OPENAIR

Operational Network of
Air quality Impact Resources

Best Practice Guide

BP504 | Act on evidence

User interfaces and data stories

Introduction

This OPENAIR Best Practice Guide chapter introduces local governments to approaches used to effectively communicate air quality data to a variety of internal and external audiences. It considers the use of data stories, dashboards, data visualisations, alerts, and other tools available to visualise and give meaning to air quality data, while conforming to established standards around air quality data reporting.

There is a wide range of open-source and proprietary platform solutions available to support these user interfaces. This chapter discusses these options, their relative advantages and disadvantages, and other factors that should be considered when procuring these platforms for your project.

Data services tools and applications (to visualise and communicate air quality data) are changing and evolving rapidly. The services listed in this chapter are examples of air quality visualisation approaches available at the time of publication. New platforms (including immersive and virtual communications platforms) will provide even greater opportunities to communicate air quality data in live settings, contributing to improved knowledge of the determinants of air pollutants, and the differential impacts on community groups.

Who is this resource for?

This chapter is for local government staff who are tasked with designing and delivering a smart low-cost air quality sensing project. It should be especially useful to staff who may be responsible for making sure that any data generated by the sensing project is shared with stakeholders and the wider community in accessible and engaging ways.

How to use this resource

This chapter presents key information on data storytelling and visualisation tools that are currently available, to make novel sources of data meaningful and impactful to different user groups. Local governments (and community organisations or stakeholders) can use this resource to support their decisions regarding how to visualise air quality data from a particular project, and to consider the needs of different users.

Data stories

> ***"In order to spread science, you need to be able to tell stories."***
>
> - *Ben Wellington, data storytelling expert*

Data stories build compelling narratives to tell a story – and influence an audience – using data and analytics. A data story can translate complicated information into a clear and persuasive narrative that prompts action. Underpinned by evidence, a data story can equip audiences with the confidence to make informed decisions – and as Ben Wellington urges, storytelling is also critical to the ability to communicate science (Wellington, 2015). Data stories are thus fundamental to the effective communication of data.

For data custodians working in local government, data stories are a powerful way to ensure the data your project creates in turn generates action by relevant audiences and stakeholders. Telling data stories well requires a clear understanding of your audience and project stakeholders, and their needs. It also requires you to define what you want your audience to know or do, in response to your data story.

Creating a data story involves the following steps:

1. Planning your data story
2. Creating your data story
3. Evaluating your data story.

1. Planning your data story

Building data stories requires careful planning, to ensure that your data story is fit-for-purpose. Planning a story takes into account key audiences and stakeholders, their context, the actions you want from your audience, and the availability of data to tell your story.

These steps can be summarised as follows (see Table 1):

1. *Know your audience*: Who is the data story for?
2. *Understand context*: How and when will they use the data?
3. *Take action*: What will they use the data for?

> *"This may sound counterintuitive, but success in data visualisation does not start with [creating] data visualisation. Rather, before you begin down the path of creating a data visualisation or communication, attention and time should be [given] to understanding the* ***context*** *for the need to communicate."*
>
> Page 33, paragraph 1 of (Knaflic, 2015)

Table 1. Key steps in planning a data story for different audiences

Key steps	Considerations
1. Know your audience Who is the story for?	• Is your audience internal or external? • Which stakeholders do you need to engage with to reach these audiences? • What tools exist to evaluate your engagement with these audiences?
2. Understand context How and when will they use the data? What experiences will you be connecting with?	• In what context will your audience be engaging? - Online – dashboard or website - In situ – in the public domain, or on location - Face to face – presentation formats for in-person presentation - Written reports • Which experiences of your audiences do you need to connect with to tell your data story well?
3. Take action What actions or insights are you aiming for? How will you measure or identify these actions?	• How do you want your audiences to respond? What actions do you aim to achieve? • Consider how you might identify and measure actions resulting from your data story.
4. Data quality and availability	• Confirm data availability for your use case: Is the data reliable, timely, and accessible for the purposes of your story or use case? • Confirm the data quality aligns with availability. • Check the requirements for your use case scenario.
5. Risk factors	• Identify any risk factors, and put in place steps for risk mitigation.

2. Creating your data story

After planning a data story, the work of building your story can begin. What makes a data story distinct from other forms of data visualisation and communication is the integration of multiple 'scenes', or data views. Narrative text can be integrated into chart or graph titles, allowing each data view to be described in a way that delivers a compelling set of insights or action points to your audience.

