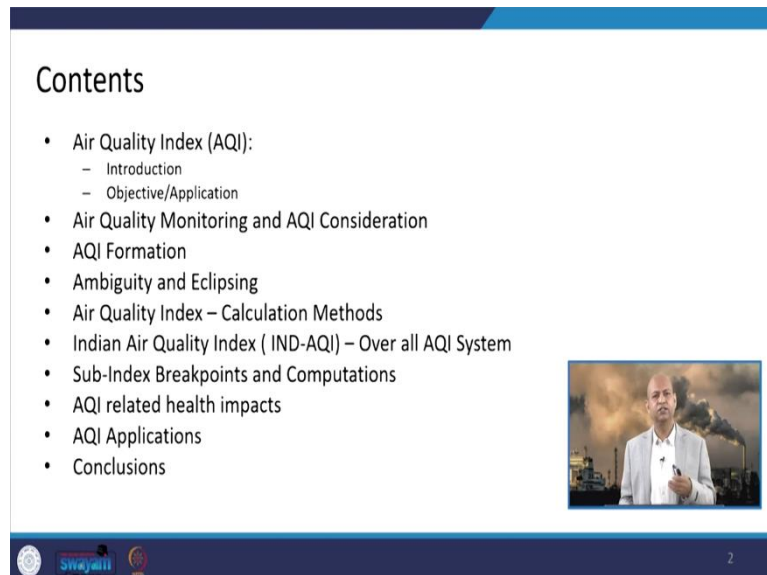


Air Pollution and Control
Professor. Bhola Ram Gurjar
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Lecture - 14
Air Quality Index (AQI)

Hello friends. Today we will discuss about Air Quality Index. Before that we have gone through about air quality monitoring status across India and what is the significance of air quality monitoring. So, there are various uses of air quality data which we collect through air quality monitoring and one of them is generating Air Quality Index. So, from the name itself it is revealed, index it is some figure or some values. So, these are the values which are used for various purposes for air quality management.

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The slide displays a table of contents for the lecture. The title 'Contents' is at the top left. Below it is a bulleted list of topics. On the right side of the slide, there is a small video thumbnail showing a man in a white shirt speaking. At the bottom of the slide, there are logos for IIT Roorkee and Swayam, along with the number '2' in the bottom right corner.

- Air Quality Index (AQI):
 - Introduction
 - Objective/Application
- Air Quality Monitoring and AQI Consideration
- AQI Formation
- Ambiguity and Eclipsing
- Air Quality Index – Calculation Methods
- Indian Air Quality Index (IND-AQI) – Over all AQI System
- Sub-Index Breakpoints and Computations
- AQI related health impacts
- AQI Applications
- Conclusions

So, today we will discuss about this Air Quality Index and its objectives, its applications, how air quality monitoring and AQI are related to each other? What are the mathematical relationships or formulations of Air Quality Index and then there are certain ambiguity or eclipsing, those kinds of issues are there, how to deal with that related to the data? Then, the methods or various methods are available for calculating Air Quality Indices. So, which is more important and in Indian context which kind of Air Quality Index is more popular or we use.



Then there are issues when we calculate the Air Quality Index then before that we also calculate some sub-index values because after combining all sub-indices, then we calculate the Air Quality Index. So, before that what is the calculation purpose of sub-indices and on what breakpoints they are based upon.

So, what are the computations methods of those? Then we will see health impacts related to different ranges of Air Quality Index, Then applications means, how do we apply those Air Quality Indices for air quality management in different cities or countries and after that we will conclude.

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Air Quality Index - Introduction

- Air Quality Index (AQI) is defined as an overall scheme that transforms the weighed values of individual air pollution-related parameters (for example, pollutant concentrations) into a single number or set of numbers. The AQI communicates primarily a number starting from 0 and goes up to 500 depending upon the method of calculation. For e.g.:
 - ❖ Method by Tiwari and Ali (1987): AQI range (0 to 100+)
 - ❖ Geometric Mean Method: AQI range (0 to 125+)
 - ❖ Pollution Index Method: AQI range (0 to 175+)
 - ❖ CPCB Method: AQI range (0 to 500)
- AQI is commonly used to report the level of severity of air pollution to public. The higher the number, the greater the health risk associated with the air quality.



Source: (www.cpcb.nic.in; Beig et al (2010)) Image Source: www.deq.ok.gov

So, when we go about Air Quality Index. So, basically this is nothing but the kind of thing which define a relationship, a figure, a value which defines an overall scheme that transformed the weighted values of individual air pollution concentrations, different air pollutants like SO₂, PM₁₀, PM_{2.5} all those into a single number. So, we first calculate the different pollutants concentrations and their weighted average or weighted value depending upon their health impacts, and then we combine them.

So, then Air Quality Index is basically kind of the communication purpose primarily a number which starts from 0 to certain high level, like in India we go from 0 to 500. In other cases, it could be like one method is there from Tiwari and Ali that gives AQI range 0 to 100 plus. Then other method is there, which gives 0 to 125 plus. Another one is 175 plus and the CPCB Central Pollution Control Method which we extensively use in India that is 0 to 500 and methodology is similar to USEPA methodology basically.

