or communicating air quality data.

- Review websites and apps from public (e.g., government agencies) and private (e.g., air sensor manufacturers) organizations to identify how air quality and weather data is communicated to the public.

- Identify areas on AirMap.ca that are not user-friendly or that need usability improvements.

- Make recommendations for improvements on Metro Vancouver's display and reporting of air quality and weather data, air quality advisory notices, and related health messaging.

Research Approach

Literature review

The literature review was conducted non-systematically. On Google Scholar, the keywords *"air pollution"*, *"AQI"*, *"AQHI"*, *"air quality"*, *"visualization"*, *"communication"*, *"website"*, and *"app development"* were used in combination to retrieve published works. From results, titles and abstracts were read for relevance check, and an initial poll (n=10) of studies was selected. A further seven studies were added to the final list by checking the references of the initial poll. The key topic distribution is shown in Figure 2.

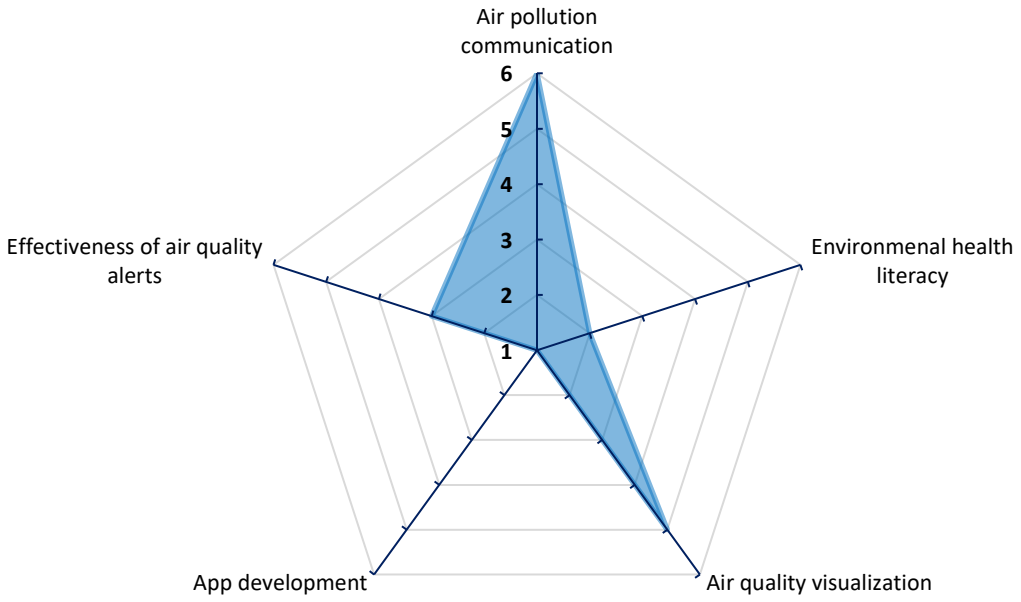


Figure 2. Number of studies identified within each key topic.

Studies were evaluated by searching for design and layout ideas for AirMap.ca, how to improve accessibility and knowledge translation, and successful and failed strategies for using air quality indexes and visualization tools.

Websites and apps review

In Carro et al., (2022) the authors provide a table with the most popular web and mobile apps used to access air quality information in the world. The Top 3 most downloaded or viewed are AirVisual (5mi+), Air Quality Index – Real Time AQI (500k+), and AirMatters (100k+). This was used as a starting point together with suggestions provided by the project supervisor, including the Province of British Columbia's Air Quality Health Index Map, the University of Northern

British Columbia and Environment and Climate Change Canada's AQmap, the AirNow Fire and Smoke Map, and the South Coast Air Quality Management District Air Current Air Quality Data.

Each source had its layout evaluated, trying to elect four key strategies, negative or positive, based on the literature reviewed. Additionally, the scholar reviewed if they have a mobile app available (or if the web version is mobile friendly), which software or package was used to build the tool, data sources, sensors and pollutants considered, layers disposition and overall navigation features.

Information exchange with person-of-contact of other websites

Finally, a few websites were selected to enquiry further information in direct contact with the person or team responsible. The idea was to obtain the 'invisible' knowledge that could be useful for AirMap.ca. Questions asked were:

- *Q1: What is the most accessed feature on the website or that has the most positive feedback from the public?*
- *Q2: What is the least accessed feature/most negative feedback?*
- *Q3: How much time (average) do users spend on the web application?*
- *Q4: Any tips about converting to a mobile-friendly interface?*

Results and Discussion

Literature review

Air pollution communication

Perhaps a good starting point is the comprehension of the four categories of the target audience, defined by Santana et al. (2021):

- *"An information-seeker primarily represents pollution-aware people who are willing to use air quality information to determine, for instance, which routes should be taken in daily commutes if exposure to air pollution is to be minimised."*

- *"A learner represents people who are invited to interact with the system using game-like strategies in order to gain air pollution awareness in an engaging way, so that one day the learner becomes an information-seeker."*

- *"An expert represents researchers and practitioners in the air quality field who need to efficiently gather bulk air pollution data for statistical analysis and model building, given a spatiotemporal window."*

- *"Finally, a developer represents people from the system's development and maintenance team, who need to monitor, supervise, diagnose, and control each node in the system at run-time."*

A typical citizen is often in the 'learner' category as they rely more on sensory cues (e.g., does the air look dirty? Are plants dying? Strong smells?) or health cues in themselves or neighbours (e.g., allergies, rhinitis) than media communication (e.g., AQHI displayed in websites or local TV channel) (Johnson, 2012). One reason for this could be the way indexes are communicated. For instance, Johnson (2003) supports knowledge barriers are imposed when using language such as *"sensitive groups"* or *"old age"* without a clear definition. However, opting to use a ladder scale rather than a standard to communicate risk helps people understand that danger does not decrease sharply if the concentrations are just below the guideline/limit. It also helps if the information can be communicated through different translations, not only in English (Ramírez et al., 2019). Nevertheless, it appears the most effective way of communicating air quality is via text messages sent by an organization the public believes to be the authority on the issue (Fish et al., 2017). Although this seems unencouraging for a web application such as AirMap.ca, it can be

used in favour of the tool by having a type of subscription that always invites the user (now an "information-seeker") to check the website during an alert.

Air quality visualization

Plotting air quality is conveying the message that certain concentration levels/pollutants have a) a spatial pattern, b) a time pattern, and c) health effects. It is hard to, in a single illustration, tackle these three aspects, but a few strategies could help. One of which is to include AQHI colours in a time series of stations distributed on a map. Another is to plot AQHI heatmaps spanning a year or in a calendar format. This way, both short-term and long-term trends are available. Additionally, this method shortens the association pathway between air pollution and health effects, which is desirable (Carro et al., 2022) – see an example in **Figure 3**. Unfortunately, there is no gold standard in this topic and more resources are commonly found in the grey literature and blogs (e.g., here) than in the form of scientific communication.

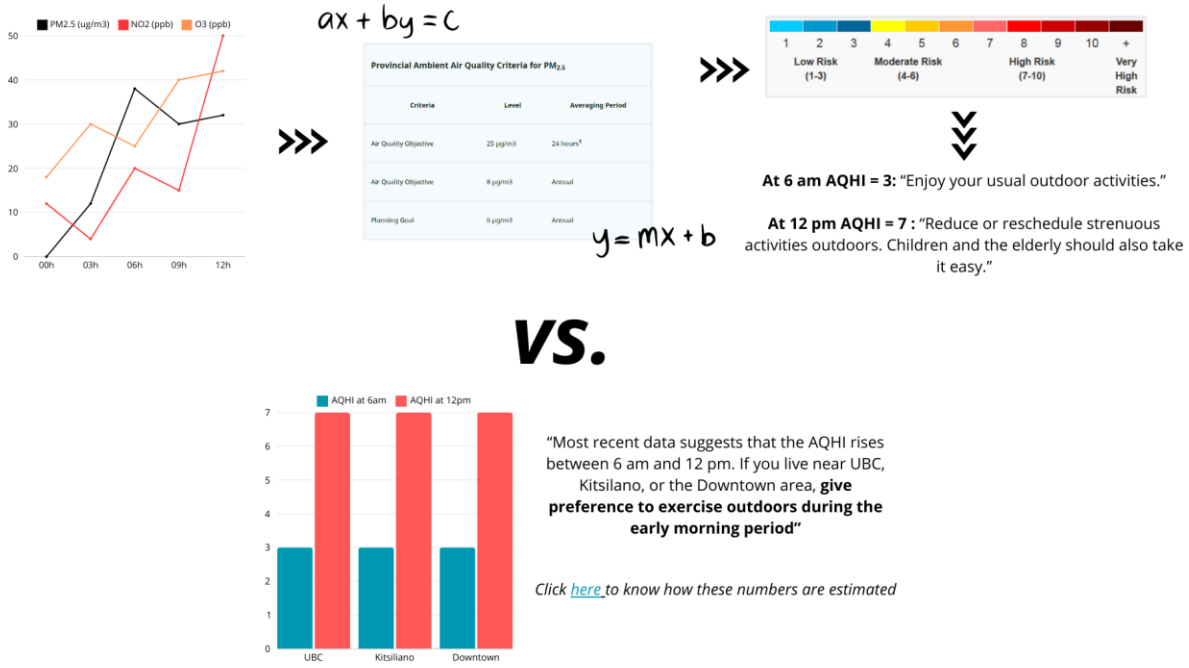


Figure 3. Two forms of informing air quality. At the top, represents a long association pathway where the information-seeker must understand a timeseries, search for equations or air quality guidelines to convert the timeseries into a scale (e.g., AQHI), compare the scale limits to the value found, and finally extract the health message. This association pathway must be done for each location or period of interest. At the bottom, the AQHI value is already displayed across locations and different periods of interest, with a clear health message associated with the figure. For the curious person, a link is provided to access more information.

Effectiveness of air quality alerts and Environmental Health Literacy

According to Radisic & Bruce Newbold (2016), who interviewed 50 people (6 health care providers, 16 parents, 13 elderly, and 15 people with existing respiratory conditions), there are four key barriers to AQHI adoption i) unclear relevance, ii) index confusion, iii) sensory cue precedence, iv) time constraints. The first barrier, relevance, is mainly due to the lack of constant communication in local media, making the AQHI seem secondary to other approaches. Index confusion reflects upon the different acronyms found in our modern society. In Radisic & Bruce Newbold (2016) study, participants often mistake AQHI for the heat and humidity index (humidex). Sensory cue precedence was discussed previously and plays a major role in the decision to adopt AQHI. Essentially, if *'it feels nice outside',* unless clear importance is given to the AQHI, people tend to ignore it. Finally, time is another critical factor, and for AQHI to reach people in need, perhaps more than a website is necessary (i.e., also needs apps and notifications).

In contrast, the study suggests five approaches to increase AQHI adherence, i) professional network promotion, ii) health benefit emphasis, iii) neighbourhood scale focus, iv) local media reporting and v) wearable device option. While i) to iv) can be pursued *after* or *while* AirMap.ca is updated, the last strategy directly addresses a need for AirMap.ca to become mobile-friendly, which leads us to the last key topic.

App development

Licskai et al. (2013) worked on a mobile solution for people with asthma that involved an app, which, among other things, conveyed AQHI information. The success of the approach relies on the app features and especially in its communication protocol:

- *"Daily AQHI forecast for the next day was sent at 15:00 with corresponding risk reduction message."*
- *"Real-time notification was sent if the AQHI forecast differed significantly from current conditions."*
- *"E-mail alerts were sent for moderate and high-risk days."*
- *"Asthma control assessment displayed as green, yellow or red zone with the corresponding asthma management advice."*

Currently, AirMap.ca does not have a protocol or notification subscription in place for AQHI. However, this is already covered by a different government application, the WeatherCAN app[3]. Thus, the new AirMap.ca design could offer to redirect the interested user to such services.

Websites and apps review

The websites reviewed are summarised in Table 1. Most of them had apps and those which did not, had a mobile-friendly version (i.e., worked well on the phone). All maps, apart from AQmap in which the focus is $PM_{2.5}$, show some form of an index as the default layer. Some offer the option to select different indexes (e.g., AirMatters), while others developed their indexes (e.g., PlumeLabs). Of those who display an air quality index, only a few have a legend that explains each category, and none uses plain language (instead they commonly imposed knowledge barriers using expressions such as 'sensitive groups', 'serious health effects', 'moderate health concern', or 'children and old people').

[3] WeatherCAN: How to set up custom notifications (AQHI), Accessed here.

Table 1. Websites consulted for AirMap.ca update (continue).

Website / App	Ownership	Software / Package	Data Sources	Layers	Spatial Interpolation?	Accessibility & Features	Mobile App Available?
WAQI	Non-profit	Leaflet	They compile data from multiple sources, with an icon differentiation if regulatory. For instance, in Metro Vancouver, the provider is the "BC Air Quality Monitoring Agency"	AQI $PM_{2.5}$ PM_{10} (most common) Sensors are from regulatory sites or Purple Air	No	Information displayed in the local language	No, but the web app works well when navigating in a mobile browser
PlumeLabs	Private	Mapbox	List of different sources per country: https://air.plumelabs.com/en/sources Canada: Air Quality Ontario **Metro Vancouver** Ontario Ministry of Environment and Climate Change Ville de Montréal	AQI $PM_{2.5}$ PM_{10} NO_2 O_3	Yes	Option to select French/English	Yes
IQAir	Private	Leaflet	There are six contributor categories: Government, Non-profit organization, Educational, Corporate, Individual, and Anonymous.	AQI Fires Wind	Yes	Wind animation	Yes

Table 1. Websites consulted for AirMap.ca update (continue).

Website / App	Ownership	Software / Package	Data Sources	Layers	Spatial Interpolation?	Accessibility & Features	Mobile App Available?
BreezoMeter	Private	Mapbox	Real-time traffic data Official governmental sensors' information Low-cost local sensors network Satellite data Weather forecast & meteorological information Reports on Active fires Land cover & more Sophisticated algorithms, multiple models and machine-learning techniques	AQI Fires (key layers)	Yes	Loops Can select multiple languages and indexes	Yes
AQI-India	Private	Leaflet	All their data seems to come from the "World Air Quality Index Project" There are no distinctions between stations (i.e., different icons if regulatory)	AQI $PM_{2.5}$ PM_{10} Wind Temperature Humidity Fires	Yes	Can select multiple languages	Yes
AirNow	Government	ESRI (ArcMap)	Only official sources such as regulatory sites or linked to the government (note: very few locations outside North America)	O_3 $PM_{2.5}$ PM_{10}	Yes	Loops and Forecast	Yes
AirMatters	Private	Leaflet	Appears to be a compilation of regulatory sites and external. For instance, in Metro Vancouver, the sources listed are: http://www.bcairquality.ca/ http://www.airnow.gov/	AQI O_3 CO $PM_{2.5}$ PM_{10} SO_2 NO_2	No	Can select multiple languages and indexes	Yes

Table 1. Websites consulted for AirMap.ca update (end).

Website / App	Ownership	Software / Package	Data Sources	Layers	Spatial Interpolation?	Accessibility & Features	Mobile App Available?
BC AQHI Map	Government	ESRI (ArcMap)	BC Air Quality Monitoring Agency	AQI $PM_{2.5}$ PM_{10} O_3 NO_2 SO_2 TRS	No	None of particular relevance	No, but the web app works well when navigating in a mobile browser
Fire and Smoke Map	Government	Leaflet	Data from established air quality monitors operated by air quality agencies, temporary monitors deployed by agencies for smoke events, and low-cost sensors made by PurpleAir. Large fire incidents, from the U.S. National Interagency Fire Center, and satellite fire detections from various satellite systems.	AQI $PM_{2.5}$ Fire	Yes	Option to select Spanish/English Dark view	No, but the web app works well when navigating in a mobile browser
Air Quality Index App	Government	ESRI (ArcMap)	This method blends measurements from high-quality regulatory monitors, hundreds of quality-controlled and calibrated low-cost sensors, and an air quality model.	AQI is the main layer. When clicking a location, other pollutants are shown	Yes	Option to change AQI colours Download data	Yes
AQmap	University	Leaflet	Canadian Environmental Agencies, Purple Air, and AQ Egg low-cost sensors	$PM_{2.5}$	No	Option to select French/English Dark view	No, but the web app works well when navigating in a mobile browser

(https://leafletjs.com/) (https://www.esri.com/en-us/home) (https://www.mapbox.com/)

Information exchange with person-of-contact of other websites

Most accessed feature/positive feedback from the public:

Most sources consulted did not have a means to track the specific features accessed on their website. However, for those who had a way to track features or received public feedback, the key takeaways were:

- *"(…) localized air quality and concise recommendations for actions the public can take to protect their health."*

- *"(…) interactivity of it is quite useful for users to be able to zoom in to the area they care about most."*

- *"(…) We have had a lot of requests to add a temporal aspect to the map as well, as in a time slider that allows you to go back in time a few days and see how the spatial pattern changes over time."*

- *"(…) easy to access the graph providing the 30-day historical data."*

It seems that the most attractive features of tools such as AirMap.ca relate to the spatial and temporal representation of the information and how the public can interact with it.

Least accessed feature/negative feedback from the public:

For the opposite category, three answers resonated above others. They talk about the need to consider technical language, care with overlaying, and a mobile-friendly interface:

- *"(…) smoke plumes are mentioned in some comments as obscuring the rest of the map, especially during dense smoke levels. Conversely, I have seen several comments that indicate that they think the smoke plumes are the most important feature."*

- *"(…) We have got feedback that it (plots which evaluate the low-cost sensor performance) is a bit technical as well, so we are working on a way to hide the superuser features from the general user while still providing extra details for those superusers who want it."*

- *"(…) Not very mobile friendly and it doesn't show user's precise location."*

The new AirMap.ca design must be aware of each point. For instance, if fires are displayed, perhaps indicate only the fire location and area burned(ing), with an option to redirect to/overlay satellite image if the user wants to see the smoke plumes. In the case of comparing stations, there could be two forms of delivery: one for the average user (learner and information-seeker) and another for the 'superuser' (expert). The 'Time Variation' and 'Calendar' plots from the openair R package (Carslaw & Ropkins, 2012) illustrate well this concept.

In the calendar plot (Figure 4), the AQHI can be displayed using the maximum, most frequent or average value in a day – thus user selected. By plotting multiple months, or the same period but for different stations would allow the learner and information-seeker to infer temporal and spatial patterns. When clicking on a particular day, the full AQHI health message can appear, alongside the time series of that day.

In the time-variation plot (Figure 5), different temporal patterns are shown for a single pollutant or AQHI. The expert user would quickly grasp how the AQHI, for instance, varies across different hours, days of the week, and months of the year. Different locations could be added to the plot using other colours and thus allowing a spatial comparison.

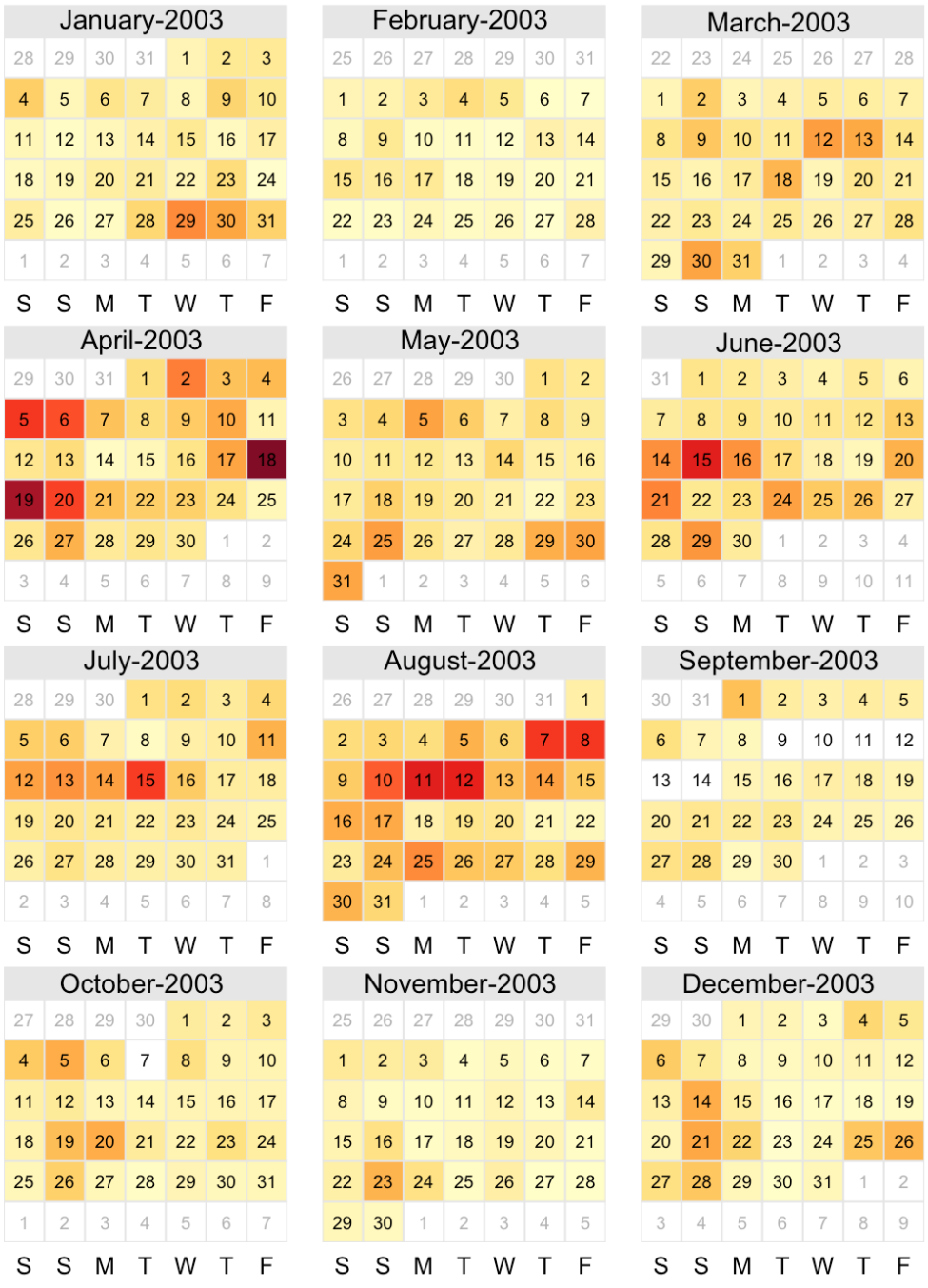


Figure 4. Example of a 'Calendar' plot, from Carslaw & Ropkins (2012) tutorials, which could be used to deliver the AQHI to the average user.