Multiple formats and data visualisation styles can also help to add variety and interest to a data story. If the same chart type or graph is used repeatedly, the audience may lose interest.

Consider the key characteristics of a data story:

- You are telling a story. Make use of available labels and descriptors as narrative devices that appear alongside data insights.
- Focus on the most important insight. Incorporating too many ideas or insights into a single visualisation (or story scene) may confuse your audience. If necessary, include clear explanations to enhance understanding.
- A good story generally has a beginning, middle, and end, and incorporates conflict and resolution. Think about the key conflict and resolution points of your story, and use these to design your sequence or story scenes (similar to a storyboard). Your story resolution should point to the key solution or action point you want your audience to adopt.
- A data story is different to a complex data visualisation, in that it creatively tells the audience what data they are looking at, rather than asking them to interpret it themselves.

There are many useful resources available online to support planning and creation of your data stories (see the additional resources listed at the end of this chapter).

3. Evaluating your data story

Once you have created a data story, it is important to monitor and evaluate how effective the data story was in achieving your goals. Your audience, context, and purpose will inform how you evaluate the effectiveness of your data story. The results of your evaluation should be used to improve the delivery and impact of new data stories.

Questions to consider include:

- Was the data story suitable for your audience?
- Did your audience engage with the data story? Use metrics that reflect your chosen context, e.g. online (web views), social media (engagement metrics), or live audience feedback (presentation format).
- Did your data story provoke action or new knowledge? Consider here the actions you wanted to prompt or promote through your data story.
- Did you encounter challenges with data availability over the time period your data story was accessible?

Example 1: Industrial air pollution

A local government is concerned about industrial air pollution in one of its communities. There is a state government air quality reference station present that does not show evidence of any concerning levels of pollution. However, there are community concerns that the pollution is highly localised, and not being identified by the reference station.

The local government invests in low-cost air quality sensing devices, in order to test whether contaminants are present at specific locations. They want to test the data before sharing it with the wider community. The sensing devices show reduced air quality levels at certain times of the day.

The data story the local government tells will be designed for internal stakeholders only, with the objective of seeking resources for ongoing support of their air quality sensing project (and working towards potential external communication of this air quality data). The data story will start as an internal presentation, drawing on live data from sensing device data feeds.

Key story points to communicate include the following:

- Identify the potential source of the pollution, and its potential impact on vulnerable groups
- Highlight the reference station air quality reading that evidences no variances in air quality levels
- Introduce the new sensing device, its location, and the readings obtained (relative to the DPE NSW DPE data)
- Use data reporting that conforms to accepted air quality categories in the air quality index
- Highlight the specific times when air quality is reduced, and any additional data of relevance
- Seek evidence of correlation between the reduction in air quality, and industrial activities present at the site
- If possible, identify vulnerable groups exposed, and potential impacts
- Discuss limitations of the data, and potential risks attached to communicating this to wider stakeholders
- Identify requirements for ongoing support of the air quality data trial, to improve data validity and quality
- Establish a roadmap for communication to external stakeholders.

Example 2: Woodsmoke

A local government is seeking to establish greater public awareness of the impacts of woodsmoke (from woodburning heaters) in the community during winter. They have installed sensing devices in their community to better understand daily air quality variations. They do not have air quality experts internally, and also have limited internal data science and visualisation resources.

The objective of their data story is to ensure they are able to publish air quality data on an external website for community use. This data story is to be presented internally, as a step towards external engagement.

Key steps include the following:

1. Identify the source of the pollutant, and its known effects on human health
2. Present the data available from the sensing device by location, time of day, with hourly intervals, and showing daily variations in pollutants present
3. Test the availability of data visualisation tools for local government use
4. Keep the focus on the air quality variations (as they correlate to the presence of the pollutant)
5. Highlight key issues around data quality and reliability experienced in the pilot project
6. Highlight resource implications of ongoing roll-out of the pilot project
7. Identify appropriate data quality statements for inclusion in any public data visualisation for external publication
8. Highlight risks to community associated with continuing exposure to pollutants
9. Discuss a staged plan for roll-out of a public dashboard for data visualisation of air quality readings in the community.

User interfaces

Once you have created your data story, you can consider the types of user interfaces that are best suited to sharing the story.

User interfaces convey information to users, and there are many different types (see Table 2). The right choice depends on the type of information you want to convey to users, and how you expect users to encounter, understand, or act on that information.