So, we can say that this Air Quality Index is commonly used to report the level of severity of air pollution to the public, means at any location, at any place, how much intensity or severity or loading of the pollution is there. So, that is reflected by Air Quality Index. Low value means cleaner, very high value means polluted region. Higher number the greater the health risk associated with the air quality.


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Air Quality Index (India) – Objective/Application (1/3)

➤ To adopt/develop an Index based on national ambient air quality standards, health impacts, and monitoring programme which represent perceivable air quality for the general public in easy-to-understand terms and assist in data interpretation and decision-making processes related to pollution mitigation measures.

The following six objectives that can be served by an AQI:

1. Resource Allocation
2. Trend Analysis
3. Ranking of Locations
4. Public Information
5. Enforcement of Standards
6. Scientific Research



Source: (AQI Report, CPCB)

swayamii

So, how to go for this? What are different objectives? What are different applications? So, basically to adopt or develop this one Index, which is AQI, it is based on national ambient air quality standards and health risk assessments. Monitoring program which are representative for different kind of pollutants in and around a location.

So, those data interpretation is there and this particular range can be coded into different colour schemes which is easily to understood by the public, general public because scientific and engineering approach may be quite complex in terms of values, equations, etc. But general public wants to know whether it is good or bad, moderate, severe, risky all those, dangerous, hazardous, those kinds of things.

So, to go for those kinds of qualitative interpretation, we should have certain quantitative approach also. So, this quantitative approach is basically Air Quality Index related values which gives certain range, according to the range we can announce that this is good or bad or poor or moderate, satisfactory something like that. Then in overall sense, we can say that there are broadly 6 objectives which are served by the AQI, like it is used for resource allocation, it can be used for trend analysis or ranking of locations in terms of polluted or cleaner one.

Then informing the public about the air quality, then enforcement of certain standards whether they are being exceeded or they are being honoured or met, then scientific research because whenever you are coming up with certain new research, new methodology, then also Air Quality Index can give you new approaches to look into that.

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Air Quality Index – Objective/Application (2/3)

01 Resource Allocation

- To assist administrators in allocating funds and determining priorities.
- Enable evaluation of trade-offs involved in alternative air pollution control strategies.

02 Trend Analysis

- To determine the change in air quality (degradation or improvement) which have occurred over a specified period.
- This enables forecasting of air quality (i.e., tracking the behavior of pollutants in the air) and plan pollution control measures.

03 Ranking of Locations

- To assist in comparing air quality conditions at different locations / cities. Thus, pointing out areas and frequencies of potential hazards.



Source: (AQI Report, CPCB)



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Air Quality Index – Objective/Application (3/3)

04 Public Information

- To inform the public about environmental conditions .
- Useful for people who suffer from illness aggravated or caused by air pollution.

05 Enforcement of Standards

- To determine extent to which the legislative standards and existing criteria are being adhered. Also helps in identifying faulty standards and inadequate monitoring programs.

06 Scientific Research

- Helps scientists engaged in research using air quality data.
- Provides better insights to researchers while conducting studies of some environmental phenomena.



Source: (AQI Report, CPCB)



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So, when we go about these six objectives basically like resource allocation as you know, because we have, that is limited resources whether it is funding etc, we want to solve certain problem. So, Air Quality Index can give you priority list. Some location is highly polluted then better we invest some resources there to clean it first. Then we can go less polluted areas something like that. So, evaluation of trade-offs, it helps in.

Then trend analysis because, over the years or over the months, we can have different values of the Air Quality Index. So, that also gives certain trends whether it is increasing or decreasing. So, those kinds of trends can give us some information whether, whatever some majors we are taking to clean the air to improve their quality, whether it is working or not, those kinds of things. So, trend analysis can give that kind of information.

Then ranking of locations as I said, you can easily rank with the, this is highly polluted, this is less polluted. So, ranking of different cities with the Air Quality Index you can go for or ranking of different locations you can go for. Then public information, it is very easy because easily understand that range, whether it is high value, then it is highly polluted, less value less polluted, and you can also link it with some colour schemes which can be through website or through boards etc, digital boards, you can give that kind of information which is visible to public and they can understand it easily.

Enforcement of standards because there are certain standards and if they are exceeded by high concentration, ambient air concentration, then this Air Quality Index will be higher. So, we can easily link means if some standards are being met or being exceeded Air Quality Index can give us information. So, we can think in a very easy and very fast way to see whether standards are being met or not.

Then scientific research like it can give new information for research purposes related to air quality data, it can give new insights for conducting studies on some environmental phenomena which could be responsible for poor AQI or something like that. Suddenly, suppose, you get AQI at a particular location very severe.


So, then you want to study what is the region? Whether some local sources is responsible or some transportation of from a wind direction some pollution has come, so, that you can do research and you can link the regions of that poor air quality.

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Air Quality Monitoring and AQI Consideration

➤ The air quality monitoring network in India includes both Online Monitoring and Manual monitoring.

1. Online Monitoring Network
 - Automated air quality monitoring stations
 - Continuous monitoring
 - Real time AQI computation
2. Manual Monitoring Network
 - Manual air quality monitoring
 - Intermittent monitoring
 - Not suitable for AQI calculation for quick interpretation
 - Historical AQIs on weekly basis for data interpretation



Source: (AQI Report, CPCB)

swayamii

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Then we can address those regions. Well, when we go for, what is the role of air quality monitoring in generating AQI or Air Quality Index. So, basically, online monitoring and more manual monitoring goes on in entire country and the online monitoring network, which is automated way of air quality monitoring, this gives continuous monitoring of different pollutants.

