Image Above: A sample design of the RESET Viral Index Dashboard.

RESET Viral Index v1.0 - FINAL

Whitepaper

v1.0 Final: 2022.11.20

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1. Abstract

Introduction

Historical and contemporary research has been conducted on virus transmission, infectivity, and survivability, as has research on the effects of humidity, temperature, and particulate matter (PM) on the human immune system. There exist few tools (infection estimators) of virus transmission via airborne pathways, but none that utilize continuous monitoring data to help inform the built environment in pandemic conditions.

One of the factors contributing to this is a lack of data linking outcomes of interest to real-time environmental sensor data. Outcomes such as airborne viral transmission in low-humidity conditions (<30%), risk of transmission of aerosolized virus particles, and increased susceptibility to mortality from COVID-19 as a result of exposure to particulate matter (PM), are all being researched as part of infection prevention protocols. However, there is a gap in our understanding and ability to link these outcomes to real-time environmental sensor data.

The goal of this effort is to interpret the available research on virus transmission, infectivity, and survivability and apply it to human health using the RESET Air Standard for continuous monitoring data to inform the built environment and building operations during a pandemic.

Methodology

The research focus would be on air quality that currently can be reliably detected by continuous, sensor technology, including:

- Temperature
- Relative humidity
- Particulate Matter
- CO2

After compiling our research, the following content was found to be:

- **virus transmission, infectivity, and survivability** using the parameters of temperature and relative humidity
- **impacts on the human immune system** using the parameters of temperature, relative humidity, and particulate matter
- **potential amount of virus particles** in the air, using CO2 as a proxy for virus particles being emitted by individuals.

Resultant Formula

The resultant formula for the RESET Viral Index is, therefore:

$$\mathbf{AIP} = \frac{\mathrm{VS} * \mathrm{IS_{PM}}}{\mathrm{IS_{RH}}} * \mathrm{PVDr}$$

AIP is the raw calculated result from the formulation

$$\mathbf{RVI} = (1 - \mathbf{AIP}) * 100\%$$

RVI turns AIP into a more straightforward index

When $(1 - \mathrm{AIP}) < 0$, RVI is taken to be 0%

VS	Virus Survivability
IS_{PM}	$PM_{2.5}$ Impact on Immune System
IS_{RH}	%RH Impact on Immune System
PVDr	Potential Viral Dosage Risk
AIP	Airborne Infection Potential
RVI	RESET Viral Index

2. Preface

Currently, there are no means to quantify a building's safety with respect to airborne viral transmission.

Many industry organizations and associations are publishing guidelines that outline best practices for the safe maintenance and operation of buildings during the SARS-CoV-2 pandemic, but oftentimes, there is a lack of empirical evidence to support the advice as outlined, potentially causing confusion and contradictions in the market. If there is empirical evidence, it is the result of scientific research conducted in laboratory settings where the conditions, boundaries, limits, and methods are purposefully narrow and specifically designed to serve a precise condition and particular objective. While this is a criterion for academic research, it limits the extrapolation of the findings to real, operating buildings. Therefore, how to maintain and operate a building under *the* conditions of a pandemic (SARS-CoV-2) is still fraught with uncertainty.

To navigate successfully through pandemic scenarios and/or air quality events, the real estate industry could significantly benefit from having a reliable index that reveals to occupants and operations teams the level of optimization an indoor space is over periods of occupancy to limit the potential risk of transmission in real-time.
Therefore, we need to:

1. translate empirical evidence from scientific research and apply it to real-world applications.
2. Identify the level of uncertainty that occurs when this translation is made.
3. Establish feedback loops between scientists and building operators.

Purpose

The purpose of this effort is to review and interpret a body of available research regarding the impact of environmental quality on viral transmission in the built environment, to improve our ability to apply it to the evaluation of indoor air quality via continuous monitoring, and to assess occupants' vulnerability to airborne transmission of SARS-CoV-2.

Building owners and operators have a role to play in protecting building occupants and facilitating improved operations. To do so, it is critical to have the ability to evaluate and optimize indoor environments in order to minimize the risk of potentially harmful pathogens, including viruses. The ability to evaluate the indoor environmental quality

(IEQ) is part of a total risk evaluation for viral transmission and/or infection prevention program and is the focus of this effort.

Goal

Leveraging an existing standard, the RESET Air Standard, which is explicitly written for the built environment and outlines rules for the proper deployment of, and data collection from, continuous monitoring sensor technology, our goal was to define an index that relates indoor air quality with the potential infection rate of an airborne virus, focusing on the air quality variables that a building can control and measure via continuous monitoring/sensors.

By monitoring and reporting levels of particulate matter (PM), temperature, relative humidity, and CO_2, the index is intended to help reveal how optimized a building or indoor space is for minimizing the potential of airborne viral transmission.

3. Methodology

To create the RESET Viral Index, intended for application to real-time conditions in the built environment, information and findings from academic/medical research were extracted and put into a format that could be processed.