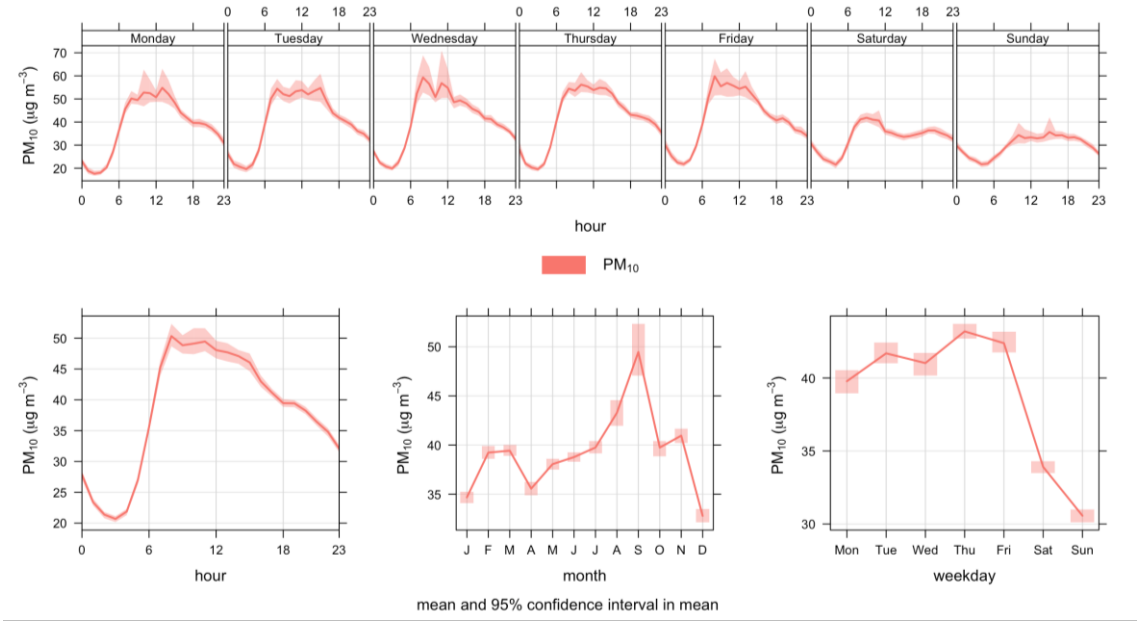


Figure 5. Example of a 'Time Variation' plot, from Carslaw & Ropkins (2012) tutorials, which could be used to deliver the AQHI to the average superuser.

Time (average) do users spend on the web application:

Developers relied on Google Analytics to get a sense of traffic flow and associate the numbers to events known to affect air quality, such as wildfires.

- *"According to Google Analytics, that is variable depending on the wildfire/smoke situation. When there are no events, maybe 30 seconds average generally. When there are events, it is over a minute on average, extreme events like the Canadian Smoke Event of last Summer it was over 3 minutes on average on the heaviest days."*

- *"We have about 20-100 daily users outside of fire season and can have upwards of 2000 per day during large scale wildfire events. Most users spend about 5 ("engaged") minutes on the page outside of fire season, and 10-30 minutes on average during those large events."*

Converting to a mobile-friendly interface:

This was considered a challenge for all sources that replied. Some opted to build entirely separate applications, while others decided to approach with a webpage that adapts to screen size. Not much could be extracted from interviews at this point as some are still developing their mobile content.

Recommendations for AirMap.ca based on Research:

The recommendations are divided into phases considering the feedback from project supervisors and the team behind AirMap.ca. The main features of the proposed version are summarized in Figure 6. The complete list of changes can be found in the Appendix (Power Point Slides) – these proposed changes are subject to review and approval by Metro Vancouver.

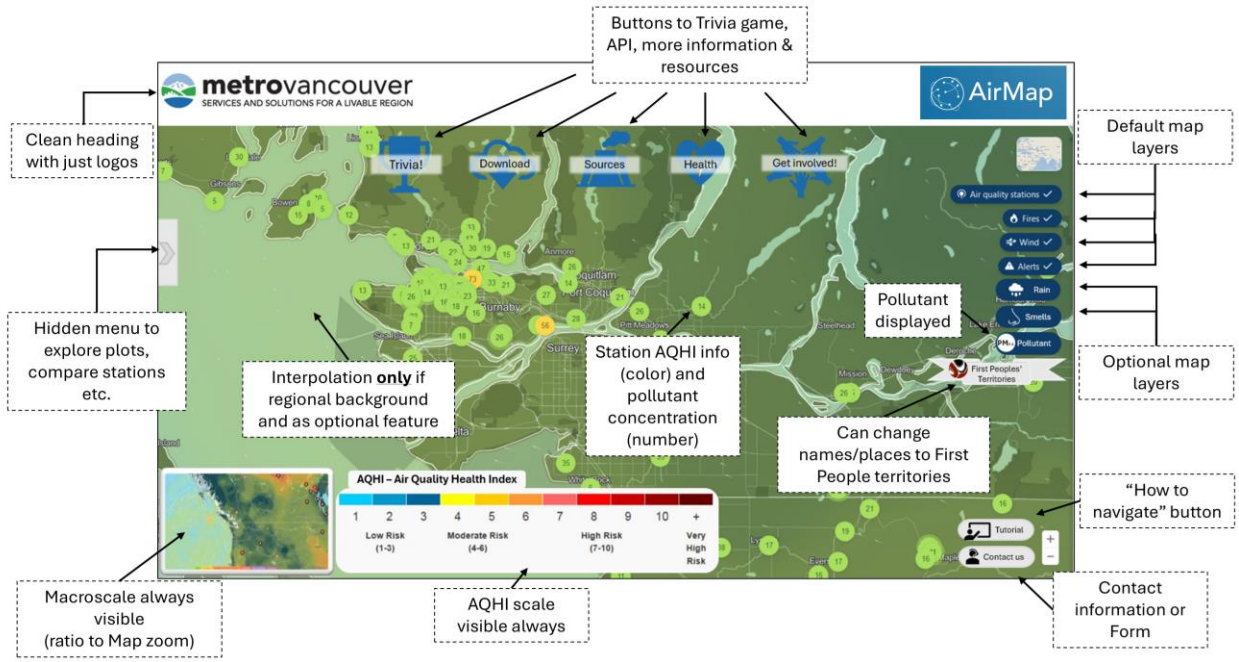


Figure 6. Main features of the improved AirMap.ca - note that the basemap was obtained from the app IQAir.com for illustration purposes. The stations in this map do not reflect regulatory monitoring sites of Metro Vancouver.

Phase 1 – Pressing updates

The following recommendations address the initial steps to improving AirMap.ca that are likely quicker to implement than other measures and yet proven effective according to sources consulted.

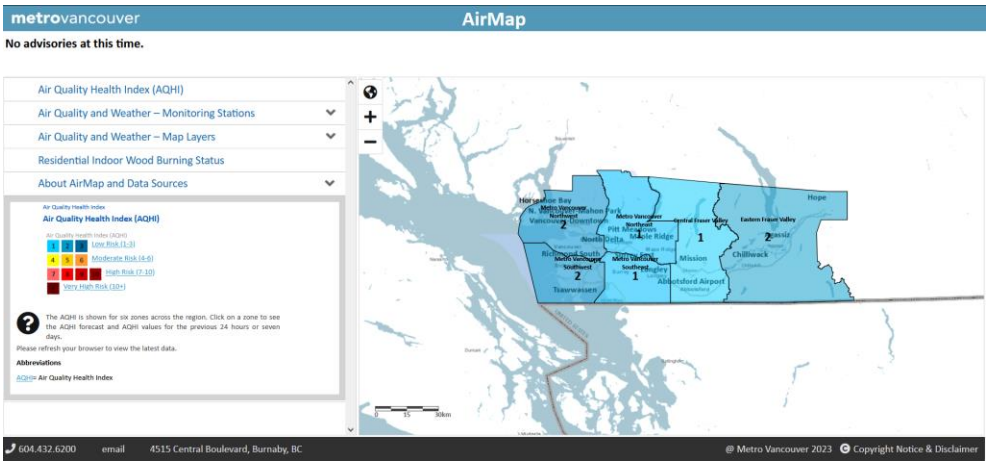
a. Redesign the website to emphasize the map

One of the key feedback items from the information exchange with other web developers is that the users interact more with the map than any other feature. One source said:

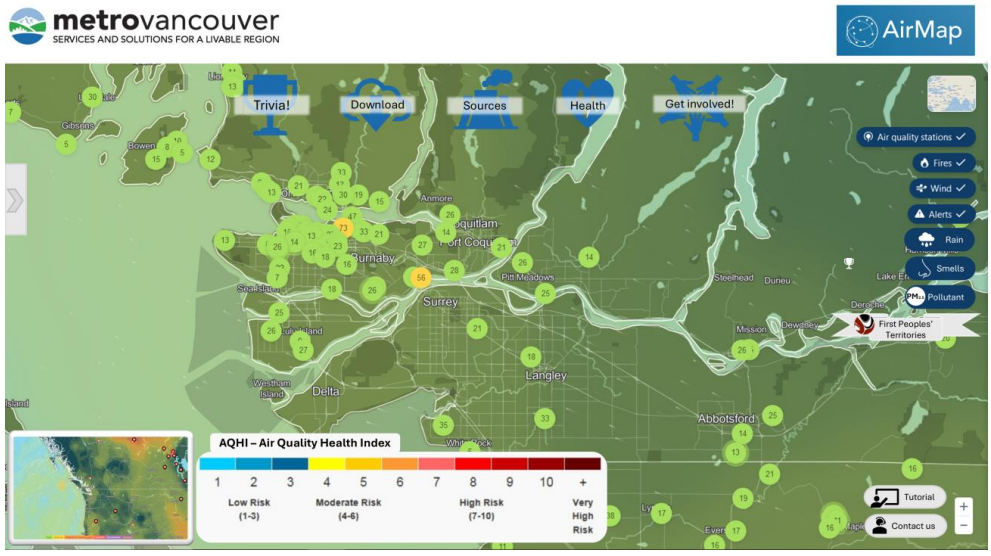
> *"(…) interactivity of it is quite useful for users to be able to zoom in to the area they care about most. This allows for an overall view as well as the ability to drill down into key*

areas of interest. (…) most users just want to look at the map (i.e. no graphs), some users want to see the timeseries (…)"

For such reasons, the new AirMap.ca could have a hidden menu instead of an open one in the left corner, with a few buttons in the right corner to select features to be displayed. Additionally, in the lower-left corner, another map can be constantly displayed with a fixed zoom ratio to the main map. This way, the user will always have an idea of what is happening in the surroundings of the current region of focus (see **Figure 7**).



(a)



(b)

Figure 7. AirMap.ca design (a) before recommended changes and (b) after - note that the basemap was obtained from the app IQAir.com for illustration purposes. The stations in this map do not reflect the regulatory monitoring sites of Metro Vancouver.

b. Have the AQHI scale always visible and health advisory upfront

Carro et al. (2022) discusses the association pathway between air pollution and health effects should be the shortest possible. When the average user must read a piece of information, for instance, a concentration value, then search for a way to translate this concentration into "good" or "bad" scale categories, and finally based on this scale what health advisory to follow, there is too much effort, and critical information is lost or ignored in the process. This is especially true if the pathway consists of links that redirect to new web pages. In Radisic & Bruce Newbold (2016) study, one user said:

> *"I just don't think many people want to go in and click 100 times to get to the thing…"*

Therefore, the best approach is to have all those steps delivered in an aesthetically pleasing manner. Additionally, cognitive psychology also supports having images to associate with a message, as it creates mental links that are easier to recognize and recollect (Baadte & Meinhardt-Injac, 2019). For those reasons, on top of always showing the AQHI scale, the new AirMap.ca could be more straightforward with the information provided when selecting air quality station data. The current time series format can be kept, as it addresses many of the recommendations of Carro et al. (2022), however, it should be moved into the panel of the station instead of outside in the left menu (see how **Figure 8** compares to **Figure 9**).

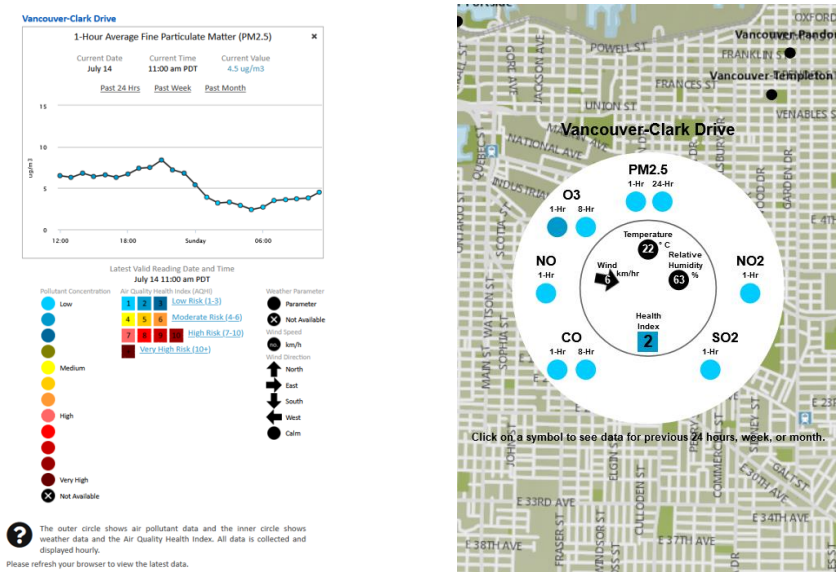


Figure 8. AirMap.ca design before recommended changes where in left panel shows up in the menu features, and the right panel information is displayed when clicking a station icon/name.

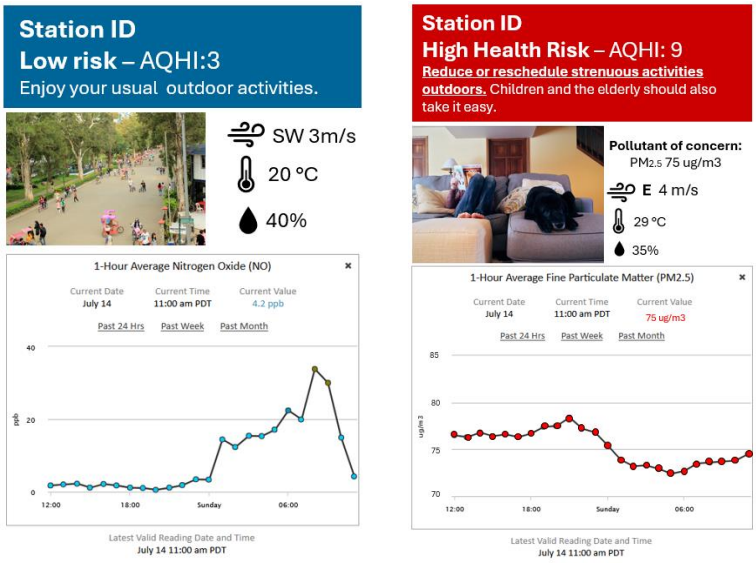


Figure 9. AirMap.ca design after proposed changes where the left panel shows an example of information shared for one station during low AQHI and the right panel an example during high AQHI. The current timeseries plot can slide to the left to introduce a new pollutant.

*Note: Different from the current version, these windows will have a closing option or will automatically close after the zoom-out option has been clicked twice.

c. Redesign default map layers to improve reliability and interpretation

Currently, AirMap.ca has two-layer types: shaded polygons and filled circles/arrows. Shaded polygons are used to communicate the AQHI for the macro-regions of Metro Vancouver Northwest, Metro Vancouver Southwest, Metro Vancouver Northeast, Metro Vancouver Southeast, Central Fraser Valley, and Eastern Fraser Valley or the Residential Indoor Wood Burning Status for Metro Vancouver municipalities (see **Figure 10**). Filled circles are used to communicate a colour-scale value for the current concentration of the selected pollutant or information on the weather (see **Figure 11**).

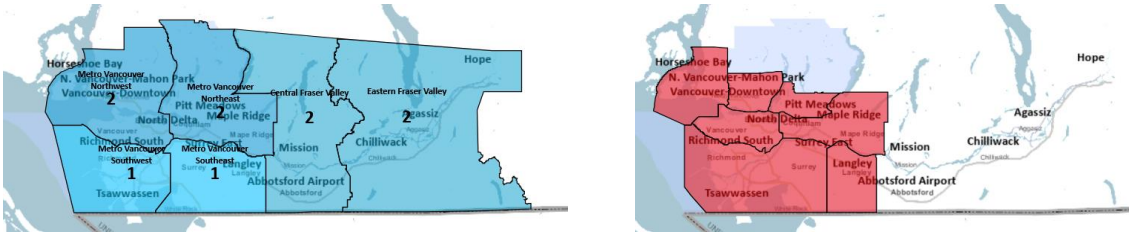


Figure 10. Current polygon layers in AirMap.ca: AQHI for different macro-regions (left panel) and Residential Indoor Wood Status for Metro Vancouver municipalities (right panel).

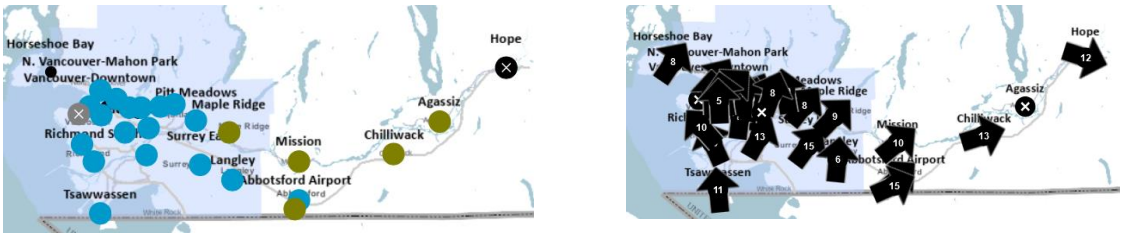


Figure 11. Examples of the current circle layer, here showing 1-hour average ozone concentration following a colour scale (left panel), and arrow layer showing wind speed and direction (right panel).

