THE TECHNOLOGY BEHIND THE HYPE OF SMART CITY AIR QUALITY MONITORING

Whilst there may be a growth in city-wide communications integration, "big data" and public interest in local air quality, the challenges of monitoring complex atmospheric chemistry have not changed. Integrating "sensors" can sound straightforward but information about air quality around a city must be handled carefully: the risks – to stakeholders, including the public, businesses and "city hall" - of providing misleading air quality information are significant. AQMesh has been used in a number of smart city projects and we would like to share our experiences of what can be achieved and where the difficulties lie.

Probably the most innovative smart city project we have been involved in is the Breathe London pilot. This project used 100 AQMesh pods to supplement the regulatory network and was led by the Environmental Defense Fund, which has issued a very helpful guide for other cities wanting to carry out local air quality monitoring. They highlight various considerations for choosing the right monitor, including defining your monitoring objectives, which pollutants you need to monitor (and the typical levels expected), installation sites, the quality of data required and your budget. Other factors listed in the guide focus on size, flexibility, longevity and vulnerability of the chosen system – ultimately, will it be fit for purpose and allow you to meet your objectives?

AQMesh has been used in a number of other smart city projects including UK (Newcastle) and USA (Minnesota), with 55 AQMesh pods installed throughout Newcastle and Gateshead as part of the Urban Observatory project, and 50 AQMesh pods deployed across Minneapolis and St. Paul, mapping live pollution levels across the cities. The objectives and approach taken by each of these projects was different, varying in terms of how and where measurement equipment was deployed, how data was analysed and how they chose to engage with the public.

These projects have all demonstrated just how much air quality varies across a city and over time. This critical information can be used to advise the public about how to protect their health and for local authorities to understand how they can mitigate, manage and measure air quality in their area of responsibility. But in order to get to this stage there are many challenges to overcome.

Choosing a small sensor system

There are many small sensor systems available and this article assumes that the smart city project managers have looked into – and asked for proof of – their chosen system's capabilities. Products are offered for this application which are not sensitive or accurate enough to monitor meaningfully around the relevant thresholds. For example, an instrument that can only offer an NO_2 measurement with an accuracy of ±30ppb is of little use when the annual average limit is 40ppb. If the sensor system can be shown to be sensitive enough and demonstrate good accuracy in environmental conditions similar to the new project, is it robust enough? Can it be installed easily? And how will it be powered?

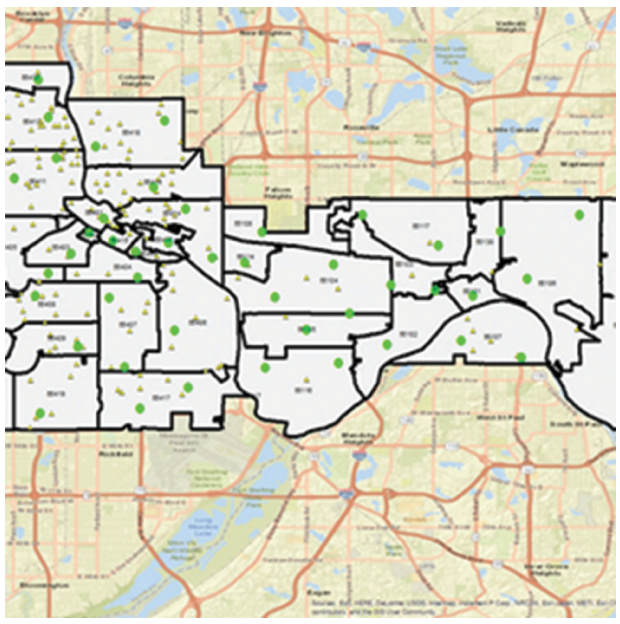
Another consideration is how the network will communicate with the central server. A range of options are available, including LoRa, WiFi and direct ethernet connection, however these can sometimes be problematic, with limited coverage of LoRa and interrupted WiFi signals or router issues. The mobile phone network, as used with systems such as AQMesh, provides a universal and reliable approach. AQMesh is designed for each pod to send sensor output to the server using the global cellular network, where each unit is independent and costs can be managed. The latest AQMesh pods are fitted with LTE CAT M1 modems to take advantage of the growth in 5G / NB-IoT – an exciting area of development for smart cities. Some monitoring systems store and process data on the hardware itself which clearly has implications in terms of data security and back-up.

