UQF2101I Quantitative Reasoning Foundation: Quantifying Environmental Quality

Introduction:

(Slide 1)
22,000. That is the average number of times we breathe a day. But how do we know that the air that fills our lungs with each breath is actually clean? The issue of polluted air is one that countries around the world grapple with. In Canada, polluted air affects thousands annually and causes over 5,000 deaths every year due to air pollution.

(Slide 2)
In light of this health concern, the national Air Quality Health Index (or AQHI) was launched to help Canadians protect their health by adjusting activity levels according to detected levels of air pollution. This is what my group and I, as shown on the screen, will be discussing today.

(Slide 3)
This slide shows a rough overview of what we will be covering today. We will start off with the introduction of the AQHI, then go into more detail about it as a health index. Next, we will compare it with the PSI used by Singapore, and lastly, we will share some takeaways and insights we have gathered from this project.

(Slide 4)
I will be introducing the AQHI.

(Slide 5)
The AQHI replaces the previous Air Quality Index system. The AQHI focuses on standardising and communicating differentiated health risks to both the at-risk population and the general public at the national level. The at-risk population refers to the young, the elderly, and people with existing respiratory or cardiovascular conditions. Originally launched as pilot projects in the British Columbia province, Nova Scotia province, and Toronto, the AQHI was later implemented in 122 locations across Canada from the year 2016.

(Slide 6)
The AQHI comprises three key components. Firstly, it measures the air quality in relation to health on a scale from 1 to 10. The higher the number, the greater the health risk associated with the air quality. When the amount of air pollution is very high, the number will be reported as 10+. Secondly, it provides a category that describes the level of health risk associated with each index reading (e.g. Low, Moderate, High, or Very High Health Risk). Lastly, health messages are customised to each of these categories for both the general population and the ‘at risk’ population. Further details will be elaborated by my fellow group members.

(Slide 7)
I will now pass the time over to Brandon to continue our presentation.

AHQI as an index

Computation:

(Slide 8)
Thank you Donovan! To continue with the discussion, I would first like to talk about one of the key reasons why AQHI was preferred over AQI.

IN the old aqi system.Studies have shown that there is still a high rate of illnesses attributed to air pollution for days that are supposed to be “good” and moderate under the old AQI system. To borrow the description of the bands, “the air quality is supposed to be satisfactory and average”

(Slide 9)
But yet, a high 90% of air-pollution related illnesses occurred within these two bands. This high percentage meant that there was a missing link, and AQHI was meant to fill in this link. AQI uses the highest sub-index, whereas AQHI uses the additive effect of the air pollutants to fit this missing link.

(Slide 10)
Now, let's take a look at AQHI computation to be used for additive effect. The equation shown on screen is the general equation used to calculate for AQHI. The two variables we will focus on are C and Beta.

(Slide 11)
Let’s begin with C. They used a dataset from 1998-2000, where the concentration of air pollutants and mortality rate are collected.
Concentration is simple, but what did they do with the mortality rate?
They calculated the mortality weighted excess deaths. With the available data, they calculated how many deaths there were usually, assuming that the conc of the pollutant is zero.
Then, any other deaths above this baseline were calculated, and termed as excess deaths.

(Slide 12)
C is a scaling factor in the equation that uses this excess death to scale the AQHI values within a range of 1-10+, which will be mentioned later during the presentation.

(Slide 13)
Moving on to beta, the coefficients for the individual pollutants are then calculated using a Poisson distribution and empirically derived based on the excess death.

(Slide 14)
And as you see for the equation, there are only a few criteria pollutants picked out and focused on. This ultimately returns to the idea of the additive effect. This study done by Steib Et al has shown that the other criteria pollutants’ effects are subsumed within the other three.

(Slide 15)
“Specifically”/ “To focus” on a snippet from the study, this particular snippets of text are taken from the study: “associations with CO and SO2 were smaller and could be driven to zero and did not appear to have important independent effects on mortality risk.”

For example So2 have been shown to exhibited at least a moderate correlation concentrations even with it not being part of the equation, indicating that this element of the mix was still being captured even when it was excluded from the index formulation”

Now, Wei Jie will continue with the next part of the presentation.

(Slide 16)
Thank you Brandon. Now, let me elaborate more on why Canada chose to focus on only 3 criteria pollutants, namely PM2.5, O3, and NO2. When formulating the AQHI, researchers conducted a time series study, based on data collected from 12 urban Canadian cities from 1991-2000. They found that the concentrations of these 3 pollutants best represent health risk, having the closest association with mortality rates.