The AQHI-shaded polygons are a critical point to be addressed. Research has shown that citizens rely on sensory cues more often than other means (e.g., media advisories, websites) (Ciarloni & Newbold, 2023; Johnson, 2003, 2012; Radisic et al., 2016; Radisic & Bruce Newbold, 2016) and when recurring to channels such as AirMap.ca they compare what the eyes can see, body can feel, and nose can smell with the numbers and colours on the screen. Thus, conflicts may arise since a few regulatory sites are not sufficient to represent entire regions. They often represent the air quality of an area of $1km^2 – 2km^2$ (Li et al., 2019; Yatkin et al., 2020) and the weather $1km^2 – 10km^2$ (WMO-No. 8, 2021; World Meteorological Organization, 2014). Additionally, research shows that AQHI reported at the neighbourhood scale benefited understanding and adoption (Radisic & Bruce Newbold, 2016). Therefore, it is preferable to have only the circles at the site location showing concentrations or the AQHI in this case. However, the circles layer has two main issues: first, the colour scale used for the concentration range of pollutants shares similarities with the AQHI scale, even if the pollutant is not included in the index equation (e.g., PM_{10}, TRS, SO_2, and CO). This may create confusion for the average user whether the concentration value reflects or not in the index. Additionally, for pollutants, only the colour is displayed when a layer is selected and the legend is found at the left corner of the webpage, in the menu. For weather variables like Temperature, Humidity, and Wind, a black circle/arrow is displayed with the number in the centre informing the magnitude of the variable. It is, thus, the opposite issue where no scale is available to compare the data with a standard/average. In the case of wind, all arrows have the same size, independent of wind speed. Based on the above, recommendations for the new AirMap.ca design are to:

i. Use a different colour scale for the pollutant's concentration, preferably one that considers the different types of colour blindness.

ii. Whether a pollutant concentration or AQHI is selected to be displayed, show circles with numbers inside. When AQHI is selected the default colour scale appears in the lower left colour (as illustrated in **Figure 6** Figure 6). When a pollutant is selected, the AQHI colour scale changes to match the pollutant scale, and a link is provided to a fact sheet with more information on the health effects of such pollutants.

iii. Develop a monochromatic colour scale for meteorological variables of Temperature, Relative Humidity, Precipitation and Pressure.

iv. For Wind Speed and Wind Direction, initially, the arrows can be scaled or colour-coded to the wind speed value and map zoom. Later, animated layers could be implemented as displayed in IQAir and other weather-focused websites such as Windy and Earth.

d. Investing in Equity, Diversity, and Inclusion

One of the key barriers to access to information highlighted in studies was language, meaning both technical vs. plain communication and translation (Ramírez et al., 2019). Thus, the new AirMap.ca could include an option to select the displaying language of the webpage, with options such as 'English', and 'French' first and later adding other languages that are representative of the region demographics (e.g., 'Chinese' and 'Spanish'). Additionally, the webpage should avoid using terms such as *'susceptible population'* as this may impose knowledge barriers on the average user. Plain language (e.g. *'people over 60 years old and children less than 10 years old'*) or easier words (e.g., *'At-risk population'*) such as the one used in the AQHI is preferred. The second recommendation is within the scope of governmental agencies to act toward reconciliation with indigenous communities[4]. In the new AirMap.ca, a button could be added (see **Figure 6**) to switch the names and boundaries of Metro Vancouver to those of First Peoples origin. Finally, to facilitate access to people with different kinds of colorblindness, monochromatic, optimized or muted colour schemes can be used - a few websites already adopted this practice, for instance Fire and Smoke Map. One example of each colour scheme can be found in **Table 2**.

[4] Government of Canada – Reconciliation: Access it here.

Table 2. Colour scales that promote accessibility.

RGB (0,0,0) HEX #590D22	RGB (128,15,47) HEX #800F2F	RGB (164,19,60) HEX #A4133C	RGB (201,24,74) HEX #C9184A	RGB (255,77,109) HEX #FF4D6D	RGB (255,117,143) HEX #FF758F	RGB (255,143,163) HEX #FF8FA3	RGB (255,179,193) HEX #FFCCD5
Monochromatic							
RGB (0,0,0) HEX #000000	RGB (230,159,0) HEX #E69F00	RGB (86,180,233) HEX #000000	RGB (0,158,115) HEX #009E73	RGB (240,228,66) HEX #F0E442	RGB (0,114,178) HEX #0072B2	RGB (213,94,0) HEX #D55E00	RGB (204,121,167) HEX #CC79A7
Optimized (source: (Wong, 2011))							
RGB (51,34,136) HEX #332288	RGB (136,204,238) HEX #88CCEE	RGB (68,170,153) HEX #44AA99	RGB (17,119,51) HEX #117733	RGB (153,153,51) HEX #999933	RGB (221,204,119) HEX #DDCC77	RGB (204,102,119) HEX #CC6677	RGB (136,34,85) HEX #882255
Muted (source: Paul Tol's Notes)							

Phase 2 – Adapt and Improve

The following recommendations would increase accessibility and follow-up with features that all (or most) external sources have but not AirMap.ca.

e. Going mobile – an urgent need

Ever since the introduction of smartphones, the world has become increasingly mobile. The average information seeker will likely check the daily AQHI and air quality alerts using their phone on the way to work, school, or home (Santana et al., 2021). Not surprisingly, eight out of the twelve tools like AirMap.ca that were consulted have an app available for download. The remaining four do not have an app, however their website works well using a small screen. To achieve this result, different strategies were followed, and one source said:

> *"(We) had to develop two map applications to meet users' requirements – desktop users and mobile users. (…) These are two separate applications to meet certain users' requirements and there is no conversion between them."*

AirMap.ca, on the other hand, must greatly improve in this area and **Figure 12** shows the proposed format. The key components discussed so far are kept, such as emphasis on the map, having the AQHI always visible, reducing the association pathway between exposure and health effects, guiding your audience, and later the highlighting features for better engagement, discussed in detail in **Phase 3**, can be added. Other layouts and features from the literature were consulted during the design process (Delmas & Kohli, 2020; Licskai et al., 2013).

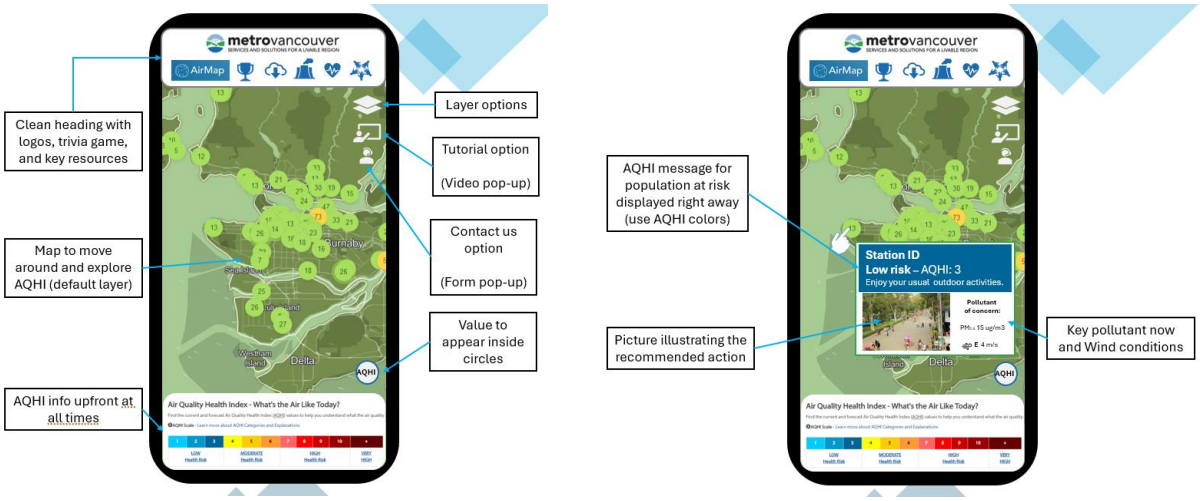


Figure 12. The proposed mobile-friendly version of AirMap.ca - - note that the basemap was obtained from the app IQAir.com for illustration purposes. The stations in this map do not reflect the regulatory monitoring sites of Metro Vancouver.

Phase 3 – Attract and consolidate users

The following recommendations would improve AirMap.ca overall, likely increase access, and expand its reputation as a reliable source of air quality data.

f. Add highlight features

The goal of the highlighted features is to increase access, transparency, and knowledge communication through five channels (see top of **Figure 6**). Each feature establishes a point of connection with the four categories of target audience. The first is a 'Trivia Game'. As pointed out by Santana et al. (2021), games are a way to pass knowledge through an interactive platform and potentially build the desire to seek more information about air quality. **Figure 13** illustrates a proposed interface for AirMap.ca trivia. In the left panel, instructions for the game and questions appear. On the right panel, is a leaderboard to motivate users to achieve their best scores, and two buttons, one to access study materials that comprehend downloadable fact sheets and air quality reports Metro Vancouver already possesses, and another button to return to the map.

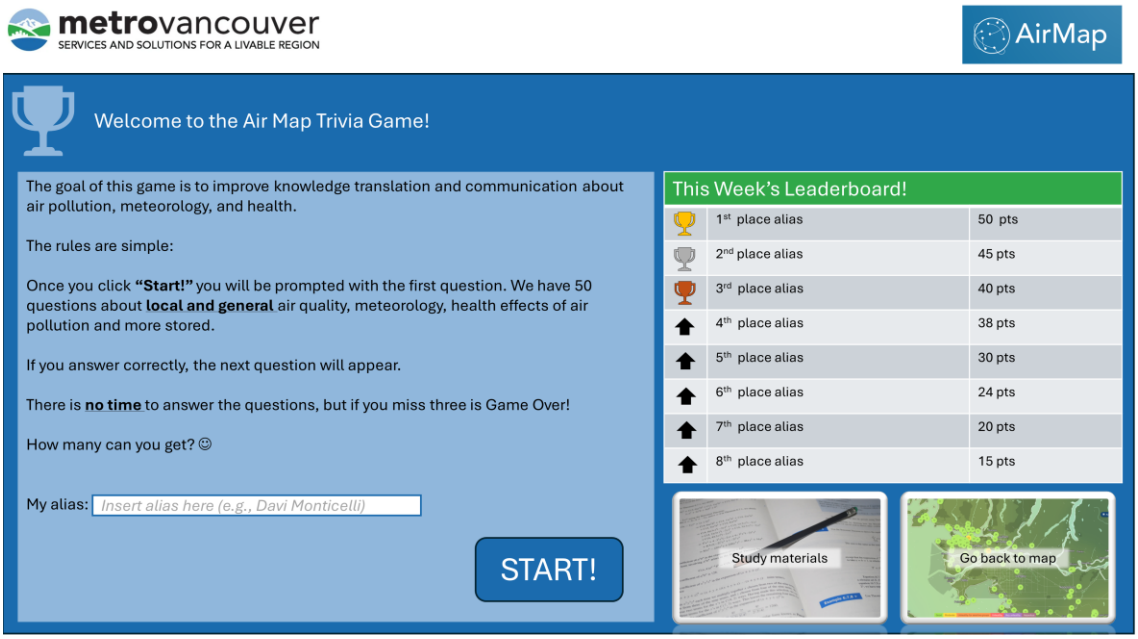


Figure 13. AirMap.ca proposed Trivia Game interface.

The second highlighted feature consists of a 'Download' button that centralizes many resources Metro Vancouver has at disposition. A few suggestions to be included are air quality reports, GIS data, station data, emission inventories, fact sheets, videos, and climate change reports and agendas. Each button inside 'Downloads' can work as a direct link or redirect to another page.

The third and fourth features, 'Sources' and 'Health', are buttons that can be used to deliver videos or infographics explaining the different sources of air pollution to affect Metro Vancouver airbed and how to protect your health during high pollution episodes. Again, the material can be displayed on top of the map as shown in Figure 14 or redirected to another page.

The final feature, 'Get involved!', is an open invitation to citizen scientists, information seekers, and other interested parties to participate in taking care of Metro Vancouver's air. Three options appear on the screen when clicking: a calendar to plan attending future events related to the topic, a button to make an air quality complaint, and another button to receive instructions on low-cost sensors (see Figure 15).

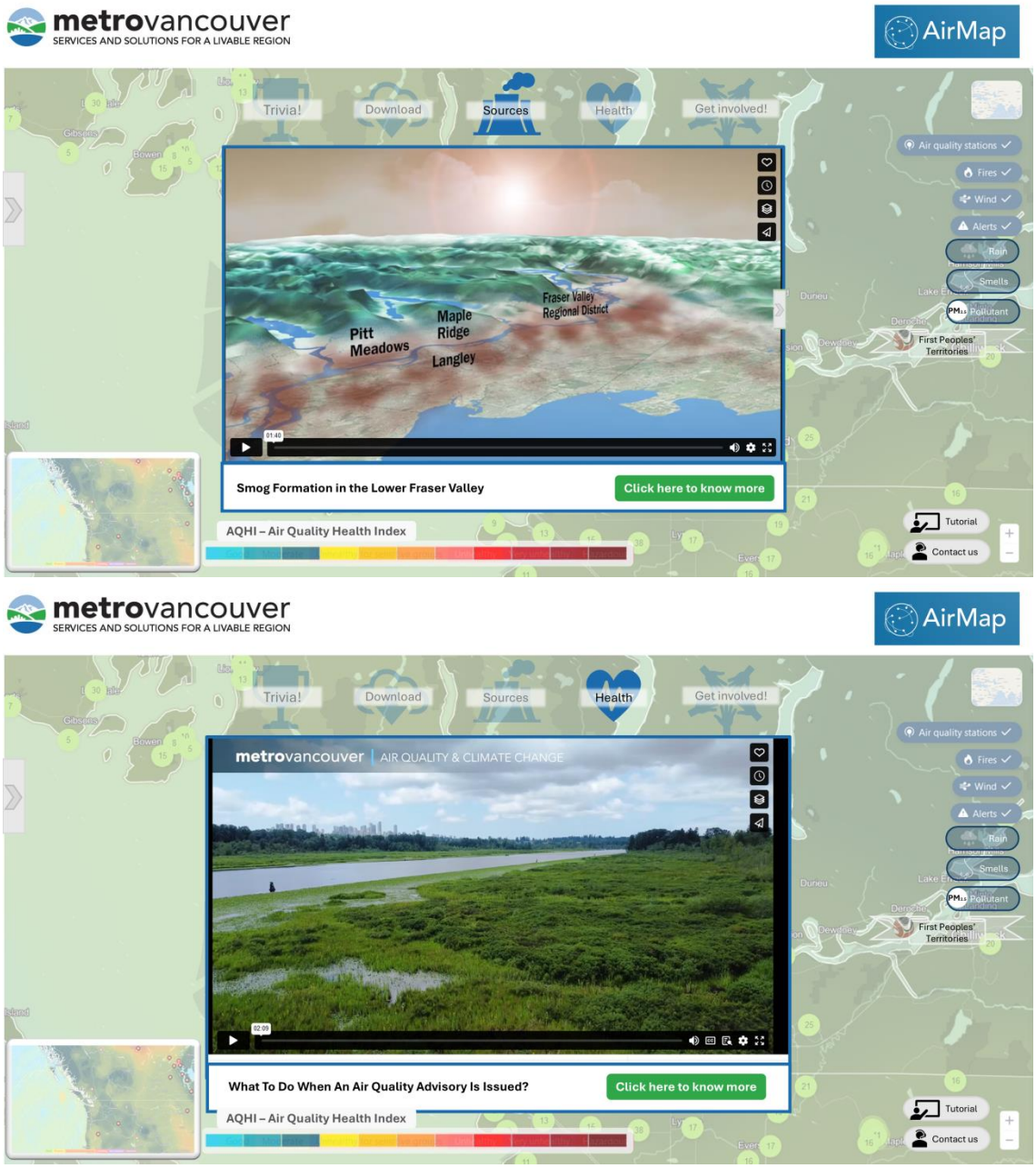


Figure 14. AirMap.ca proposed 'Sources' and 'Health' features - note that the basemap was obtained from the app IQAir.com for illustration purposes. The stations in this map do not reflect the regulatory monitoring sites of Metro Vancouver.

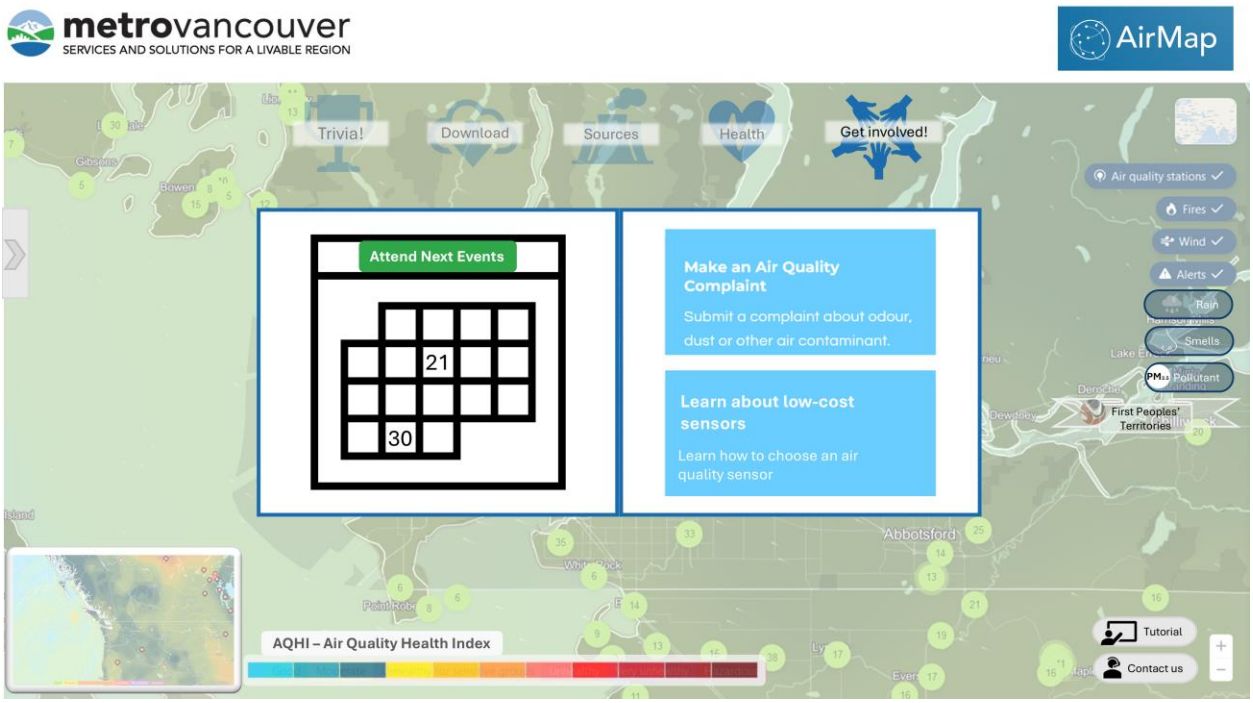


Figure 15. AirMap.ca proposed 'Volunteer!' feature- - note that the basemap was obtained from the app IQAir.com for illustration purposes. The stations in this map do not reflect the regulatory monitoring sites of Metro Vancouver.

g. Add smell reports, wildfires and high pollen days

Odours are a key component of air quality in the Metro Vancouver region (Bhandari et al., 2024; Eykelbosh et al., 2021) and submitting reports has even been shown to be a part of the response to outstanding emission events experienced by its citizens[5]. Wildfire smoke is another environmental stressor that never misses to catch the attention of citizens, being a topic of many air quality studies in BC (Meyn et al., 2010; Parisien et al., 2023; Yao, Brauer, et al., 2020; Yao, Stieb, et al., 2020). At last, when there is too much pollen in the air it can trigger people's allergies and rhinitis. Thus, three optional layers to be displayed in AirMap.ca are the smell reports received by the Metro Vancouver agency, active wildfires and a forecast of pollen. Different icons could be used to represent the odour encounters. For wildfires, a fire icon and a shaded area indicating the burning and smoke produced would suffice. For pollen an interpolation with different colours can be displayed. Thess actions would corroborate with the

[5] VancouverSun News: Parkland Refinery Accident

sensory and health cues the average user relies on an everyday basis to lower their exposure to air pollutants.

h. Add tutorial and contact information buttons

By now, AirMap.ca would have many changes and new features added. Thus, it would benefit the average user to have a 'Tutorial' to facilitate the experience of navigating the tool. The instructions could be given as a series of balloon pop-ups with an option to be spoken (🔊).

Additionally, the 'Contact us' button could have two options: one to talk to an automated bot, which would answer information asked on the website using writing messages with an option to answer with sound (🔊). The other is a form to be addressed to the Metro Vancouver agency.

Phase 4 – Additional Features for the Long-Term

The following recommendations are extra features that may be hard to implement but would put AirMap.ca in the spotlight *vs.* other sources.

i. New hidden menu options and layers

In Phase 1 it was discussed that AirMap.ca should have a hidden menu. Here we present new options that can be added to it (see Figure 16). Details on the layout of each option can be found in the Appendix.

- FAQ: The first item of the hidden menu is a 'Frequent Asked Questions' section which could comprehend from 10 to 30 questions.
- Compare stations: The second item comprehends a button to compare AQHI or other pollutant timeseries/calendar/time variations between different stations.
- Plan my route!: Inspired by the work of Santana et al. (2021), this option would allow the user to select a means of transportation, the criteria to run the calculation (e.g., lowest AQHI, no odour encounter etc.) and as a result, have the best possible pathway to follow.
- Residential wood burning status: This option is currently available in AirMap.ca and it would only be displayed differently.

- **Compare to world cities:** This option would display a map or list highlighting the concentration of the selected air pollutant or AQHI in the selected station vs. other cities globally.