Our approach was to map the relevant data directly with minimal interpretations, extrapolations, or interpolations. If extrapolations and/or interpolations were made, we did so by making note of the assumptions and noting the resulting degree of confidence (%) in the data. When research findings could not be extracted and/or processed due to lack of information, unitless data, or data that could not be converted, we retained the research in our body of reference material, but did not include it in our tabulation(s).

Due to the lack of research studies directly on airborne viral transmission, we expanded the scope of our research to include other parameters that can affect airborne viral transmission. We focused on research that corresponded with indoor air quality parameters that can currently be easily monitored in the built environment, including temperature, relative humidity, $PM_{2.5}$, and CO_2.

We mapped the findings from the research publications and the resulting framework consists of four parts:

a. Virus Survivability
b. Immune System Health
c. $PM_{2.5}$ Health Impact
d. Potential Viral Dosage

Note that research publications typically pertained to only one type of virus: Influenza, SARS-1, or SARS-CoV2. Additionally, research publications typically did the research at only one temperature.

Our organization methodology for the research publications and the data collected involved first separating the research into the different virus types. Then, for each virus type, we further separated the results into different temperatures, where we would include the relevant research paper and highlight the results.

4. Results and Findings

The results and findings were compiled into the following:

a. Virus Survivability (VS)

Virus Survivability (VS) is the first part of the equation and is a percent index expressing how long viruses can survive airborne or in aerosolized particles. For the virus survivability's percent index, a higher percentage means that the virus is capable of surviving as an airborne virus for a longer period of time.

VS is affected by relative humidity and temperature. To derive the formula for VS, data from three papers were referenced:

- G. J. Harper. Airborne microorganisms: survival tests with four viruses. 1961.
- Kaizen Lin and Linsey C. Marr. Humidity Dependent Decay of Viruses, but Not Bacteria, in Aerosols and Droplets Follows Disinfection Kinetics. 2020.
- John D. Noti. High Humidity Leads to Loss of Infectious Influenza Virus from Simulated Coughts. 2013.

For the RESET Viral Index, the research heavily leans on virus survivability data for influenza because the only viable research results were for the influenza virus. The data was collected in studies that were performed in temperatures of approximately 22°C, a comfortable indoor temperature, therefore relevant for typical indoor environments.

The data is organized by reviewing each research paper and gathering the infection results at differing levels of relative humidity. Results from the three research publications were then combined and averaged and the mean standard deviation was used to derive the worst-case scenario to be conservative, producing the following graph and table:

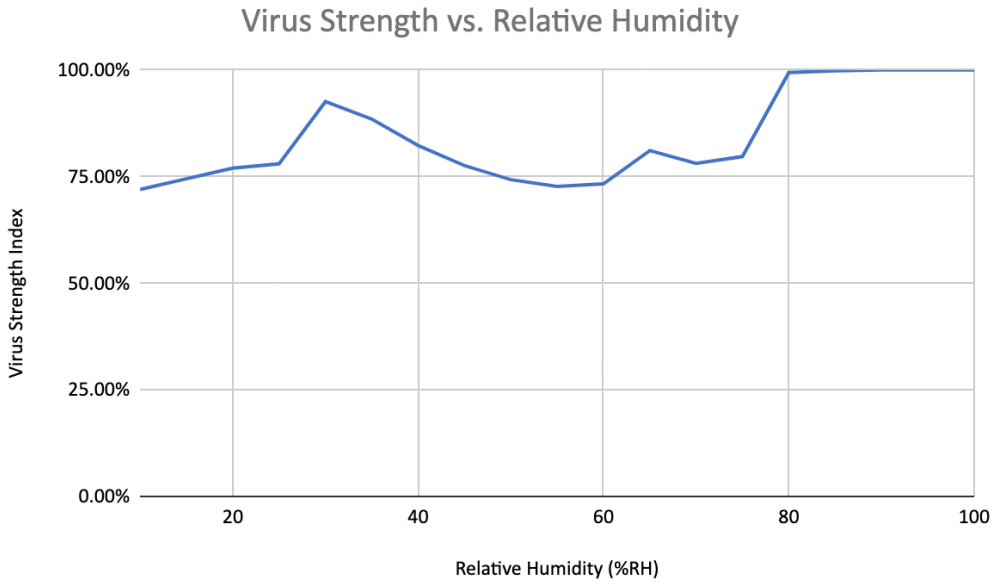

Figure 1 shows the interpolated results for virus strength relative to relative humidity.

RH (%RH)	VS	VS (%)
10	0.720	72.0
15	0.745	74.5
20	0.770	77.0
25	0.780	78.0
30	0.926	92.6
35	0.885	88.5
40	0.823	82.3
45	0.776	77.6
50	0.743	74.3
55	0.727	72.7
60	0.733	73.3
65	0.811	81.1
70	0.781	78.1
75	0.797	79.7
80	0.994	99.4
85	0.998	99.8
90	1.000	100.0
95	1.000	100.0
100	1.000	100.0

Table 1 shows the interpolated results for virus strength relative to relative humidity.

