You can't manage indoor air quality without measuring it first

Kenneth Freeman
BSc (Hons), RESET AP, MCIHort

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Lots of businesses are selling products that are supposed to improve indoor air quality. They may be air purifiers, filter systems, complex green walls or even pot plants. Many claims are made, but how do you know whether the systems you are buying are doing what you need them to do? This is where air quality monitoring comes into its own.

(By the way - I'm not trying to sell you an indoor air quality monitor, or any form of air purifier. However, I can help your business set up an IAQ monitoring project and even help you on your way to gaining a RESET certification for your buildings, which will also help you with WELL and Fitwel certifications - please get in touch if you want to know more).

Why monitor indoor air quality

Good indoor air quality is often thought of subjectively. Human perception of good air quality is difficult as our senses evolved to deal with environments that were unpolluted. As long as we could detect smoke, which suggested an immediate threat (or, conversely, the possibility of a cooked meal and convivial company), air quality was not much of a concern to our plains-dwelling ancestors.

Inside buildings, we often only notice an issue with air quality when it directly affects our comfort. We might describe the air as heavy, fusty, stale or stuffy. Stuffiness (often as a result of elevated carbon dioxide from our exhalation, combined with warm temperatures and high humidity) can be alleviated by opening a window. Carbon dioxide (and airborne viruses, such as Covid-19) inside the building is diluted by bringing outside air in, and humidity and temperature might also be made more comfortable. This improvement to our comfort, achieved by a perceived improvement to indoor air quality, is not the whole story.

Opening the windows might risk exposure to other harms that are not readily detected by human senses. Fine particulates, volatile organic compounds or various oxides of nitrogen or sulphur are not usually detectable by human senses, so how do we know whether they are present?

Only by using calibrated IAQ monitors that measure, record and report key parameters of air quality can you then set out to manage air quality and reassure the users of the building that their safety and comfort is being looked after.

Without data from air monitoring, any management of indoor air quality is pretty-much based on guesswork, which is inadequate for the proper management of risk in a building.

Developing an IAQ monitoring strategy

An IAQ monitoring strategy is usually developed by understanding the physical space and the usage patterns of that space. Typically, an IAQ monitoring project relates to clearly defined spaces with distinctive occupancy patterns. Measuring IAQ in a corridor does not help anyone to understand IAQ issues in frequently-occupied small meeting rooms, so if a building has a variety of different types of space, then representatives of each typology must be monitored in order to provide any meaningful information.

Defining the project boundaries

RESET is a data standard for indoor air quality monitoring, and the standards employed enable a consistent and robust approach to setting up an IAQ monitoring project that will produce meaningful data. Even if an organization does not wish to pursue a full RESET certification (which comes with a cost), the RESET approach to IAQ monitoring will still be beneficial.

This means that the physical boundary of the space under assessment must be defined, the various types of space within the boundary be identified and the likely occupancy of the space be known. Meeting rooms occupied for, say, six hours a day are very different from large staff canteens that may be empty for most of the day, but packed at meal times.