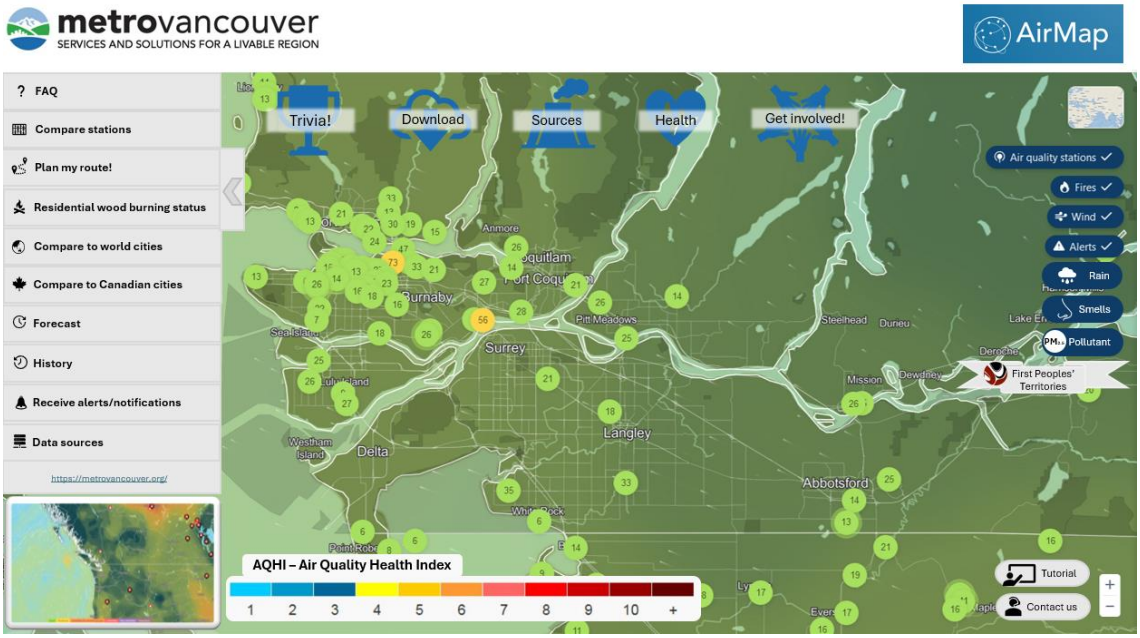


Figure 16. Hidden menu options. - - note that the basemap was obtained from the app IQAir.com for illustration purposes. The stations in this map do not reflect the regulatory monitoring sites of Metro Vancouver.

- **Compare to Canadian cities:** This option would display a map or list highlighting the concentration of the selected air pollutant or AQHI in the selected station vs. other cities in Canada.
- **Forecast:** This option would display a map with enough zoom to account for all active stations. Then the user would be able to check the AQHI forecast ideally for up to 14 days, or 24 hours like seen on other websites[6] and see the changes in colours and numbers of the circle layer in each station.
- **History:** Similar to Forecast, however backwards in time.
- **Receive alerts and notifications:** This option would present the user with a form where they can check the type of information they desire to receive, and by which means. Alternatively, it can redirect users to the WeatherCAN app.

[6] Air Quality Health Index Forecast for BC, Accessed here.

- **Data sources:** This option is currently available in AirMap.ca and it would only be displayed differently.

Air Quality Alerts

One of the current uses for AirMap.ca is to communicate an Air Quality Alert and warn the population of exposure to poor air quality during certain periods and conditions. This is a feature that could be improved within each Phase previously described.

Phase 1: It can be displayed resembling a news piece where you have more words describing the event and they "slide left" as you read. There can also be a link for the user to be redirected to another page with more info (see **Figure 17**).

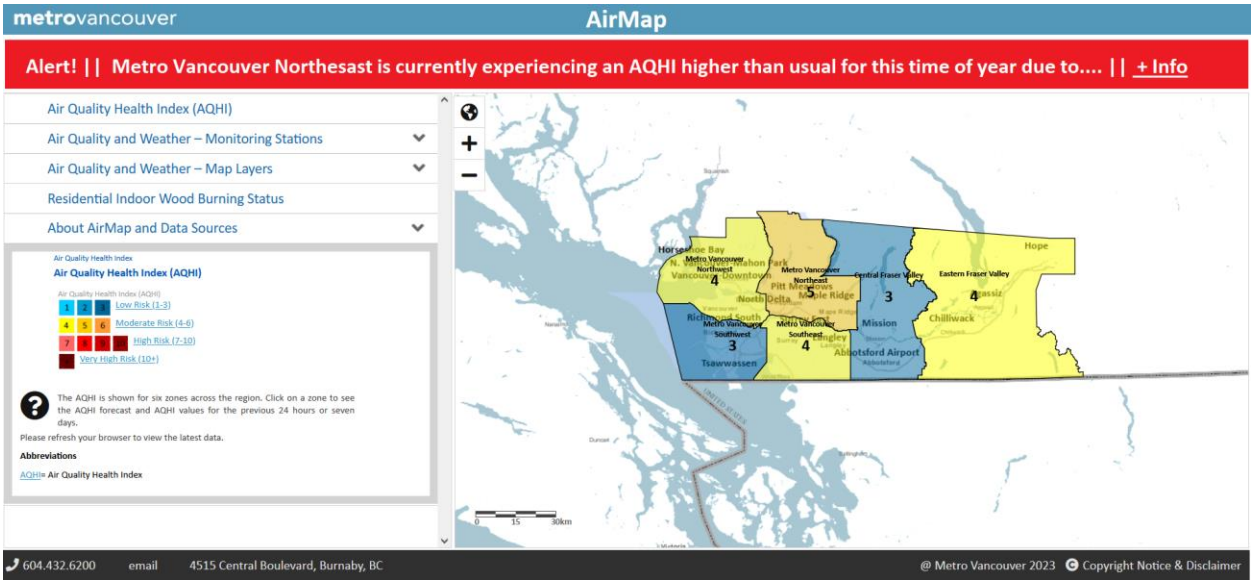


Figure 17. Air Quality Advisory style to be displayed during Phase 1.

Phase 2 and 3: Headline together with coloured polygon layers showing the areas affected (e.g., immediately at risk, near affected areas, and safe but under watch).

Phase 4: In the new design, once the pages load, the first information viewed are the layers showing areas at risk that can blink three times and then a balloon box opens explaining the alert (and remains opened until the user minimizes it or clicks "ignore alert").

Extra: improve the AirMap.ca indexing

One issue found during this study was that AirMap.ca has consistently not appeared in the Top #3 results of search engines when using the words “air quality” + municipality of Metro Vancouver region (e.g., “Vancouver”), see **Figure 18**.

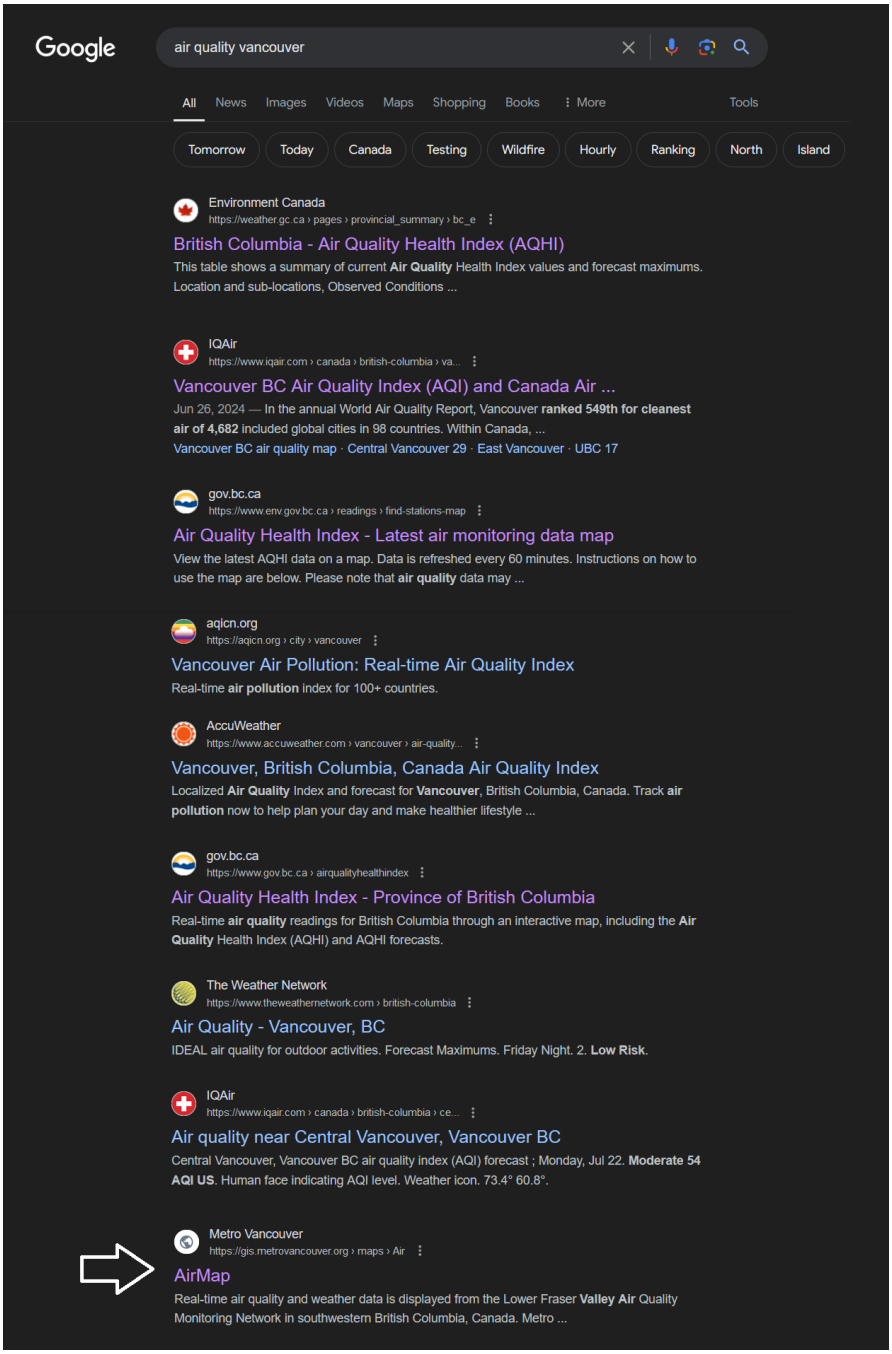


Figure 18. Results of a Google Search for the words "air quality" and "Vancouver".

Thus, a website that should be a reference to access information about air quality in the region is not reaching its full potential with private and non-profit organizations tools having the advantage. Although outside the scope of this project, it would benefit the AirMap.ca average user, as well as increase the website's reach, to improve the indexing. Fortunately, Google provides guidelines for developers to help increase their website notoriety (link here). There are also other manuals with verified content available online as well (example here).

Summary

In summary, AirMap.ca is a great tool for communicating the air quality state of the Metro Vancouver region, however, it needs to undergo updates to match the recommendations provided in the scientific literature and compete with other sources that currently have a modern layout and superior indexing. In this report, we provide a glance at the state-of-the-art in air quality communication, knowledge translation, and visualization. We used this review to evaluate other websites for positive and negative features and design ideas. We also exchanged information with other website developers to acquire knowledge of the back-end space (i.e., what the user does not see). Based on the methodology followed, nine recommendations are given, separated into four phases for the update. Additionally, the indexing of AirMap.ca in search tools was briefly discussed.

Future research

As for the next steps, three different studies can be pursued:

I. Survey the Metro Vancouver region's population about how they evaluate air quality daily and if they follow the AQHI guidance, akin to what has been performed in the literature consulted for this report. This would require ethics approval and the development of a questionnaire, as well as a study of the target population.

II. Survey Metro Vancouver's citizens for feedback from the public about the changes suggested by the scholar. This would require ethics approval and the development of a questionnaire, as well as a study of the target population.

III. Develop 50 questions to be used in the AirMap.ca trivia game based on concepts about air pollution and health.

References

Baadte, C., & Meinhardt-Injac, B. (2019). The picture superiority effect in associative memory: A developmental study. *British Journal of Developmental Psychology*, *37*(3), 382–395. https://doi.org/10.1111/bjdp.12280

Bhandari, S., Monticelli, D., Xie, K., Ramkairsingh, A., Maher, R., Eykelbosh, A., Henderson, S. B., Zimmerman, N., & Giang, A. (2024). Odor, air quality, and well-being: understanding the urban smellscape using crowd-sourced science. *Environmental Research: Health*, *22*(1), 16–20. https://doi.org/10.1088/2752-5309/ad5ded

Brunekreef, B., & Holgate, S. T. (2002). Air pollution and health. *The Lancet*, *360*(9341), 1233–1242. https://doi.org/10.1016/S0140-6736(02)11274-8

Carro, G., Schalm, O., Jacobs, W., & Demeyer, S. (2022). Exploring actionable visualizations for environmental data: Air quality assessment of two Belgian locations. *Environmental Modelling and Software*, *147*(December 2020), 105230. https://doi.org/10.1016/j.envsoft.2021.105230

Carslaw, D. C., & Ropkins, K. (2012). openair --- An R package for air quality data analysis. *Environmental Modelling \& Software*, *27--28*(0), 52–61. https://doi.org/10.1016/j.envsoft.2011.09.008

Ciarloni, R., & Newbold, K. B. (2023). Air Pollution Health Literacy among Active Commuters in Hamilton, Ontario. *International Journal of Environmental Research and Public Health*, *20*(13). https://doi.org/10.3390/ijerph20136282

Delmas, M. A., & Kohli, A. (2020). Can Apps Make Air Pollution Visible? Learning About Health Impacts Through Engagement with Air Quality Information. *Journal of Business Ethics*, *161*(2), 279–302. https://doi.org/10.1007/s10551-019-04215-7

Eykelbosh, A., Maher, R., de Ferreyro Monticelli, D., Ramkairsingh, A., Henderson, S., Giang, A., & Zimmerman, N. (2021). Elucidating the community health impacts of odours using citizen science and mobile monitoring. *Environmental Health Review*, *64(2)*(July), 24–27. https://doi.org/10.5864/d2021-010

Fish, J. A., Peters, M. D. J., Ramsey, I., Sharplin, G., Corsini, N., & Eckert, M. (2017). Effectiveness of public health messaging and communication channels during smoke events: A rapid systematic review. *Journal of Environmental Management*, *193*, 247–256. https://doi.org/10.1016/j.jenvman.2017.02.012

Hidy, G. M., & Pennell, W. T. (2010). Multipollutant air quality management. *Journal of the Air and Waste Management Association*, *60*(6), 645–674. https://doi.org/10.3155/1047-3289.60.6.645

Johnson, B. B. (2003). Communicating air quality information: Experimental evaluation of

alternative formats. *Risk Analysis*, *23*(1), 91–103. https://doi.org/10.1111/1539-6924.00292

Johnson, B. B. (2012). Experience with Urban Air Pollution in Paterson, New Jersey and Implications for Air Pollution Communication. *Risk Analysis*, *32*(1), 39–53. https://doi.org/10.1111/j.1539-6924.2011.01669.x

Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. *Environmental Pollution*, *151*(2), 362–367. https://doi.org/10.1016/j.envpol.2007.06.012

Li, H. Z., Gu, P., Ye, Q., Zimmerman, N., Robinson, E. S., Subramanian, R., Apte, J. S., Robinson, A. L., & Presto, A. A. (2019). Spatially dense air pollutant sampling: Implications of spatial variability on the representativeness of stationary air pollutant monitors. *Atmospheric Environment: X*, *2*(November 2018), 100012. https://doi.org/10.1016/j.aeaoa.2019.100012

Licskai, C. J., Sands, T. W., & Ferrone, M. (2013). Development and pilot testing of a mobile health solution for asthma self-management: Asthma action plan smartphone application pilot study. *Canadian Respiratory Journal*, *20*(4), 301–306. https://doi.org/10.1155/2013/906710

Mauderly, J. L., Burnett, R. T., Castillejos, M., Özkaynak, H., Samet, J. M., Stieb, D. M., Vedal, S., & Wyzga, R. E. (2010). Is the air pollution health research community prepared to support a multipollutant air quality management framework. *Inhalation Toxicology*, *22*(SUPPL 1), 1–19. https://doi.org/10.3109/08958371003793846

Metro Vancouver. (2016). *Climate Projections for Metro Vancouver*. http://www.metrovancouver.org/services/air-quality/AirQualityPublications/ClimateProjectionsForMetroVancouver.pdf

Meyn, A., Schmidtlein, S., Taylor, S. W., Girardin, M. P., Thonicke, K., & Cramer, W. (2010). Spatial variation of trends in wildfire and summer drought in British Columbia, Canada. *International Journal of Wildland Fire*, *19*(3), 272–283. https://doi.org/10.1071/WF09055

Parisien, M. A., Barber, Q. E., Bourbonnais, M. L., Daniels, L. D., Flannigan, M. D., Gray, R. W., Hoffman, K. M., Jain, P., Stephens, S. L., Taylor, S. W., & Whitman, E. (2023). Abrupt, climate-induced increase in wildfires in British Columbia since the mid-2000s. *Communications Earth and Environment*, *4*(1), 1–11. https://doi.org/10.1038/s43247-023-00977-1

Radisic, S., & Bruce Newbold, K. (2016). Factors influencing health care and service providers' and their respective "at risk" populations' adoption of the Air Quality Health Index (AQHI): A qualitative study. *BMC Health Services Research*, *16*(1), 1–11. https://doi.org/10.1186/s12913-016-1355-0

Radisic, S., Newbold, K. B., Eyles, J., & Williams, A. (2016). Factors influencing health behaviours in response to the air quality health index: a cross-sectional study in Hamilton, Canada. *Environmental Health Review*, *59*(1), 17–29. https://doi.org/10.5864/d2016-002

Ramírez, A. S., Ramondt, S., Van Bogart, K., & Perez-Zuniga, R. (2019). Public Awareness of Air Pollution and Health Threats: Challenges and Opportunities for Communication Strategies To Improve Environmental Health Literacy. *Journal of Health Communication*, *24*(1), 75–83. https://doi.org/10.1080/10810730.2019.1574320

Santana, P., Almeida, A., Mariano, P., Correia, C., Martins, V., & Almeida, S. M. (2021). Air quality mapping and visualisation: An affordable solution based on a vehicle-mounted sensor network. *Journal of Cleaner Production*, *315*(June). https://doi.org/10.1016/j.jclepro.2021.128194

Slavik, C. E., Chapman, D. A., Smith, H., Coughlan, M., & Peters, E. (2024). Motivating parents to protect their children from wildfire smoke: the impact of air quality index infographics. *Environmental Research Communications*, *6*(7). https://doi.org/10.1088/2515-7620/ad5931

Tan, X., Han, L., Zhang, X., Zhou, W., Li, W., & Qian, Y. (2021). A review of current air quality indexes and improvements under the multi-contaminant air pollution exposure. *Journal of Environmental Management*, *279*(December 2020), 111681. https://doi.org/10.1016/j.jenvman.2020.111681

To, T., Shen, S., Atenafu, E. G., Guan, J., Mclimont, S., Stocks, B., & Licskai, C. (2013). The air quality health index and asthma morbidity: A population-based study. *Environmental Health Perspectives*, *121*(1), 46–51. https://doi.org/10.1289/ehp.1104816

Trieu, J., Yao, J., McLean, K. E., Stieb, D. M., & Henderson, S. B. (2020). Evaluating an Air Quality Health Index (AQHI) amendment for communities impacted by residential woodsmoke in British Columbia, Canada. *Journal of the Air and Waste Management Association*, *70*(10), 1009–1021. https://doi.org/10.1080/10962247.2020.1797927

WMO-No. 8. (2021). Guide to Instruments and Methods of Observation. In *World Meteorological Organization: Vols. I & II* (Issue 8).

