The National Air Quality Index: A silent disaster

By:

Varun Jain (IGCSE), Saadi Save (IGCSE),

Suyash Kabra (IGCSE), Meetrayu Raut (IGCSE)

And

Special thanks to our teachers Mrs. Reema Shah and Ms. Sana Bandukia for guiding us through this project

Rustomjee Cambridge International School, Dahisar, Mumbai

Contents

Notice: This paper contains large amounts of secondary data. While some sections may initially look as if they were plagiarised, every reference has been clearly included as a footnote. Inline footnotes are underlined superscripts like this: [10]

Abstract

Is the Indian air quality index, officially the National Air Quality Index (NAQI), suitable for indicating air quality to the general population in Mumbai? This paper hypothesises that the NAQI is highly inadequate for its purpose. Using air pollutant data from the Central Pollution Control Board (CPCB) to determine air pollution trends, data on the health effects of air pollutants from the World Health Organisation and the European Environmental Agency, and comparing the NAQI to indices around the world, we have concluded that the hypothesis is correct. The findings reveal that the NAQI places too much importance on pollutants of lower concern, frequently underestimating the pollution levels in the air. This research has massive implications for the city. Apart from the prevention of the deaths of thousands from sensitive populations, exposing the inadequacy of the NAQI is likely to bring back political and democratic pressure on the government to reduce air pollution, and possibly replace the NAQI with a more transparent air quality index that indicates the proper pollution levels.

170 Words

Introduction

Around 32000 people die on average in Mumbai every year due to air pollution.[1] Many of these deaths can be prevented by informing the people, especially from sensitive populations about the quality of the air they breathe. Several governments around the world, including India, have designed air quality indices for this purpose. An air quality index (AQI) indicates the air pollution levels with a simple number or description that can be easily understood by the general public.

The NAQI was developed and defined by the CPCB in 2015[2]. Like every other air quality index, it was adapted to the typical pollution levels in large cities like Mumbai and Delhi. However, this strategy did not account for the fact that the typical pollution levels in a city like Mumbai are very high by global standards. Therefore, we must ask, "Is the NAQI suitable for indicating air quality to the general population?" We think that it is extremely inadequate for that purpose because its thresholds on particulate matter are too low, making it prone to frequently underestimating the air pollution.

The underestimation of air pollution is especially dangerous for sensitive groups, i.e. people with asthma, COPD, and other respiratory problems, pregnant women, children, etc. Each year, thousands of people from these sensitive groups die due to spikes in air pollution in Mumbai alone, spikes that the NAQI fails to warn the people about. Thousands of preventable deaths, if only these people had been warned to stay indoors. The NAQI also misleads people about the true air pollution levels, lulling the citizenry into a false sense of security. The exposure of the inadequacy of NAQI is likely to lead to a revival of democratic pressure to reduce air pollution in cities where air pollution is not patently obvious, like Mumbai.

This research has the potential to save many lives by possibly pressuring the CPCB to modify the NAQI in 2021, as stated in the paper that defined the NAQI[3]. A revival of public pressure to reduce air pollution is likely to result in cleaner air for everyone, so that the newer generations of Mumbai's population retain their healthy lungs.

1 Hindustan Times, 20.01.2017, Archived
2 CPCB, National Air Quality Index (2015)
3 pg. 37, CPCB, National Air Quality Index (2015), "CPCB may consider reviewing the AQI breakpoints every three years"

Methods

Information Collected

The following information was collected:

- Typical pollution levels in Mumbai, India
- Effects of specific pollutants on human health
- Safe pollution limits
- The calculation of NAQI
- The calculation of the European Air Quality Index (EAQI)

Typical pollution levels

The data was obtained from the CPCB's monitoring website[4]. The following parameters were used:

- State Name: Maharashtra
- City Name: Mumbai
- Station Name: Bandra, Mumbai – MPCB
- Parameters:
  - » PM2.5
  - » PM10
  - » SO2
  - » NO2
  - » CO
  - » Ozone
- From Date: 01-Aug-2018
- To Date: 31-Jul-2020
- Criteria: 24 hours
- Report Format: Tabular

4 Central Control Room for Air Quality Management – All India

Air Quality Standards (AQS)

Table 1: EU, WHO and CPCB air quality standards[5] [6] [7] [8] [9]

Pollutant	EU reference level ($\mu g\ m^{-3}$)		WHO reference level ($\mu g\ m^{-3}$)		CPCB reference level ($\mu g\ m^{-3}$)	
	24 h/8 h	Year	24 h/8 h	Year	24 h/8 h	Year
$PM_{2.5}$	35	20	25	10	60	40
PM_{10}	50	40	50	20	100	60
NO_2	–	40	–	40	80	40
SO_2	125	20	20	–	80	50
O_3	120	–	100	–	100	–
CO	10000	–	10000	–	2000	–

Air Quality Indices

National Air Quality Index

Table 2.1: National Air Quality Index (All values in $\mu g\ m^{-3}$, unless stated otherwise)[10]

AQI Category (Range)	**PM_{10} 24 h**	**$PM_{2.5}$ 24 h**	**NO_2 24 h**	**O_3 8 h**	**CO 8 h ($mg\ m^{-3}$)**	**SO_2 24 h**
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800
Very Poor (301-400)	351-430	121-250	281-400	209-748	17.1-34	801-1600
Severe (401-500)	430+	250+	400+	748+	34+	1600+

5 pg. 26, 35, 39, 45, 46, EEA (2019), Air Quality in Europe
6 pg. 31, EEA (2013), Environment and human health – joint EEA-JRC report
7 pg. 19, CPCB (2015), National Air Quality Index
8 European Council & Parliament (2015), 2008/50/EC
9 Ministry of Environment and Forests Notification, 16.11.2009, Archived
10 pg. 37, CPCB (2015), National Air Quality Index

The sub-index (I_p) for a given pollutant concentration (C_p), is calculated as[11]:

$$I_p = \left[\frac{I_{HI} - I_{LO}}{B_{HI} - B_{LO}} \times (C_p - B_{LO}) \right] + I_{LO}$$

Where,

B_{HI} is the breakpoint concentration greater or equal to given concentration

B_{LO} is the breakpoint concentration smaller or equal to given concentration

I_{HI} is AQI value corresponding to B_{HI}

I_{LO} is AQI value corresponding to B_{LO} , subtract one from I_{LO} , if I_{LO} is greater than 50

Finally,

$$I = \text{set of sub indices}$$

$$AQI = Max(x : x \in I)$$

Table 2.2: Health messages corresponding to the National Air Quality Index[12]

AQI	Associated Health Impacts
Good (0 – 50)	Minimal Impact
Satisfactory (51 – 100)	May cause minor breathing discomfort to sensitive people
Moderate (101 – 200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201 – 300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure
Very Poor (301 – 400)	May cause respiratory illness to the people on prolonged exposure. Effects may be more pronounced in people with lung and heart diseases
Severe (401 – 500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

11 pg. 39, CPCB (2015), National Air Quality Index
12 pg. 38, CPCB (2015), National Air Quality Index

European Air Quality Index

Table 3.1: European Air Quality Index[13]

Index level	**Pollutant (concentrations in μg m^{-3})**				
	$PM_{2.5}$	**PM_{10}**	**NO_2**	**O_3**	**SO_2**
Good	0-10	0-20	0-40	0-50	0-100
Fair	10-20	20-40	40-90	50-100	100-200
Moderate	20-25	40-50	90-120	100-130	200-350
Poor	25-50	50-100	120-230	130-240	350-500
Very poor	50-75	100-150	230-340	240-380	500-750
Extremely poor	75-800	150-1200	340-1000	380-800	750-1250

Each pollutant concentration is categorised into one of the six index levels according to the table. The worst index achieved is the final air quality index.