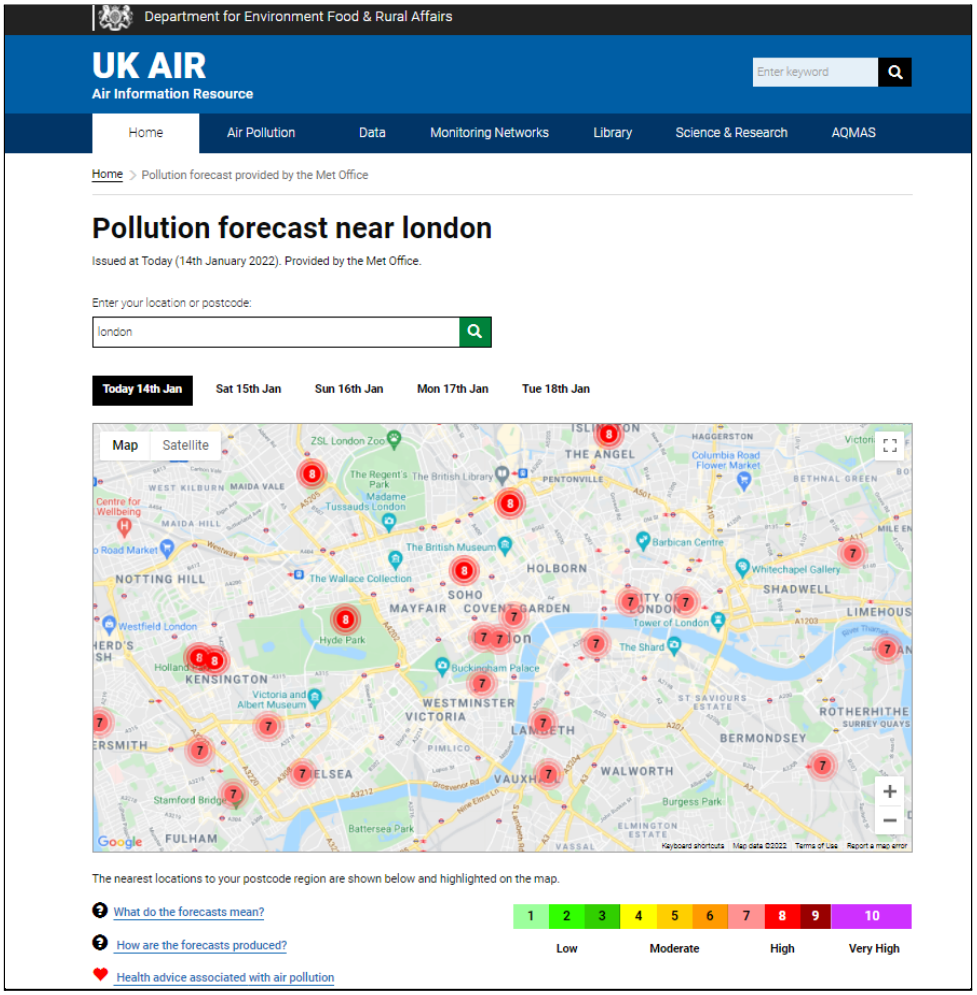
This means that for any location, a detailed site visit and copies of floor plans and occupancy statistics would be needed to ensure that the project scope and boundaries make sense and that monitors are deployed to get the most meaningful and useful data.

Baseline measurements

Before any interventions, such as the use of air purifiers, vegetation or changes to the HVAC systems are considered, it is necessary to measure the IAQ in all relevant locations for several days, ideally during a typical working week. Spot measurements with hand-held monitors are not suitable for understanding IAQ in large spaces. Their main use is to measure specific IAQ concerns at a particular location at a particular time - for example when investigating whether an industrial process results in the generation of pollutants, or to test whether a piece of equipment (e.g. an air purifier) is performing properly.

Indoor air quality is affected by both the indoor environment and the prevailing outdoor conditions. Because of this, a prolonged period of pre-intervention monitoring is recommended. Whilst there is a relationship between IAQ and outdoor AQ (often expressed as a ratio), this is not always representative of typical conditions in a building. Measuring IAQ during a period of lockdown (or even when workplaces are operating at significantly below 'normal' occupancy levels), or if the weather causes excess smog outdoors would both give very misleading information.

For example, if a spot measure of IAQ in London was taken this morning (14 January 2022), there is a very good chance that the prevailing outdoor conditions would give a very misleading result.



Outdoor air quality in London is very bad at the time of writing, and warnings have been issued to avoid exercise and strenuous activities if you are at risk of respiratory illness. The forecast for tomorrow, however, is for the outdoor air quality to be very good.

Air quality is often indicated by a score, or index. This is, effectively, a summary of the overall quality of the air, or the risk that is posed. Air quality indices (AQIs) are reported on websites from networks of external air quality monitors. There are many air quality monitors in place, as the map of central London (above) shows. You can find the data for other parts of the UK seen in real time here by entering a postcode or location into the search box.

Parameters

Indoor air quality monitors also often show a score, or index figure, as well as individual data points for the key parameters.