Wong, B. (2011). Color blindness. *Nature Methods*, *8*(6), 441. https://doi.org/10.1038/nmeth.1618

World Meteorological Organization. (2014). *Siting classifications for surface observing stations on land*. *2014*(ANNEX 1 . B .), 13. https://www.wmo.int/pages/prog/www/IMOP/SitingClassif/CIMO_Guide_2014_en_I_1-2_Annex_1B.pdf

Yao, J., Brauer, M., Wei, J., McGrail, K. M., Johnston, F. H., & Henderson, S. B. (2020). Sub-daily exposure to fine particulate matter and ambulance dispatches during wildfire seasons: A case-crossover study in British Columbia, Canada. *Environmental Health Perspectives*, *128*(6), 1–10. https://doi.org/10.1289/EHP5792

Yao, J., Stieb, D. M., Taylor, E., & Henderson, S. B. (2020). Assessment of the Air Quality Health Index (AQHI) and four alternate AQHI-Plus amendments for wildfire seasons in British

Columbia. *Canadian Journal of Public Health*, *111*(1), 96–106. https://doi.org/10.17269/s41997-019-00237-w

Yatkin, S., Gerboles, M., Belis, C. A., Karagulian, F., Lagler, F., Barbiere, M., & Borowiak, A. (2020). Representativeness of an air quality monitoring station for PM2.5 and source apportionment over a small urban domain. *Atmospheric Pollution Research*, *11*(2), 225–233. https://doi.org/10.1016/j.apr.2019.10.004

Appendices

Websites consulted

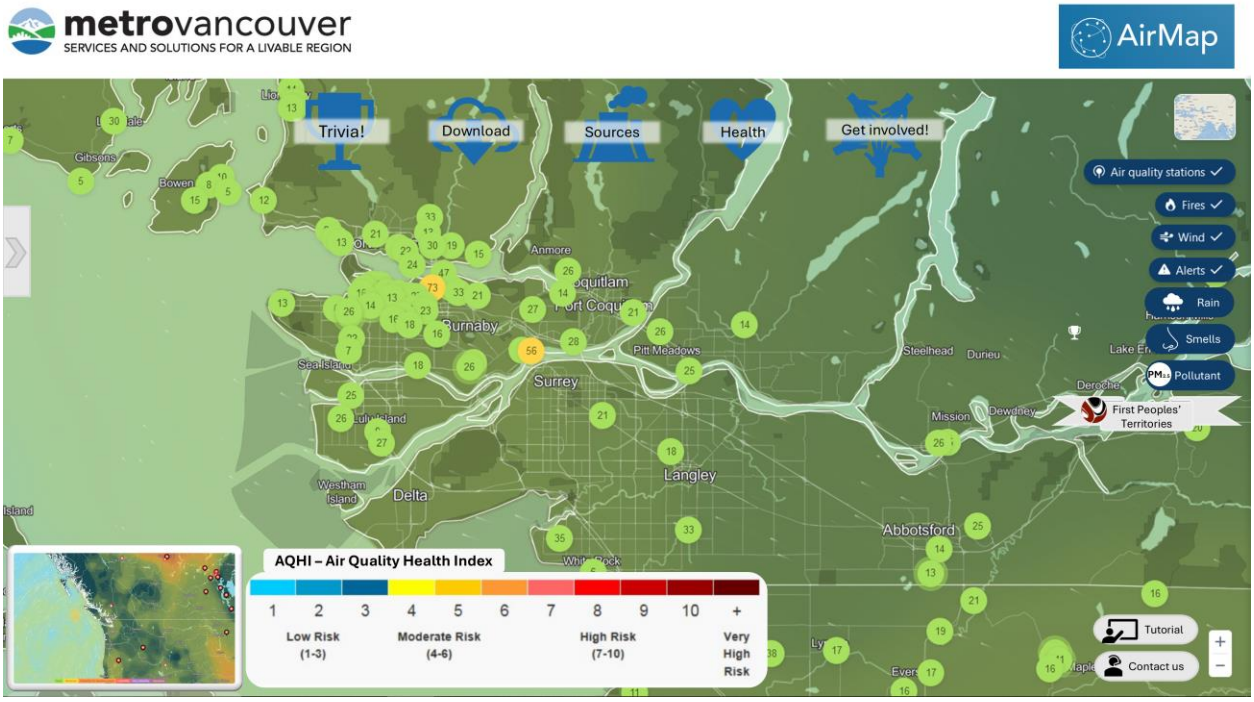
Fire & Smoke Map
Fire and Smoke Map (airnow.gov)

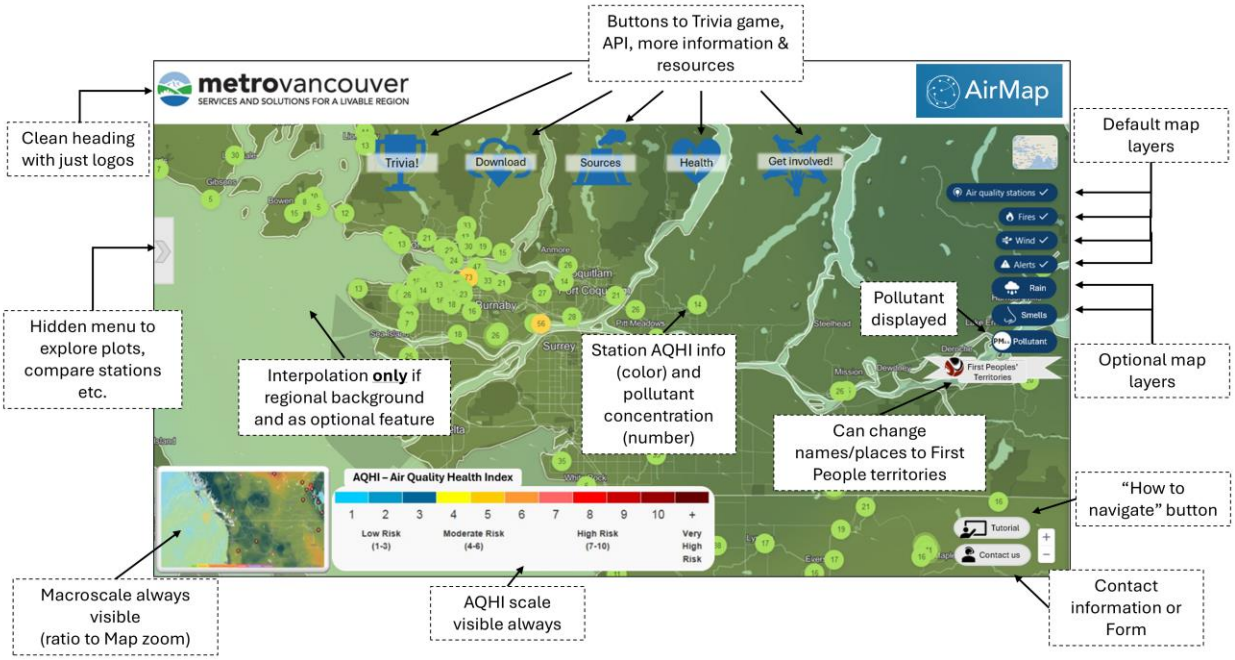
South Coast Air Quality Management District
Current Air Quality Data (aqmd.gov)

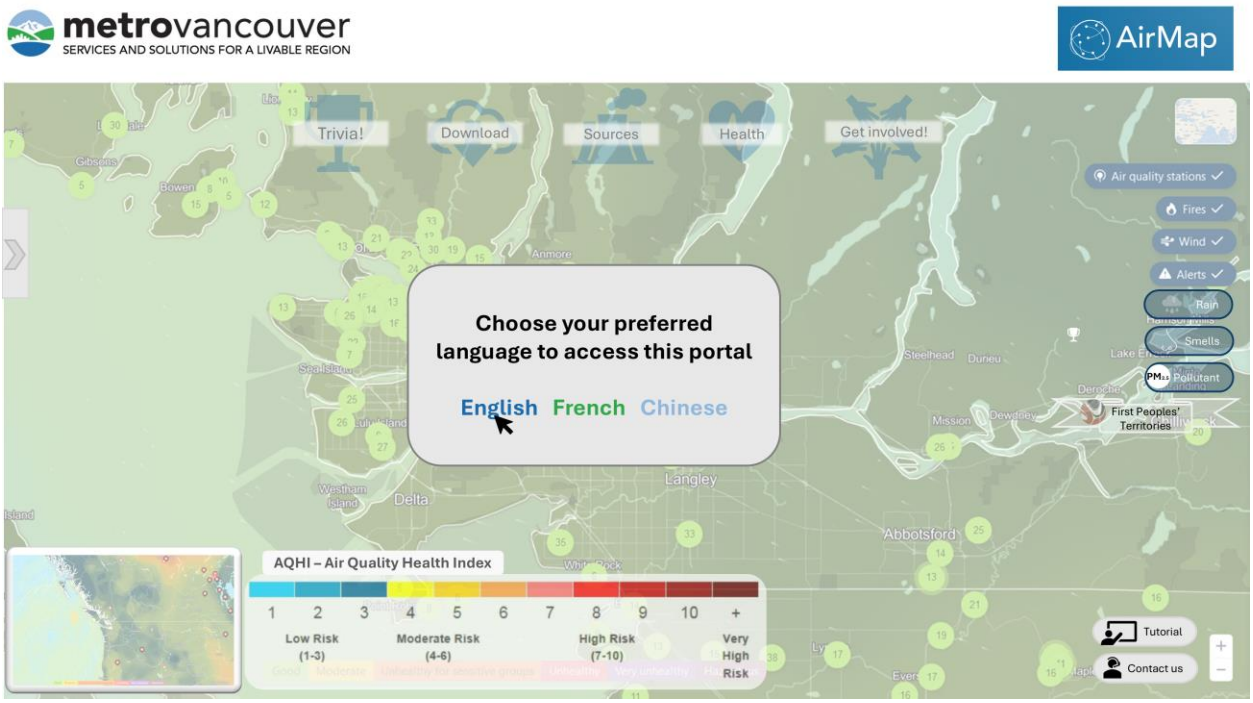
University of Northern British Columbia
AQmap (unbc.ca)

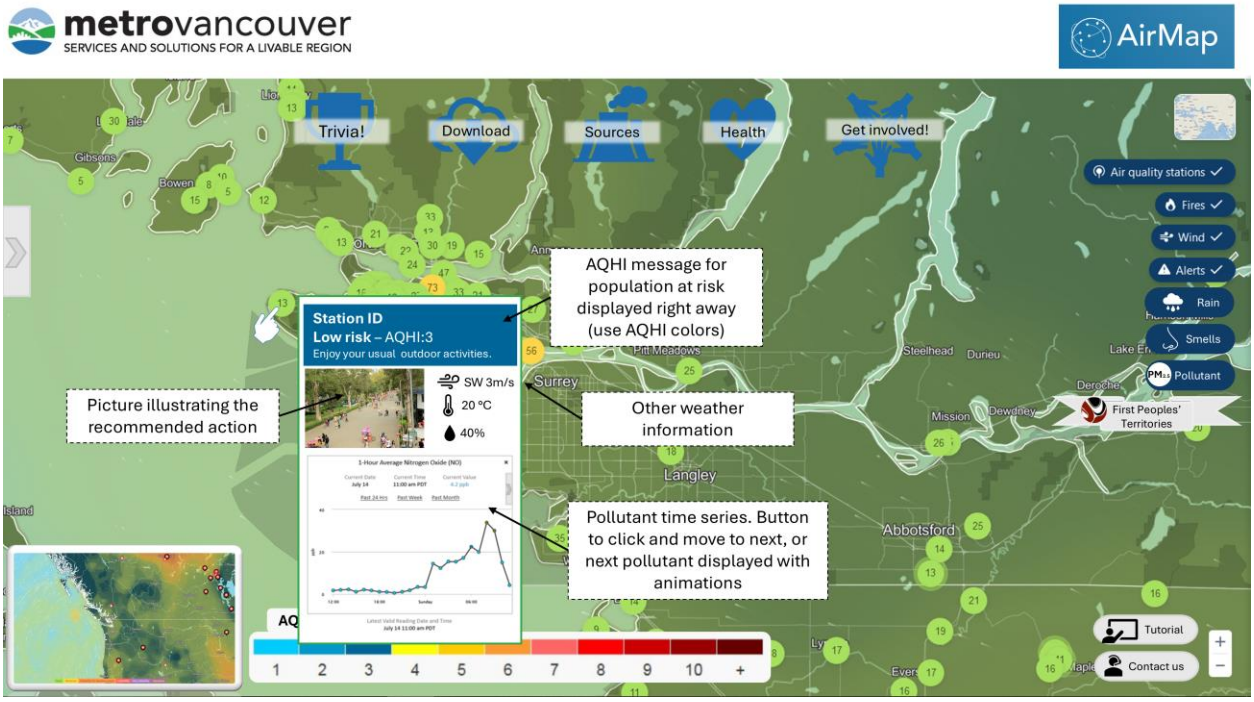
BC Ministry of Environment and Climate Change Strategy
Air Quality Health Index - Latest air monitoring data map - BC Air Quality - Province of British Columbia (gov.bc.ca)

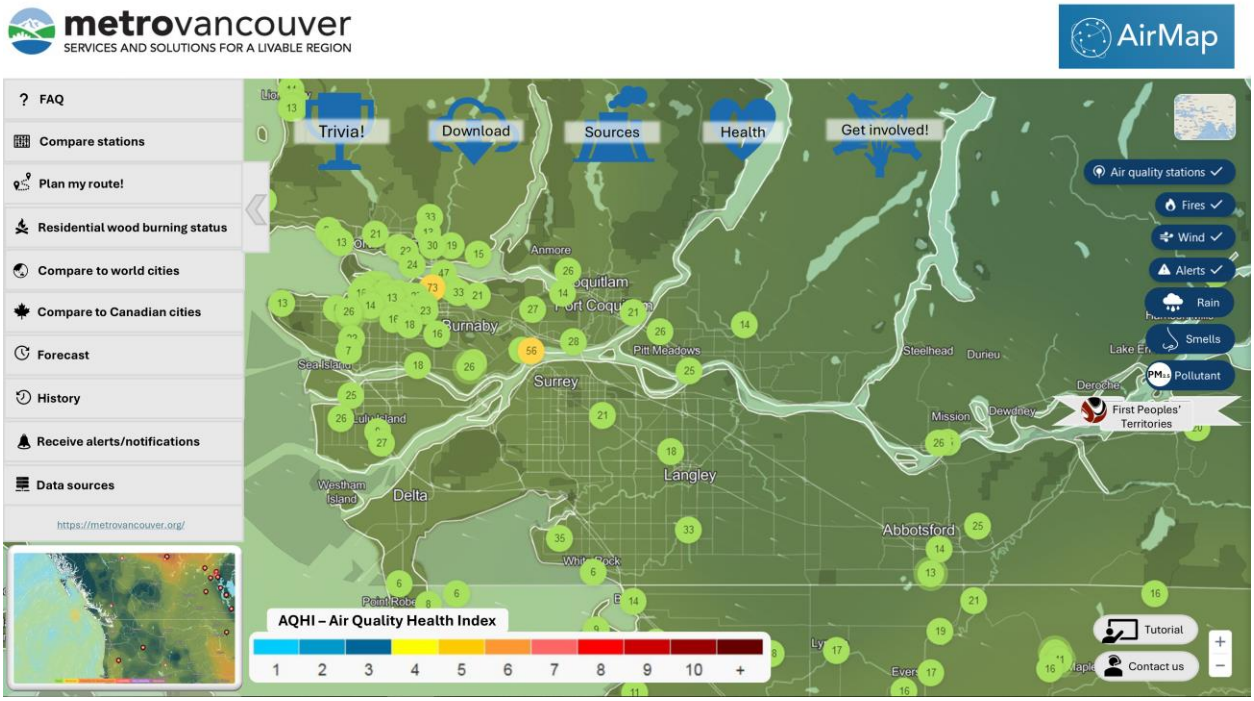
All design ideas for AirMap.ca






metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Trivia!
Download
Sources
Health
Get involved!
Choose your preferred language to access this portal
English French Chinese
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Low Risk (1-3)
Moderate Risk (4-6)
High Risk (7-10)
Very High Risk
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Trivia!
Download
Sources
Health
Get involved!
Station ID
Low risk – AQHI:3
Enjoy your usual outdoor activities.
SW 3m/s
20 °C
40%
AQHI message for population at risk displayed right away (use AQHI colors)
Picture illustrating the recommended action
Other weather information
Pollutant time series. Button to click and move to next, or next pollutant displayed with animations
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
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Compare stations
Plan my route!
Residential wood burning status
Compare to world cities
Compare to Canadian cities
Forecast
History
Receive alerts/notifications
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https://metrovancouver.org/
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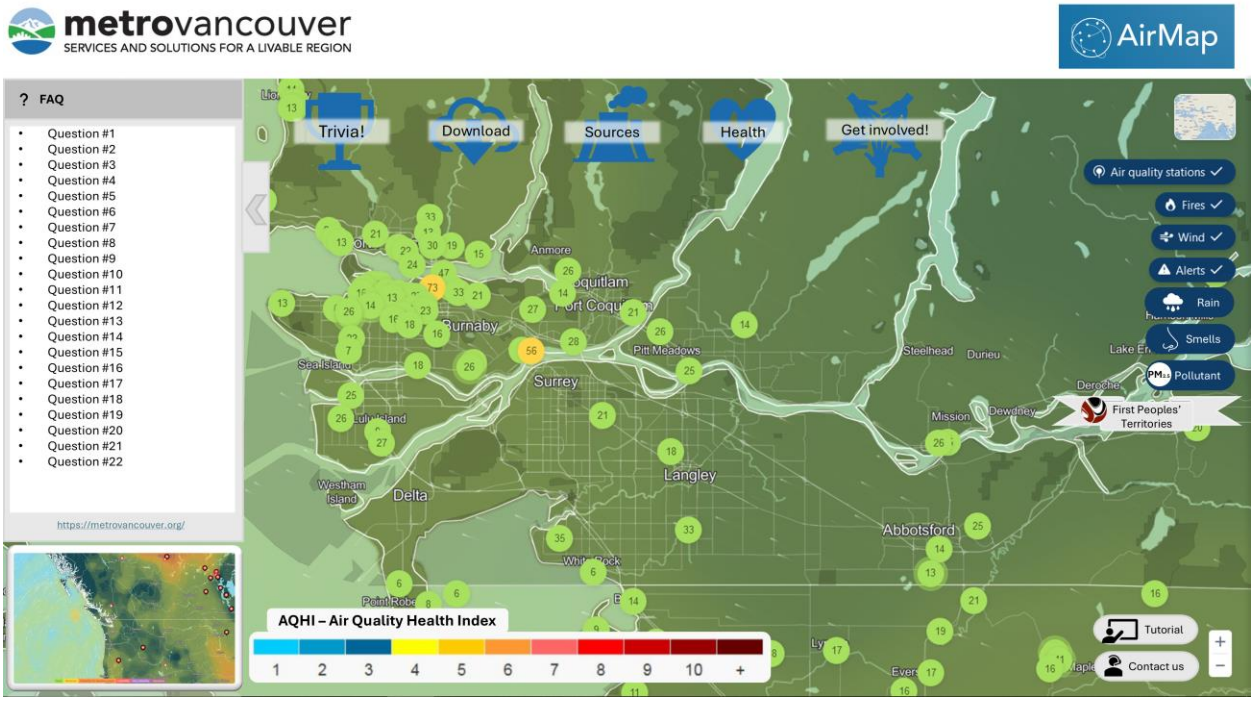
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Anmore
Burnaby
Pitt Meadows
Surrey
Langley
Delta
Abbotsford
Mission
Steelhead
Durieu
Dewdney