So, this is the real time AQI computation is possible with those data. But in case of manual monitoring there is a data gap. Because intermittent monitoring is there, you have to change, you have to analyse in the lab, so real time concentration values are not available for those purpose. So, this is not suitable for AQI calculation for quick interpretation.

But historical AQI is on weekly basis for data interpretation is possible, means just to see some kind of relationship but if you want to go real time AQI to public that every day or some forecasting something then only this online monitoring network is really helpful.

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Air Quality Index – Formation (1/7)

➤ Primarily **two steps** are involved in formulating an AQI:

1. **Formation of sub-indices** (for each pollutant)
2. **Aggregation of sub-indices** to get an overall AQI

Source: (AQI Report, CPCB)

Air Quality Index – Formation (2/7)

1. Formation of Sub-indices

- Formation of sub-indices (I_1, I_2, \dots, I_n) for n pollutant variables (X_1, X_2, \dots, X_n) is carried out using sub-index functions that are based on air quality standards and health effects.
- $I_i = f(X_i), i = 1, 2, 3, \dots, n$
- Each sub-index represents a relationship between pollutant concentrations and health effects.

Source: (AQI Report, CPCB)

Air Quality Index – Formation (3/7)

- The general equation for the sub-index (I_i) for a given pollutant concentration (C_p); as based on 'linear segmented principle' is calculated as:


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

- B_{HI} = Breakpoint conc. higher or equal to given conc.
- B_{LO} = Breakpoint conc. lower or equal to given conc.
- I_{HI} = AQI value corresponding to B_{HI}
- I_{LO} = AQI value corresponding to B_{LO}
- C_p = Pollutant Concentration


Source: (AQI Report, CPCB)

Air Quality Index – Formation (4/7)

- For example, PM_{10} with conc. of $85 \mu\text{g}/\text{m}^3$, $B_{HI} = 100$, $B_{LO} = 50$, $I_{HI} = 100$, $I_{LO} = 50$, $C_p = 85 \mu\text{g}/\text{m}^3$
- Sub Index, $I_p = \left[\left(\frac{100 - 50}{100 - 50} \right) * (85 - 50) \right] + 50 = 85$
- Similarly, Sub Index can be calculated for other pollutants as well.



Source: (AQI Report, CPCB)


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Well, then how to calculate this Air Quality Index? So, these are two calculation steps like first of all we go for each pollutant like X_1, X_2, X_3, X_4, X_n . So, we know that for each pollutant we can calculate one index, like I_1, I_2 something like that, this is the function of the concentration of that pollutant X_1, X_2 something like that.

Then we develop these indices sub-indices I_1, I_2, I_n for each pollutant. That will give us whether this pollutant is highly like polluting that particular place or it is okay, it is satisfactory within the range of acceptable limits. Then we combine all these sub-indices, we aggregate, we aggregate, so the combination of all these indices when we integrate or aggregate then we come up with a single index value, I , that is the summation or multiplication or integration you can call of those individual indices depending upon different pollutants.

So, that is the basically aggregation single value of the Air Quality Index, which incorporates or which take into account all sub-indices related to different pollutants. So, this is the way like sub-indices we form I_1, I_2, I_3 for different variables, these are nothing but concentration of pollutants. Then, this is the function, so we get values and then we go for this kind of summation like this equation is there.

So, for each kind of pollutant you can calculate I and then you have single value of summation or integration of aggregation of all those values and here this particular formula which is used in India also basically, so, you can see this I_{LO} , this is AQI value corresponding to B_{LO} and B_{LO} is nothing but Breakpoint Concentration lower or equal to the given concentration, which is available concentration, monitored concentration.

B_{HI} breakpoint concentration higher or equal to given concentration and these are related to like I_{HI} , AQI value corresponding to B_{HI} , I_{LO} , AQI that is Air Quality Index value corresponding to B_{LO} and C_P is the pollutant concentration basically. So, you put those values and you get this index I . Then you go for different pollutants and then you summation occurs then you can get the single value.


So, there is one example like for PM_{10} , let us assume that concentration is 85 micrograms per cubic meter and B_{HI} is 100 and this B_{LO} is 50 and I_{HI} is 100, I_{LO} is 50. So, the calculation becomes very easy and you get this value you put those values 150, 85, this is 85 and 50, this is 50. So, you get the 85, this sub-index of this pollutant P is 85. Similarly, you can calculate for different pollutants and then you can aggregate them.

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Air Quality Index – Formation (5/7)

2. Aggregation of sub-indices to get an overall AQI

- Aggregation of sub-indices, I_i is carried out with a mathematical function (described below) to obtain the overall index (I), referred to as AQI.
- $I = F(I_1, I_2, \dots, I_n)$
- The aggregation function usually is a summation or multiplication operation or simply a maximum operator.




