Airvoice Indoor Air Quality Index (IAQI): How It Works and Why It Matters

Introduction

This document explains the logic, structure, and methodology behind the Airvoice Indoor Air Quality Index (IAQI). It is intended for:

- Facility managers and operators
- Green building and HVAC consultants
- Health & safety officers
- Researchers, regulators, and other professionals working with indoor environmental data

The IAQI helps users translate complex indoor air quality measurements into clear, actionable categories. It is built on internationally recognized health guidelines, scientific research, and practical insights from real-world building operations.

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What Is the Airvoice IAQI?

The Airvoice Indoor Air Quality Index (IAQI) is a numerical indicator designed to help users understand the current state of indoor air quality and whether any action is needed. It translates measured concentrations of key air pollutants into an intuitive, categorical assessment:
Good, *Fair*, or *Poor*.

This categorization is determined based on scientifically grounded thresholds for the following core air quality parameters:

- PM2.5 (fine particulate matter),
- PM10 (coarse particulate matter),
- CO_2 (carbon dioxide).

To provide a more detailed view, Airvoice also uses a 10-point IAQI scale, which assigns a score from 1 (Good) to 10 (Hazardous) based on the levels of these same pollutants. The exact breakpoints used in this extended scale are provided in the How We Calculate IAQI section.

The IAQI is not just a passive measurement. It serves as a practical guide indicating when air quality is acceptable and when it may *pose risks to health, comfort, or cognitive performance*. While not all values represent immediate danger, the system is designed to make complex air quality data understandable and actionable for building operators, facility managers, and everyday users.

How Airvoice Interprets Indoor Air Quality

a. Air Quality Parameters: PM2.5, PM10, CO_2

Airvoice interprets air quality using three universally relevant parameters: PM2.5 (particulate matter with diameter ≤ 2.5 microns), PM10 (particulate matter with diameter ≤ 10 microns), and CO_2 (carbon dioxide).

These are selected for their direct links to human health and cognitive performance. Unlike thermal comfort parameters, which vary by region, the thresholds for these pollutants are consistent across all locations where Airvoice systems are deployed.

Each parameter is evaluated within three bands:

- Good – No action required
- Fair – Acceptable, but improvement is recommended

- Poor – May impact health or performance; action should be considered

The scientific rationale behind these breakpoints is detailed in the Scientific Foundations and Methodology section below.

Parameter	Good	Fair	Poor
PM2.5 (µg/m³)	< 9 [1]	9 – 35 [1]	≥ 35 [1]
PM10 (µg/m³)	< 50	50 – 150 [1]	≥ 150 [1]
CO_2 (ppm)	< 600 [2,3]	600 – 900 [2,3]	≥ 900 [2,3]

Table 1. Airvoice IAQI Core Parameters and Thresholds.
Each range includes its lower bound, while the upper bound belongs to the next higher AQI range.

b. Air Comfort Parameters: Temperature and Relative Humidity

In addition to air quality, indoor thermal and humidity comfort plays a critical role in well-being, productivity, and health. Airvoice monitors two key comfort-related parameters:

- Temperature (°C)
- Relative Humidity (RH, %)

Unlike air quality thresholds, which are based on physiological limits and are largely universal, comfort parameters vary by region. Airvoice adapts these breakpoints based on regional standards and recommendations from local environmental and health agencies, while still referencing globally recognized research.

Parameter	Very Low	Low	Normal	High	Very High
Temperature (°C)	< 18 [4]	18 – 20	20 – 26 [5]	26 – 28	≥ 28
Humidity (%)	< 25	25 – 40	40 – 60 [5]	60 – 75 [7,8]	≥ 75 [7,8]

Table 2. Comfort Parameters: Temperature and Humidity Ranges.
Each range includes its lower bound, while the upper bound belongs to the next higher AQI range.

c. TVOC as a Supplementary Metric

Total Volatile Organic Compounds (TVOC) are monitored by Airvoice as a supplementary air parameter. While TVOC is not included in the core IAQI calculation, it is displayed in the user interface and can be potentially referenced in air quality reports when required by certification standards or customer expectations.

TVOC readings are widely available in low-cost indoor monitoring devices, but the metrics remain poorly standardized, and its health relevance is unclear. For this reason, Airvoice treats TVOC separately and transparently communicates its measurement limitations.

Parameter	Good	Fair	Poor
TVOC (μg/m³) [9]	< 500	500 – 800	≥ 800
TVOC (ppb)	< 215	215 – 343	≥ 343

Table 3. TVOC Supplementary Thresholds.
Each range includes its lower bound, while the upper bound belongs to the next higher AQI range.