Table 3.2: Health messages corresponding to the European Air Quality Index[14]

AQI	General population	Sensitive populations
Good	The air quality is good. Enjoy your usual outdoor activities.	The air quality is good. Enjoy your usual outdoor activities.
Fair	Enjoy your usual outdoor activities.	Enjoy your usual outdoor activities.
Moderate	Enjoy your usual outdoor activities.	Consider reducing intense outdoor activities, if you experience symptoms.
Poor	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat.	Consider reducing physical activities, particularly outdoors, especially if you experience symptoms.
Very poor	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat.	Reduce physical activities, particularly outdoors, especially if you experience symptoms.
Extremely poor	Reduce physical activities outdoors.	Avoid physical activities outdoors.

13 European Air Quality Index (Click on "About the European Air Quality Index")
14 European Air Quality Index (Click on "About the European Air Quality Index")

Effects of Air Pollutants on Human Health

Collected from a report[15] by the WHO and various other sources

Processing of raw data

The raw data on typical pollution levels collected from the CPCB spans over 730 days from 01.08.2018 to 31.07.2020. Five of the six pollutants have concentrations given in μg m^{-3}, namely:

- Sulphur Dioxide
- Nitrogen Dioxide
- Particulate Matter 2.5 μm
- Particulate Matter 10 μm
- Ozone

One pollutant, Carbon Monoxide, had values in mg m^{-3}, which were converted to μg m^{-3} using the formula:

$$C_{\mu g m^{-3}} = C_{mg m^{-3}} \times 1000$$

Then, anomalous values were identified and removed. After that, monthly mean concentration was calculated for each pollutant for the 24 months between 01.08.2018 and 31.07.2020. The NAQI and EAQI for each month was then calculated using the methods mentioned above. The table of processed data can be found in Appendix II.

Why do AQIs consider the worst index value?

The worst index value is considered because health effects of combinations of pollutants (synergistic effects) are not known and thus a health-based index cannot be **combined** or **weighted**. Additionally, indices that use the maximum value are less likely to be prone to overestimating (ambiguity) or underestimating (eclipsing) the air pollution than combined or weighted indices.

15 WHO EURO (2005), Air Quality Guidelines

Findings

Pollution Trends

Note that the means are calculated from Aug-18 to Jul-19 (referred to as 2018) and Aug-19 to Jul-20 (referred to as 2019).

$PM_{2.5}$

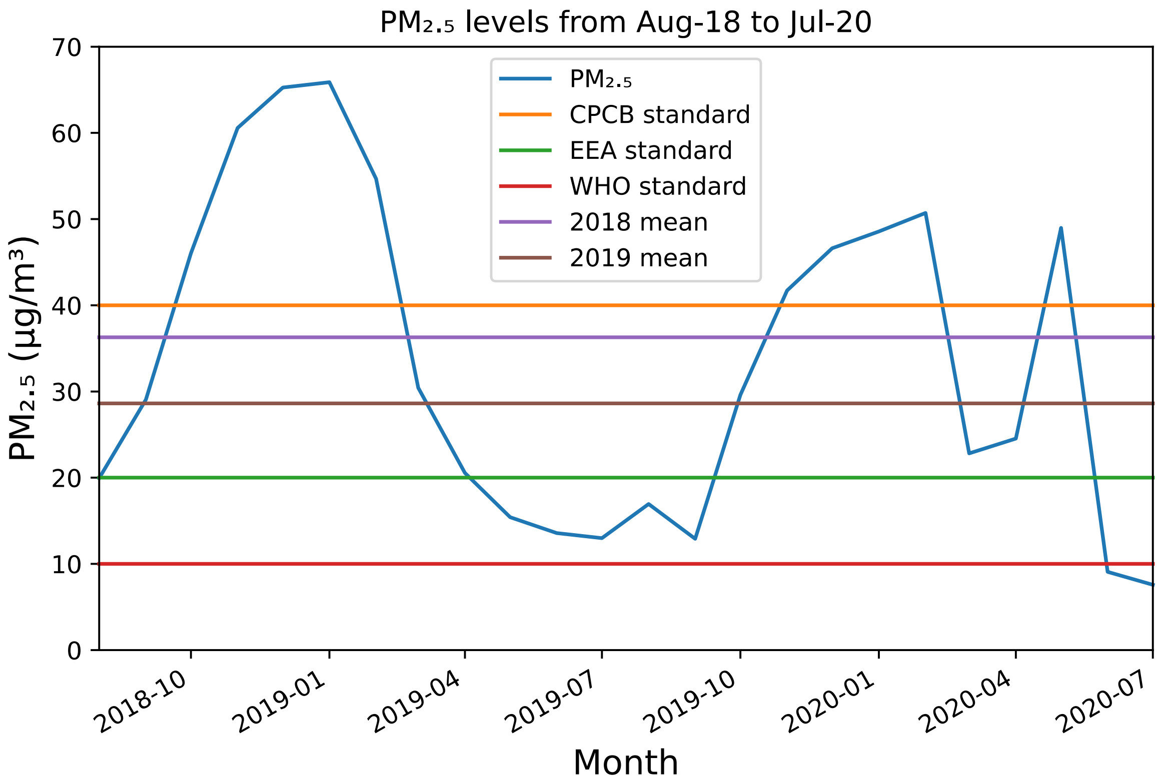

Figure 1.1: $PM_{2.5}$ concentration from Aug-18 to Jul-20

The concentration of particulate matter <2.5 μm usually peaks between January and February each year. These peaks always exceed the CPCB AQS. The concentration usually dips to its lowest value around the month of July. During a period of 6 months from May-19 to September-19, the pollution levels were lower than those of the EEA AQS. The mean for 2018 was higher than the mean for 2019. This suggests that while pollution is decreasing, it is still a major concern, since the $PM_{2.5}$ concentrations have exceeded the WHO AQS for all months except July-20.

PM_{10}

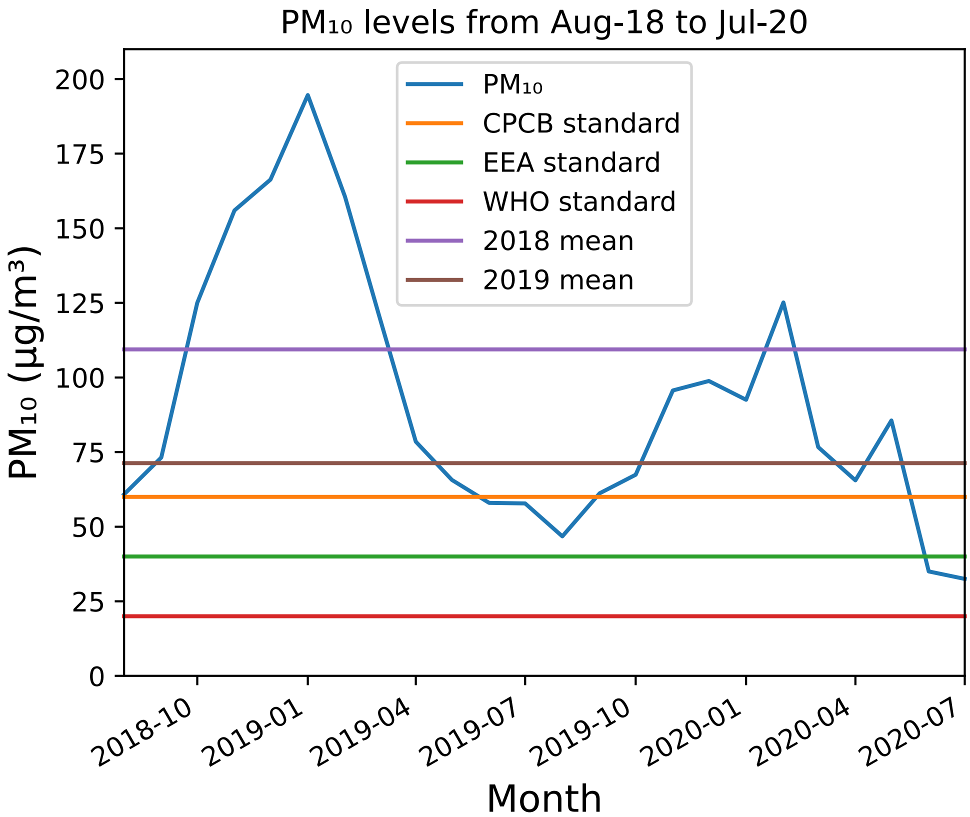

Figure 1.2: PM_{10} concentration from Aug-18 to Jul-20

The concentration of particulate matter <10 µm usually peaks between January and February. For most of the year, values exceed the CPCB AQS, except the months from June-19 to September-19, and June-20 to July-20. The mean for 2018 is much greater that the mean for 2019. This may be an indication that PM_{10} pollution is decreasing. For most of the graph, the concentration exceeds the EEA and WHO AQS, but for June-20 and July-20, the concentration is within the EEA AQS due to the Covid-19 pandemic lockdowns.