Source: (AQI Report, CPCB)

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Air Quality Index – Formation (6/7)

- Aggregation functions can be:
- ❖ **Weighted Additive Form** ✓
- $I = \text{Aggregated Index} = \sum w_i I_i$ (For $i = 1, 2, \dots, n$), where,
 - $\sum w_i = 1$ (weight given to all the pollutant must adds to 1)
 - $I_i =$ sub-index for pollutant i ✓
 - $n =$ number of pollutant variables
 - $w_i =$ weightage of the pollutant ✓



Source: (AQI Report, CPCB)

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So, this Air Quality Index aggregation is there for all I_1, I_2, \dots, I_n . So, aggregation is possible and you can get the single value like summation may be there, but there are other ways like weighted additive form can be there. So, this is like for each pollutant weighting is there. Weight means for depending upon their intensity, depending upon their health impacts etc.

So, you can go for that number of pollutants is N , W_i weightage for the pollutant I . And I_i is sub-index for the pollutant I , that kind of thing is there. So, you can go for aggregation in the fashion have weighted additive form.


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Air Quality Index – Formation (7/7)


- ❖ **Root-Sum-Power Form (non-linear aggregation form)**
 - $I = \text{Aggregated Index} = [\sum I_i^p]^{(1/p)}$
 - where, p is the positive real number > 1 .

- ❖ **Root-Mean-Square Form**
 - $I = \text{Aggregated Index} = \left\{ \frac{1}{k} (I_1^2 + I_2^2 + \dots + I_k^2) \right\}^{0.5}$

- ❖ **Min or Max Operator**
 - $I = \text{Min or Max}(I_1, I_2, \dots, I_n)$



Source: (AQI Report, CPCB)


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Other ways are there like for example, root sum power non-linear aggregation form. So, this is submission I_i^p so, integration is there and $1/p$. So, this kind of you know p is no positive real number greater than one, so that you can have from other sources.

Similarly, root mean square form is also there for aggregation. So, this is the way for root mean square, you get square root of this. All the I values square of submission and then a square root. Minimum or maximum operator will be there I_1, I_2 so, you can get minimum and maximum values.

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What are Eclipsing and Ambiguity? (1/2)

- Two important characteristics, **eclipsing and ambiguity** are significant to interpret any index in the right perspective.
- **Eclipsing** occurs when an air pollution index does not indicate poor air quality even though concentrations of one or more air pollutants may have reached unacceptably high values.
- Pollution is **underestimated** by AQI if there is eclipsing.




Source: [Kanchan, Gorai, A.K., Goyal, P., 2015]

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What are Eclipsing and Ambiguity? (2/2)

- **Ambiguity** occurs when an air pollution index gives a false alarm even though concentrations of all the pollutants are within the permissible limit except for one pollutant.
- Pollution is **overestimated** by AQI if there is ambiguity.



Source: [Kanchan, Gorai, A.K., Goyal, P., 2015]

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So, different ways are there for aggregation purpose. Then when we go for these kinds of numbers or indices, there are issues like eclipsing or ambiguity like this eclipsing is something when an air pollution index does not indicate poor air quality even though concentration of one or more polluted may be reaching unacceptable high levels, high values. So, that is the eclipsing, means polluted environment is there, but index is saying that it is fine, no problem. So, that kind of error may be there.


So, that is kind of underestimation means single value AQI is coming underestimated although the parts of it, certain pollutants are having poor air quality range but when we are going kind of aggregation then it erroneously comes out that it is fine. That means, underestimation is there so, that is eclipsing.

Ambiguity is there when air pollution index gives you a false alarm means, there is no individual pollutants are within the range. They are not exceeding those standards, but when we are summing up we are aggregating, then the value is higher that means it is overestimating. So, this gives the false alarm, so, that is ambiguity. So, we have to deal with that kind of statistical thing.

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Eclipsing and Ambiguity

- In order to **remove the Eclipsing and Ambiguity**, new indices which have been proposed are not of additive or multiplicative type.
- **Maximum operator approach** is adopted to remove Ambiguity and Eclipsing.
- $AQI = \text{Max} (I_1, I_2, \dots, I_n)$ ✓
- Health effects of the combination of pollutants are not known and thus in the health-based index, sub-indices cannot be added or multiplied.



Source: (AQI Report, CPCB)

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We should be careful otherwise, even if air is clean, we are giving false alarm to the public and public is confused, they say that we have been alarmed that we should not go, we should not go to that particular place where air quality index is poor, but in real sense it is not there. So, those issues we have to deal with.

So, in order to remove these kind of error eclipsing and ambiguity related problems, new indices have been developed. So, like maximum operator approach is adopted to remove these kinds of errors. So, AQI maximum, I_1, I_2, I_n , those kinds of values are computed. And the health impacts of the combination of pollutants are not known, because synergy is not known and thus in the health-based index sub-indices cannot be added or multiplied. So, that is another issue basically.


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Air Quality Index (AQI) – Calculation Methods (1/8)

- AQI is representing the cumulative effect of all the pollutants to show overall air quality status in a better way. The four methods of calculating AQI is as follows:

- Method 1:**
 - First used by Tiwari and Ali (1987)
 - Used by CPCB until 2009.