Scientific Foundations and Methodology

While developing Airvoice breakpoints, we aimed to base them on scientific findings related to human physiology wherever possible. This approach contrasts with the more common method of adopting thresholds directly from national regulations or green building certification frameworks.

This science-based method, however, is complicated by two main factors:

- Lack of clearly defined threshold effects: In real-world conditions, there are no abrupt step changes in health risk as pollutant concentrations increase. This makes the task of defining discrete breakpoints inherently abstract.

- Limited scientific data for certain pollutants: For some compounds, especially particulate matter, scientific evidence on health and cognitive effects remains insufficient. At present, Airvoice uses only mass concentration as the basis for its PM-related thresholds, without factoring in other parameters such as chemical composition.

Although we recognize that assigning categorical labels to values along a continuous scale may introduce ambiguity, particularly near category boundaries, we believe this remains the clearest and most usable way to interpret indoor air quality data.

Moreover, the interpretation of these categories continues to offer statistically meaningful insights for assessing air quality and informing action.

While we make every effort to ensure that our breakpoints are scientifically grounded, in some cases, where direct evidence is lacking, we follow recommendations from national agencies. One exception is TVOC, for which Airvoice applies thresholds defined by the Indian Green Building Council, in line with the regional focus of our current products.

Below, we describe the methodology used for each monitored parameter.

Particulate Matter (PM2.5 and PM10)

Breakpoints for PM2.5 and PM10 are derived from the U.S. EPA National Ambient Air Quality Standards (NAAQS) [1] and supported by the WHO Global Air Quality Guidelines [10]. These are among the most widely used references in environmental health and are also reflected in several green building certification programs.

While originally developed for outdoor air, these standards offer a practical benchmark for indoor air as well. However, their application indoors presents two key challenges:

- Characteristic time scale mismatch: Ambient air quality standards are defined for fixed and relatively long averaging periods, such as 24-hour or annual means, that correspond to the characteristic time scales of the atmospheric processes affecting air quality change. Indoor air quality, however, can vary substantially over much shorter time scales (minutes to hours) due to occupant activities and ventilation dynamics. Therefore, directly applying ambient thresholds to indoor environments may not adequately reflect short-term exposure patterns.

- Different potential for control and amenability for interventions: Outdoor air is harder to manage while indoor environments offer more potential for intervention, therefore it may be feasible and appropriate to impose stricter requirements for indoor air quality than for ambient air in the future.

Despite these limitations, NAAQS-derived values remain the most consistent, scientifically recognized basis available for evaluating indoor particulate concentrations.

Carbon Dioxide (CO_2)

CO_2 thresholds are based on findings from controlled exposure studies, including those by Allen et al. (2016) and Satish et al. (2012). These studies demonstrated statistically significant declines in cognitive performance at elevated indoor CO_2 levels.

- 600 ppm is associated with optimal cognitive functioning and is used as the lower limit of the “Fair” range.
  900 ppm corresponds to the point where declines in decision-making and information processing begin to emerge.

Though these are not formal health limits, they offer a scientifically meaningful benchmark for interpreting indoor CO_2 levels in relation to cognitive performance and ventilation effectiveness.

In addition to cognitive effects, elevated CO_2 is a strong indicator of insufficient ventilation, which has been directly linked to increased risk of airborne transmission of respiratory infections, including influenza and COVID-19. While CO_2 itself is not infectious, poor ventilation allows airborne pathogens to accumulate, making CO_2 a reliable proxy for evaluating the likelihood of cross-contamination in shared indoor spaces.

As such, maintaining lower CO_2 concentrations is important not only for comfort and productivity, but also for health protection in schools, offices, hospitals, and other high-occupancy environments.

Temperature and Relative Humidity

Airvoice groups temperature and humidity under Air Comfort parameters. Unlike pollutant thresholds, these values are regionally adaptable and based on a combination of health, comfort, and productivity factors.

- Temperature breakpoints are based on a systematic review by Tham et al. (2020), which links indoor temperatures above 26 °C to increased respiratory health risks.
- Relative Humidity (RH) thresholds draw from Moriyama et al. (2020), who recommend maintaining 40–60% RH to reduce viral transmission. The upper limit of 75% is based on WHO guidance and Johansson et al. (2005), which highlight the risk of mold growth, especially on wooden surfaces.

Since temperature and humidity interact, combined thermal comfort models are entering widespread adoption, e.g. models using RH(T) zones in accordance with ASHRAE Standard 55. [11]

Total Volatile Organic Compounds (TVOC)

TVOC is treated as a supplementary metric, not included in IAQI scoring due to its complex and non-standardized nature.