Sulphur dioxide

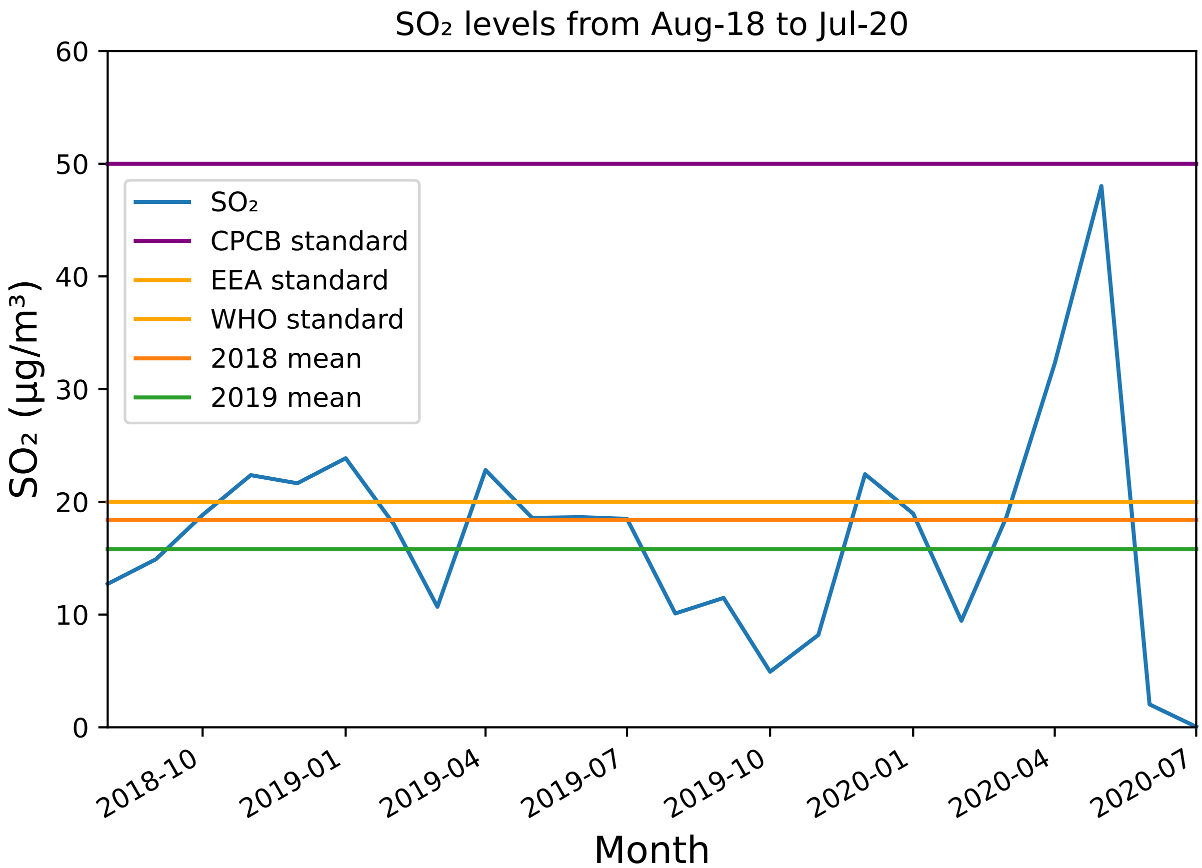

Figure 1.3: Sulphur dioxide levels from Aug-18 to Jul-20

The sulphur dioxide concentrations are usually less than half the CPCB AQS. For most of the time, the concentration also remains below the EEA and WHO AQS. The mean for 2018 is slightly higher than the mean for 2019. Both the means are below the EEA and WHO standards, signalling that SO_2 pollution is under control in Mumbai. There is one unusual peak in May-20 due to pollution fluctuations during the COVID-19 pandemic lockdowns.