- $\frac{C_i}{C_s} = q$ and q is the air quality rating of any individual pollutant.
- C_i = observed value of the parameter
- C_s = standard value of recommended parameter
- n = number of parameter considered

$$AQI = \frac{1}{n} \left[\sum_{i=1}^n \left(\frac{C_i}{C_s} \right) \right] * 100 \quad \text{where,}$$



Source: (Hemavani et al., 2020)

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AQI – Calculation Methods: Method 1 (2/8)

Index values	Quality Category
Below 10	Very clean
10-25	Clean air
26-50	Fairly clean
51-75	Moderately polluted
76-100	Polluted
>100	Heavily polluted

Air Quality categories based on Air Quality Index by Tiwari and Ali (1987)



Source: (Hemavani et al., 2020)

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Well, when we talk about calculation methods, we can go for different methods like this method 1 is from Tiwari and Ali in 1987, they published. So, this is a AQI 1 by n, summation of 1 to n, C_i upon C_s into 100, where C_i upon C_s is the small q and this q is air quality rating of any individual pollutant and C_i is observed value of that particular parameter and C_s is standard value of recommended parameter, n is the number of parameters.

$$AQI = \frac{1}{n} \left[\sum_{i=1}^n \left(\frac{C_i}{C_s} \right) \right] * 100$$

So, that kind of again integration is there and possible. And for that particular purpose, there are a range like, if it is below 10, then it is known as very clean. If it is between 10 to 25, then it is known as clean air, if it is 26 to 50, then it is known as fairly clean, 51 to 75 signifies

moderately polluted, not very high, 76 to 200 polluted and more than 100 heavily polluted. So, those kind of differences there as per the range of those indices values.

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AQI – Calculation Methods (3/8)

❖ **Method 2:**

- AQI is calculated by taking the geometric mean of the ratio of the concentration of pollutants to the standard value of that pollutant.
- $AQI = \text{antilog} \left(\frac{1}{n} (\log Q_1 + \log Q_2 + \dots + \log Q_n) \right)$
- $Q_n = \left[\frac{C_n}{C_s} \right] * 100$

where,

- Q_n = quality rating
- C_n = observed value of pollutant
- C_s = recommended value of pollutant
- n = number of pollutant considered




Source: (Lingan et al, 2014)

AQI – Calculation Methods: Method 2 (4/8)

Category	AQI of ambient air	Description of ambient air quality
I	Below 10	Very clean
II	Between 10- 25	Clean
III	Between 25- 50	Fairly clean
IV	Between 50-75	Moderately polluted
V	Between 75-100	Polluted
VI	Between 100-125	Heavily polluted
VII	Above 125	Severely polluted

Air Quality Categories based on Air Quality Index



Source: (Lingan et al, 2014)

$$\text{antilog} \left(\frac{1}{n} (\log Q_1 + \log Q_2 + \dots + \log Q_n) \right)$$

Second method is like geometric mean of the ratio of concentration of pollutants to the standard value. So, AQI is by antilog of this 1 by n, log Q₁, log Q₂, log Q_n and where this Q_n value comes? Q_n is nothing but C_n upon C_s into 100. So, Q_n is quality rating, C_n is observed value of

that pollutant and C_s is recommended value of the pollutant and is number of pollutants considered.


AQI =

$$Q_n = \left[\frac{C_n}{C_s} \right] * 100$$

Then according to this method, there are again range similar to the earlier one like below 10 very clean, 10 to 25 clean, 25 to 50 fairly clean and then, there is another range like beyond 100, 100 to 125 heavily polluted and above 125 severely polluted. So, this kind of next level of pollution, it also gives them information about. (Refer Slide Time: 19:06)

AQI – Calculation Methods (5/8)

- ❖ **Method 3:**
 - Pollution Index Method was first used by Cannistraro in 2009 for AQI of Naples City in Italy.
 - It is calculated by an arithmetic average of sub-indices of the two most critical pollutants
 - Pollution Index, $I = \left[\frac{I_1 + I_2}{2} \right]$
 - Sub Index, $I_x = \frac{V_{max\ hx}}{V_{rif}} * 100$
- I_1 & I_2 = Sub-indices of two most critical pollutants having higher concentration
- $V_{max\ hx}$ = the maximum 1 hour mean value of the critical pollutant
- V_{rif} = maximum 1-hour limit value of the critical pollutant




Source: (Hemavani et al., 2020)

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AQI – Calculation Methods: Method 3 (6/8)

Numeric Value	Quality Indicator	Numeric Index	Health Risk
0-50	Optimum	1	No risks for people
51-75	Good	2	No risks for people
76-100	Moderate	3	No risks for people
101-125	Mediocre	4	Generally, there aren't risks for people. People with asthma, chronic bronchitis, cardiopathy may feel light respiratory symptoms only during intense physical activity.
126-150	Not much healthy	5	There are risks for people with heart diseases, olds, and children.
151-175	Unhealthy	6	Many people may feel light adverse symptoms, however reversible. Weak people may feel the gravest symptoms
>175	Very Unhealthy	7	People may feel light adverse effects on health. There are more risks for olds, children, and people with respiratory diseases.