Airvoice measures TVOC using metal-oxide (MOX) gas sensors, which are broadly sensitive but non-specific. These sensors:

- React to a wide range of gases with varying strength
- Suffer from cross-sensitivity effects (e.g., gas mixtures causing exaggerated signals)
- Lack standardized conversion from signal output (mV/Ohms) to ppb or $\mu g/m^3$

Additionally, TVOC presents two major interpretation challenges:

1. Mass vs. volume inconsistency — different VOCs contribute unequally to $\mu g/m^3$ and ppb values
2. Low practical relevance — similar readings may reflect harmless activities (e.g. spraying perfume) or hazardous ones (e.g. solvent spills), offering little clarity on what action is needed

Despite this, Airvoice displays TVOC levels for users and uses thresholds from the Indian Green Building Council (IGBC) Health & Well-being Rating System, with µg/m3 to ppb conversion based on isobutylene equivalency, as per the the RESET Air Standard v2.0 [12].

> TVOC is not factored into IAQI scoring or automated recommendations but is often useful in trend analysis, especially for detecting activities like cooking, cleaning, smoking, or alcohol consumption indoors.

How We Calculate IAQI

The Airvoice Indoor Air Quality Index (IAQI) is calculated based on three key air quality parameters: PM2.5, PM10, and CO_2.

For each parameter, a partial IAQI score is determined according to its concentration. The final IAQI value is calculated as the highest of the three partial scores. This method ensures that the most critical pollutant at any given time is reflected in the overall IAQI.

A full table of partial IAQI breakpoints is provided below.

IAQI	Label	PM2.5, µg/m³	PM10, µg/m³	CO_2, ppm
1	Good	< 5 [10]	< 15 [10]	< 450
2	Good	5 – 9 [1]	15 – 50	450 – 600 [2,3]
3	Fair	9 – 20	50 – 100	600 – 750
4	Fair	20 – 35 [1]	100 – 150 [1]	750 – 900 [2,3]
5	Poor	35 – 50	150 – 200	900 – 1,200
6	Poor	50 – 75	200 – 250	1,200 – 1,500
7	Poor	75 – 100	250 – 300	1,500 – 1,900
8	Poor	100 – 150	300 – 350	1,900 – 2,400
9	Poor	150 – 250	350 – 500	2,400 – 5,000 [13]
10	Hazardous	≥250	≥500	≥5,000

Table 4. Complete 10-Point IAQI Scale with Parameter Breakpoints.
Each range includes its lower bound, while the upper bound belongs to the next higher AQI range.

Limitations of the Current Model

While the highest-score approach offers a simple and conservative way to highlight potential risks, it has three main limitations:

- **Non-dominant pollutants have no influence on the overall score**
  For example, if PM2.5 is elevated but CO_2 and PM10 remain within acceptable levels, the IAQI will reflect only the PM2.5 level. This may underrepresent the combined impact of all pollutants present.

- **Health impacts vary significantly between pollutants**
  Particulate matter and carbon dioxide differ not only in their physical properties but also in how they affect health. PM2.5 and PM10 are linked to long-term respiratory and cardiovascular risks, while CO_2 primarily affects cognitive function, with short-term, reversible effects. As a result, two environments with the same IAQI score could pose very different health risks depending on which pollutant is dominant.

- **Actions prompted by the dominant pollutant may ignore (or even worsen) the needs related to other pollutants**
  For instance, elevated CO_2, often a result of insufficient ventilation, can typically be mitigated by opening a window. But in areas with high outdoor pollution, doing so may increase indoor PM2.5 concentrations, reducing overall air quality.
  This tradeoff is not captured by the current IAQI model, which presents a single score without context about pollutant sources or mitigation strategies.

Looking Ahead

To address these challenges, Airvoice is developing a revised IAQI framework. In this updated version, the IAQI will be represented as a three-dimensional vector with distinct components:

- Air Clarity – based on particulate matter (PM2.5 and PM10)
- Freshness – based on CO_2 levels
- Comfort – based on temperature and humidity

This new approach will enable a more nuanced and actionable interpretation of indoor air quality, more accurately reflecting both the health impacts of different pollutants and the interventions they require.

Conclusion

The Airvoice Indoor Air Quality Index (IAQI) is designed to bridge the gap between raw environmental data and practical, health-relevant insights. By combining physiological research, regulatory guidance, and field experience, we aim to make indoor air quality measurable, interpretable, and actionable for building operators, health officers, and individuals alike.

While the current IAQI model already provides clear and conservative assessments of indoor environments, we recognize its limitations and are actively working to improve its precision and responsiveness.

We believe that informed decisions begin with transparent data. This document is part of our commitment to making the invisible visible, and the complex clear.

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