Table 2. Examples of user interfaces

User interface	Features
Summary dashboard	Provides an overview of air quality, using lists and graphs. Dashboards may provide the ability to 'drill down' to see more detail.
Map-based visualisation	Creates an at-a-glance overview of air quality over a large area (e.g. local government areas).
Analytical workbench	Provides examples of air quality trends and patterns. This may be used in combination with other types of data (e.g. demographics, or transportation patterns).
Reports	Provides periodic updates, using a standard format (e.g. compliance reporting).
Alerts	Creates email or SMS alerts to be sent when certain conditions are met (e.g. when air quality is very poor). Useful for compliance purposes, or to warn people when conditions may be hazardous.

User interface platforms

User interfaces are made available via a variety of technology platforms, including:

- Dashboards – such as those found in business intelligence applications
- Data portals – predominately used for data sharing and access, but also include user interfaces
- Data widgets and alerts – specific user interface components incorporated into websites and operational systems.

Dashboards

Dashboard platforms are available for many different service requirements, from internal business analytics, sales targets, sustainability measures, research tools, and more. They are often described as 'business intelligence tools' because they focus on ensuring data is well understood in relation to relevant key performance requirements or measures.

If you are combining different visual tools (e.g. maps; charts; graphs) to present data, make sure your dashboard is simple and easy to understand. For example, a simple number can be made meaningful if it is clearly understood in relation to a set target, or wider context.

While many dashboards digitally display live data feeds to generate their visualisations, a dashboard can also be created through a static data set, and published as a stand-alone set of charts or graphs. Live data can be hosted externally to the dashboard itself, and sourced via an application programming

interface (API). In particular, use of REST APIs[1] (or RESTful APIs) can ensure that data conforms to the requirements of the dashboard.

Dashboards should always ensure their users can access raw data underpinning the visualisations, as well as data quality statements. Digital dashboards are available as free/open-source versions, or through subscription models. Procurement considerations for readily available digital dashboards are considered in Table 3. Air quality sensing device vendors often provide dashboards to visualise air quality data from their sensors/devices. An example of a publically-available dashboard is the NSW Air Quality Dashboard.

Data portals

Data portals support cloud-based hosting, and delivery of machine-readable data for use by external software applications and dashboards. They typically also include user interfaces. Data portals are often supported by government agencies, to ensure standardised publication of data across multiple data publishers (e.g. government agencies). This is known as 'federation', and allows users to access a single interface for all data, regardless of where it is sourced from, or stored.

Many data portals publish data under Creative Commons attribution licences. These data portals are known as Open Data portals. Examples include the Data.NSW data portal and SEED (Sharing and Enabling Environmental Data). Some of these data portals also provide map-based visualisations of data.

Widgets

Widgets are elements of user interfaces that show a single piece of information. They can be integrated into local government websites (e.g. to show current air quality via a local government web page). Behind the scenes, widgets will draw on data from data portals, or other types of data platform. Real-time data feeds can be used to generate live data visualisations across a variety of local government-run digital services (including websites, social media feeds, and SMS communications platforms).

Text message alerts and notifications can also be established, to communicate data to users who have elected to sign up for notifications. For example, NSW Air Quality alerts are issued on days when pollution levels are forecast to be unhealthy, or very unhealthy. Users can also sign up to receive SMS and email notifications for current alerts in their region.

[1] REST stands for 'representational state transfer' architectural style. For more information about RESTful APIs see What is REST.

Combining multiple user interfaces

You can use or combine multiple user interfaces, in order to convey air quality information in different ways. For example, a planner may need to understand in-depth historical information and trends, while a compliance officer will need alerts and dashboards to convey more immediate, real-time information (see Figure 1).