Values, Index, and Health Risk for Pollution Index Method



Source: (Hemavani et al., 2020)

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When third method is there, which is known as pollution index method and this was used in this Naples City in Italy. So, this is the method like pollution index is I_1 , I_2 upon two and sub-index I_x , $V_{\text{maximum } h_x}$ upon V_{rif} into 100 and the values of I_1 , I_2 , these are nothing but sub-indices of two most critical pollutants having higher concentrations.

$$I = \left[\frac{I_1 + I_2}{2} \right]$$

$$I_x = \frac{V_{\text{max } h_x}}{V_{\text{rif}}} * 100$$

So, means there are many pollutants, but select those two highly critical pollutants. Then $V_{\text{max } h_x}$, the maximum 1 hour mean value of the critical pollutant and V_{rif} maximum one hour limit value of the critical pollutants. So, these values are used for calculation purpose of sub-indices and then AQI can be calculated and according to this, 0-50 gives the quality indicator it is optimum. So, no risk for the people.

So, you can see 51 to 75 is good no risk, 76 to 200 moderate no risk. Then 101 to 125 then it is like mediocre and the numerical index is four and this is generally associated with kind of like asthma, chronic bronchitis, cardiopathy, light respiration symptoms and during intense physical activities. So, those kinds of things are there within the AQI range of one, 01 to 125.

Similarly, there are other values like 126 to 150 not much healthy. There are risk for people with heart disease, old people, children. And this numerical value is 5 here, 151 to 175 it is unhealthy. And many people feel light adverse symptoms and weak people may feel the gravest symptoms. Then more than 175 very unhealthy and the seven is the numerical index. And this is like very adverse health impacts may be there, it may be very risky to old people, children and respiratory diseases may be very high in those particular situations.

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AQI – Calculation Methods (7/8)

❖ Method 4:

• Linear Segmented Principle is used to calculate the **sub-indices based on breakpoint concentrations**.

• Adopted by CPCB

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

• $AQI = \text{Max} \{I_p\}$ (where $p = 1, 2, 3, \dots, n$; denotes n pollutants range)

- I_p = Sub Index for a given pollutant concentration
- B_{HI} = Breakpoint concentration greater or equal to give concentration (C_p)
- B_{LO} = Breakpoint concentration smaller or equal to give concentration (C_p)
- I_{HI} = AQI value equivalent to B_{HI}
- I_{LO} = AQI value equivalent to B_{LO}



Source: (Hemavani et al., 2020)



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AQI – Calculation Methods: Method 4 (8/8)

AQI	Remark	Colour Code	Quality rating
0-50	Good	Dark Green	Minimal impact
51-100	Satisfactory	Light Green	Minor breathing discomfort to sensitive people
101-200	Moderate	Yellow	Breathing discomfort to the people with lungs, asthma and heart diseases
201-300	Poor	Light Orange	Breathing discomfort to most people on prolonged exposure
301-400	Very Poor	Dark Orange	Respiratory illness on prolonged exposure
401-500	Severe	Red	Affects healthy people and seriously impacts those with existing diseases

Index values, Remarks, and Quality rating of the method adopted by CPCB



Source: (Hemavani et al., 2020)



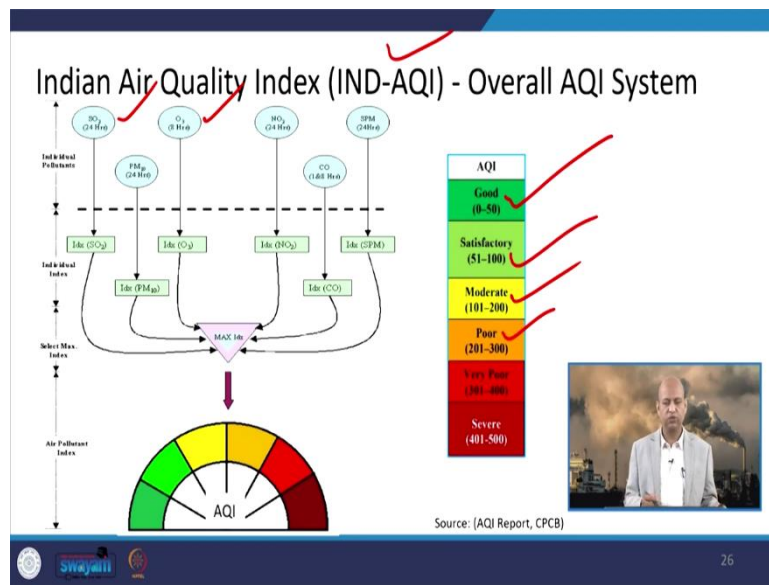
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Then method four, which is also used in India and adopted by CPCB basically. This is linear segmented principle, which is used to calculate the sub-indices. In this case, you can see this formula, earlier also we have seen this. So, I_p equals I_{HI} minus I_{LO} , B_{HI} minus B_{LO} into C_p minus B_{LO} plus I_{LO} , we have already seen I_p sub-index for a given pollutant p concentration.

B_{HI} breakpoint concentration for greater or equal to given concentration that is C_p . B_{LO} breakpoint concentration is smaller or equal to given concentration C_p . I_{HI} AQI equivalent to B_{HI} , I_{LO} , AQI value equivalent to B_{LO} . So, those values, we can get from certain studies like these kinds of tables are there. So, we are AQI 0-50 good and colour scheme is dark green for that, this is minimal impact means there is no impact you can say. 51 to 203 satisfactory and this is light green colour scheme, then minor breathing discomfort, maybe they are too sensitive people. Otherwise, normal people will not have any problem.