Nitrogen dioxide

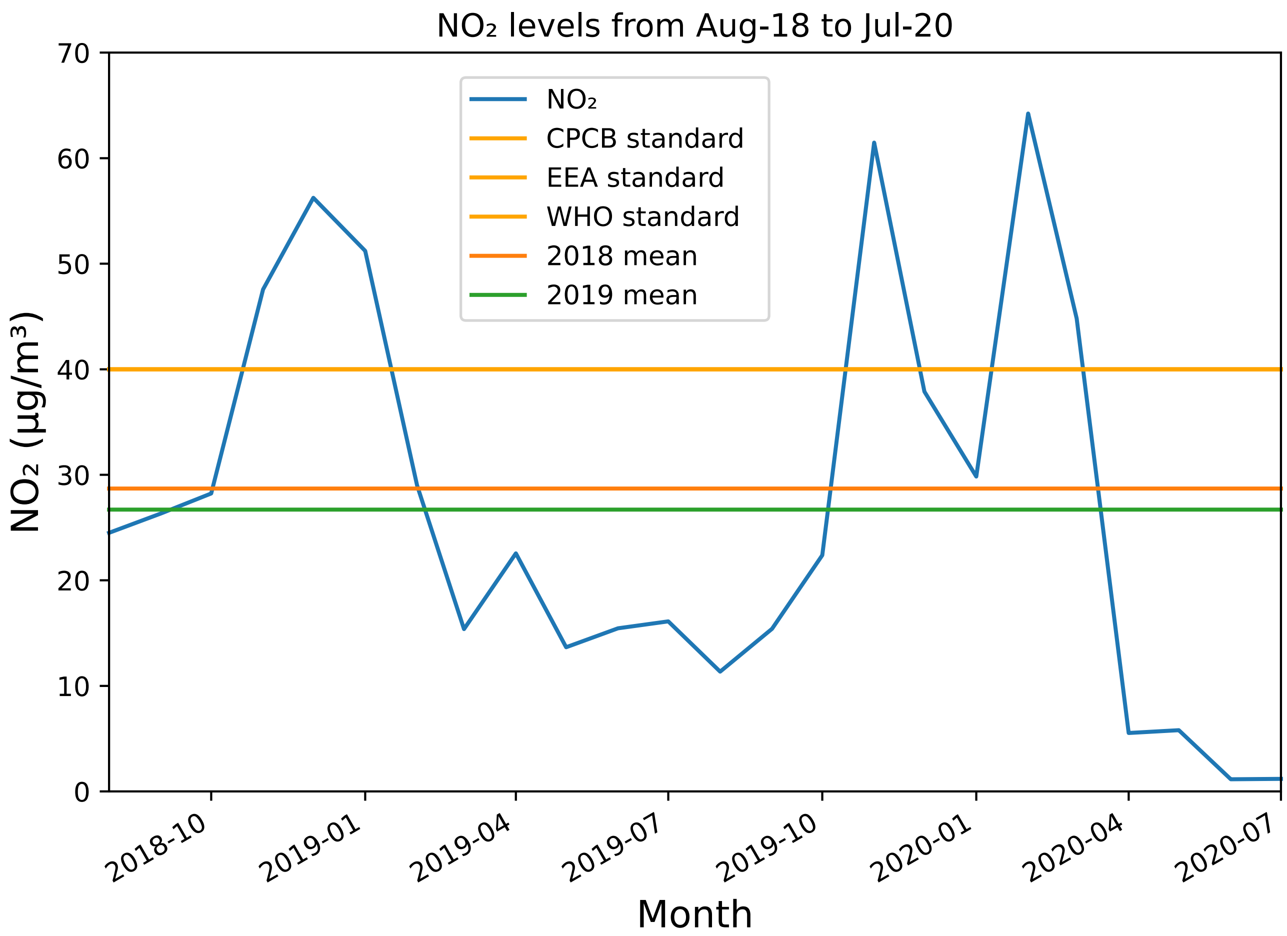

Figure 1.4: Nitrogen dioxide levels from Aug-18 to Jul-20

This pollutant peaked three times from August-18 to July-20. All these peaks are above the CPCB, EEA and WHO AQS. The effect of the COVID-19 pandemic on pollution can be easily observed in the graph by looking at the abrupt and drastic decrease in the concentration after March-20. Values in the period from March-19 to October-19 were below the CPCB and EEA AQS, and showed a progressive decrease. A Similar pattern was observed in 2020, apart from the unusual spike in March. The mean for 2018 was just above the mean for 2019.

Carbon monoxide

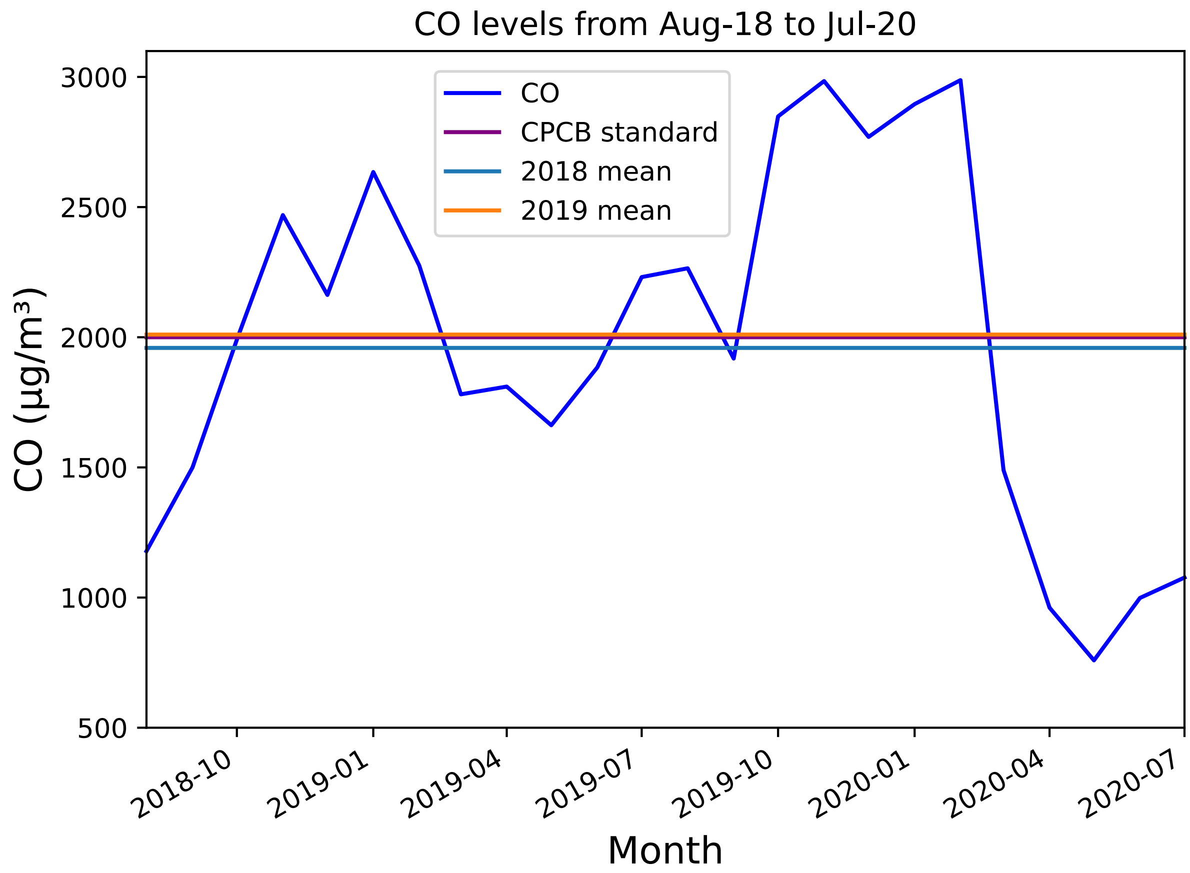

Figure 1.5: Carbon monoxide levels from Aug-18 to Jul-20

The carbon monoxide concentration fluctuates about the CPCB AQS. The mean for 2018 is higher than the mean for 2019. The mean for 2019 is also ~ 10 µg/m3 higher than the CPCB safe limit. However, it must be noted that the EEA and WHO AQS for carbon monoxide (10000 µg m^{-3}) are 5 times the CPCB AQS for carbon monoxide (2000 µg m^{-3}), which makes it a pollutant of least concern.