Formula for VS

The formula for VS is derived from the results in Table 1. The formula uses a linear piecewise function. Relative Humidity (RH) = x, where x is a number between 10 and 100.

$$f(x) = \begin{cases} 0.5(x-10)+72, & 10 < x \leq 15 \\ 0.5(x-15)+74.5, & 15 < x \leq 20 \\ 0.2(x-20)+77, & 20 < x \leq 25 \\ 2.92(x-25)+78, & 25 < x \leq 30 \\ -0.82(x-30)+92.6, & 30 < x \leq 35 \\ -1.24(x-35)+88.5, & 35 < x \leq 40 \\ -0.94(x-40)+82.3, & 40 < x \leq 45 \\ -0.66(x-45)+77.6, & 45 < x \leq 50 \\ -0.32(x-50)+74.3, & 50 < x \leq 55 \\ 0.12(x-55)+72.7, & 55 < x \leq 60 \\ 1.56(x-60)+73.3, & 60 < x \leq 65 \\ -0.6(x-65)+81.1, & 65 < x \leq 70 \\ 0.32(x-70)+78.1, & 70 < x \leq 75 \\ 3.94(x-75)+79.7, & 75 < x \leq 80 \\ 0.08(x-80)+99.4, & 80 < x \leq 85 \\ 0.04(x-85)+99.8, & 85 < x \leq 90 \\ 100, & 90 < x \leq 100 \end{cases}$$

Function 1 shows the interpolated results for Viral Strength (VS) relative to relative humidity.

The above piecewise function features a series of functions relevant to the x between a certain relative humidity reading. For example, when x is between 10% and 15% RH, VS can be calculated using the equation f(x) = 0.5(x-10) + 72, where x = RH.

b. Immune System Health (IS_{RH})

Immune System Health due to %RH (IS_{RH}) is a percent index expressing how strong an average individual's immune system is in relation to relative humidity. IS_{RH} is optimal at 100%, while at 0%, reflects that the average individual's IS_{RH} is severely affected and compromised, and thus more susceptible to airborne viral infections.

IS_{RH} is affected by relative humidity and temperature. To derive the formula for IS_{RH}, data from the following paper was used:

- Arundel. Indirect Health Effects of Relative Humidity in Indoor Environments. 1986

For the RESET Viral Index, the research explores how different levels of relative humidity affect the immune system and an individual's susceptibility to catching influenza. The data collected in the study was performed in temperatures of approximately 22°C, a comfortable indoor temperature, therefore relevant for typical indoor environments.

The data is organized by reviewing the research and gathering the infection results at differing levels of relative humidity. The results from the research publication were used to derive the worst-case scenario to be conservative, producing the following graph and table:

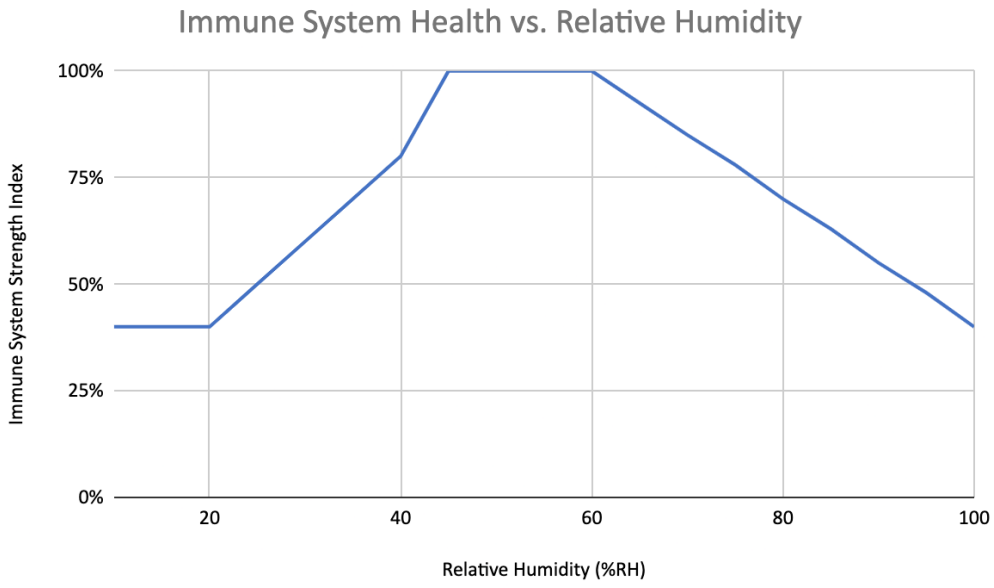

Figure 2 shows the interpolated results for immune system health relative to relative humidity.