In 2012, the Director in Canada’s Environment Ministry (Bill Appleby) further elaborated that although the concentration of SO2 and CO were not insignificant, they were not associated with additional health risks once the 3 criteria pollutants were taken into account. For instance, CO was highly correlated with the level of NO2 which was a more robust measure of the source of combustion/traffic emissions. Additionally, the concentrations of SO2 and CO have been declining over the years, and are currently at very low - almost undetectable - rates.

(Slide 17)
Now, very briefly, how then is pollutant concentration data obtained? It is gathered through the NAPS (national air pollutant surveillance) program, which comprises around 300 monitoring stations countrywide. Although only NO2, O3 and PM concentrations are factored into the AQHI, the stations still measure for other pollutants like SO2 and CO, and these data are still publicly available on the air quality reports for each province.

Health Messages:

(Slide 18)
With the measurement of the 3 criteria pollutants, the AQHI value can then be derived along a 1-10+ index, which was theorised to be more intuitive and understandable by the public. The values then correspond to 1 of 4 possible health risk bands, as shown here. They are “low risk”, “moderate risk”, “high risk”, and “very high risk”. Note that all AQHI values over 10 are classified under the very high risk band. Such instances are possible but very rare, and have only been connected to anomalous events like wildfire.

For each band, the health messages are separately addressed to 2 different groups: the general population and the at-risk population. As seen here, the advice for the “at-risk” population is more stringent than for the general population. This trend is very similar to Singapore’s PSI, but there remains some subtle differences between the two messaging systems. We will elaborate more on this later.

(Slide 19)
Having introduced the logistics and statistics behind the AQHI, Chelsea and Ashley will now explicitly compare between Canadian AQHI and Singapore PSI

Comparisons:

(Slide 20)
Thank you Wei Jie! The first difference stems from the computation of the AQHI and PSI. For the AQHI, as Brandon mentioned earlier, the concentrations of the 3 criteria pollutants are aggregated using the following formula. For the PSI, the concentrations are first converted to sub-indices before the maximum value is used to report the 24-hour PSI.

- On one hand, in aggregating the concentrations of criteria pollutants in the AQHI based on empirical scaling factors, the additive effect of the criteria pollutants are accounted for. Aggregation in the AQHI will allow for the compounded health risk from moderately high pollutant concentrations to be reflected. However, for the PSI, even with a higher health risk due to the compounding effect, we are likely to just obtain a reported value in the moderate range.
- On the other, precisely because of the aggregation of data, even with empirical adjusters, an abnormally high concentration is likely to have its risk underestimated. In this scenario, the PSI’s selection of maximum value would then be a more accurate representation of the health risk brought about by air pollution.
- This point of comparison illustrates how a given method of computation can be both a strength and weakness

(Slide 21)
Secondly, unlike Singapore’s PSI, the AQHI uses a 3-hour average concentration, in order to be responsive to short term changes in air pollution, without becoming overly unstable.
However, the PSI’s 24-hour average value is meant to allow for forecasting while the supplementary 1-hour average PM2.5 concentration is meant to be used to gauge for immediate activities. Hence, the AQHI’s use of only 1 indicator may be more convenient and less confusing for the public, but Singapore’s PSI is more targeted to its 2 outlined purposes.

(Slide 22)
In terms of pollutants used, the AQHI uses these 3 pollutants because studies found that these best represented health risk in Canada. On the other hand, the PSI uses 6 pollutants because it follows from the US EPA standard and historically significant pollutants in Singapore’s context, and looks at these criteria pollutants in isolation. While the AQHI’s computation of only 3

pollutants may be more efficient, the effect of anomalous sources of CO and SO2 may not have been accounted for and reflected in the AQHI.

Ashley will now go through the next 2 differences.

(Slide 23)
Thank you Chelsea! The third difference is in reference to the indexes used. For the AQHI, they use a scale from 1-10+, which is broken up into 4 distinct bands. On the other hand, the PSI uses an index from 0-500, which is broken up into 5 distinct bands. This brings up the idea of how to simplify data to present to the public. Comparing the AQHI to the PSI, it is much more intuitive to understand a scale from 1-10+ than 0-500.

However, there is also the issue of transparency. In Singapore, you are able to access the individual sub-indices of the pollutants, and from there you can determine the range of concentrations for the pollutants. This is compared to the AQHI, where you cannot easily access the individual sub-indices of the pollutants.