Ground level ozone

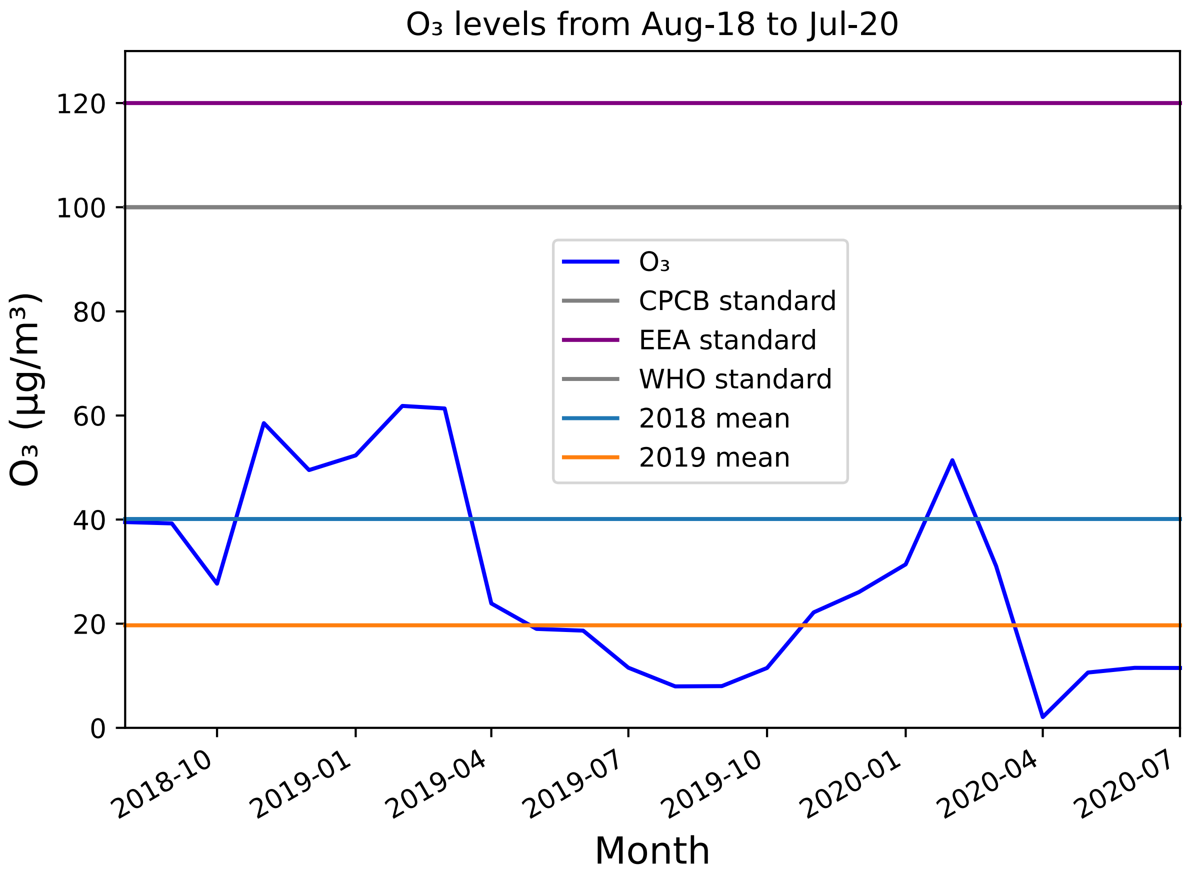

Figure 1.6: Ground level ozone concentration from Aug-18 to Jul-20

Ground-level ozone concentrations have been under control in Mumbai. They have stayed below the EEA, CPCB and WHO AQS. The concentration of ozone peaks around March every year, but never exceeds any AQS. Just like other pollutants, Ozone levels have been affected significantly after March 2020 due to the COVID-19 pandemic lockdowns, so the mean for 2019 is half the mean for 2018. Overall, ozone is a pollutant of least concern.

The effects of air pollutants on human health

Particulate Matter[16] [17]

The damage inflicted by particulate matter depends on its size, but there are some prominent effects. It affects the respiratory system in multiple ways that include irritation, inflammation, infections, asthma, reduced lung function, lung cancer and chronic obstructive pulmonary disease. Particulate matter can enter bloodstream from the lungs, and cause deterioration of blood vessels. It may then cause adverse effects the central nervous system and the reproductive system. The person might also develop cardiovascular diseases.

Sulphur dioxide[18] [19] [20]

Short-term exposures to high concentrations of sulphur dioxide can be life-threatening. Low sulphur dioxide concentrations lead to irritation of eyes, nose and throat. After prolonged exposure, the irritation causes respiratory problems including bronchitis and difficulty in breathing. It may lead to the worsening of existing heart-related diseases which could increase the risk of heart attacks.

Nitrogen dioxide[21] [22]

Short-term exposure nitrogen dioxide causes the irritation of the eyes, nose and throat. Prolonged exposure causes inflammation of the airways, which may lead to reduced lung function and increase in asthma attacks for asthmatics. Newer research also links exposure to cardiovascular harm and increased risk of premature death.

Ground level ozone[23] [24] [25]

It irritates the eyes, nose, and throat, causing redness of eyes and breathing difficulties. Prolonged exposure can cause heart-related ailments, which include severe heartache (angina), and an increased risk of heart attacks.

16 WHO (2013), Health Effects of Particulate Matter, Archived
17 pg. 262-267, WHO EURO (2005), Air Quality Guidelines
18 CDC (1998), Public Health Statement – Sulfur Dioxide, Archived
19 pg. 410-422, WHO EURO (2005), Air Quality Guidelines
20 National Park Service (US) (2018), Sulfur Dioxide Effects on Health, Archived
21 American Lung Association, Nitrogen Dioxide, Archived
22 Michigan State University (2013), Indoor air quality may be hazardous to your health, Archived
23 pg. 325-335, WHO EURO (2005), Air Quality Guidelines
24 Spare the Air (2019), Air Pollutants and Health Effects, Archived
25 EPA (2009), Air Quality Index (AQI): A Guide to Air Quality and Your Health

Carbon monoxide[26]

Carbon monoxide, upon entering the body, reduces the oxygen carrying capacity of blood, so the body receives lesser amounts of oxygen. This causes the body to be deprived of oxygen, which may lead to death if exposure is not stopped and the person isn't immediately given treatment. Long periods of oxygen deprivation may cause strokes and brain death.

26 Mayoclinic, Carbon monoxide poisoning, Archived

Analysis

A comparison of EAQI and NAQI

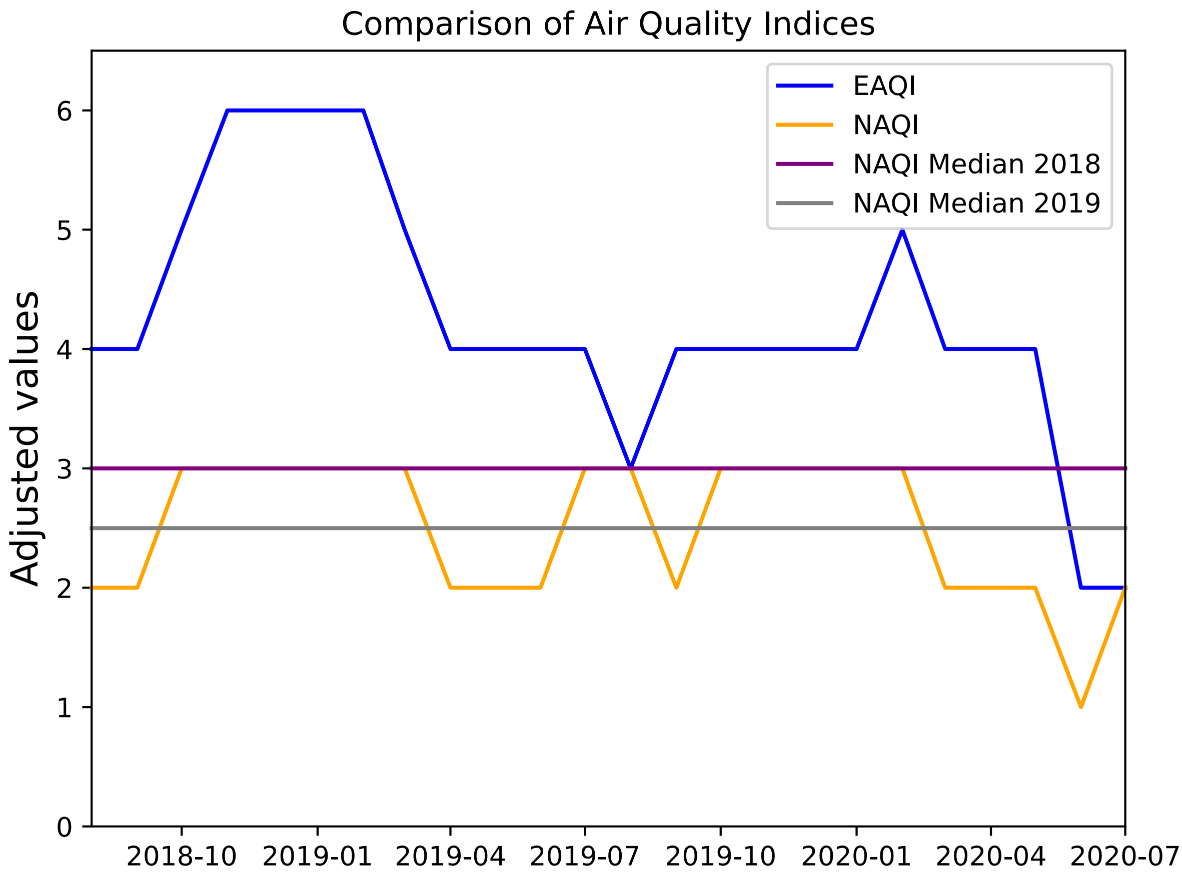

Figure 2: A comparison of EAQI and NAQI

The graph above is a direct comparison of the EAQI and NAQI. This has been achieved by converting the scale of both indices to adjusted values on a six point qualitative scale, based on their index levels indicated in the tables above. On average, NAQI is 39% lower than the EAQI when calculated using a derived method. Additionally, the maximum deviation of NAQI from the EAQI is 50%, and the minimum deviation is 25%.