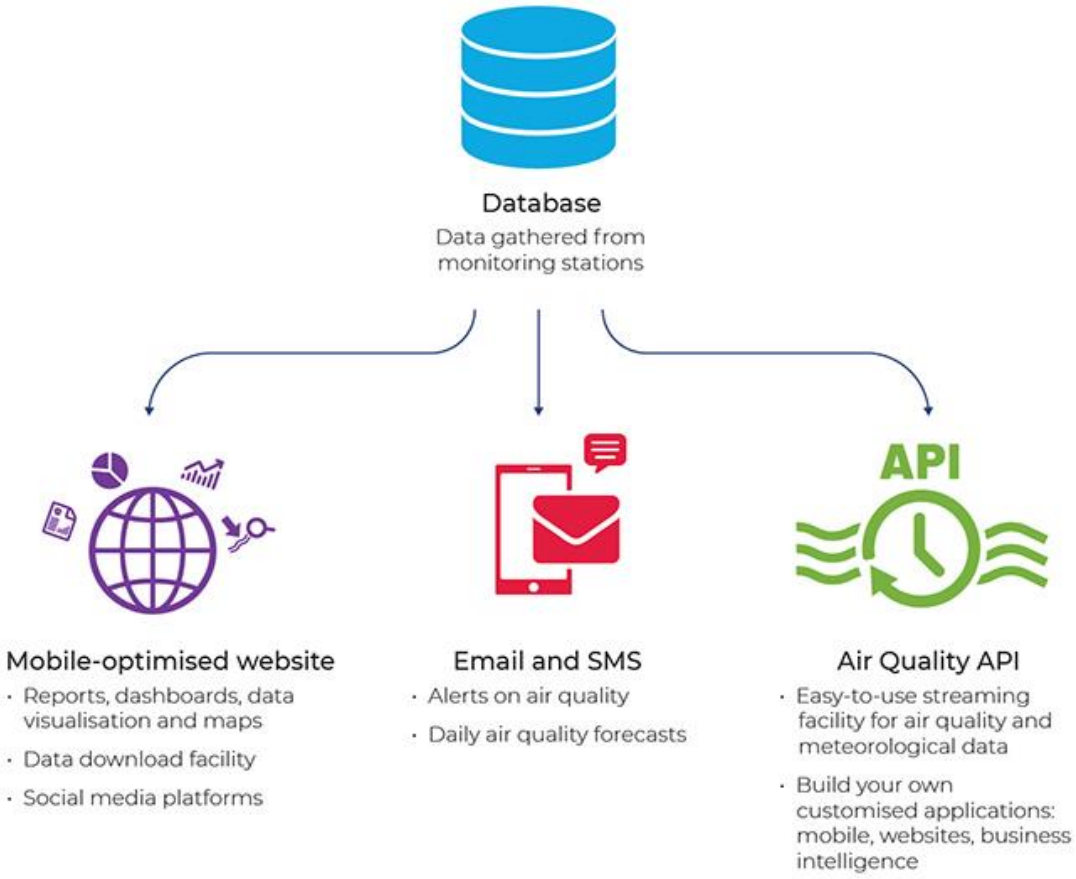

Figure 1. Different user interfaces may use the same air quality data, but to suit different purposes. Figure source: NSW DPE

Data visualisation

Tools and conventions for visualising air quality data build on best practice frameworks for the evaluation and sharing of air quality data.

Key concepts and visualisation techniques described in this section include:

- air quality indices
- public reporting of air quality
- limitations of low-cost air quality sensing devices
- air quality categories
- maps
- tracking and showing changes over time
- infographics.

Air quality indices

Raw air quality data is converted into meaningful information through a set of air quality standards and calculations. These are underpinned by public health recommendations, and established scientific methodologies. The resulting information is generally conveyed as ‘air quality indices’. Within air quality indices, the higher the indicator, the higher the level of air pollution present.

Public reporting of air quality

In Australia, the National Environment Protection (Ambient Air Quality) Measure (NEPM) is the national framework for public reporting against air quality indicators.

The NEPM includes recommendations and guidelines that can be used to ensure any raw data communicated through air quality pilots aligns with current recommendations around air quality standards. The NEPM informs the approach to be used for hazard and exposure assessment and risk characterisation, and provides guidance on the application of the precautionary principle. It also includes approaches to address environmental justice issues in setting air quality standards in Australia (National Environment Protection Council, 2011).

The NEPM is continually revised to reflect up-to-date knowledge on exposure levels and methodologies, to ensure consistent application across all tiers of government (Parliament of Australia, 2021).

Limitations of low-cost air quality sensing devices

Low-cost environmental sensing devices (ranging in price from roughly $100 to $10,000) are necessarily of lower quality than those used in state government-operated air quality reference stations. The hardware in these less expensive devices is of lower quality, and there is less rigour applied to locating, installing, calibrating, and maintaining low-cost sensing devices. Data generated by low-cost sensing devices is not always quality checked before being made available to users.

For these reasons, the air quality measurements recorded by smart low-cost sensing devices are not always identical to the measurements generated by reference stations. User interfaces must account for (and explain) these differences when conveying air quality information to users.