So, this way you can see AQI go 0 to 50, 51 to 100, 101 to 200 and ultimately for O1 to 500 which is severe and this affects even healthy people. So, this is very serious, red colour is there for that. Before that dark orange is there 301 to 400 that is very poor quality. So, according to the range the quality of air is given some name, the colour scheme is given name and health impacts are associated which are also tabulated.

(Refer Slide Time: 23:07)



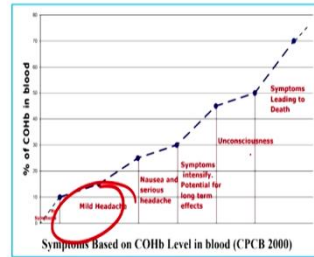
So, Indian Air Quality Index or IND-AQI, you can go for short, the overall AQI system is basically like this we talk good 0 to 50 dark green, satisfactory 51 to 100, the moderate 101 to 200 yellow. Then this poor to 201 to 300 then very poor, so you can have these colour schemes also and different pollutants are there, SO₂, O₃, NO₂, all these pollutants, their concentrations are included when we calculate the AQI.

(Refer Slide Time: 23:42)

IND-AQI: Sub-index Breakpoints (1/8)

❖ Carbon Monoxide (CO)

- The affinity of Hb (hemoglobin) for CO is 200-250 times that of oxygen.
- Approximately 80-90% of absorbed CO binds with Hb to form Carboxyhemoglobin (CO-Hb), which is a specific biomarker of exposure in blood.



Source: (AQI Report, CPCB)



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So, like for example, if we consider CO, carbon monoxide and we have, we know that CO is problematic because it has tendency to get absorbed into the blood and it reduces the capacity of getting the oxygen into the blood. So, that is the reason it is dangerous, and you can see its healthy impacts like mild headache, when the percentage is less than 20 or so, it goes on increasing, then its impact is also increasing and unconscious can be there, if it is 50 percent or so, and it can also lead to death, in fact it is very high concentration in the blood.

(Refer Slide Time: 24:23)

IND-AQI: Sub-index Breakpoints (2/8)

Breakpoints for CO (mg/m ³)					
India (8-hr)		US (8-hr) ¹⁰⁰		China (24-hr)	
AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration
Good	1	Good	5	Excellent	2
Satisfactory	2	Moderate	11	Good	4
Moderate	10	Unhealthy for sensitive groups	14	Lightly Polluted	14
Poor	17	Unhealthy	18	Moderately Polluted	24
Very Poor	34	Very Unhealthy	35	Heavily Polluted	36
Severe	34+	Hazardous	35+	Severely Polluted	36+

The variation in Breakpoint Concentration of different countries is due to **country-specific National Ambient Air Quality Standards**.



Source: (AQI Report, CPCB)



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So, when we talk about its breakpoints, you can see the values and different countries have different values. Like AQI category good, breakpoint 1, satisfactory 2, this is for India. 8-hour concentration please note it. In us 8 hour concentration, good 5, 11, those values are there.

China, they have 24-hour concentration. And they are categories are like excellent, good and they have different values, breakpoint concentration like 2, 4.

In European Union, this is again 8-hour concentration and they have different names like very low, low and ultimately very high. In China it is severely polluted, we also have like severe at last and US considers hazardous. So, different nomenclatures are there depending upon the values of those indices and those breakpoint concentrations values.


(Refer Slide Time: 25:19)

IND-AQI: Sub-index Breakpoints (3/8)

INDIA (24-hr)		US (1-hr) ^(a)		China ^(b) (24-hr)		EU ^(c) (8-hr)	
AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration
Good	40	Good	100	Excellent	40	Very low	50
Satisfactory	80	Moderate	190	Good	80	Low	100
Moderate	180	Unhealthy for sensitive groups	680	Lightly Polluted	180	Medium	200
Poor	280	Unhealthy	1220	Moderately Polluted	280	High	400
Very Poor	400	Very Unhealthy	2350	Heavily Polluted	565	Very high	400+
Severe	400+	Hazardous	2350+	Severely Polluted	565+		

❖ Nitrogen Dioxide (NO₂)

- 70–90% of NO₂ can be absorbed in the respiratory tract of humans.
- Physical exercise increases the total percentage absorbed.
- NO₂ exposure can cause a **decrement in lung function** (increased airway resistance.)



(a) EPA (2015) (b) CAQI (2012) converted from ppb to µg/m³ and rounded off


Source: (AQI Report, CPCB)

IND-AQI: Sub-index Breakpoints (4/8)

INDIA (24-hr)		US (24-hr) ^(a)		China ^(b) (24-hr)		EU ^(c) (8-hr)	
AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration
Good	30	Good	12	Excellent	35	Very low	10
Satisfactory	60	Moderate	35	Good	75	Low	20
Moderate	90	Unhealthy for sensitive groups	55	Lightly Polluted	115	Medium	30
Poor	120	Unhealthy	150	Moderately Polluted	150	High	60
Very Poor	250	Very Unhealthy	250	Heavily Polluted	250	Very high	60+
Severe	250+	Hazardous	250+	Severely Polluted	250+		

❖ Particulate Matter

There is a **strong correlation between PM conc. and increase in mortality and hospitalizations** due to respiratory diseases including premature mortality, chronic respiratory disease, aggravated asthma, acute respiratory symptoms, and a decrease in lung function.