What does this mean? It means that the NAQI falsely indicates that the air quality is ~40% better than the EAQI indication for the same day. This can be disastrous for sensitive groups that have begun to rely on AQIs to show them when it will be safe to venture outdoors.

Why has the EAQI been considered as the standard?

We have considered the EAQI to be the standard against which the NAQI is measured because the particulate matter thresholds in the EAQI are the closest to WHO standards. This is very important because particulate matter pollution is the most worrying in cities like Mumbai. Additionally, the EAQI is very consistent when the difference between thresholds for all pollutants is considered. Further explanation can be found in *Discussion – Influencing Factors*.

Eclipsing and ambiguity due to carbon monoxide

The CPCB AQS for carbon monoxide limits the 8-hour exposure to 2 000 µg m^{-3}. While a lower threshold may appear to be better than the equivalent WHO AQS, that is not the case when it is used in the NAQI. Since the AQIs use a maximum operator, this means that the other pollutants may be ignored, leading to underestimation (eclipsing), or the carbon monoxide concentration might artificially inflate the AQI (ambiguity). Both are undesirable properties in an air quality index[27]. The table below demonstrates this. It shows the months between Aug-18 and Jul-20 when the AQI was determined by carbon monoxide.

Table 4: Months when CO determined the NAQI

Month	Pollutant Concentration in µg m^{-3}						Indices			
							EAQI		NAQI	
	$PM_{2.5}$	PM_{10}	NO_2	CO	O_3	SO_2	Raw	Adj (1-6)	Raw	Adj (1-6)
Sep-18	29.05	73.18	26.33	1499.33	39.26	14.91	Poor	4	73	2
Apr-19	20.54	78.51	22.56	1810.33	23.89	22.82	Poor	4	90	2
May-19	15.42	65.67	13.66	1661.94	19.00	18.57	Poor	4	82	2
Jun-19	13.58	57.96	15.46	1884.33	18.68	18.64	Poor	4	94	2
Jul-19	12.98	57.79	16.12	2231.03	11.54	18.49	Poor	4	103	3
Aug-19	16.94	46.77	11.35	2265.00	7.97	10.09	Moderate	3	103	3
Sep-19	12.91	61.21	15.41	1917.78	8.02	11.48	Poor	4	96	2
Oct-19	29.61	67.40	22.38	2848.33	11.50	4.93	Poor	4	110	3
Nov-19	41.72	95.67	61.48	2984.00	22.18	8.19	Poor	4	112	3
Dec-19	46.61	98.83	37.89	2769.35	26.06	22.45	Poor	4	109	3
Jan-20	48.57	92.53	29.84	2895.48	31.40	18.96	Poor	4	111	3
Jun-20	9.08	34.99	1.15	998.15	11.52	2.03	Fair	2	50	1
Jul-20	7.58	32.53	1.19	1076.79	11.50	0.04	Fair	2	54	2

27 pg. 16 – 18, CPCB (2015), National Air Quality Index

The WHO carbon monoxide AQS limits the 8-hour exposure to 10 000 μg m^{-3}. It is clearly visible in the table above that carbon monoxide pollution in Mumbai is far lower than the WHO standard. Despite this, the NAQI places unnecessary emphasis on carbon monoxide, theoretically inflating the value of the NAQI. However, this almost never happens in practice, because, when combined with very relaxed particulate matter thresholds, the NAQI regularly underestimates air pollution.

Particulate matter thresholds

Particulate matter is the pollutant of most concern today.[28] The NAQI sets the satisfactory threshold for $PM_{2.5}$ and PM_{10} at 60 and 100 μg m^{-3} respectively. This is higher than the WHO AQS by 140% and 100% respectively, which automatically makes it a threat to the health of the general population even when the NAQI stays below 100, and the threat is much greater for sensitive populations. In this case, categorising the air quality as satisfactory can be considered as misleading the people.

The original purpose of NAQI

The NAQI began as an effort to develop an index for the National Capital Territory, i.e. New Delhi. Since Delhi is infamous for its extraordinary pollution levels, the index was naturally more lenient to accommodate the large concentrations. However, Mumbai has much lesser air pollution than Delhi, but the pollution in Mumbai is by no means healthy for residents. When the index was extended beyond its true purpose, it became defunct, even dangerous in some cases, because every city has a different pollution profile.

In a large nation like India, a coastal city has a very different cocktail of pollutants in its air than an inland city. A coastal city might have a lot of pollution blown away by the sea breeze, which is what is observed in Mumbai during the summer months when the city has, on some days, the cleanest air in a major Indian city. The exact opposite is observed during winter. While the pollution never gets close to the levels in the NCT, it is still quite dangerous, with PM_{10} concentration exceeding 150 μg m^{-3}, nearly 3 – 7 times the WHO AQS. Since the NAQI is adapted to the pollution patterns in the NCT, the leniency built into the index makes it unsuitable for the city of Mumbai. The pollution profile of Mumbai requires a stricter index.

28 pg. 16, WHO (2013), Health Effects of Particulate Matter, Archived

Discussion

It can be concluded from the analysis that the NAQI is not suitable indicator of air pollutant for the city of Mumbai. Its tendency to underestimate, and less often, overestimate air pollution makes it incapable of inducing public awareness about pollution levels. Furthermore, it may be said that underestimation of air pollution sends the wrong message to the people, due to which people take less precautions to safeguard their respiratory health than they should. This can also prove fatal for those from sensitive populations that have been lulled into a false sense of security. A continuation of these policies could result in the loss of entire generations to poor respiratory health.

Implications of this research

- This may be the first assessment that the NAQI has been subjected to. The conclusions obtained are likely to increase pressure on the CPCB to overhaul the NAQI, or create a new AQI altogether which will provide an accurate indication of air pollution to the people.
- The increase in air quality awareness that would follow the creation of such an index would allow people, especially those from sensitive populations, to take appropriate precautions when venturing outdoors.
- The increase in awareness would also be followed by increased democratic pressure on the government to reduce air pollution in cities like Mumbai. This would ensure that the respiratory health of younger generations is not compromised.
- A reduction in air pollution would also make it a lot easier for those in public services to do their jobs, i.e. traffic police, bus and autorickshaw drivers, etc.

Influencing factors

EAQI has been assumed to be the standard for AQIs. While this may be an unintended bias, there are reasons why we have done so:

- EAQI is one of the few indices that comply as closely as possible to WHO AQS. It does so exceptionally well for PM pollution, which is the pollutant of highest concern in Mumbai today.
- The EU has some of the highest AQS in the world after the WHO. It also has the best environmental protection laws in the world.[29]

Another factor that may have influenced the research is data integrity. Our raw data had some gaps in pollutant concentrations, so the absence of these values may have given us averages after processing that may not have reflected the true conditions during that month. However, we are confident that collection of 4,380 data points has balanced out any such errors.

A potential solution

Mumbai Metropolitan Air Quality Index

After studying the EAQI and NAQI, our group has created our own AQI, one that could potentially replace the NAQI within the Mumbai Metropolitan region after further development.

Table 5.1: Mumbai Metropolitan Air Quality Index

Index level	**Pollutant (concentrations in µg m^{-3}, unless stated otherwise)**					
	$PM_{2.5}$	**PM_{10}**	**NO_2**	**O_3**	**SO_2**	**CO (mg m^{-3})**
Good (1 – 50)	0 – 10	0-20	0 – 40	0 – 50	0 – 40	0 – 3.0
Fair (51 – 100)	11 – 25	21-50	41 – 80	51 – 100	41 – 80	3.1 – 10.0
Moderate (101 – 200)	26 – 50	51 – 75	81 – 120	101 – 130	81 – 200	10.1 – 15.0
Poor (201 – 300)	51 – 75	76 – 150	121 – 230	131 – 240	201 – 500	15.1 – 25.0
Very poor (301 – 400)	76 – 150	151 – 230	231 – 340	241 – 380	501 – 750	25.1 – 34.0
Extremely Poor (400+)	150+	230+	340+	380+	750+	34.0+

29 Statista, 16.01.2020, Archived

This index will be henceforth referred to **in this paper** as the Mumbai Metropolitan Air Quality Index (MMAQI). MMAQI is calculated using the same method as NAQI.