Air quality categories

Specific colour indicators are attached to air quality categories within an Air Quality Index, classifying air quality as 'Good', 'Fair', 'Poor', 'Very Poor', or 'Extremely Poor'. Each category incorporates data readings for pollutant and visibility measurements, classified according to predetermined cut-off values for different pollutant inputs (see Figure 2).

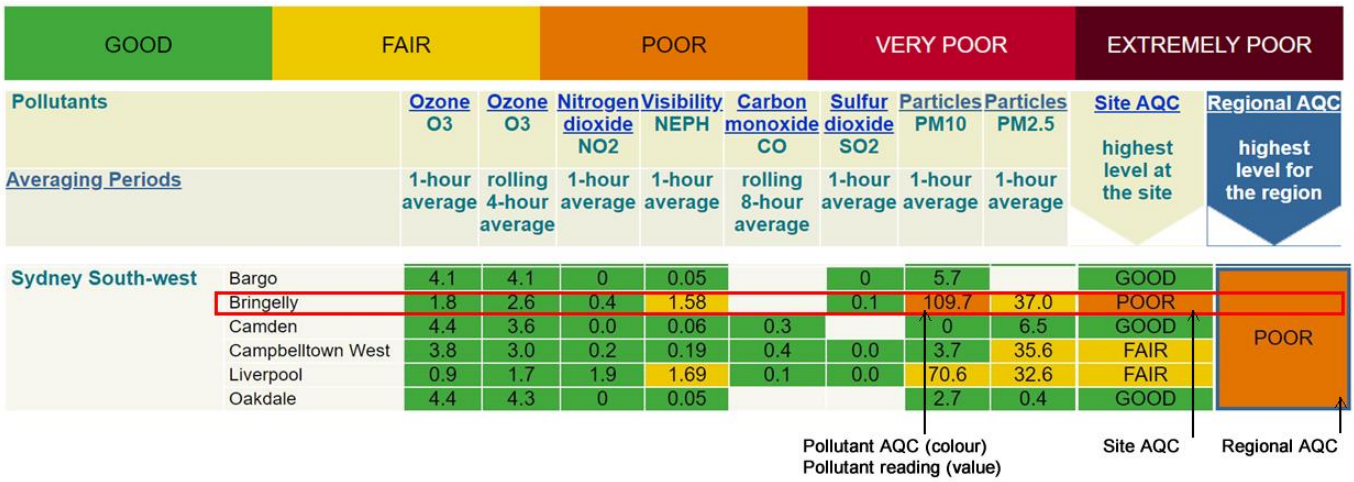

Figure 2. Air quality categories – components diagram. Figure source: NSW DPE

The air quality category colours are designed to provide ‘at-a-glance’ information to help users plan their activities. In NSW, the Environmental Health Standing Committee (enHealth) provides an activity guide attached to each colour rating. Colour indicators should be consistently applied across dashboards.

These colour indicators are also present in physical computing devices located at the source of an air quality monitoring device, or accessed on location (via mobile apps). Figure 3 and Figure 4 demonstrate this simple, colour/category approach to air quality data visualisation.