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
FAQ
Question #1
Question #2
Question #3
Question #4
Question #5
Question #6
Question #7
Question #8
Question #9
Question #10
Question #11
Question #12
Question #13
Question #14
Question #15
Question #16
Question #17
Question #18
Question #19
Question #20
Question #21
Question #22
https://metrovancouver.org/
Trivia!
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Health
Get involved!
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Rain
Smells
Pollutant
First Peoples' Territories
Tutorial
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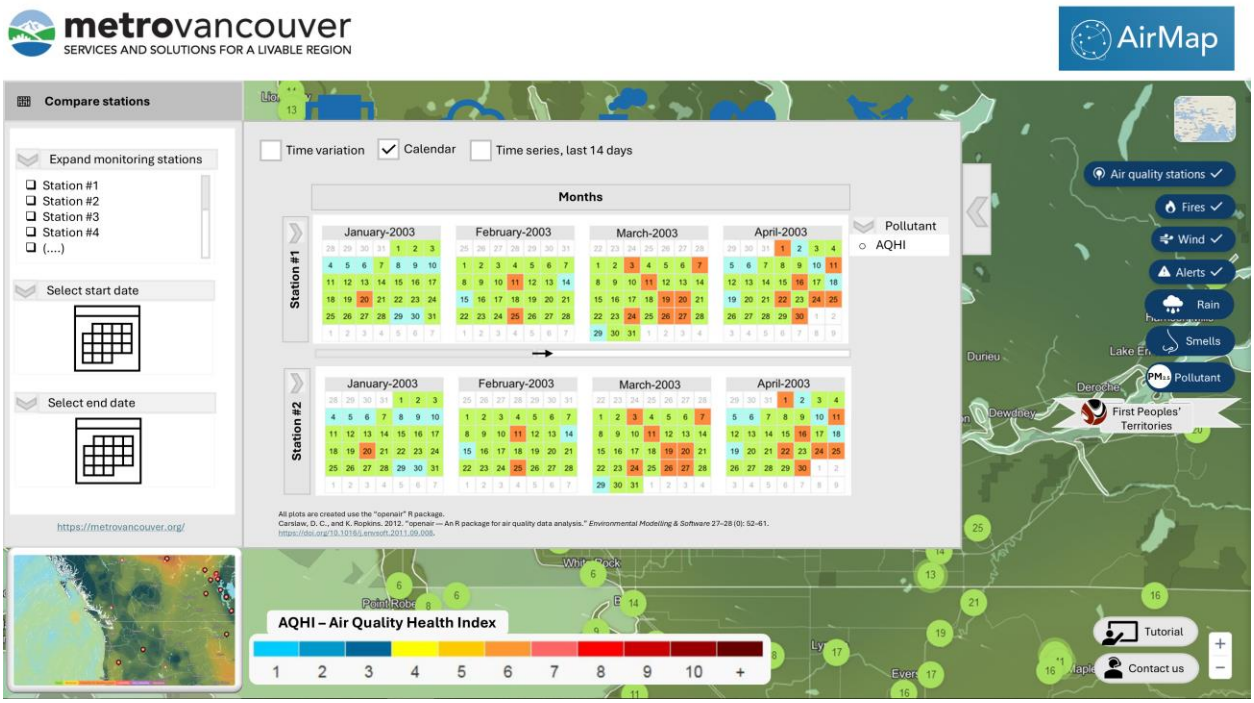
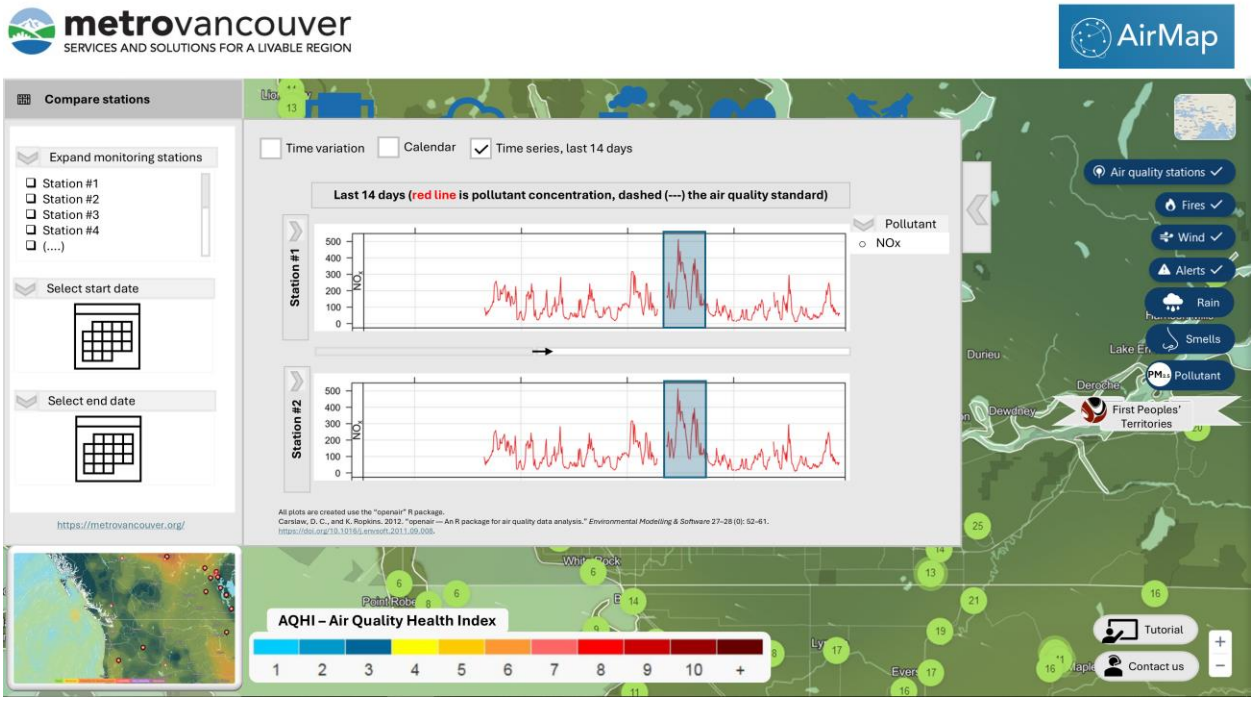
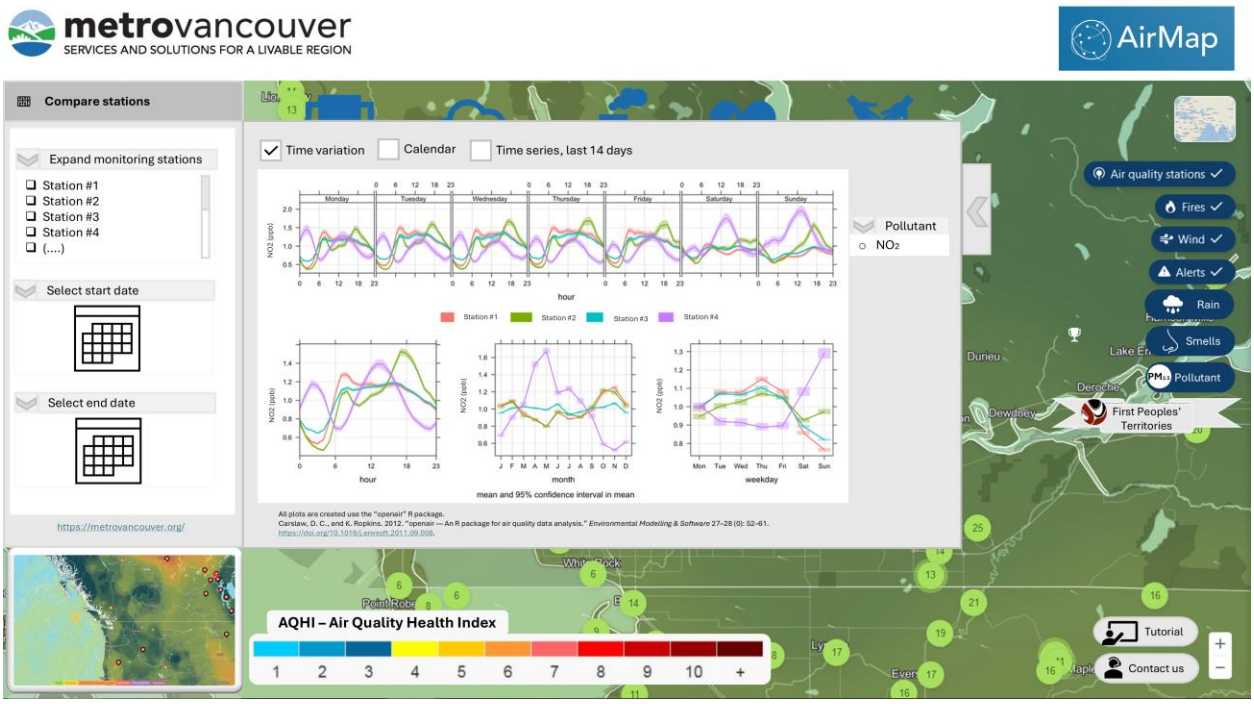
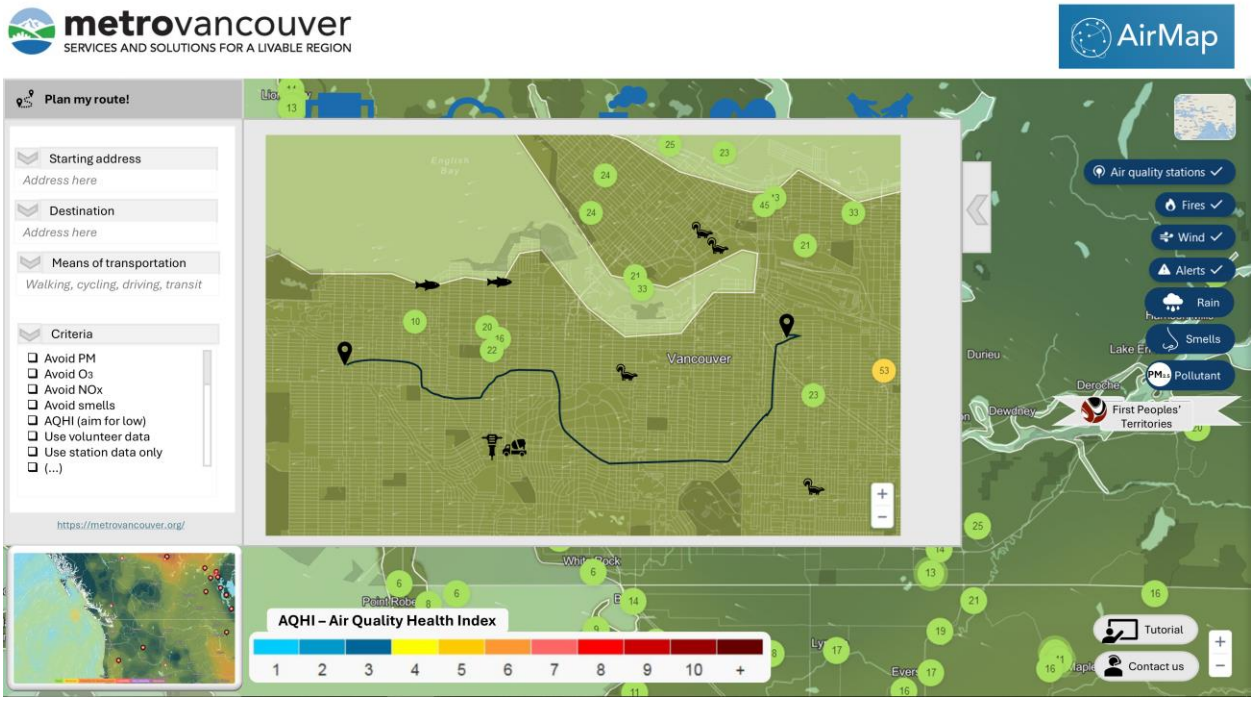
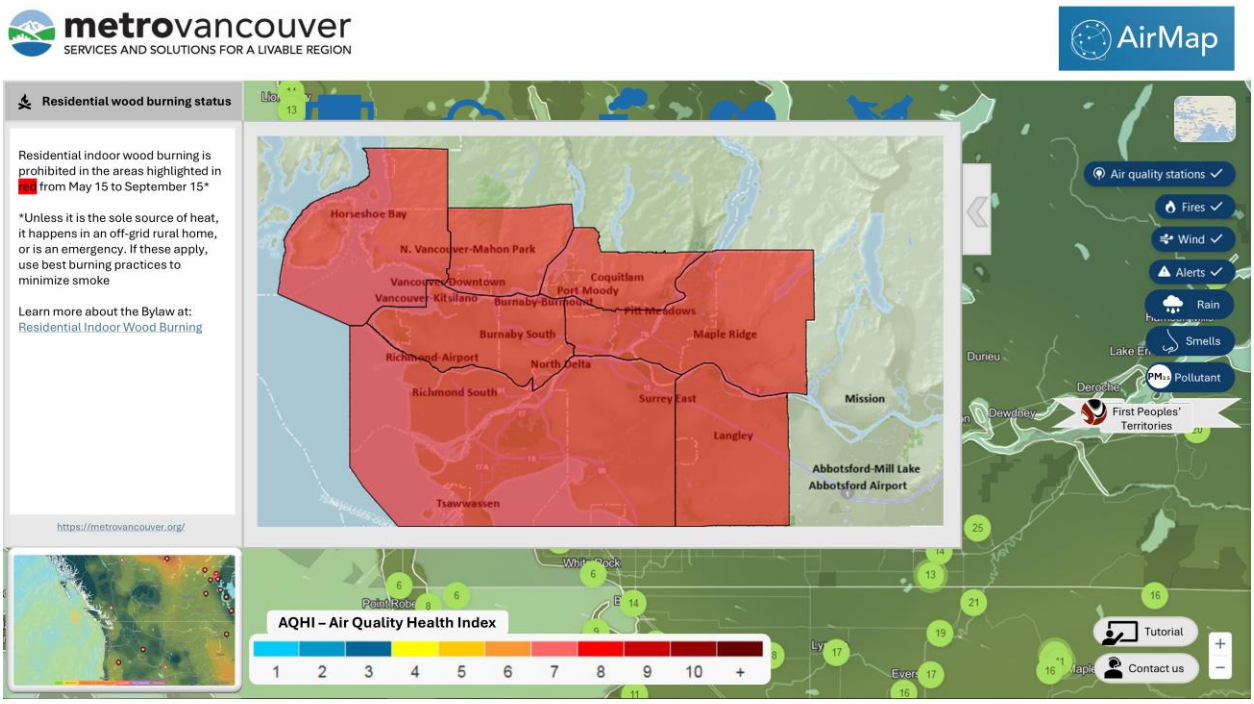
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Anmore
Burnaby
Pitt Meadows
Surrey
Langley
Delta
Abbotsford
Mission
Steelhead
Durieu
Dewdney


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Compare stations
Expand monitoring stations
Station #1
Station #2
Station #3
Station #4
(....)
Select start date
Select end date
https://metrovancouver.org/
Time variation
Calendar
Time series, last 14 days
Months
Station #1
Station #2
January-2003
February-2003
March-2003
April-2003
Pollutant
AQHI
All plots are created use the "openair" R package.
Carslaw, D. C., and K. Ropkins. 2012. "openair — An R package for air quality data analysis." Environmental Modelling & Software 27-28 (0): 52-61.
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Compare stations
Expand monitoring stations
Station #1
Station #2
Station #3
Station #4
(....)
Select start date
Select end date
https://metrovancouver.org/
Time variation
Calendar
Time series, last 14 days
Last 14 days (red line is pollutant concentration, dashed (---) the air quality standard)
Station #1
Station #2
NOx
Pollutant
All plots are created use the "openair" R package.
Carslaw, D. C., and K. Ropkins. 2012. "openair — An R package for air quality data analysis." Environmental Modelling & Software 27-28 (0): 52-61.
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Compare stations
Expand monitoring stations
Station #1
Station #2
Station #3
Station #4
(....)
Select start date
Select end date
https://metrovancouver.org/
Time variation
Calendar
Time series, last 14 days
Pollutant
NO2
hour
month
weekday
mean and 95% confidence interval in mean
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Plan my route!
Starting address
Address here
Destination
Address here
Means of transportation
Walking, cycling, driving, transit
Criteria
Avoid PM
Avoid O3
Avoid NOx
Avoid smells
AQHI (aim for low)
Use volunteer data
Use station data only
(...)
https://metrovancouver.org/
Vancouver
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us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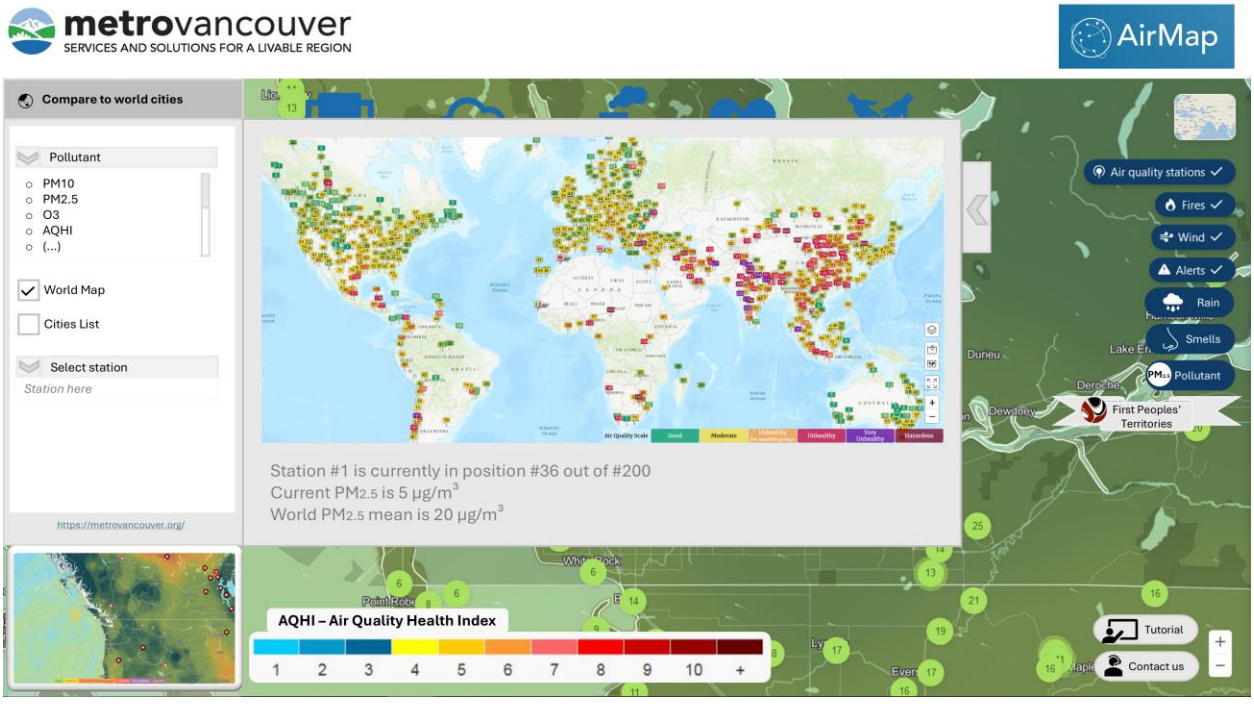
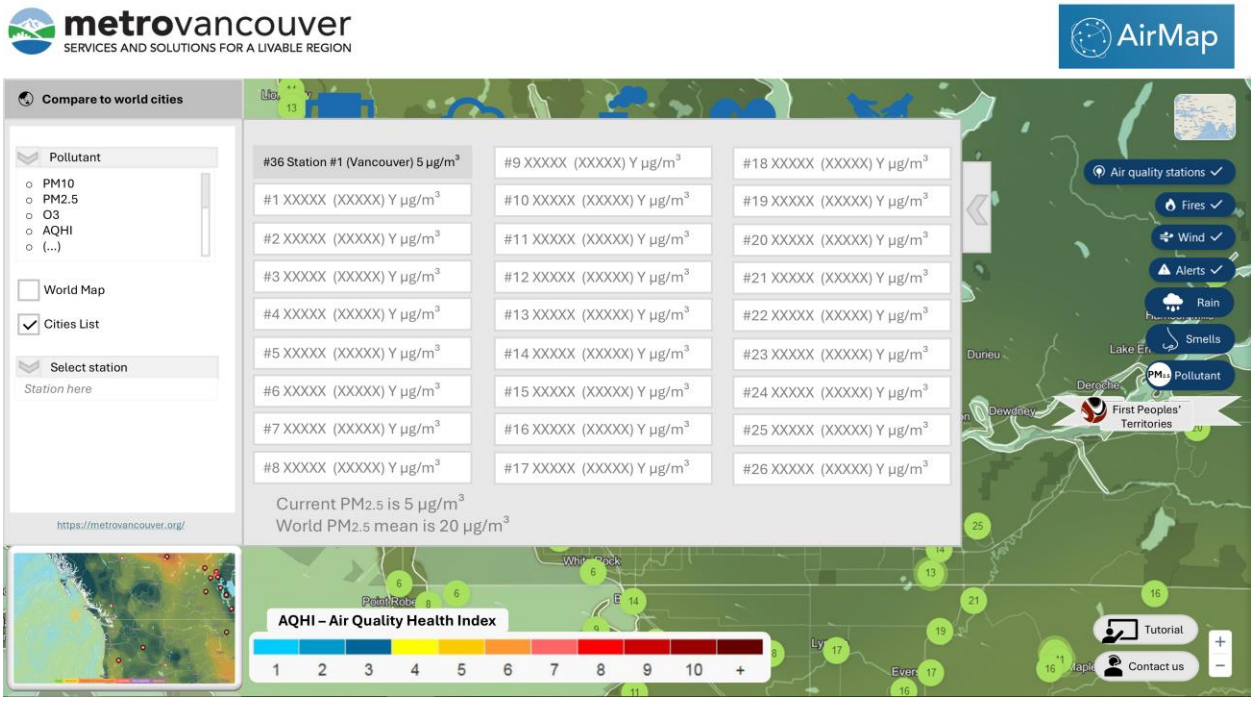
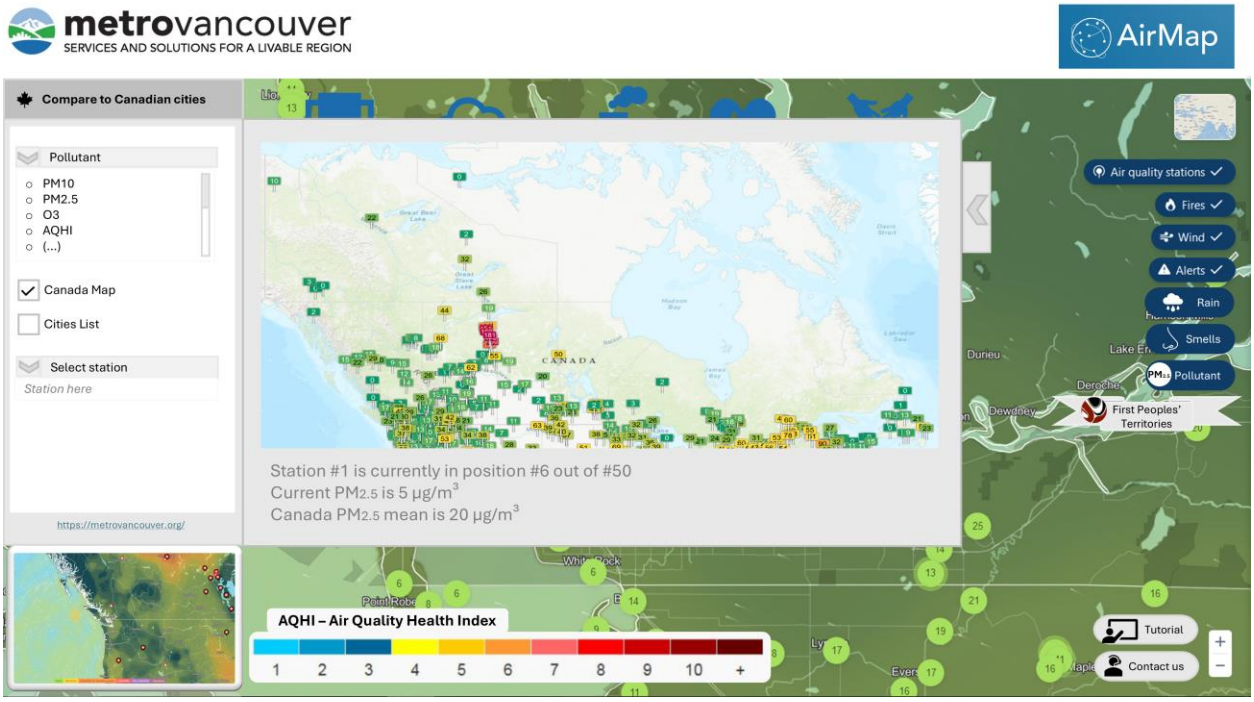
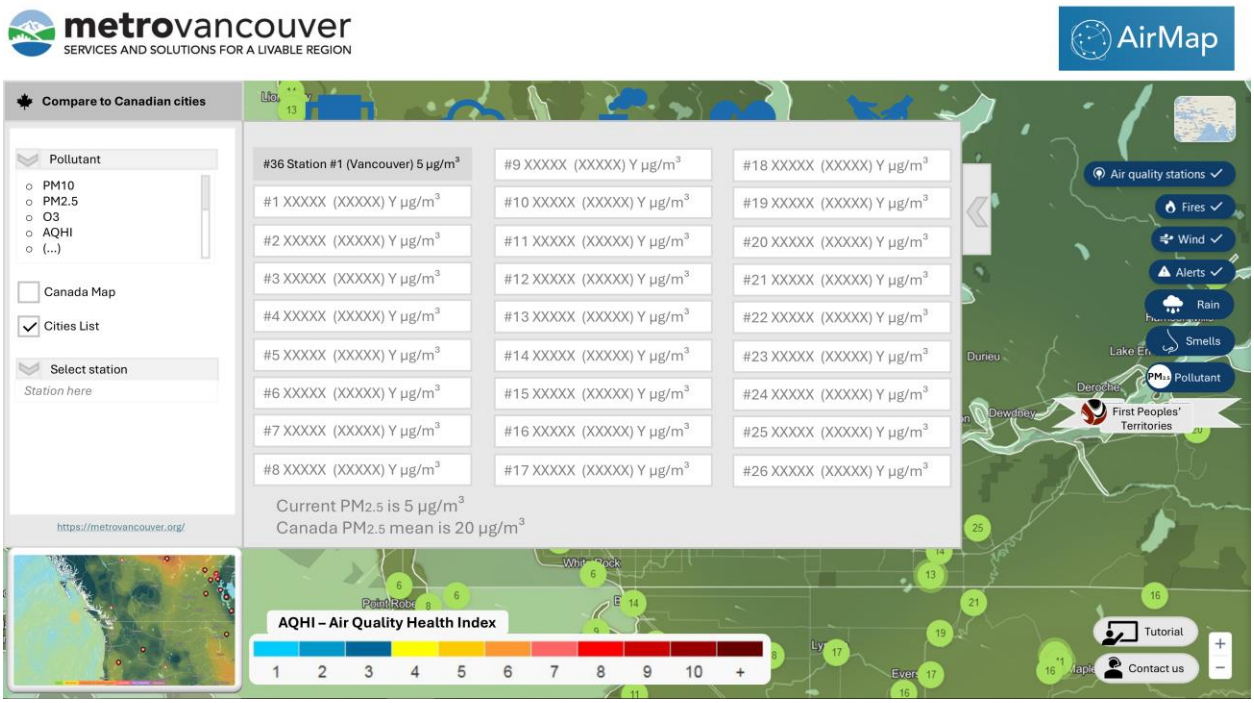
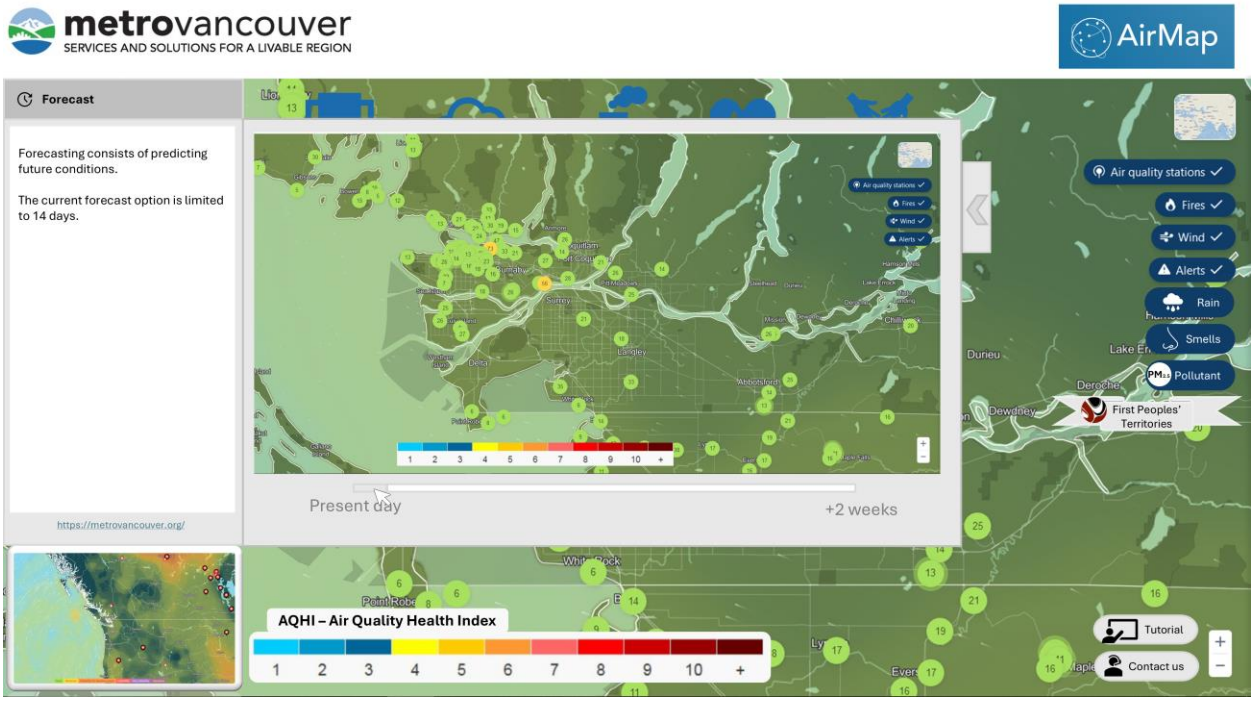
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Residential wood burning status
Residential indoor wood burning is prohibited in the areas highlighted in red from May 15 to September 15*
*Unless it is the sole source of heat, it happens in an off-grid rural home, or is an emergency. If these apply, use best burning practices to minimize smoke
Learn more about the Bylaw at:
Residential Indoor Wood Burning
https://metrovancouver.org/
Horseshoe Bay
N. Vancouver-Mahon Park
Vancouver-Downtown
Vancouver-Kitsilano
Burnaby-Burrmount
Coquitlam
Port Moody
Pitt Meadows
Burnaby South
Maple Ridge
Richmond-Airport
North Delta
Richmond South
Surrey East
Mission
Langley
Abbotsford-Mill Lake
Abbotsford Airport
Tsawwassen
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us