Table 5.2: Health messages corresponding to the Mumbai Metropolitan Air Quality Index

AQI	General population	Sensitive populations
Good (0 – 50)	The air quality is good. Enjoy your usual outdoor activities.	The air quality is good. Enjoy your usual outdoor activities.
Fair (51 – 100)	Enjoy your usual outdoor activities.	Enjoy your usual outdoor activities.
Moderate (101 – 200)	Enjoy your usual outdoor activities.	Consider reducing intense outdoor activities, if you experience symptoms.
Poor (201 – 300)	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat.	Consider reducing physical activities, particularly outdoors, especially if you experience symptoms.
Very poor (301 – 400)	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat.	Reduce physical activities, particularly outdoors, especially if you experience symptoms.
Extremely poor (401 – 500)	Reduce physical activities outdoors.	Avoid physical activities outdoors.
Severe (501 – 775)	Avoid physical activities outdoors.	Do not go outdoors.
Hazardous (775+)	Do not go outdoors. An air purifier is recommended.	Avoid coming into contact with any outdoor pollution. An air purifier is essential.

This index has not been arbitrarily defined. Instead, it is a combination of the ability of the NAQI to go above values defined in its thresholds table, and the strict thresholds in EAQI. Additionally, some of the thresholds are derived directly from the WHO, EEA and CPCB air quality thresholds. The resilience of this index is demonstrated in the table on the next page. We believe that, with some additional work on this index by professionals, it would be perfectly suited for the Mumbai Metropolitan region.

Comparison of MMAQI with other indices

Table 6: Comparison of MMAQI with EAQI and NAQI ([adjusted values](#) only)

Month	Adj (1-6)			Month	Adj (1-6)		
	EAQI	NAQI	MMAQI		EAQI	NAQI	MMAQI
Aug-18	4	2	3	Aug-19	3	3	2
Sep-18	4	2	3	Sep-19	4	2	3
Oct-18	5	3	4	Oct-19	4	3	3
Nov-18	6	3	5	Nov-19	4	3	4
Dec-18	6	3	5	Dec-19	4	3	4
Jan-19	6	3	5	Jan-20	4	3	4
Feb-19	6	3	5	Feb-20	5	3	4
Mar-19	5	3	4	Mar-20	4	2	4
Apr-19	4	2	4	Apr-20	4	2	3
May-19	4	2	3	May-20	4	2	4
Jun-19	4	2	3	Jun-20	2	1	2
Jul-19	4	3	3	Jul-20	2	2	2

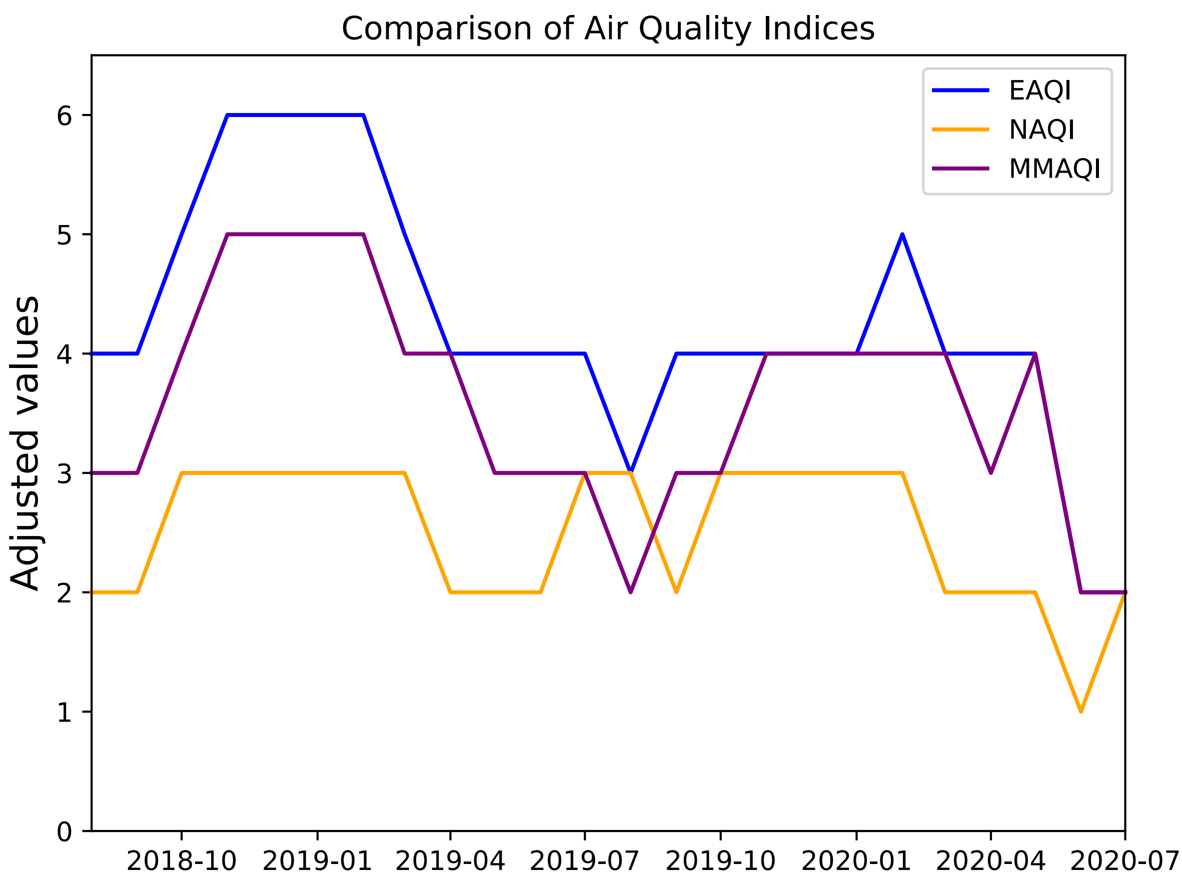

Figure 2: Comparison of MMAQI with EAQI and NAQI (graph)

It is clear from the tables and the graph above that MMAQI is already a capable index in its current form. In table 5.3, there is one instance when the MMAQI is lower than NAQI, in August 2019. After referring to table 4, we can see that carbon monoxide was the determinant of the NAQI for August 2019. This is a clear example of ambiguity (overestimation) due to the low carbon monoxide thresholds in the NAQI.

Furthermore, we can see that MMAQI follows the EAQI more closely than NAQI, with a mean deviation of just 15% lower than the EAQI. Additionally, the MMAQI indication is 47% higher than the NAQI on average. However, the most important reason why MMAQI is perfectly suited for Mumbai can be seen by comparing the graph above with the graphs for $PM_{2.5}$ and PM_{10}. Particulate matter is the pollutant of most concern in Mumbai, and the shape of the curve for the MMAQI closely follows the pattern in the curves for particulate matter concentrations. This demonstrates how uncannily the MMAQI is adapted to the pollution patterns in Mumbai, which might make it the perfect replacement for NAQI in the Mumbai Metropolitan region, after professional review.

Further Action

There are two paths of further action on this research:

- Promote the MMAQI in the pollution analysis community, so that CPCB pays attention to this research, and possibly adopts the MMAQI after modifications.
- Petition the CPCB to redefine the NAQI, or petition the MPCB create a new index for the Mumbai Metropolitan region.