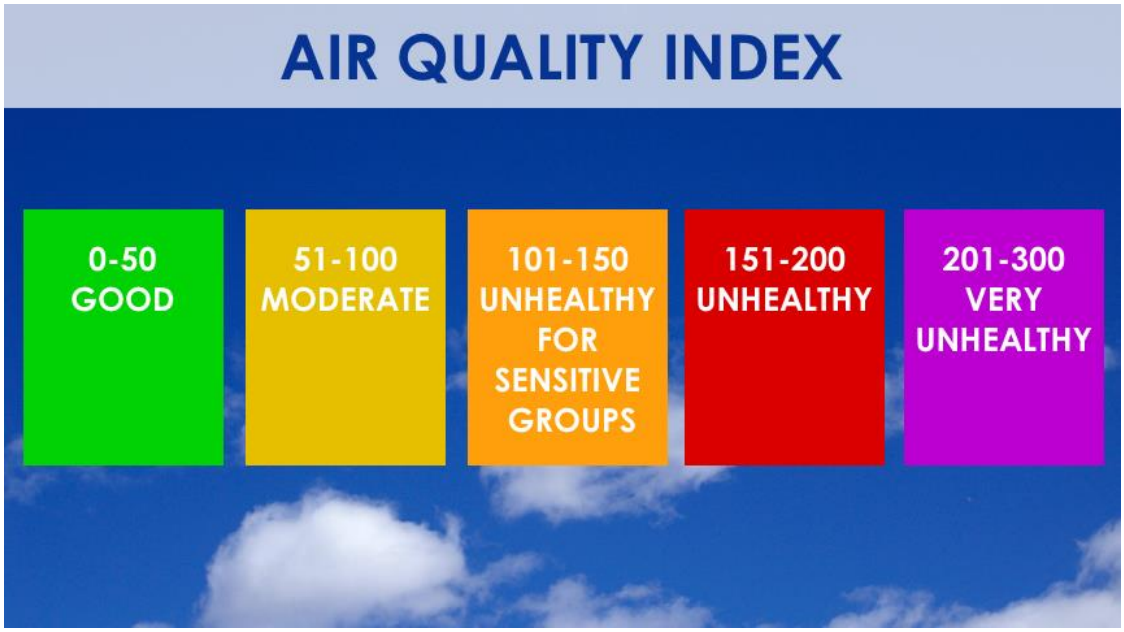

Figure 3. Simple air quality index visualisation using colour indicators. Figure Source: Clean Air Partners

Figure 4. Simple air quality index visualisation using colour bands. Figure source: MDPI AG (2021)

Maps

Maps are fundamental to visualising air quality data. They improve contextual understanding for users (e.g. location, time of day, and other overlapping environmental factors). There are many mapping applications available to create digital maps that can be embedded into a website. These include ArcGIS by ESRI, Mapbox, CartoDB, Leaflet, and Google Maps.

Public data portals (including those operated by governments) also display spatial maps of air quality data. See Figure 5 and Figure 6 for demonstrations of this.

Maps integrate multiple data points, in addition to the air quality data feed. These include:

- GPS coordinates to indicate where an air quality monitoring device is located (i.e. where data is being sourced from).
- Environmental contextual information, such as wind speed to inform the likely direction of air movement. GPS data, air quality data, and wind speed data can be integrated into a 'rose map' – see Figure 5.
- Additional data interpretation, such as spatial interpolations (estimates) to indicate the likely distribution of pollutants across a predetermined area (e.g. in a heat map – see Figure 6).
- Map visualisations can also be used to identify at-risk groups, for example by defining specific populations, such as children or the elderly, or those in a specific demographic area

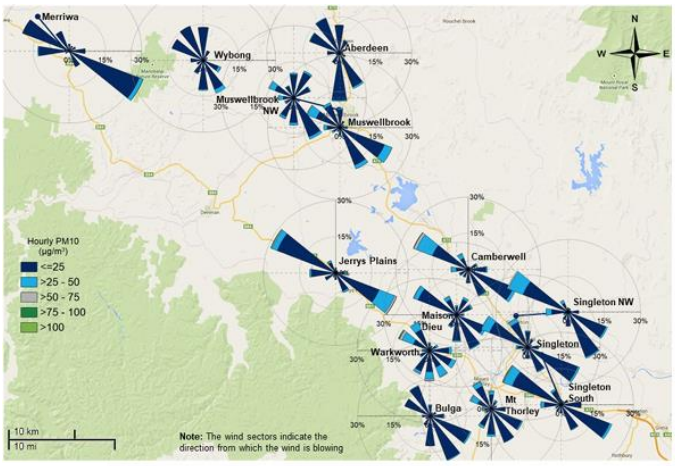

Figure 5. Rose map visualisation presenting data according to wind direction. Figure source: NSW DPE

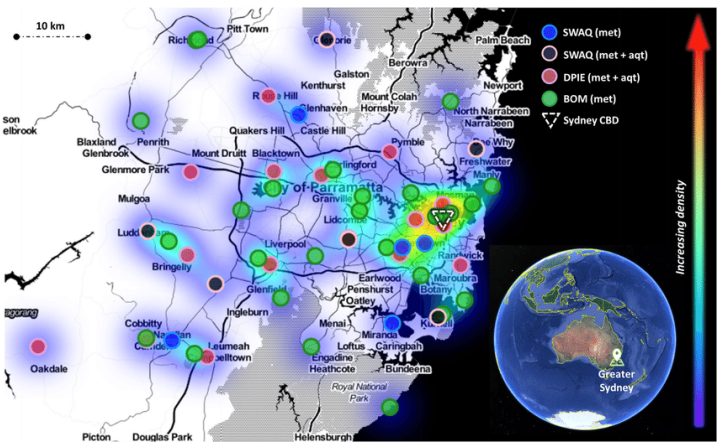

Figure 6. Density heat map of meteorological and air quality observations across the Greater Sydney region. This shows different types of air quality stations operating across the region, and includes stations specifically representing at-risk demographics (e.g. schoolchildren).
Figure source: Nature Publishing Group (2022)

Showing changes over time

Temporal data can be averaged over specific time periods (e.g. daily and hourly averaging) to assist with data sensitivities.