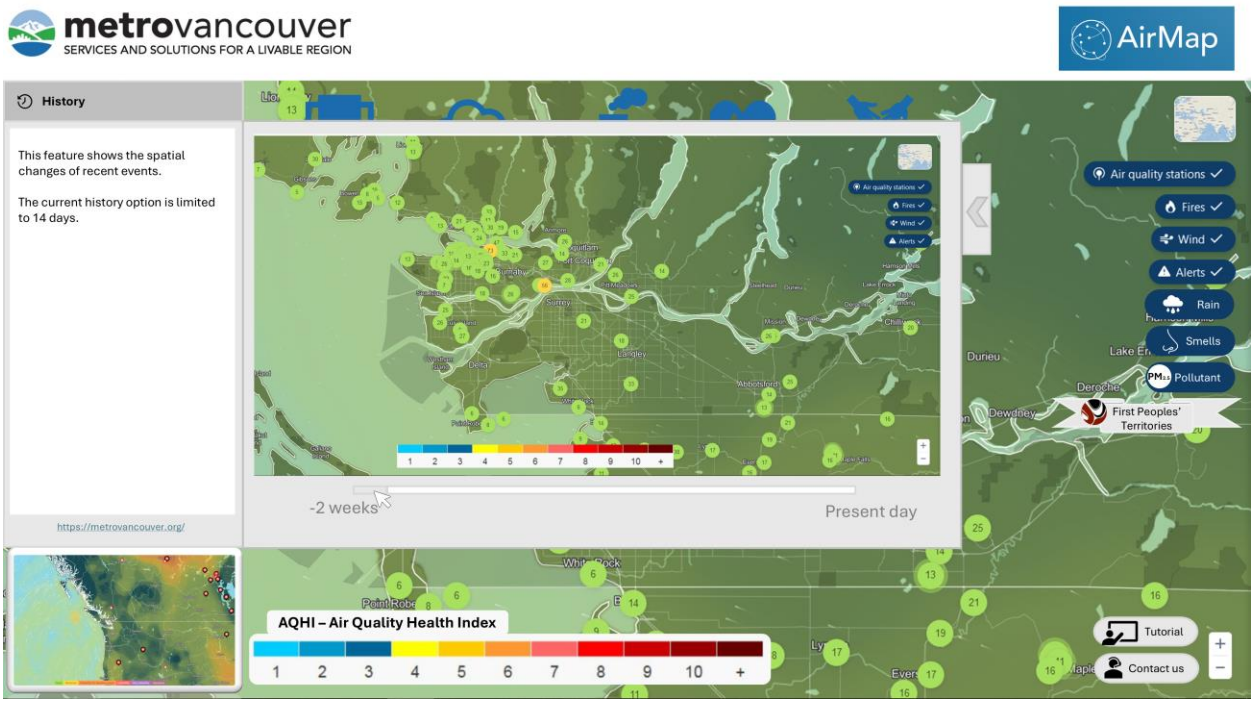

metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Compare to world cities
Pollutant
PM10
PM2.5
O3
AQHI
(...)
World Map
Cities List
Select station
Station here
https://metrovancouver.org/
Station #1 is currently in position #36 out of #200
Current PM2.5 is 5 µg/m3
World PM2.5 mean is 20 µg/m3
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us

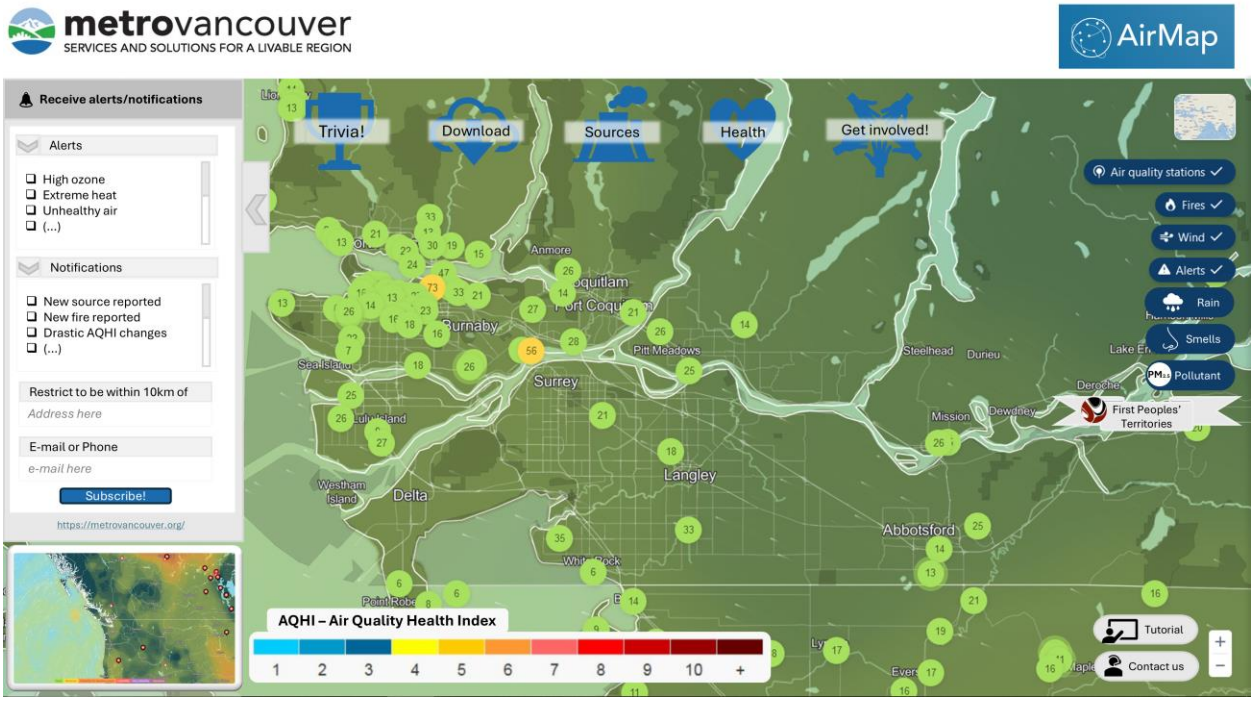

metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Compare to world cities
Pollutant
PM10
PM2.5
O3
AQHI
(...)
World Map
Cities List
Select station
Station here
https://metrovancouver.org/
#36 Station #1 (Vancouver) 5 µg/m³
#1 XXXXX (XXXXX) Y µg/m³
#2 XXXXX (XXXXX) Y µg/m³
#3 XXXXX (XXXXX) Y µg/m³
#4 XXXXX (XXXXX) Y µg/m³
#5 XXXXX (XXXXX) Y µg/m³
#6 XXXXX (XXXXX) Y µg/m³
#7 XXXXX (XXXXX) Y µg/m³
#8 XXXXX (XXXXX) Y µg/m³
#9 XXXXX (XXXXX) Y µg/m³
#10 XXXXX (XXXXX) Y µg/m³
#11 XXXXX (XXXXX) Y µg/m³
#12 XXXXX (XXXXX) Y µg/m³
#13 XXXXX (XXXXX) Y µg/m³
#14 XXXXX (XXXXX) Y µg/m³
#15 XXXXX (XXXXX) Y µg/m³
#16 XXXXX (XXXXX) Y µg/m³
#17 XXXXX (XXXXX) Y µg/m³
#18 XXXXX (XXXXX) Y µg/m³
#19 XXXXX (XXXXX) Y µg/m³
#20 XXXXX (XXXXX) Y µg/m³
#21 XXXXX (XXXXX) Y µg/m³
#22 XXXXX (XXXXX) Y µg/m³
#23 XXXXX (XXXXX) Y µg/m³
#24 XXXXX (XXXXX) Y µg/m³
#25 XXXXX (XXXXX) Y µg/m³
#26 XXXXX (XXXXX) Y µg/m³
Current PM2.5 is 5 µg/m³
World PM2.5 mean is 20 µg/m³
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Compare to Canadian cities
Pollutant
PM10
PM2.5
O3
AQHI
(...)
Canada Map
Cities List
Select station
Station here
https://metrovancouver.org/
CANADA
Station #1 is currently in position #6 out of #50
Current PM2.5 is 5 µg/m³
Canada PM2.5 mean is 20 µg/m³
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Compare to Canadian cities
Pollutant
PM10
PM2.5
O3
AQHI
(...)
Canada Map
Cities List
Select station
Station here
https://metrovancouver.org/
#36 Station #1 (Vancouver) 5 µg/m³
#1 XXXXX (XXXXX) Y µg/m³
#2 XXXXX (XXXXX) Y µg/m³
#3 XXXXX (XXXXX) Y µg/m³
#4 XXXXX (XXXXX) Y µg/m³
#5 XXXXX (XXXXX) Y µg/m³
#6 XXXXX (XXXXX) Y µg/m³
#7 XXXXX (XXXXX) Y µg/m³
#8 XXXXX (XXXXX) Y µg/m³
#9 XXXXX (XXXXX) Y µg/m³
#10 XXXXX (XXXXX) Y µg/m³
#11 XXXXX (XXXXX) Y µg/m³
#12 XXXXX (XXXXX) Y µg/m³
#13 XXXXX (XXXXX) Y µg/m³
#14 XXXXX (XXXXX) Y µg/m³
#15 XXXXX (XXXXX) Y µg/m³
#16 XXXXX (XXXXX) Y µg/m³
#17 XXXXX (XXXXX) Y µg/m³
#18 XXXXX (XXXXX) Y µg/m³
#19 XXXXX (XXXXX) Y µg/m³
#20 XXXXX (XXXXX) Y µg/m³
#21 XXXXX (XXXXX) Y µg/m³
#22 XXXXX (XXXXX) Y µg/m³
#23 XXXXX (XXXXX) Y µg/m³
#24 XXXXX (XXXXX) Y µg/m³
#25 XXXXX (XXXXX) Y µg/m³
#26 XXXXX (XXXXX) Y µg/m³
Current PM2.5 is 5 µg/m³
Canada PM2.5 mean is 20 µg/m³
Air quality stations
Fires
Wind
Alerts
Rain
Smells
PM2.5 Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Forecast
Forecasting consists of predicting future conditions.
The current forecast option is limited to 14 days.
https://metrovancouver.org/
Present day
+2 weeks
Air quality stations
Fires
Wind
Alerts
Rain
Smells
PM2.5 Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us


metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
History
This feature shows the spatial changes of recent events.
The current history option is limited to 14 days.
https://metrovancouver.org/
-2 weeks
Present day
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
Tutorial
Contact us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SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Receive alerts/notifications
Alerts
High ozone
Extreme heat
Unhealthy air
(...)
Notifications
New source reported
New fire reported
Drastic AQHI changes
(...)
Restrict to be within 10km of
Address here
E-mail or Phone
e-mail here
Subscribe!
https://metrovancouver.org/
Trivia!
Download
Sources
Health
Get involved!
Air quality stations
Fires
Wind
Alerts
Rain
Smells
Pollutant
First Peoples' Territories
Anmore
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Pitt Meadows
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Delta
Abbotsford
Mission
AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
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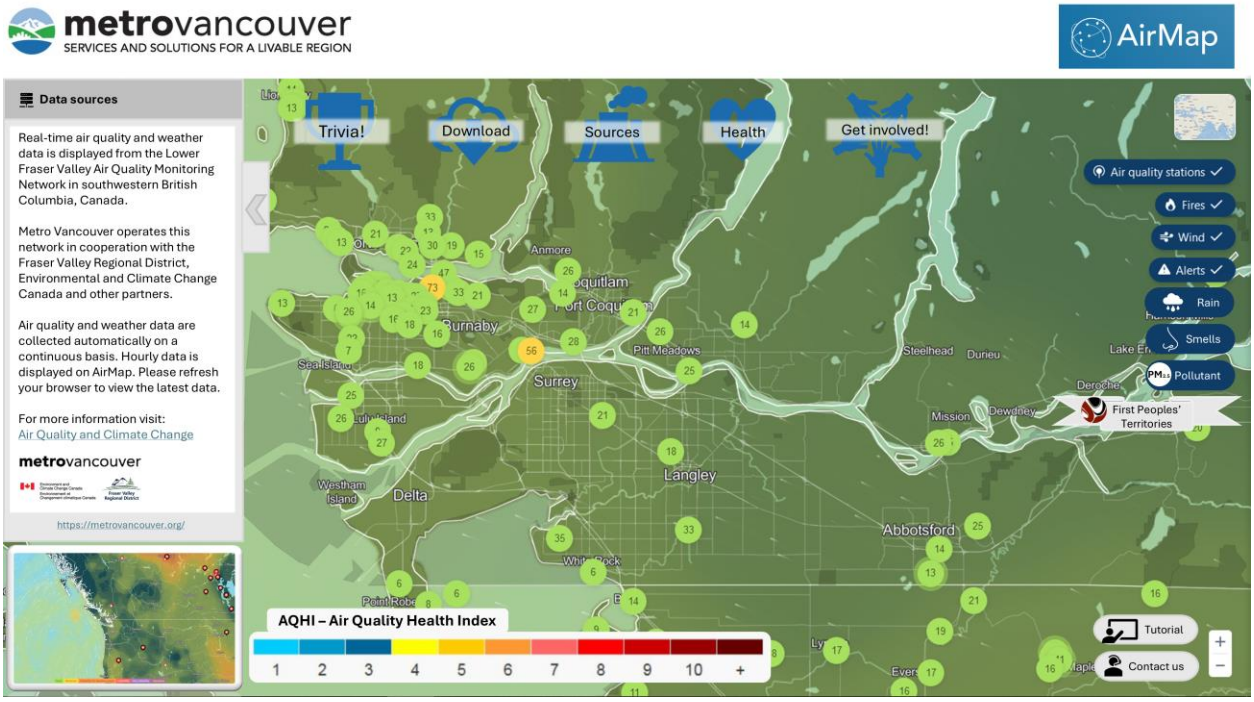
Contact us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SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Data sources
Real-time air quality and weather data is displayed from the Lower Fraser Valley Air Quality Monitoring Network in southwestern British Columbia, Canada.
Metro Vancouver operates this network in cooperation with the Fraser Valley Regional District, Environmental and Climate Change Canada and other partners.
Air quality and weather data are collected automatically on a continuous basis. Hourly data is displayed on AirMap. Please refresh your browser to view the latest data.
For more information visit:
Air Quality and Climate Change
metrovancouver
https://metrovancouver.org/
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AQHI – Air Quality Health Index
1 2 3 4 5 6 7 8 9 10 +
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Surrey
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Langley
Abbotsford
Mission
Pitt Meadows
Steelhead
Durieu
Dewdney
Westham Island