RH (%RH)	IS_{RH}	IS_{RH} (%)
10	0.400	40.0
15	0.400	40.0
20	0.400	40.0
25	0.500	50.0
30	0.600	60.0
35	0.700	70.0
40	0.800	80.0
45	1.000	100.0
50	1.000	100.0
55	1.000	100.0
60	1.000	100.0
65	0.925	92.5
70	0.850	85.0
75	0.780	78.0
80	0.700	70.0
85	0.630	63.0
90	0.550	55.0
95	0.480	48.0
100	0.400	40.0

Table 2 shows the interpolated results for immune system health relative to relative humidity.

Formula for IS_{RH}

The formula for IS_{RH} is derived from the results in Table 2. The formula uses a linear piecewise function. Relative Humidity (RH) = y, where y is a number between 10 and 100.

When Relative Humidity (%RH) = y, then IS_{RH} is given by:

$$f(x) = \begin{cases} 40, & 10 < x \leq 20 \\ 2(x-20)+40, & 20 < x \leq 45 \\ 100, & 45 < x \leq 60 \\ -1.5(x-60)+100, & 60 < x \leq 70 \\ -1.4(x-70)+85, & 70 < x \leq 75 \\ -1.6(x-75)+78, & 75 < x \leq 80 \\ -1.4(x-80)+70, & 80 < x \leq 85 \\ -1.6(x-85)+63, & 85 < x \leq 90 \\ -1.4(x-90)+55, & 90 < x \leq 95 \\ -1.6(x-95)+48, & 95 < x \leq 100 \end{cases}$$

Function 2 shows the interpolated results for immune system health relative to relative humidity.

The above piecewise function features a series of functions relevant to the x between a certain relative humidity reading. This means that when the Relative Humidity (RH) in a space lies between 20-25%, IS_{RH} can be calculated using the equation 2(y-20) + 40, where y = relative humidity.

c. $PM_{2.5}$ Health Impact (IS_{PM})

$PM_{2.5}$ is particulate matter that has a diameter of 2.5 microns or less. $PM_{2.5}$ can remain suspended in the air for long periods of time and when inhaled, can penetrate deep inside the human lungs.

$PM_{2.5}$ Health Impact (IS_{PM}) describes the connection between exposure to $PM_{2.5}$ on human health and the increased potential to contracting a viral infection via airborne transmission. IS_{PM} is a percent index that describes the impact of $PM_{2.5}$ on an individual's health and susceptibility to viral infections. IS_{PM} is a supplement to the second formula, Immune System Health, and it starts at 100% and increases linearly depending on the amount of $PM_{2.5}$.

IS_{PM} is affected by $PM_{2.5}$. To derive the formula for IS_{PM}, data from the following paper was used:

- Cindy Feng, Jian Li, Wenjie Sun, Yi Zhang, Quanyi Wang. 2016. Impact of ambient fine particulate matter (PM) exposure on the risk of influenza-like-illness: a time-series analysis in Beijing, China. Environ Health 15, 17 (2016). https://doi.org/10.1186/s12940-016-0115-2

The research looked at how different levels of $PM_{2.5}$ affect the immune system and an individual's susceptibility to catching influenza.

The data was interpreted by reviewing the research and gathering the infection results at differing concentrations of $PM_{2.5}$. Specifically, data for the 25-59 age group was used during the flu season, comparing $PM_{2.5}$ concentration with the number of cases, which was then extrapolated.

Disclaimer: The results show ambient $PM_{2.5}$ concentration does have a positive effect on infection risk, but there is not enough data to calculate an exact impact. As more research gets shared, this part of the equation will be updated.

The results from the research were then combined to derive the worst-case scenario, producing the following table:

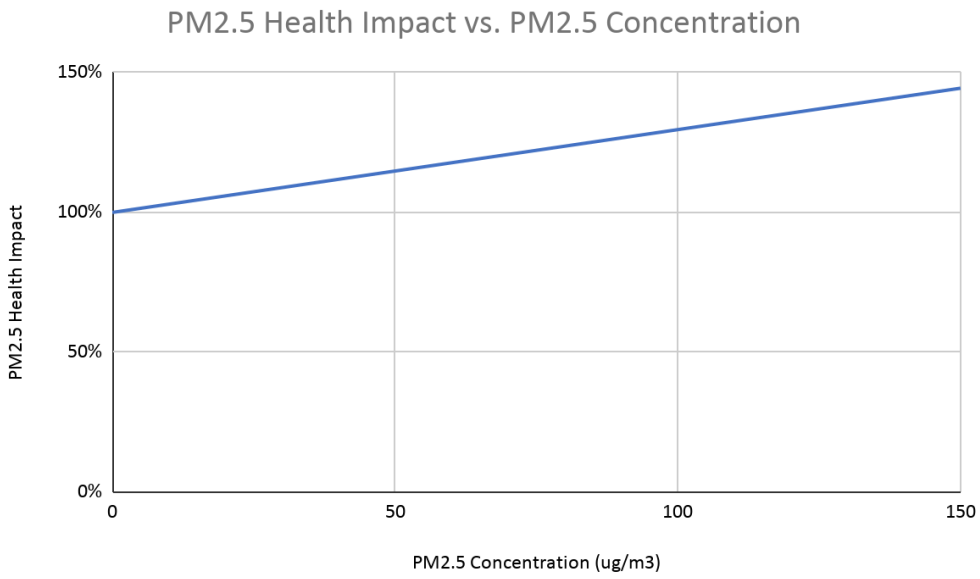

Figure 3 shows the extrapolated results for immune system health relative to $PM_{2.5}$.