Bar charts are useful for trend data, or comparisons between data sets. These charts can present trend data at multiple locations simultaneously (see Figure 8).

Air quality data can also be presented in comparison tables, showing relative concentrations and readings over time. This is useful for long-term planning purposes, and trend analysis (see Figure 7 and Figure 8).

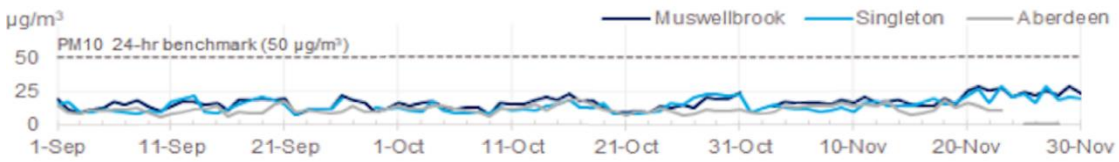

Figure 7. Time-based visualisation over 10-day intervals at multiple locations. Figure source: NSW DPE

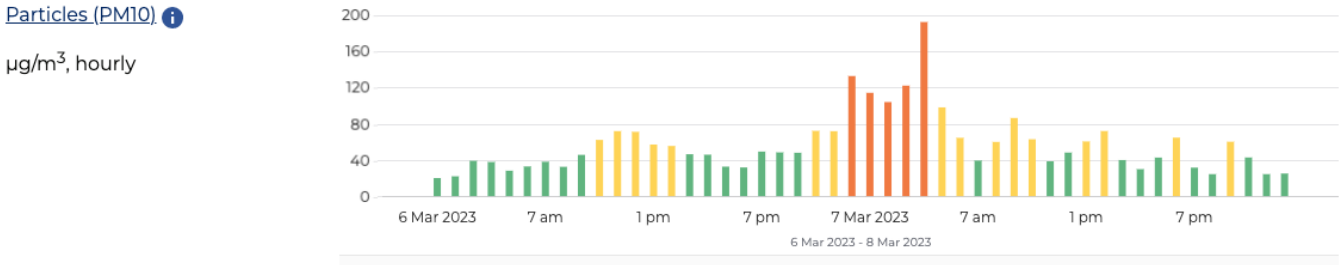

Figure 8. Simple bar chart visualisation with hourly averages coded according to air quality category colour guides. Figure source: NSW DPE

Infographics

Infographics use visual elements to highlight key information and data in an easy-to-understand way. They are critical to the communication of air quality data.

There are many ideas and tools for the generation of air quality infographics that are widely accessible via air quality mobile applications and mapping tools (see the additional resources listed at the end of this chapter).

For example, in Figure 9 you can see how the ESRI Living Atlas presents U.S. EPA AirNow Visualisations via the Air Quality Aware app, which uses simple infographics to ensure key data is communicated effectively to users. The infographics show relevant air quality data in a defined area according to at-risk population groups, and draw on data from the American Community Survey, as well as extrapolated ESRI data.

Figure 9. ESRI Living Atlas U.S. EPA AirNow Visualisations. Hosted on ARC GIS Living Atlas using EPA Now data, census data, and NOAA data. Figure source: Air Quality Aware, ESRI

There are many different kinds of data visualisations that can be used to show sources of pollution in an easy-to-understand way, and novel forms of concentration mapping. It is beyond the scope of this chapter to delve into these in any detail, but see Figure 10 and Figure 11 for two examples.