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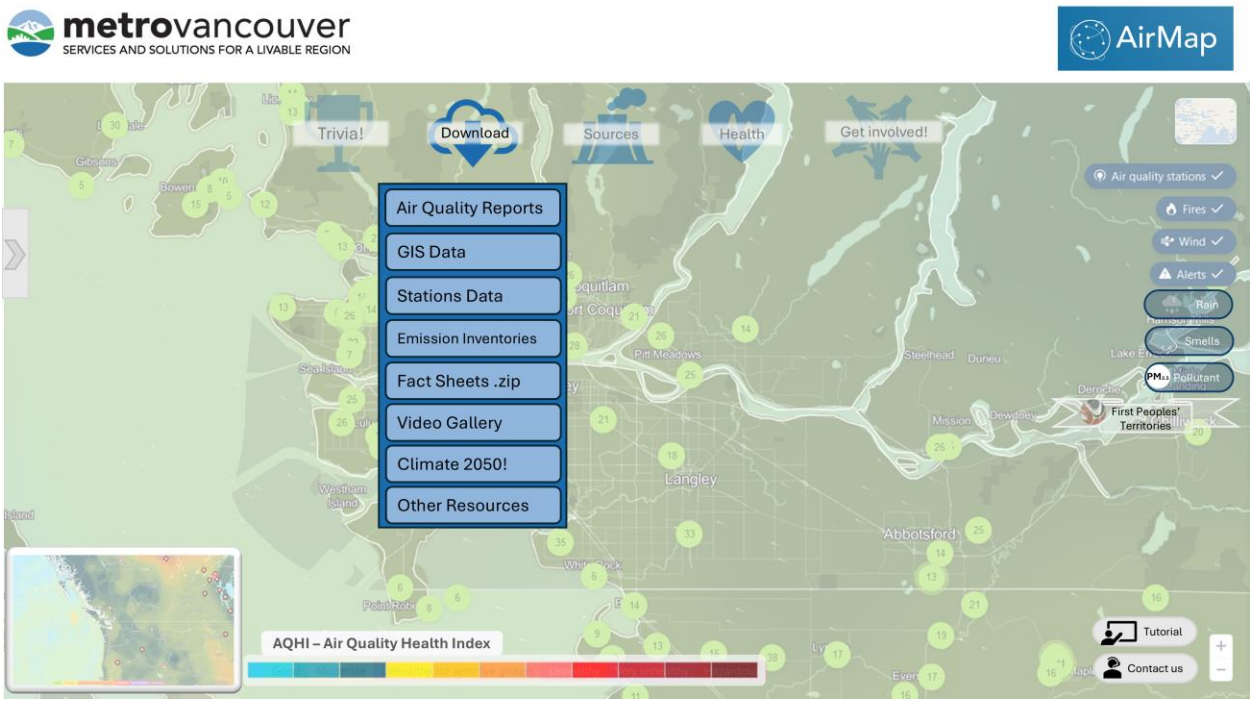
SERVICES AND SOLUTIONS FOR A LIVABLE REGION
AirMap
Welcome to the Air Map Trivia Game!
The goal of this game is to improve knowledge translation and communication about air pollution, meteorology, and health.
The rules are simple:
Once you click "Start!" you will be prompted with the first question. We have 50 questions about local and general air quality, meteorology, health effects of air pollution and more stored.
If you answer correctly, the next question will appear.
There is no time to answer the questions, but if you miss three is Game Over!
How many can you get? ☺
My alias: Insert alias here (e.g., Davi Monticelli)
START!
This Week's Leaderboard!
1st place alias 50 pts
2nd place alias 45 pts
3rd place alias 40 pts
4th place alias 38 pts
5th place alias 30 pts
6th place alias 24 pts
7th place alias 20 pts
8th place alias 15 pts
Study materials
Go back to map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Air Quality Reports
GIS Data
Stations Data
Emission Inventories
Fact Sheets .zip
Video Gallery
Climate 2050!
Other Resources
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Wind
Alerts
Rain
Smells
PM2.5 Pollutant
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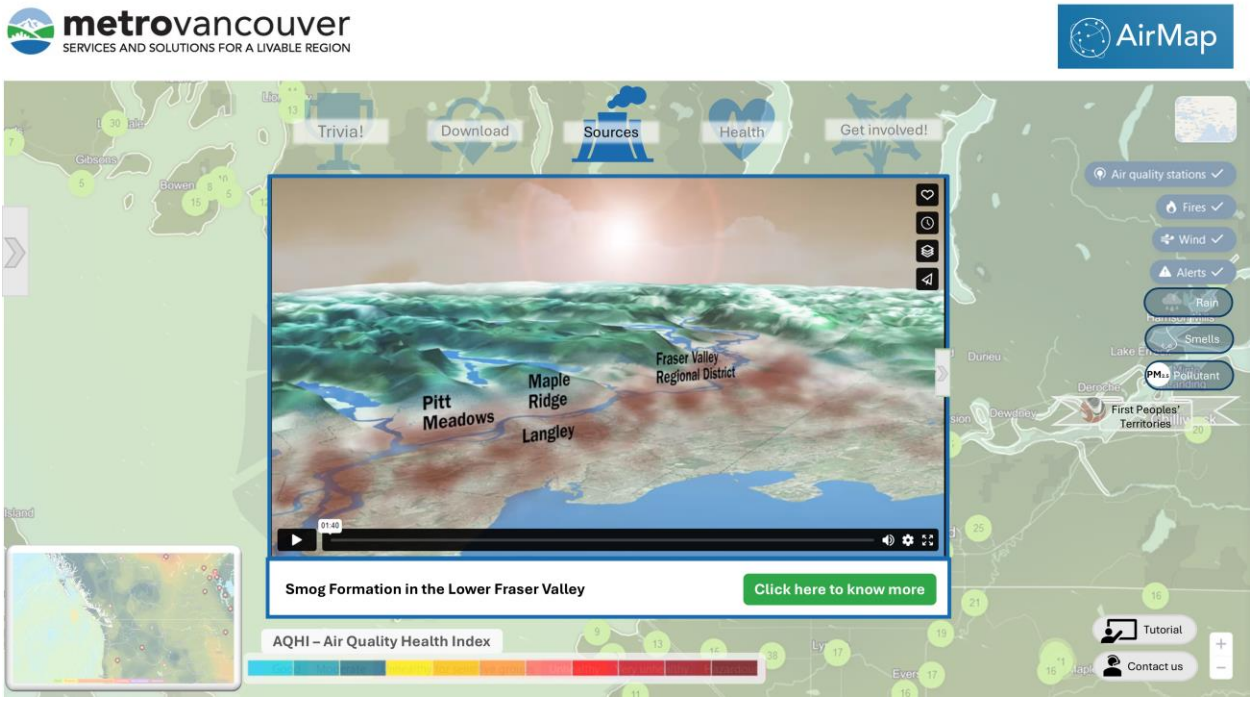
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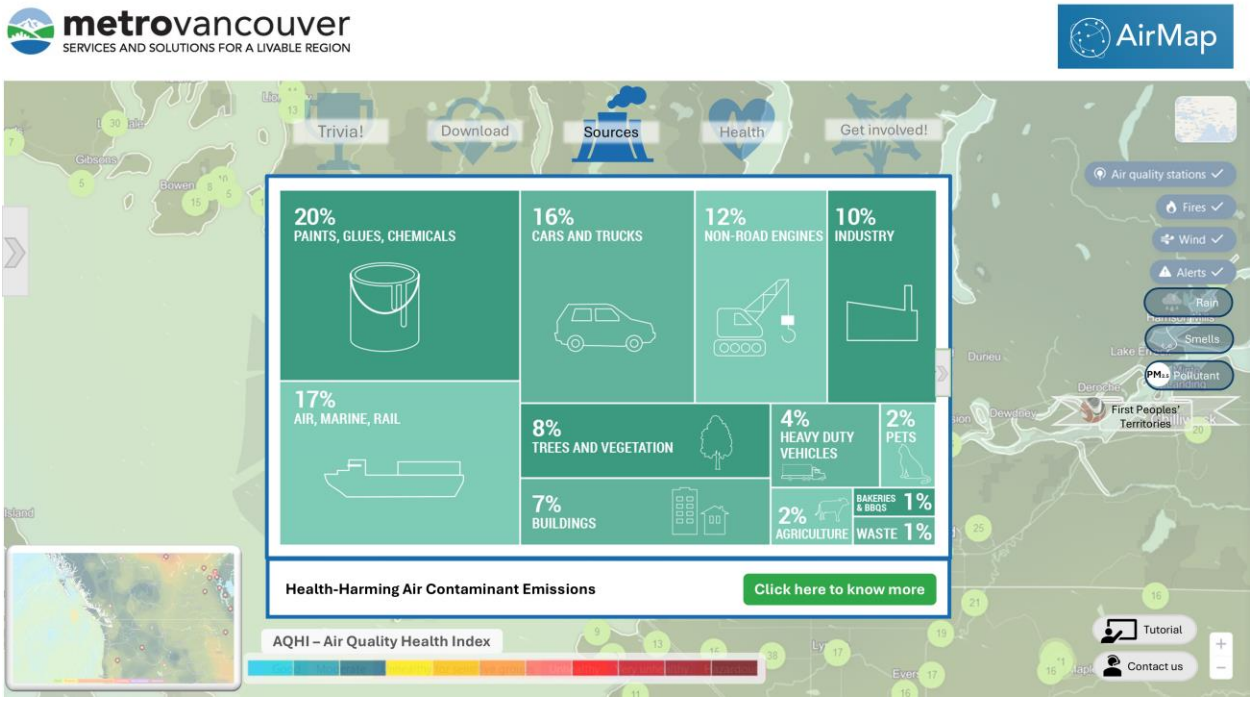
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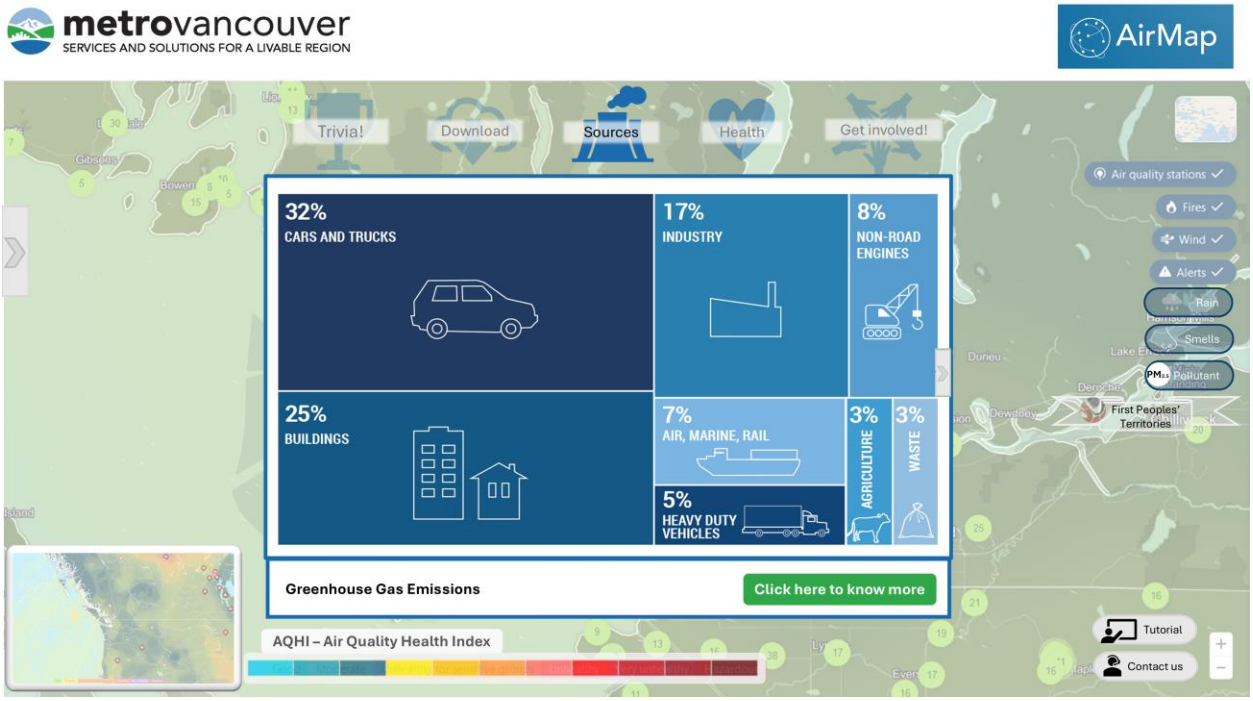
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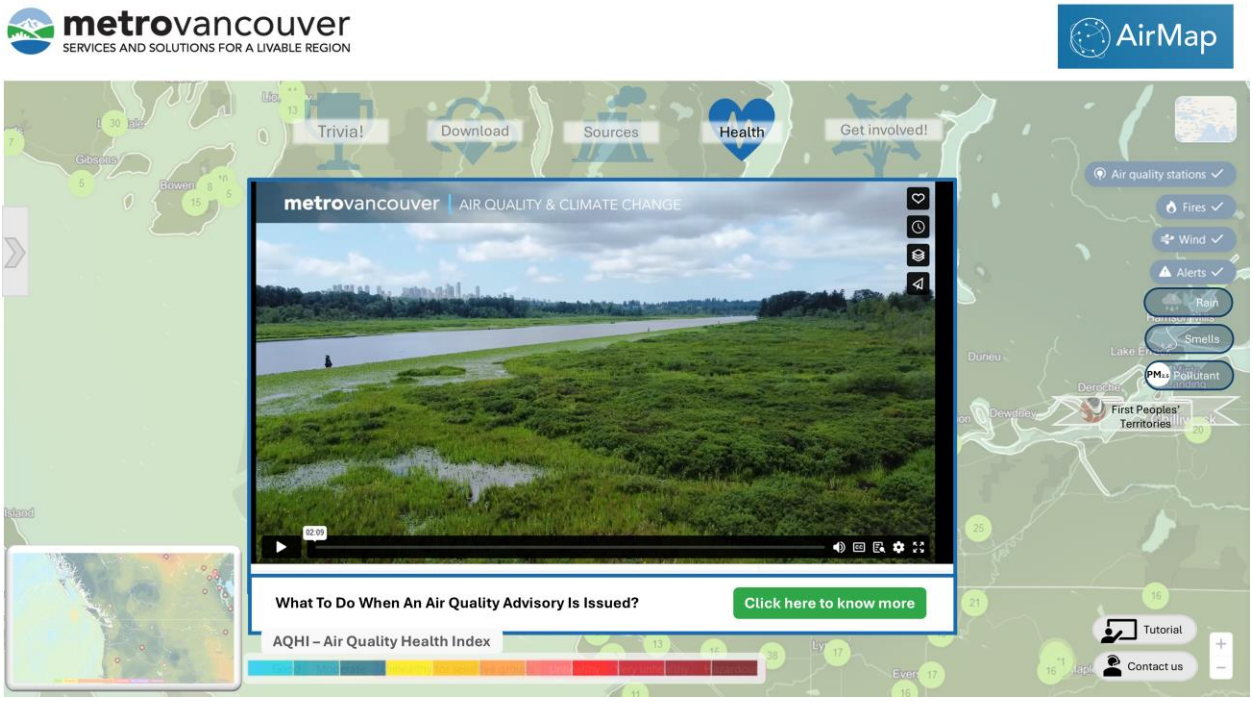
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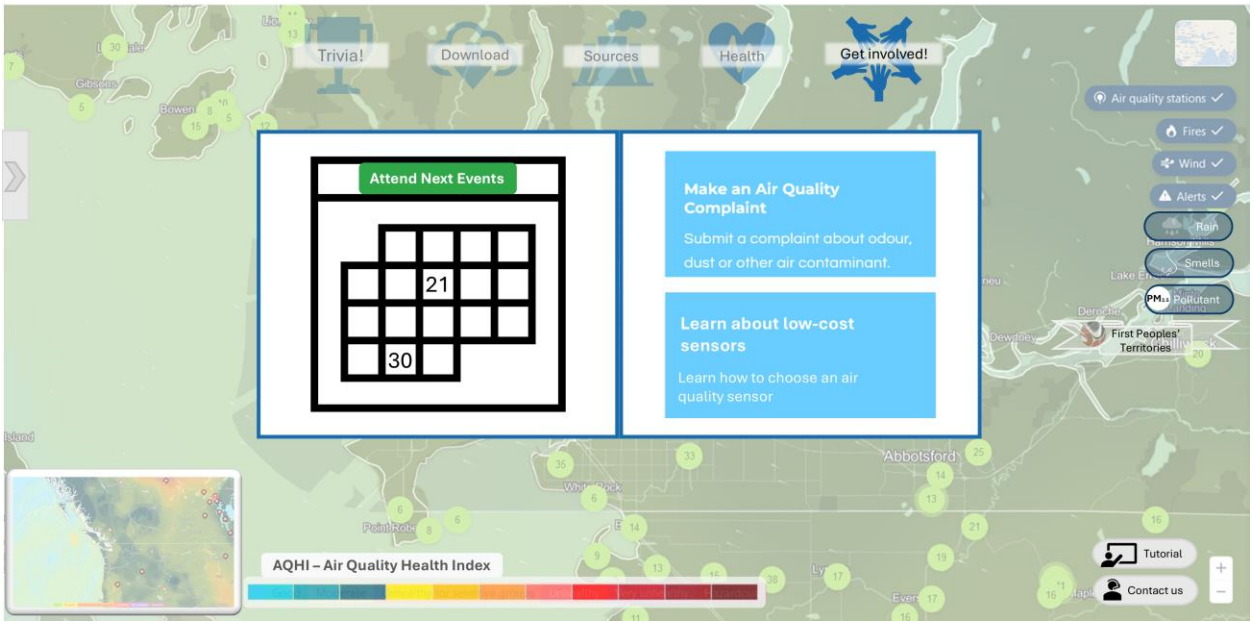
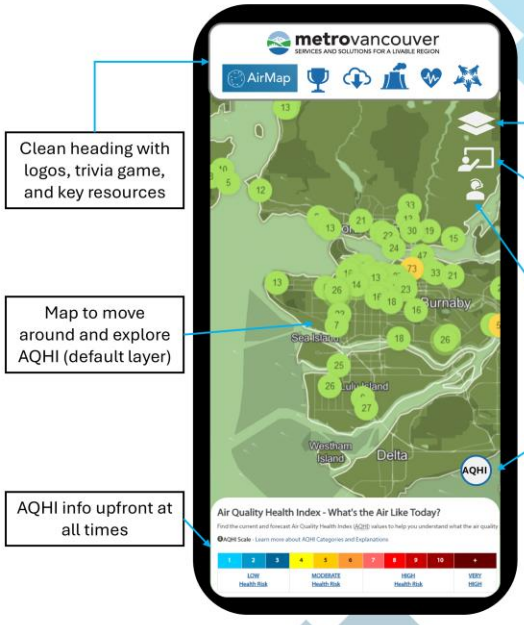




Clean heading with logos, trivia game, and key resources

Map to move around and explore AQHI (default layer)

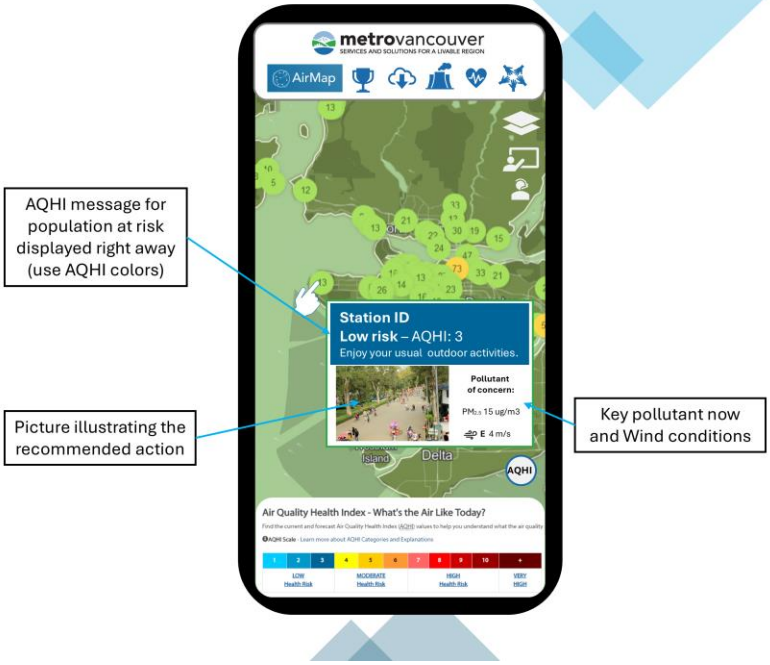
AQHI info upfront at all times

Layer options

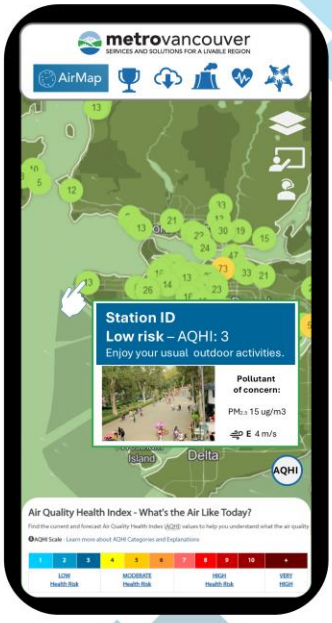
Tutorial option (Video pop-up)

Contact us option (Form pop-up)

Value to appear inside circles



Animations to add more options to the panel:



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