$PM_{2.5}$ (ug/m3)	IS_{PM}	IS_{PM} (%)
10	1.030	103.0
20	1.059	105.9
30	1.089	108.9
40	1.118	111.8
50	1.148	114.8
60	1.178	117.8
70	1.207	120.7
80	1.237	123.7
90	1.266	126.6
100	1.296	129.6
110	1.326	132.6
120	1.355	135.5
130	1.385	138.5
140	1.414	141.4
150	1.444	144.4

Table 3 shows the extrapolated results for immune system health relative to $PM_{2.5}$.

Formula for IS_{PM}

The formula for IS_{PM} is then derived by leveraging the table above.

The formula is a linear equation which, estimates the effect of $PM_{2.5}$ on the increased risk of viral transmission at a given concentration of $PM_{2.5}$.

When $PM_{2.5}$ = x, then IS_{PM} is given by:

$$f(x) = 1 + \left(0.0296 * \frac{x}{10} \right)$$

Function 3 shows the interpolated results for immune system health relative to $PM_{2.5}$.

The findings show a linear trend for IS_{PM}. When the concentration of $PM_{2.5}$ increases, so does the susceptibility of an individual to contract an influenza-like illness.

d. Potential Viral Dosage

Potential Viral Dosage (PVDr) is a percent index that represents the chance of becoming infected by measuring the potential amount of virus particles breathed in by an occupant. This is determined by calculating potentially how many virus particles are in the air in a defined space.

PVDr is extrapolated by correlating the number of potential viruses in the space, exposure strength, and exposure duration with CO_2 levels in an indoor space. To calculate PVDr, the breakdown includes eight different parts (skip to the bottom of this section to see the final calculation for PVDr):

i. **Average CO_2 exhaled per person per minute in ppm**
This calculation extrapolates how much a person breathes and correlates that with the CO_2 levels in the air.

PPM (particles per million) is equivalent to ml/m^3, so we calculate that by taking the [average CO_2 exhaled per person in ml/min] and dividing it by the "volume of space". The [average CO_2 exhaled per person in ml/min] is defined as 280 ml/min.

The 280 ml/min is calculated using the following logic:

If a healthy young adult weighs 75 kg, he/she exhales 7 ml/kg, or 500 ml as the tidal volume (https://en.wikipedia.org/wiki/Tidal_volume), the breath volume without extra effort.

Exhaled air has 4% CO_2, while inhaled air has 0.04%, with an approximate difference of 4%. 500 ml with 4% CO_2 equals 20 ml of CO_2. Averaging the typical 12 to 16 breaths per minute (https://www.hopkinsmedicine.org/health/conditions-and-diseases/vital-signs-body-temperature-pulse-rate-respiration-rate-blood-pressure), we're looking at an average of 14 breaths per minute, which equates to 280 ml/min.

$$[average\ CO2\ exhaled\ per\ peson\ per\ minute\ in\ ppm] = \frac{[average\ CO2\ exhaled\ per\ person\ in\ ml\ per\ minute]}{[volume\ of\ space]}$$

ii. **Total CO_2 exhaled per minute by all people in the space**
This calculation is extrapolated by multiplying the "average CO_2 exhaled per

person per minute in ppm" by the number of "people in the space". For the purposes of this equation, we will have 10 people in the space. The "number of people in the space" is arbitrary because this variable gets canceled out.

$$[total\ CO2\ exhaled\ per\ minute\ by\ all\ people\ in\ the\ space] = [average\ CO2\ exhaled\ per\ person\ per\ minute\ in\ ppm] * [number\ people\ in\ the\ space]$$

i. **Number of minutes to get to a certain CO_2 level**

This calculation is extrapolated by dividing the total increase of CO_2 levels by how long it takes for Total CO_2 to be exhaled. To do this, we needed to define the "size of the space" and the "number of people in the space". For the purposes of this experiment, we decided to use 750 m^3 and 10 people. At a rate of 280 ml/min of CO_2 exhaled per person, we were able to determine that 10 people would take approximately 13.4 minutes to increase the CO_2 levels by 50 ppm to 450 ppm, starting from an optimal CO2 level of 400 ppm, in a 750 m^3 enclosed space.

ii.

$$[number\ of\ minutes\ to\ get\ to\ a\ certain\ CO2\ level] = \frac{[current\ CO2\ level] - [optimal\ CO2\ level]}{[total\ CO2\ exhaled\ per\ minute\ by\ all\ people\ in\ the\ space]}$$

iii. **Virus particles in the air in this space**

The fourth part is determining the number of "virus particles in the air in this space". To calculate this, we look at the number of "minutes to get to a certain CO_2 level" and multiply it by the number of "people in the space" and "Average number of virus particles released per person per minute".