(Slide 24)
In terms of health messaging, in the AQHI, the elderly and children are only given a separate advisory as part of the at-risk population from the third band onwards, as you can see on the screen. Even though the at-risk health messaging targets them too, this is not made clear by the health messages. This is very different from the PSI, where the elderly, children and pregnant women have a unique health message directed to them.

- As a group, we feel that not having a separate category for the elderly, children and pregnant women may lead to some confusions regarding the health messaging. this may lead them to respond inappropriately at the different bands, possibly putting themselves at risk

Also, in the AQHI, the health messages only pertain to carrying out strenuous activities outdoors, not going outdoors in general. However, in the PSI, once the pollutant level index reaches 200 and above, certain groups are asked to avoid going outdoors completely.

- This could boil down to cultural differences. For example, the Singapore government may be taking a more paternalistic stance with a stricter-sounding approach to health messaging. In comparison, “message fatigue” is a reason cited by the Canadian government to word their messages less strictly as they worry that people may not respond appropriately to a real crisis

(Slide 25)
Now, we will be sharing some takeaways and insights gained from this project.

Takeaways and Insights:

(Slide 26)
Importance of context (insights)

1) We realised that context affects the way we ask questions, carry out the scientific method and analyse our data
    a) For example, in the case of Canada, when they realised there was a disconnect between the AQI readings and the number of illnesses observed, they worked to plug the gap through aggregation and changed their computation. Whereas in Singapore, when we realised that PM2.5 was becoming more severe after the 2014 haze, we added the indicator for PM2.5 in and reported its 1-hour concentrations.
    b) In addition, though both the AQHI and PSI use different calculations, it works for the countries, showing how differences in approaches are acceptable
2) Furthermore, context also affects how we communicate health messages, as I have explained earlier

(Slide 27)
Recommendations for SG

- For Canada, they changed to mortality in their computation because they found that it was more effective than illness. Perhaps Singapore could do a research comparing which measure is better, and see if this could improve our current PSI

(Slide 28)
These are the references that we used as we came up with this presentation.

(Slide 29)
Thank you for your kind attention!

22,000

AQHI in Canada

Ashley Low
Brandon Kee
Chelsea Wong
Donovan Singh
Ng Wei Jie

Overview

1 **Introduction to the AQHI**

Background,
Aims

2 **AQHI as a health index**

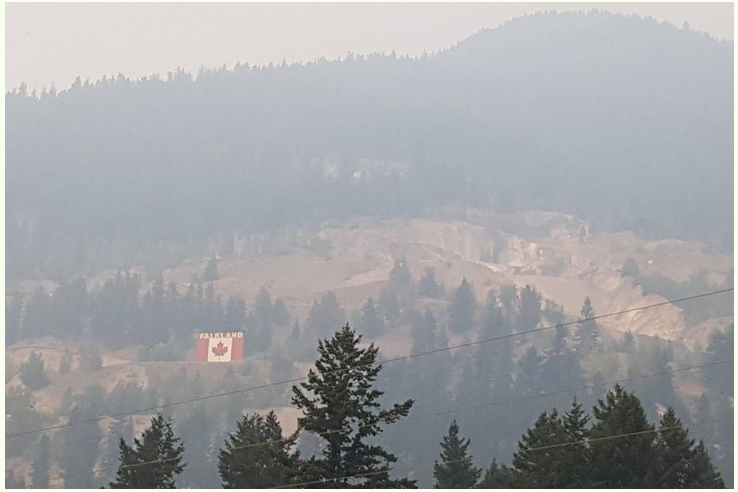
Criteria pollutants,
Computation and Scale,
Health messages,