"One of 100 AQMesh pods installed during the Breathe London pilot

Getting sensor nodes installed

How many sensor nodes do you need? Where should they be? How will the hardware be installed? The first two questions are often answered in a non-scientific but equally important way: what is the budget and where is most important to measure? Many cities choose to monitor around schools and vulnerable communities, some want to understand the dynamics of a particular traffic corridor, some already know where pollution is concentrated and choose to focus there.

Installation of the systems is harder than it sounds. There are plenty of posts around a city and most small sensor systems are designed to attach to them. But who owns the posts and will they let you install equipment on them? Even trickier is getting a power supply from a lamp post, where the administration can be burdensome, access can be restricted (only certain contractors may be able to carry out installations) and the power supply may not suit sensitive equipment. Solar power is a convenient option but high buildings in a city can restrict the direct sunlight essential for generating power and this adds an extra dimension to the planning of unit siting. The bottom line is that planning for installation must start early and installing a network is likely to take longer than expected.



Plan of 50 air quality monitoring sites across different ZIP code areas in Minneapolis – St. Paul

Quality assurance

Even the best small sensor air quality systems need to have their output managed through an appropriate QA/QC process. At a fundamental level it is important to confirm that the readings to be published can be relied upon. AQMesh users are supported by a range of measures which automate handling of the most common issues. For example, electrochemical sensors can fail but this can be detected remotely and the sensor output stopped (until the warranty replacement automatically issued can be installed). Measurement of particulate matter can be affected by high levels of moisture in the air and its effect on particles so AQMesh flags measurements that are likely to have been affected in this way and they can be automatically redacted (if the heated inlet option is not being used to address the issue at source). Even after these and other measures have been taken, it is necessary to confirm that readings are in line with those of a maintained, regulatory air quality management – or reference – station.

Many cities have a ready choice of reference stations to use in their smart city project. This can be by co-locating all units - or pods, in the case of AQMesh - with the reference station(s) or by co-locating a small number, which can then be adjusted against the reference station, before being co-located with other units in the network, in turn - this is known as the 'gold pod' method. The gold pod approach is proven to be effective but it does require regular moving of equipment and the people on the ground to do this. Emerging methodology – such as that used in the Breathe London pilot – has shown that similar accuracy can be achieved by remote comparison of nodes in the network and reference station(s). This "network calibration", as pioneered by Professor Rod Jones at the University of Cambridge, is not the same as using AI to "train" a small sensor system. Network calibration must offer repeatability and traceability. As various air quality experts have pointed out, while modelling and remote calibration may have their place alongside monitoring, there is a danger of generating numbers that are more the product of modelling than measurement.

In any case, such discussions are redundant in cities which do not currently have any managed reference stations offering validated measurements. It is much easier to bring small sensor systems into a city, which is just starting to measure air quality, than it is to install and maintain a reference station. A smart city network can still be set up without a reference system, with nodes calibrated within a mesh, but QA/QC systems must be in place. An air quality index may be helpful for communicating pollution levels but it will still be possible to publish misleading information about local pollution if all the steps described are not considered.

Size, installation, power supply and communications are key considerations when choosing a small sensor system

In conclusion

As always, setting expectations is key. Whilst air quality may be just one part of a complex, integrated smart city project, air quality monitoring itself is inherently challenging. Small sensor air quality monitors are deceptively small and versatile but they are pieces of scientific equipment which have been carefully designed to achieve the most accurate possible air quality information. And use of data from even the best small sensor air quality systems, when used optimally, requires care. Having said all that, the investment in effort can pay back in vital and meaningful information which can protect the health of large numbers of people in a new and dynamic way.

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