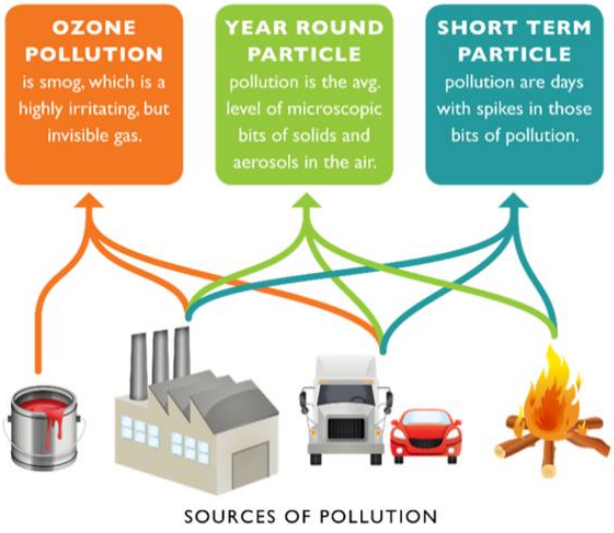

Figure 10. Data visualisation showing sources of pollutants. Figure source: NYC Data Science Academy (2016)

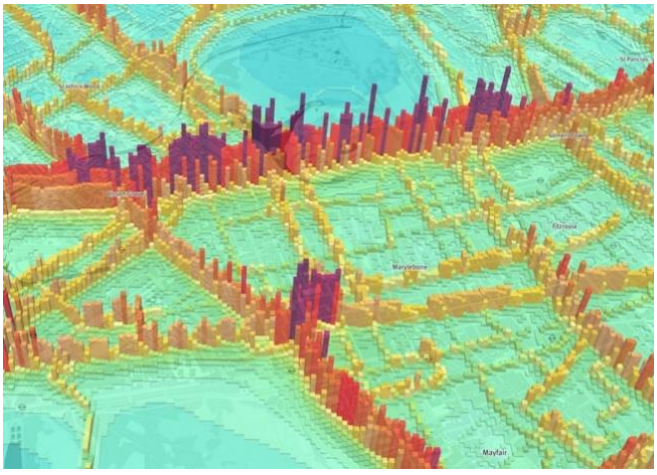

Figure 11. 3D data visualisation of nitrogen dioxide pollution in London. Figure source: Mapping London (2018)

Procurement considerations

Once you have established the types of user interface your project requires, use Table 3 to help define your requirements when procuring suitable platforms.

Table 3. Procurement considerations

Procurement aspect	Questions to consider
Functionality	What *type* of visualisations are needed? Should the platform support geographic maps, charts, heat maps, graphs, or tables?
	Are *configurable alerts* required? If so, should these be SMS, email, or both?
	Customisations: Do users need the ability to change charts and graphs, or are standard 'canned' visualisations sufficient?
	Useability: Are users technically sophisticated, or relatively unsophisticated? If programming skills are required to use a platform, this may not be suitable for non-technical users.
	Will there be *additional features*? Features can include data sharing, integration with enterprise systems, and user access permissions management.
Business needs	What *licence models* are used? Will this be cost-effective if the number of users increases over time?

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Additional resources

Data stories

- ***Terria Maps* | *Data Stories: Getting Started***
- ***Harvard Business Review* | *Telling Stories with Data in 3 Steps (Quick Study)***
- ***Ben Wellington* | *Making data mean more through storytelling***

Dashboards and datastores

- ***Jamie Juviler* | *REST APIs: How They Work and What You Need to Know***
- ***TERN* | *Data Licensing FAQ***
- ***Creative Commons* | *Attribution 4.0 International***

Examples of city dashboards and datastores

- ***Greater London Authority (GLA)* | *London Datastore***
- ***City of Gold Coast* | *Disaster and Emergency Dashboard***
- ***City of Casey* | *Open Data Exchange***

Dashboard procurement: comparative reviews

- ***DataCamp* | *Power BI vs Tableau: Which Should You Choose in 2023?***
- ***Absent Data* | *Power BI, Tableau and Google Data Studio Comparison***

Air quality data standards

- ***NSW Department of Planning and Environment* | *About the air quality categories***
- ***NSW Department of Planning and Environment* | *Air quality data averaging periods***

Data visualisations and infographics

- ***ArcGIS* | *Living Atlas of the World***
- ***Bin Lin* | *Data Visualization on Air Quality***
- ***Robin Price* | *Written in the wind: visualising air pollution levels – in pictures***
- ***Mapping London* | *3D Map of Nitrogen Dioxide Pollution***

Further information

For more information about this project, please contact:

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This Best Practice Guide chapter is part of a suite of resources designed to support local government action on air quality through the use of smart low-cost sensing technologies. It is the first Australian project of its kind. Visit www.openair.org.au for more information.

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