3 **Comparisons with PSI**

Canada vs Singapore

4 **Takeaways and Insights**

Reflections,
Contextual Differences

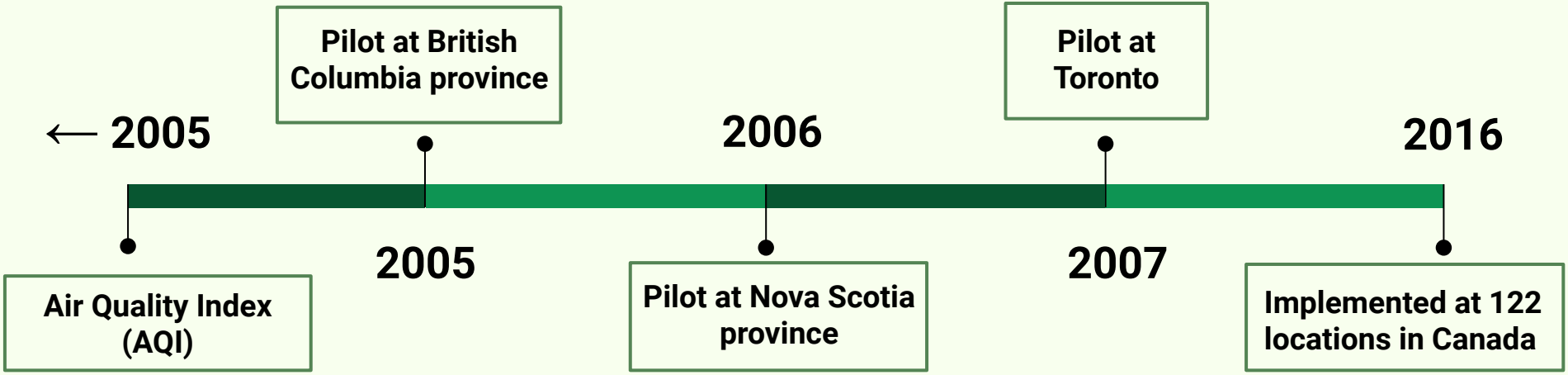


1

Introduction to the AQHI

Background, Aims

1 Background on AQHI



1 What is the AQHI?

1. AQHI scale

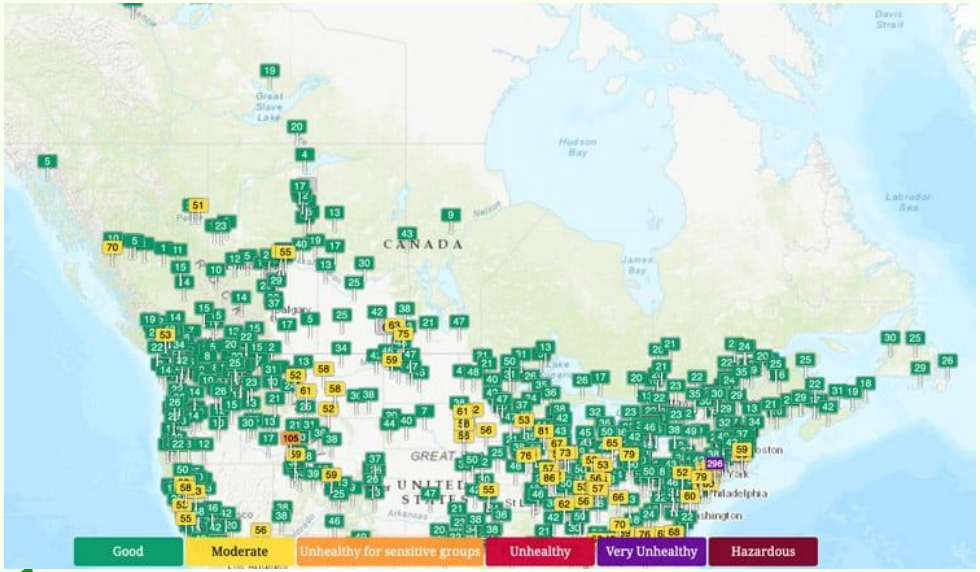
2. Health Risk level

3. Health messages

AQHI Health Messages

Each level of health risk is associated with a pair of health messages, for the at risk and the general populations. It suggests steps you can take to reduce your pollution exposure.

Health Risk	Air Quality Health Index	Health Messages	
		At Risk Population	General Population
Low Risk	1 - 3	**Enjoy** your usual outdoor activities.	**Ideal** air quality for outdoor activities.
Moderate Risk	4 - 6	**Consider** reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	**No need to modify** your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High Risk	7 - 10	**Reduce or reschedule** strenuous activities outdoors. Children and the elderly should also take it easy.	**Consider** reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very High Risk	10+	**Avoid** strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	**Reduce or reschedule** strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