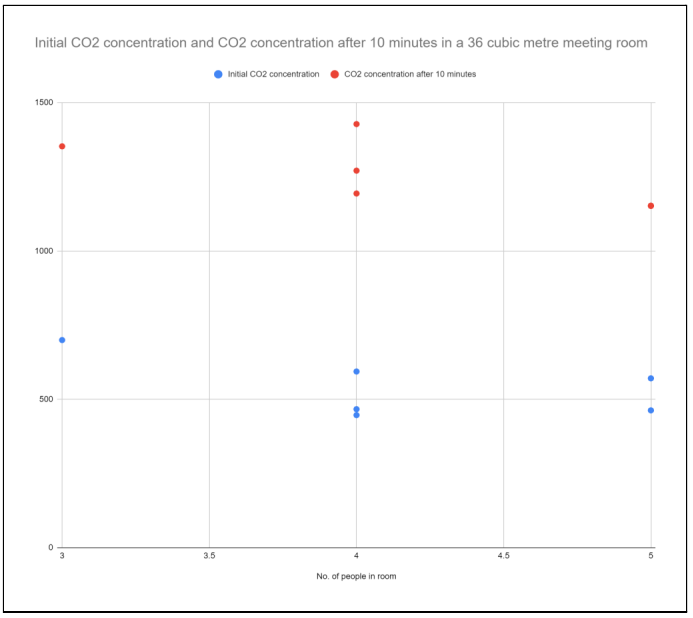
Awair Omni IAQ monitor showing an index score of 89

For indoor air quality monitors, the indices are often based on the worst score of the main measured parameters, and the IAQ index is often a score out of 100, where 100 represents excellent air quality (where all parameters exceed their threshold values). It is important to note that each monitor manufacturer has their own index (if used at all), so an index score displayed on one device may not be directly comparable with that displayed on a device made by a different manufacturer. However, if using calibrated or RESET certified IAQ monitors, the absolute values of each IAQ parameter should be comparable. The key parameters measured by IAQ monitors are as follows.

Carbon dioxide (RESET prerequisite)

The main source of carbon dioxide in a building is from people. Atmospheric CO₂ is roughly 415 ppm. Above 1,000 ppm people feel fatigued and at concentrations above 1,500 ppm various aspects of cognitive ability start to fall. A study carried out at the Lawrence Berkeley National Laboratory in the USA showed that "*On nine scales of decision-making performance, test subjects showed significant reductions on six of the scales at CO_2 levels of 1,000 parts per million (ppm) and large reductions on seven of the scales at 2,500 ppm. The most dramatic declines in performance, in which subjects were rated as 'dysfunctional,' were for taking initiative and thinking strategically.*"

I have carried out my own experiments at the Building Research Establishment (BRE) that consistently showed that as few as 4 people in a 35m^3 meeting room could elevate CO_2 levels from around 500 ppm to over 1,000 ppm in just10 minutes.



In many organizations, important business decisions are made in relatively small, closed rooms with insufficient ventilation. Information on high CO_2 levels might be useful in such situations.

VOCs (RESET prerequisite, recorded as tVOC)

Volatile organic compounds can include harmful pollutants, and high levels of VOCs should be investigated. However, most VOCs are not harmful in the quantities found in most buildings. In newly-refurbished, new-build properties, the source of VOCs is likely to be from furnishings and products used in the construction and finishing of the space (adhesives, painsts, etc.). In older buildings, the main source of VOCs is likely to be people (cosmetics, toiletries, biological emissions) or products related to cleaning and hygiene (toilet air fresheners, ambient scenting systems, etc.)

Different VOCs are difficult to distinguish, so a total VOC concentration (tVOC) measurement is recorded.

Fine particulates ($PM_{2.5}$ is a RESET prerequisite)

Fine particulates are implicated in respiratory illness and have been associated with premature deaths. Many fine particulates are the result of combustion, especially vehicle emissions. Most fine particulates inside buildings are brought in from outside through doors, windows and air handling systems, and many can evade filters. Monitoring of, and controlling fine particulates is important in managing risks to health in the indoor environment. $PM_{2.5}$ refers to particulates smaller than 2.5 µm in diameter.

Relative humidity (RESET prerequisite)

Relative humidity is an indicator of comfort. Dry air can exacerbate respiratory irritation, and high humidity can make a room feel stuffy and uncomfortable.

Temperature (RESET prerequisite)

As well as legal requirements for maintaining a comfortable working environment (in the UK, there are legal requirements to maintain a safe temperature in most workplaces), there is an interaction between temperature and humidity that affects thermal comfort and satisfaction of a space.