For "average number of virus particles released per person", we assumed the worst-case scenario where everyone is sick and we assume that 80% of people are sitting and breathing while 20% of people are talking.

According to [Sima Asadi, Anthony S. Wexler, Christopher D. Cappa, Santiago Barreda, Nicole M. Bouvier & William D. Ristenpart. 2019. Aerosol emission and superemission during human speech increase with voice loudness. Sci Rep 9, 2348 (2019). https://doi.org/10.1038/s41598-019-38808-z], someone who is sitting and breathing generates approximately 30 virus particles per minute, while someone who is talking will generate 200 virus particles per minute. Adding in the 80% and 20% assumptions, it comes out to 64

virus particles for “average number of virus particles released per person per minute”.

Putting all this together, we get:

$$[virus\ particles\ in\ the\ air\ in\ this\ space] = [minutes\ to\ get\ to\ a\ certain\ CO2\ level] * [people\ in\ space] * [average\ number\ of\ virus\ particles\ released\ per\ person\ per\ minute$$

iv. **Virus Particles per m^3**

This calculation extrapolated by dividing the “number of virus particles in the air in this space” by the “volume of the space”. With this, we remove the volume of the space from the equation so that the equation can apply to any sized space.

$$[virus\ particles\ per\ m3] = \frac{[number\ of\ virus\ particles\ in\ the\ air\ in\ this\ space]}{[volume\ of\ space]}$$

v. **Virus particles inhaled per person per min**

The sixth part is breaking this down once more into “**virus particles inhaled per person per min**”. To do this, we take “**virus particles per m^3**” and divide it by the “**average volume of air inhaled per person**”. The average volume of air inhaled per person is typically between 6-8 liters/min, which we will round up. To convert from liters to cubic meter, we multiply by 0.001 to get 0.008 m^3/min.

$$[virus\ particles\ inhaled\ per\ person\ per\ minute] = [virus\ particles\ per\ m3] * [average\ volume\ of\ air\ inhaled\ per\ person]$$

vi. **How many virus particles will be inhaled after a certain amount of time**

The seventh part is looking at “how many virus particles will be inhaled after a certain amount of time”. This is calculated by multiplying the “virus particles inhaled per person per min” by “minutes in an hour” to get to an hour, and then multiplying by the “number of hours someone will be in the space”. For the purposes of this formula, we will be using a standard working hour time of 8 hours.

$$[how\ many\ particles\ will\ be\ inhaled\ after\ a\ certain\ amount\ of\ time] = [virus\ particles\ inhaled\ per\ person\ per\ minute] * [minutes\ in\ an\ hour] * [number\ of\ hours\ someone\ will\ be\ in\ the\ space]$$

vii. **How many virus particles will be inhaled after a certain amount of time**
Finally, to calculate the PVDr, we take "how many virus particles will be inhaled after a certain amount of time" and divide it by 1000 to get the risk. Dosage leverages the following research to infer that it takes approximately inhalation of 1000 virus particles to become infected:

- Sima Asadi, Anthony S. Wexler, Christopher D. Cappa, Santiago Barreda, Nicole M. Bouvier & William D. Ristenpart. 2019. Aerosol emission and superemission during human speech increase with voice loudness. Sci Rep 9, 2348 (2019). https://doi.org/10.1038/s41598-019-38808-z

$$[PVDr] = \frac{[how\ many\ virus\ particles\ will\ be\ inhaled\ after\ a\ certain\ amount\ of\ time]}{[number\ of\ particles\ inhaled\ to\ be\ infected]}$$

The final result generates a basic table where the risk of hitting the 1000 virus particles inhaled increases linearly.

CO_2 Levels	PVDr	PVDr (%)
400	0.000	0.0
450	0.044	4.4
500	0.088	8.8
550	0.132	13.2
600	0.176	17.6
650	0.220	22.0
700	0.264	26.4
750	0.308	30.8
800	0.352	35.2
850	0.396	39.6
900	0.440	44.0
950	0.484	48.4
1000	0.528	52.8
1050	0.572	57.2
1100	0.616	61.6
1150	0.660	66.0

1200	0.704	70.4
1250	0.748	74.8
1300	0.792	79.2
1350	0.836	83.6
1400	0.880	88.0
1450	0.924	92.4
1500	0.968	96.8

The formula for PVDr is then interpolated by leveraging the table above.