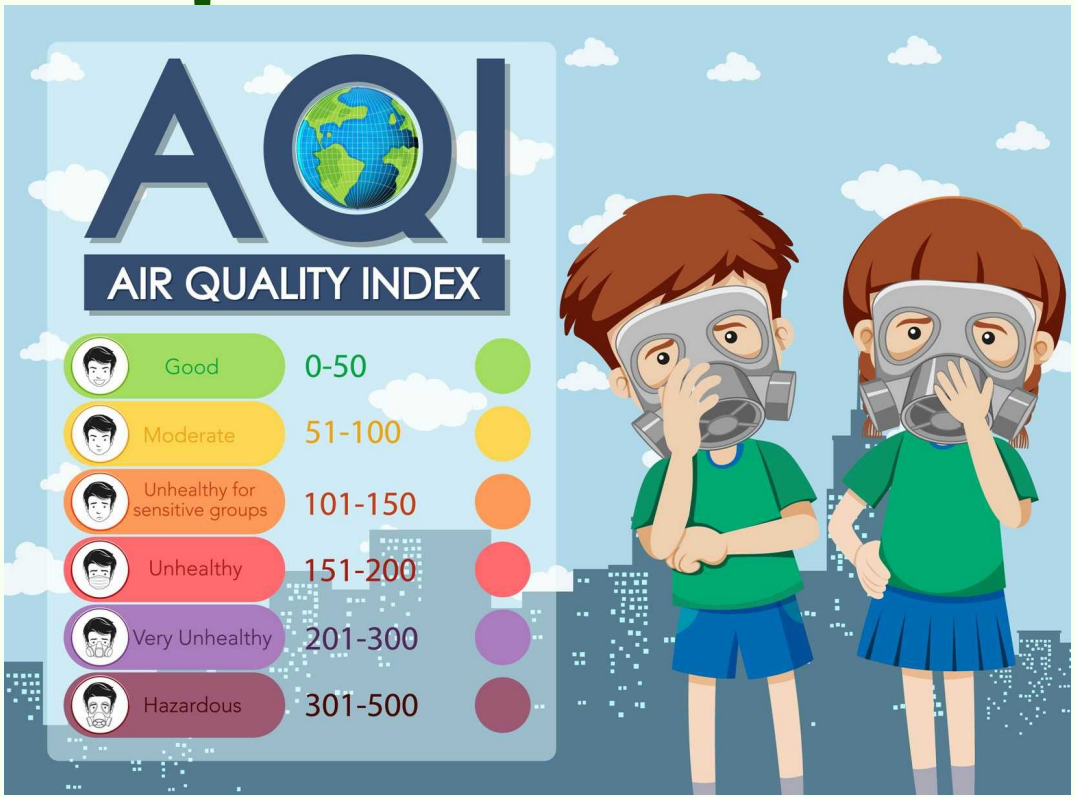


2

AQHI as a health index

Criteria Pollutants, Computation and Scale, Health Messages

2 Computation and scale



“Air quality is Satisfactory…”

“Air quality is Acceptable…”

2 Computation and scale

90% ?

2 Computation and scale

AQHI accounts for the additive effect.

$$AQHI = (10/c) \sum_{i=1...p} 100(e^{\beta_i x_i} - 1)$$

↓

c and β

2 Computation and scale

$$AQHI = (10/c) \sum_{i=1...p} 100(e^{\beta_i x_i} - 1)$$

1998-2000

Concentration of Air Pollutants

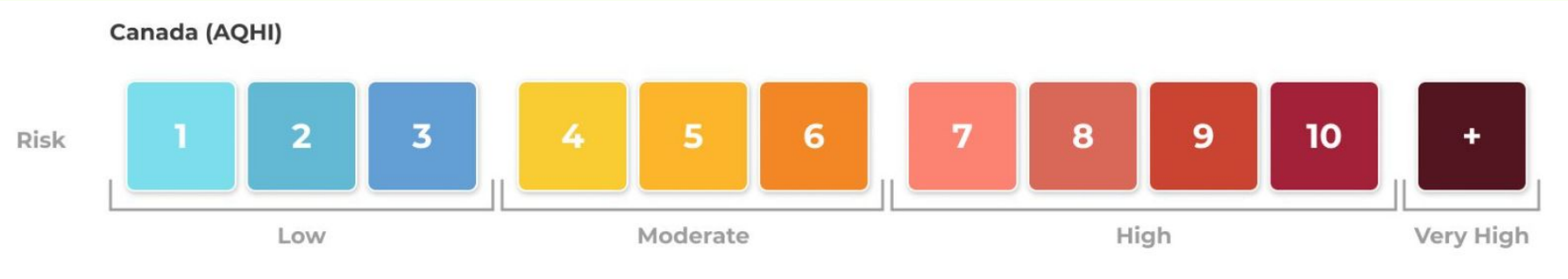
Mortality Rate

$$c = \max_{t=1...q} \left\{ \sum_{j=1...n} \left[\left(m_j / \sum_{j=1...n} m_j \right) \sum_{i=1...p} 100 \left(e^{\beta_i x_{ijt}} - 1 \right) \right] \right\}$$

2 Computation and scale

$$\mathrm{AQHI} = \left(\frac{10}{c}\right) \sum_{i=1\ldots p} 100\left(e^{\beta_i x_i} - 1\right)$$

c scales for the AQHI range of 1-10+.