Carbon monoxide (only required in areas where gas is burned directly, e.g. kitchens or boiler rooms)

Monitoring of carbon monoxide is essential in areas where there is combustion. Carbon monoxide is a colourless, odourless gas that is fatal at high concentrations. Spaces that are heated by direct combustion (e.g. gas fires, or where a heating boiler is in an occupied space), or kitchens where naked flames are used for cooking, require a carbon monoxide monitor.

Covid-19 risk index (this is not a RESET prerequisite, but has been developed as a risk indicator)

Research carried out in late 2020 and early 2021 as a result of the Covid-19 pandemic has shown how ventilation is a very effective method of reducing the risk of infection. Carbon dioxide concentration is a good proxy measure of ventilation (the lower the CO_2, the more air changes are taking place). However, additional research has also shown that humidity and temperature are also mediating factors and a more fine-tuned assessment of risk is now possible (this also applies to other respiratory viruses, and research carried out as far back as 2013 shows a relationship between RH and influenza virus transmission). This is in the early stages of development, but worth bearing in mind.

Performance targets

The RESET standard has the following performance targets

$PM_{2.5}$	tVOC	CO_2	Temperature	RH	CO
Acceptable < 35 µg/m3	Acceptable < 500 µg/m3	Acceptable < 1,000 ppm	Monitored	Monitored	< 9 ppm
High performance < 12 µg/m3	**High performance < 400 µg/m3**	**High performance < 600 ppm**	Although there are no requirements for temperature and humidity under RESET™ Air, both must be monitored given their impact on sensor readings for $PM_{2.5}$ and tVOC.		CO monitors are only required in spaces with combustion.

Different grades of IAQ Monitor

The RESET standard recognises three grades of IAQ monitor.

Grade A monitors are used to calibrate other monitors under laboratory conditions and each sensor is independently calibrated according to published standards. These monitors are not suitable for monitoring IAQ in buildings, and they are also very expensive.

Grade B monitors are tested against Grade A monitors under laboratory conditions, and can also self calibrate to a degree. Their sensors are also repairable and replaceable, and these are the most appropriate monitors for IAQ monitoring in buildings, and are the type required by the RESET standard (and by extension, standards such as WELL, Fitwel and LEED). These devices are available for under £300 each and provide data certified to a high standard, which is available to building managers as well as building users. Some monitors are hard-wired and cannot be moved (so initial choice of

monitor location must be spot on), but others are more portable and can be moved as needed around the building.

Grade C monitors are designed for consumers and accuracy is not certified. Some are made by manufacturers of professional-grade (Grade B) monitors, but have not been certified. Some consumer grade IAQ monitors are available for under £100, but there is no guarantee of accuracy or consistency.

Currently-certified RESET Grade B monitors can be found here. The monitors also need to be associated with a certified data provider to ensure that IAQ data is available. Many monitor manufacturers are also certified data providers, but not all.

Many certified monitors provide data that can be integrated with existing building management information systems.

Interpretation of data and limitations

To have a real understanding of the IAQ of a space, data from monitors must be interpreted correctly. Snapshots of data are unlikely to provide valuable insight, as various parameters of IAQ can fluctuate quite quickly and may not be representative of real conditions.

It is also necessary to understand how the different parameters interact to create an overall condition of quality, and how quality requirements may change according to a given situation. For example, in order to reduce carbon dioxide and temperature (to increase ventilation), it may be necessary to tolerate higher short-term levels of fine particulates and VOCs. This may lead to an overall IAQ score being only 'satisfactory', but the important individual parameters - under the particular circumstances at that time - might provide an 'excellent' score. Relying on an overall IAQ score might not always be appropriate.

Having said that, most monitors that display an index score (as well as data for each IAQ parameter) base that score on the worst score of the key parameters. Nevertheless, interpretation of data in order to develop an IAQ management strategy should be based on an understanding of what the data over time show, not just a blind following of scores.