Further Research

This research leads us to another research question:

Can the MMAQI replace the NAQI for the Mumbai Metropolitan region? What modifications, if any, would be required to achieve this?

Supplement

We have created a web application that calculates the AQI for the three indices in this paper. It is hosted at https://saadisave.github.io/. Additionally, the application also compares the indices so that anyone visiting the website can see for themselves what the differences between the indices are, and how those differences are narrowed or widened by different pollutants at different concentrations. The application is also the recommended way to calculate the MMAQI.

*To access the complete repository with all the source code and licenses, go to https://github.com/SaadiSave/aqical. Note that the application is a part of this research, not a separate project.

Reflection

Group Indicators

Table 7: Indicators from group reflection template

Indicators – Collaboration	4	3	2	1
Every member of the team was always prepared, well informed on the project topic and ready to work.		✓		
Every member of the team always completed assigned tasks on time without having to be reminded.		✓		
As a team, we created a detailed task list that divided project work reasonably among the team members.		✓		
As a team, we set a schedule and tracked progress toward goals and deadlines.	✓			
As a team, we used time and ran meetings efficiently; kept materials, drafts, notes organized	✓			
As a team, we developed ideas and created products with the involvement of all team members	✓			
Indicators – Communication	4	3	2	1
Every member of the team listened to others' ideas without interrupting; responded positively to ideas even if rejecting.	✓			
Team members communicated openly and treated one another with respect.	✓			
Every member of the team felt safe and free to seek assistance and information, share resources and insights, provide advice, or ask questions of each other.	✓			

Varun

The research was quite interesting and gave me a lot of knowledge about AQI. The only thing that I regret is not being able to interview anyone. Also, the search for data and indices took a lot of time. We have done a great job, as no one has researched this before. This was also particularly interesting for me because as a testing side project, we created an AQI calculator using python which included web designing and programming with JavaScript, which helped me develop my web development skills by increasing my knowledge of JavaScript.

Suyash

The research was quite thought-provoking and pleasing. Trying to carry out research during the pandemic was tiresome – because we were unable to get an opportunity to interview pulmonologists who were busy with treating COVID patients, and the internet, which has countless unofficial and bogus websites, became our only option. Filtering info just by comparing data from numerous sites for reliability, using giant AQI formulae and searching & making a list of references were the most difficult and time-consuming tasks. Yet, I enjoyed comparing the AQIs and studying the role of something so valuable and important. I honestly considered it to be rather insignificant before this research.

Meetrayu

Researching about AQI and its importance gave me exposure to something that I wasn't aware of. I felt it's something that must be bought in front of everyone, as it is crucial to keep an eye on the toxic pollutants that have been a leading cause of air pollution and check the accuracy of the NAQI. Although we had to work rigorously to search and arrange valid information, it was interesting to fall into depths of such a fascinating topic, which involved research, programming, and biology. It gave me an opportunity to learn about the different types of AQI's around the globe and a variety of research techniques.

Saadi

This research helped me realise exactly how inadequate the NAQI is. Since most of our data was secondary, it helped me develop my data collection skills. But it was very difficult to collect all the data. Apart from the research, designing and programming the calculator itself was quite enjoyable and rewarding, since it helped me understand advanced programming and deployment concepts, another skill that will serve me well later in life.

Appendix I – Bibliography

a. CPCB (2015), National Air Quality Index, Archived

b. European Council & Parliament (2015), 2008/50/EC, Archived

c. EEA (2013), Environment and human health – joint EEA-JRC report

d. EEA (2019), Air Quality in Europe

e. EEA (2020), Signals 2020 – Towards zero pollution in Europe

f. EPA (2009), Air Quality Index (AQI): A Guide to Air Quality and Your Health

g. WHO EURO (2005), Air Quality Guidelines, Archived

Appendix II – Data & Formulae

Data

Table II.A: Monthly Data from Aug-18 to Jul-20

Month	Pollutant Concentration in µg m^{-3}						Indices	
	$PM_{2.5}$	PM_{10}	NO_2	CO	O_3	SO_2	EAQI	NAQI
Aug-18	19.95	60.86	24.51	1178.06	39.52	12.72	Poor	61
Sep-18	29.05	73.18	26.33	1499.33	39.26	14.91	Poor	73
Oct-18	46.04	125.02	28.23	1990.69	27.69	18.83	Very Poor	117
Nov-18	60.58	155.99	47.56	2469.29	58.54	22.37	Extremely Poor	101
Dec-18	65.26	166.30	56.24	2162.26	49.51	21.65	Extremely Poor	116
Jan-19	65.88	194.61	51.22	2634.84	52.33	23.87	Extremely Poor	163
Feb-19	54.67	160.59	29.00	2275.00	61.84	18.02	Extremely Poor	141
Mar-19	30.42	121.29	15.38	1780.67	61.35	10.69	Very Poor	114
Apr-19	20.54	78.51	22.56	1810.33	23.89	22.82	Poor	90
May-19	15.42	65.67	13.66	1661.94	19.00	18.57	Poor	82
Jun-19	13.58	57.96	15.46	1884.33	18.68	18.64	Poor	94
Jul-19	12.98	57.79	16.12	2231.03	11.54	18.49	Poor	103
Aug-19	16.94	46.77	11.35	2265.00	7.97	10.09	Moderate	103
Sep-19	12.91	61.21	15.41	1917.78	8.02	11.48	Poor	96
Oct-19	29.61	67.40	22.38	2848.33	11.50	4.93	Poor	110
Nov-19	41.72	95.67	61.48	2984.00	22.18	8.19	Poor	112
Dec-19	46.61	98.83	37.89	2769.35	26.06	22.45	Poor	109
Jan-20	48.57	92.53	29.84	2895.48	31.40	18.96	Poor	111
Feb-20	50.72	125.13	64.23	2987.93	51.40	9.44	Very Poor	117
Mar-20	22.82	76.64	44.81	1488.97	31.06	18.67	Poor	77
Apr-20	24.53	65.54	5.54	960.67	2.07	32.28	Poor	66
May-20	48.98	85.61	5.80	758.39	10.62	48.02	Poor	86
Jun-20	9.08	34.99	1.15	998.15	11.52	2.03	Fair	50
Jul-20	7.58	32.53	1.19	1076.79	11.50	0.04	Fair	54

Method to compare indices

To calculate how much less index A is compared to index B (for qualitative values on a 6 point scale)

$$\Delta = 1 - \frac{A}{B}$$

To calculate how much larger index A is compared to index B (for qualitative values on a 6 point scale)

$$\Delta = \frac{A}{B} - 1$$

Multiply by 100 to convert answer to percentage.

Table II.B: Six point scales for all three indices

Point	EAQI	NAQI	MMAQI
1	Good	0 – 50	0 – 50
2	Fair	51 – 100	51 – 100
3	Moderate	101 – 200	101 – 200
4	Poor	201 – 300	201 – 300
5	Very Poor	301 – 400	301 – 400
6	Extremely Poor	401 – 500	401 – 500

Appendix III – Glossary

NAQI – National Air Quality Index

CPCB – Central Pollution Control Board (India)

AQS – Air Quality Standards

PM – Particulate Matter, umbrella term for $PM_{2.5}$ and PM_{10}

SO_2 – Sulphur dioxide

NO_2 – Nitrogen dioxide

CO – Carbon monoxide

O_3 – Ozone

COPD – Chronic Obstructive Pulmonary Disease

NCT – National Capital Territory

EAQI – European Air Quality Index

MPCB – Maharashtra Pollution Control Board

EU – European Union

EEA – European Environmental Agency (EU)

EPA – Environmental Protection Agency (US)

WHO – World Health Organisation (UN)

eclipsing – overestimation by an index

ambiguity – underestimation by an index

MMAQI – Mumbai Metropolitan Air Quality Index