2 Computation and scale

$$AQHI = (10/c) \sum_{i=1...p} 100(e^{\beta_i x_i} - 1)$$

β_i is the regression coefficient from Poisson model linking the i^{th} air pollutant with mortality

2 Computation and scale

$$PM_{2.5}AQHI = 10/10.4*(100*(e^{(0.000871*NO_2)} - 1 + e^{(0.000537*O_3)} - 1 + e^{(0.000487*PM_{2.5})} - 1)) \quad (4)$$

Stieb, D. M., Burnett, R. T., Smith-Doiron, M., Brion, O., Shin, H. H., & Economou, V. (2008). A New Multipollutant, No-Threshold Air Quality Health Index Based on Short-Term Associations Observed in Daily Time-Series Analyses. *Journal of the Air & Waste Management Association*, *58*(3), 435–450. https://doi.org/10.3155/1047-3289.58.3.435

2 Computation and scale

"[…] associations with CO and SO_2 were **smaller** [...] did **not appear to have important independent effects** on mortality risk"

"[…] AQHI version based on NO_2, O_3, and PM2.5 [...] exhibited at least a **moderate correlation** with SO2 concentrations [...] this element of the mix was **still being captured even when it was excluded** from the index formulation"

2 Selection of Criteria Pollutants

PM2.5

O_3

NO_2

- Most representative against mortality rate (vis-à-vis SO_2 and CO)
- Most representative of current pollutant mixture

2 Measurement of Criteria Pollutants

National Air Pollution Surveillance Programme (NAPS)

2 Health Messages

Health Risk	Air Quality Health Index	Health Messages	
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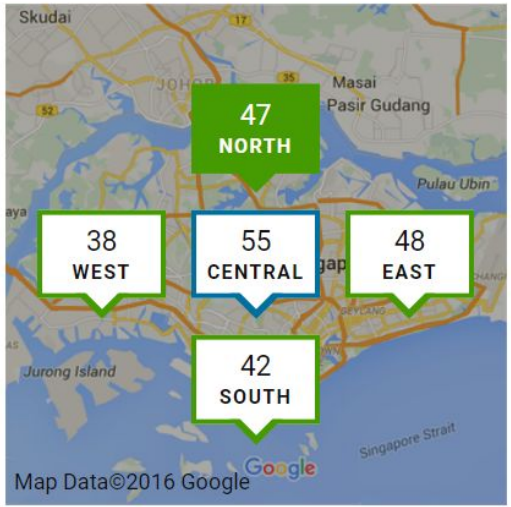
Low Risk	1 – 3	**Enjoy** your usual outdoor activities.	**Ideal** air quality for outdoor activities.
Moderate Risk	4 – 6	**Consider** reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	**No need to modify** your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High Risk	7 – 10	**Reduce or reschedule** strenuous activities outdoors. Children and the elderly should also take it easy.	**Consider** reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very High Risk	Above 10	**Avoid** strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	**Reduce or reschedule** strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

3 Comparisons with PSI

Canada vs Singapore

AIR QUALITY



47

Good

PSI Value
At 10pm on 20 Feb 2022

PSI Value	Air Quality Descriptor
0 - 50	Good
51 - 100	Moderate
101 - 200	Unhealthy
201 - 300	Very unhealthy
Above 300	Hazardous

as of 10pm on 20 Feb 2022

3 Comparison: Calculation of AQHI vs PSI

AQHI:

AGGREGATION

$$AQHI = (10/c) \sum_{i=1...p} 100(e^{\beta_i x_i} - 1)$$

- Additive effect
- Muted outlier effect

vs

PSI:

MAXIMUM VALUE

$$PSI = \text{maximum}\ (I_1, I_2, I_3, I_4, I_5, I_6)$$

- Pollutant effects in silos
- Obvious outlier effect

3 Comparison: Calculation of AQHI vs PSI

AQHI:

3-HR

vs

PSI:

24-HR

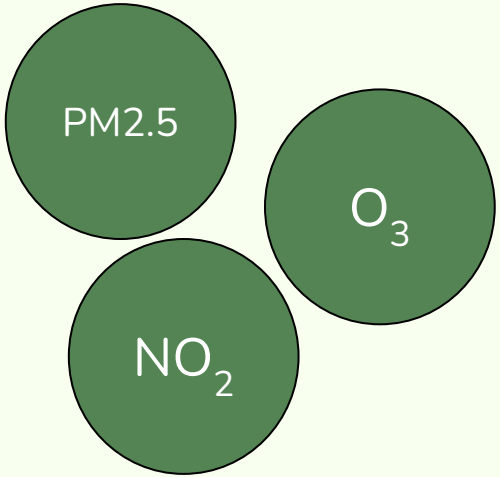
\+ 1-HR PM2.5

- 1 single index
- Responsive to short-term change
- Relatively stable

- 2 indices for 2 purposes
- Less responsive to short-term change

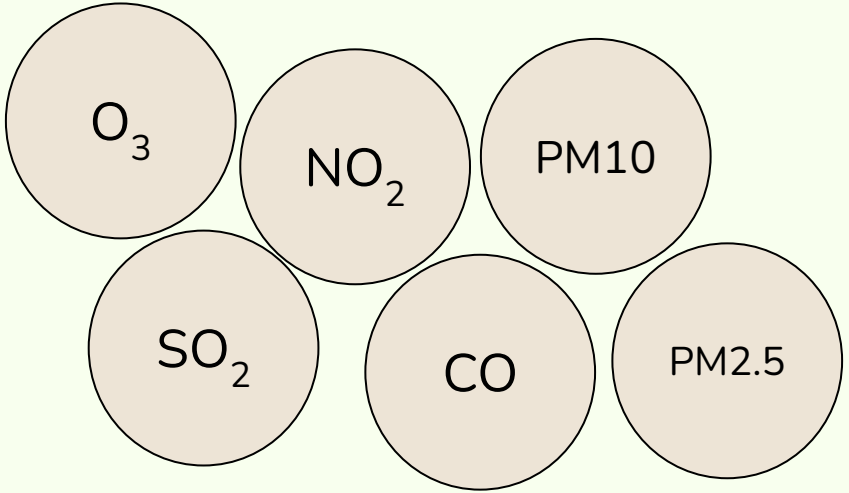
3 Comparison: Criteria Pollutants

AQHI:



vs

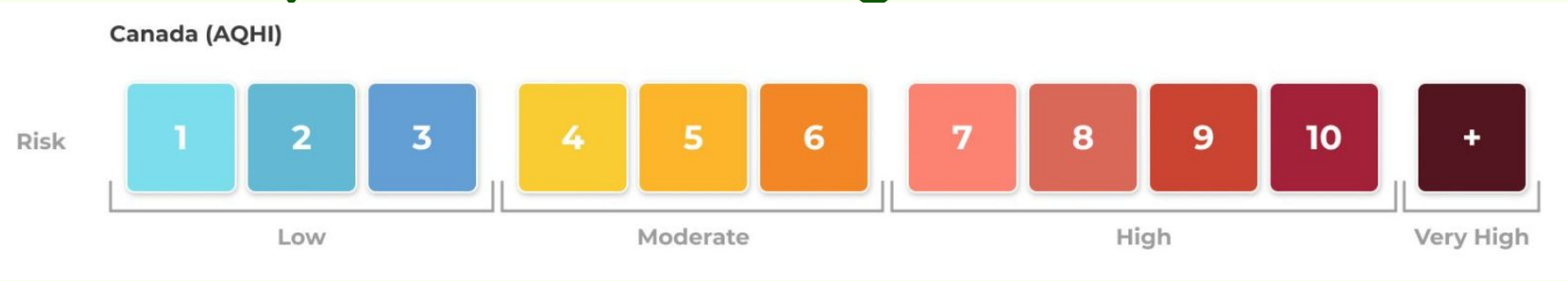
PSI:



- More efficient

- Accounts for potential spikes in 3 historically significant pollutants

3 Comparison: Indexing



SG

PSI Value	Air Quality Descriptor
0 - 50	Good
51 - 100	Moderate
101 - 200	Unhealthy
201 - 300	Very unhealthy
Above 300	Hazardous