Benefits of RESET certification

Whilst it is entirely possible to develop an effective IAQ management strategy without RESET certification, there are some benefits in having the project certified. These are as follows:

Data quality assurance

RESET certified projects must use accredited monitors and data providers, so the quality of the information that you receive will be consistently high and reliable

Alignment with other building standards

Building standards such as WELL and Fitwel have a requirement for IAQ monitoring. RESET certification satisfies the IAQ prerequisites for both standards, so if your organization later pursues certification under WELL or Fitwel, then this aspect of the certification will be satisfied.

Transparency, engagement and empowerment

One of the requirements of RESET is that IAQ data is available in real time to building *users* as well as building managers and operators. This means that users of the building, such as office workers, customers, students or visitors can be assured that their health and safety is being well managed by the building operator, and it also empowers users of a space to make requests for changes to their environmental conditions based on objective data rather than emotion or gut feeling.

Choice / ratings

Organizations that are transparent in their reporting of health, wellbeing and sustainability are beginning to find that they are highly rated on reviews sites such as Glassdoor (as employers) or more informal review sites. This may have a positive effect on recruiting or retaining staff and attracting customers.

Impact of various interventions

Once an IAQ monitoring programme is in place, it becomes possible to start developing an IAQ management strategy and implement various interventions where needed.

Ventilation

This may be achieved by adjusting or modifying an HVAC system or making more use of opening windows and doors. By having IAQ data, the impact of the intervention, and the changes in risk associated with that can be better understood.

Air purification

Sometimes, the use of air purifiers and filters is suggested as a means to improve indoor air quality. These may be incorporated into the air handling system or be standalone devices placed as needed. Some newer air purifiers are very small (such as the Eteria, by Vitesy) and can be placed on desks - they provide very localized purified air, but are also very effective reducing the risk of transmitting air-borne viruses by capturing and purifying air breathed out by people nearby.

Larger air purifiers can take up a lot of space and frequently have the aesthetic appeal of a filing cabinet. In order to treat large volumes of air, they have to be powerful enough to draw untreated air over long distances to be purified before exhausting cleaned air with sufficient force to be distributed around the space.

Filters built into HVAC systems are also useful, especially to remove pollutants brought in from outside.

Some air purifiers have built-in air quality monitors. These can give some potentially useful indications of IAQ, but they are not RESET-certified monitors and, of course, only give information about the air immediately adjacent to the purifier, rather than for the whole space being treated.

Vegetation-based systems

Plants are often cited as being natural air purifiers, but their abilities are often over exaggerated. Laboratory research has shown that indoor plants are capable of removing VOCs (this seems to happen around the roots, and soil-dwelling bacteria associated with plant roots are responsible for the effect), but in real-life situations, there is often not - enough active physiology or sufficient quantity of plants to make much of an impact - especially if relying on plants in pots.

However, high densities of actively growing plants on green walls can make a real and measurable impact. Such systems encourage active growth and a healthy root environment, which can have useful impacts on carbon dioxide, VOCs and even fine particulates.

If indoor vegetation is also coupled with an increase in outdoor vegetation, especially if that is placed near HVAC intakes, then the positive impact on IAQ can be magnified.

Buildings close to large volumes of vegetation (e.g. near parks or woodland) may gain some additional benefit, especially when trees have all their leaves. The effect is, of course, less in the winter, when outdoor air quality can be poor, and which can be exacerbated by domestic wood burners.

Get in touch to arrange the development of an evidence-based IAQ monitoring and management system

My approach is evidence-based and consultative - there are no out-of-the-box solutions. These are the key steps in the process.

1. Detailed discussion to understand your air quality concerns and reasons why you might need a solution
2. Detailed site survey to confirm the areas under consideration for monitoring
3. Report and recommendations about the number and placement of monitors
4. Installation of monitors. Continuous monitoring to take place for a few weeks (I recommend a minimum of 4 weeks) to gain an understanding of IAQ issues in each area
5. Analyse IAQ data in the context of local outdoor air quality (available from public sources)
6. Produce a report and recommendations for action
7. Discuss whether the client wishes to pursue RESET certification along with recommendations for interventions
8. Maintain IAQ monitors in required locations in the building to provide useful data and evidence of the efficacy of the interventions.
9. Ongoing interpretation of the data and make recommendations as needed as part of an ongoing service.

Contact me on +44 (0) 7543 500729 or send an email to kenneth@purposefulplaces.co.uk