Formula

The formula is a linear equation that estimates the effect of CO_2 on the risk of viral transmission at a given concentration of CO_2. The formula below is derived from the 8 parts above, with the only variable being the current CO_2 reading as x.

When CO_2 = x, then Dosage is given by:

$$f(x) = \frac{x - 400}{50} * 0.044, where\ x \geq 400$$

Function 4 shows the interpolated results for potential viral dosage risk.

It is assumed that CO_2 at 400 ppm is considered excellent, so any CO_2 reading under 400 will be treated the same.

e. Resulting RESET Viral Index Formula

Putting all of this together, this is the final formula for Airborne Infection Potential and the RESET Viral Index:

$$\mathbf{AIP} = \frac{\mathrm{VS} * \mathrm{IS_{PM}}}{\mathrm{IS_{RH}}} * \mathrm{PVDr}$$

AIP is the raw calculated result from the formulation

$$\mathbf{RVI} = (1 - \mathbf{AIP}) * 100\%$$

RVI turns AIP into a more straightforward index

When $(1 - \mathrm{AIP}) < 0$, RVI is taken to be 0%

VS	Virus Survivability
IS_{PM}	$PM_{2.5}$ Impact on Immune System
IS_{RH}	%RH Impact on Immune System
PVDr	Potential Viral Dosage Risk
AIP	Airborne Infection Potential
RVI	RESET Viral Index

The above formula gets you the Airborne Infection Potential, where 1% is the best-case scenario. The RESET Viral Index = 1 - Airborne Infection Potential, where 99% is the best-case scenario. The formula uses decimals instead of percent.

Comparably, RVI is significantly more intuitive than the AIP for regular users to understand what is good vs what is bad due to 100% being the best reading available.

Note that the RESET Viral Index is capped between 1% and 99%.

Rounding Conventions

Rounding conventions are established to normalize the format of calculation results across all implementations of RVI, whose value should be expressed as an integer percentage (i.e. RVI = 99%).

When doing the final calculations, VS, IS_{RH}, IS_{PM}, and PVDr should all be rounded accordingly:

Viral Survivability (VS) should be rounded to 3 decimal places, or 1 decimal place when expressed as a percentage.

$PM_{2.5}$ Impact on Immune System (IS_{PM}) should be rounded to 3 decimal places, or 1 decimal place when expressed as a percentage.

RH Impact on Immune System (IS_{RH}) should be rounded to 3 decimal places, or 1 decimal place when expressed as a percentage.

Potential Viral Dosage Risk (PVDr) should be rounded to 3 decimal places, or 1 decimal place when expressed as a percentage.

RESET Viral Index (RVI) should be rounded to 2 decimal places, or 0 decimal place when expressed as a percentage.

Performance Categories

We have developed RVI to inform building facilities and occupants to better understand how well a building is optimized for lowering the potential of airborne virus transmission. We categorize the indoor performance, based on the values of RVI, in the following table:

v1.0 Labels	v1.0 RVI
Excellent	85% - 99%
Good	70% - <85%
Fair	55% - <70%
Needs Improvement	40% - <55%
Unsatisfactory	20% - <40%
Poor	0% - <20%

Examples

Below are example scenarios and the resulting RVI readings:

Situation	PM 2.5	CO2	RH%	VS	IS	PVD	PM2.5	VS/IS x PM2.5 x PVD	RVI = % Optimized	Label
Perfect situation (Low CO2, good humidity levels, low PM2.5)	3	400	60	0.733	1	0	1.009	1.00%	99%	Excellent
Low occupancy (Good CO2 levels, good humidity, low PM2.5)	3	600	60	0.733	1	0.176	1.009	13.00%	87%	Excellent
Low occupancy with no Fresh Air (Decent CO2 levels, good humidity, low PM2.5)	3	800	60	0.733	1	0.352	1.009	26.00%	74%	Good
Occupied (Passable CO2 levels, good humidity, low PM2.5)	3	1000	60	0.733	1	0.528	1.009	39.00%	61%	Fair
Occupied with underwhelming fresh air (Fair CO2 levels, good humidity, low PM2.5)	3	1100	60	0.733	1	0.616	1.009	46.00%	54%	Needs Improvement
Occupied with not very good fresh air (Not great CO2 levels, good humidity, low PM2.5)	3	1330	60	0.733	1	0.818	1.009	60.00%	40%	Unsatisfactory

Poor Fresh Air (High CO2, good humidity levels, low PM2.5)	3	1638	60	0.733	1	1.089	1.009	81.00%	19%	Poor
Perfect CO2 w/ very high humidity (Low CO2, very high humidity levels, low PM2.5)	3	400	80	0.994	0.7	0	1.009	1.00%	99%	Excellent
Low occupancy w/ very high humidity (Good CO2 levels, very high humidity, low PM2.5)	3	600	80	0.994	0.7	0.176	1.009	25.00%	75%	Good
Low occupancy with no Fresh Air w/ very high humidity (Decent CO2 levels, very high humidity, low PM2.5)	3	800	80	0.994	0.7	0.352	1.009	50.00%	50%	Needs Improvement
Occupied w/ very high humidity (Passable CO2 levels, very high humidity, low PM2.5)	3	1000	80	0.994	0.7	0.528	1.009	76.00%	24%	Unsatisfactory
Occupied with underwhelming fresh air w/ very high humidity (Fair CO2 levels, very high humidity, low PM2.5)	3	1099	80	0.994	0.7	0.615	1.009	88.00%	12%	Poor