3 Comparison: Health Messages

AQHI Health Messages

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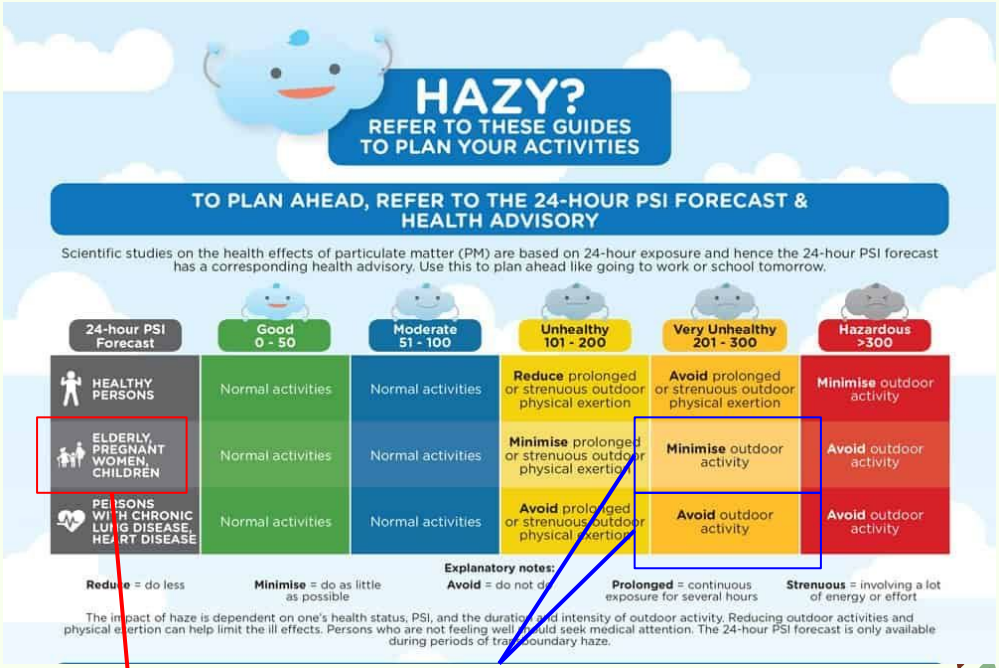
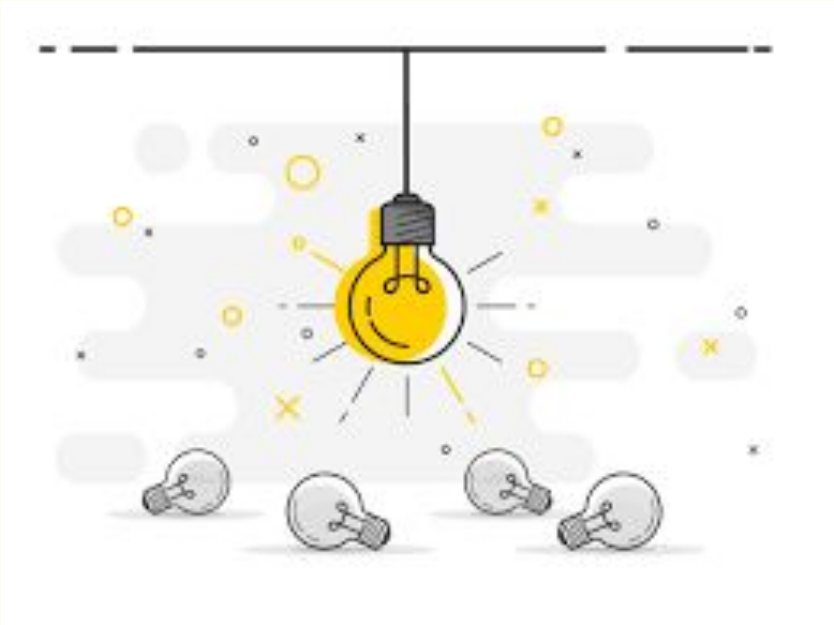
Strenuous activities only

Only included from High Risk onwards



Separate band

Going outdoors in general



4

Takeaways and Insights

Reflections, Contextual Differences

4 Insights

Importance of context

1. Affects how we ask questions and carry out the scientific method
   - Adjusting the indicators
   - Differences in approach

2. Affects how we communicate health risks

4 Takeaways

→ Mortality vs illness?

5 References

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Thank you!

We look forward to answering your questions :)