Perfect CO2 w/ high humidity and decent PM2.5 (Low CO2, high humidity levels, decent PM2.5)	35	400	70	0.781	0.85	0	1.104	1.00%	99%	Excellent
Low occupancy w/ high humidity and decent PM2.5 (Good CO2 levels, high humidity, decent PM2.5)	35	600	70	0.781	0.85	0.176	1.104	18.00%	82%	Good
Low occupancy with no Fresh Air w/ high humidity and decent PM2.5 (Decent CO2 levels, high humidity, decent PM2.5)	35	800	70	0.781	0.85	0.352	1.104	36.00%	64%	Fair
Occupied w/ high humidity and decent PM2.5 (Passable CO2 levels, high humidity, decent PM2.5)	35	1000	70	0.781	0.85	0.528	1.104	54.00%	46%	Needs Improvement
Occupied with underwhelming fresh air w/ high humidity and decent PM2.5 (Fair CO2 levels, high humidity, decent PM2.5)	35	1100	70	0.781	0.85	0.616	1.104	62.00%	38%	Unsatisfactory

Occupied with not very good fresh air w/ high humidity and decent PM2.5 (Not great CO2 levels, high humidity, decent PM2.5)	35	1330	70	0.781	0.85	0.818	1.104	83.00%	17%	Poor

5. Conclusion and Next Steps

The real estate industry requires a meaningful way to leverage performance-based data to build and operate better buildings that are optimized to minimize the risk of COVID-19 transmission. Because indoor environments are dynamic, building systems must also be equally responsive. The value of the RESET Viral Index is therefore one that improves our understanding of critically important environmental factors in real time so that remediation efforts can be enacted expeditiously and effectively.

With respect to the SARS-COV-2 virus, the World Health Organization (WHO) is warning that transmission via aerosols is an infection pathway. SARS-CoV-2 RNA/DNA was detected in samples taken from HVAC systems in buildings. Research demonstrates that environmental parameters ($PM_{2.5}$, temperature, humidity, CO_2) are associated with transmission risks and can be measured by continuous monitoring sensors and can be regulated within the built environment.

The availability of research for each area of research, including the overall outcome, allows us to cross-check and refine the relationship between variables and calculation of the overall index from input parameters. This starts to make the application of scientific research applicable to buildings, with controlled environmental parameters measured by sensors.

Limitations

The RESET Viral Index does not describe the total probability of infection for occupants. At the current stage, it is constrained by office measurable air quality parameters. It does not account for the following aspects that contribute to the transmission of viruses:

- Contact & fomite transmission
- Lack of conclusive %RH impact on immune system strength
- Number of infected individuals and the severity of infections
- Virus prevention protocols (i.e. wearing masks, social distancing)
- Filtration or other solutions (i.e. UV)
- Additional parameters that influence virus survival or indicate activity levels

Additionally, the RESET Viral Index assumes the indoor air to be evaluated is uniformly distributed. These factors require the tracking of variables and mechanisms beyond the scope of the RESET Viral Index.

Conclusion and Future Directions

Transmissions via aerosols are a prominent infection pathway for various viruses, including SARS-CoV-2. Research has found that SARS-CoV-2 RNA/DNA can be detected in samples taken from HVAC systems in buildings, suggesting the high level of transmissibility of Covid-19 in indoor built environments. In the Covid-19 era and possible future outbreaks, the real estate industry can benefit from a meaningful way to leverage performance-based data to build and operate better buildings and minimize the risk of COVID-19 transmission. Since indoor environments are dynamic, building systems must be equally responsive. Leveraging continuous monitoring based on the RESET Air Standard, the RESET Viral Index tracks important environmental factors in real-time to inform occupants about the risk of airborne infection so that remediation efforts can be enacted expeditiously.

As mentioned previously in this text, there are limitations in what RESET Viral Index can tell about the actual risk. The next steps for us to improve this work include but are not limited to accounting for the effect of the UV strength in the indoor space on virus survival and using noise level as an indicator of activity level. Such add-on parameters should also abide by the current approach of continuous monitoring. Finally, much of the data used for the formulation will be reevaluated and updated accordingly as RVI is implemented under more real-life situations, and as newer research emerges.

We hope that our attempt to deconvolute airborne infection potential can initiate collaborations from industries and academia. We advocate our industry partners to pilot the application of RVI to test its operational efficacy and interested academia to verify our formulations and build upon what we have established.

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