(a) EPA (2012) (b) CAQI (2012) (c) CAQI (2012)

Source: (AQI Report, CPCB)

IND-AQI: Sub-index Breakpoints (5/8)

❖ Particulate Matter (PM10)

Breakpoints for PM ₁₀ (µg/m ³)							
INDIA (24-hr)		US (24-hr) ^(a)		China ^(b) (24-hr)		EU ^(c) (8-hr)	
AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration
Good	50	Good	55	Excellent	50	Very low	15
Satisfactory	100	Moderate	155	Good	150	Low	30
Moderate	250	Unhealthy for sensitive groups	255	Lightly Polluted	250	Medium	50
Poor	350	Unhealthy	355	Moderately Polluted	350	High	100
Very Poor	430	Very Unhealthy	425	Heavily Polluted	420	Very high	100+
Severe	430+	Hazardous	425+	Severely Polluted	420+		

Source: (AQI Report, CPCB)



Now, if you go for NO₂, like CO, different values are there for this, like break point 40 for good, satisfactory 80. So, different values are there. Similarly, for US, China and EU, it is given and similarly, PM 2.5 and PM 10, all these tables give those values of their breakpoints as well as their name whether it is good or bad, something like that.

(Refer Slide Time: 25:47)

IND-AQI: Sub-index Breakpoints (6/8)

Breakpoints for Ozone (ppb)							
INDIA (8-hr)		US (8-hr) ^(a)		China ^(b) (8-hr)		EU ^(c) (8-hr)	
AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration
Good	50	Good	120	Excellent	100	Very low	60
Satisfactory	100	Moderate	150	Good	160	Low	120
Moderate	168	Unhealthy for sensitive groups	190	Lightly Polluted	215	Medium	180
Poor	208	Unhealthy	230	Moderately Polluted	265	High	240
Very Poor	748**	Very unhealthy	750	Heavily Polluted	800	Very high	240+
Severe	748+**	Hazardous	750+**	Severely Polluted	-		

Source: (AQI Report, CPCB)

❖ Ozone

Ozone can aggravate bronchitis, heart disease, asthma and reduce lung capacity, irritation in the respiratory system, causing coughing, and uncomfortable sensations in the chest.



IND-AQI: Sub-index Breakpoints (7/8)

❖ Sulphur Dioxide (SO₂)

- SO₂ is soluble in aqueous media and affects mucous membranes of the nose and upper respiratory tract. Reduction in mean lung function values among groups of healthy individuals have been observed for 10-minute exposures at 4000 ppb (11,440 µg/m³) (Linn et al. 1984) and at 5000 ppb (14,300 µg/m³) (Lawther et al., 1975).

INDIA (24-hr)		US (1-hr) ⁽¹⁾		China ⁽²⁾ (24-hr)		EU ⁽³⁾ (8-hr)	
AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration	AQI Category	Break point concentration
Good	40	Good	95	Excellent	50	Very low	50
Satisfactory	80	Moderate	200	Good	150	Low	100
Moderate	380	Unhealthy for sensitive groups	485	Lightly Polluted	475	Medium	350
Poor	800	Unhealthy	795	Moderately Polluted	800	High	500
Very Poor	1600	Very Unhealthy	1580	Heavily Polluted	1600	Very high	500+
Severe	1600+	Hazardous	1580+	Severely Polluted	2620		

(1) EPA (2012) (2) GB 3095-2012 (3) CAQI (2012) converted from ppb to µg/m³ and rounded off



Source: (AQI Report, CPCB)



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IND-AQI: Sub-index Breakpoints (8/8)

❖ Lead and Ammonia (NH₃)

- Most of the countries have not taken Lead and Ammonia and only six pollutants (described above) for the formulation of AQI.
- Increased inhalation of ammonia may result in cough and an increased respiratory rate as well as respiratory distress.
- 1µg/m³ of annual lead level will result in 5µg/dL (on an average) of blood lead level (WHO 2000) which will cause hematological changes (blood-related issues).

Table 3.10 AQI Breakpoints for NH₃ and Pb (24-hr)
India (Pb from gasoline phased out in 2000)

AQI Category	NH ₃ µg/m ³	Pb µg/m ³
Good (0-50)	200	0.5
Satisfactory (51-100)	400	1.0
Moderate (101-200)	800	2.0
Poor (201-300)	1200	3.0
Very poor (301-400)	1800	3.5
Severe (401-500)	1800+	3.5+



Source: (AQI Report, CPCB)



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So, ozone related, SO₂ related, all these values are their tables, you can go through at leisure and see different values are there for different pollutants please remember. So, the different sub index will be calculated for each pollutant, then we will aggregate them. Lead and ammonia also, some countries do not consider, but in India we are considering these also and these are the values, good 200 for ammonia, 0.5 lead because that is heavy metal and very problematic.

(Refer Slide Time: 26:19)


IND-AQI: Breakpoint on AQI Scale 0-500

Breakpoints for AQI Scale 0-500 (units: $\mu\text{g}/\text{m}^3$ unless mentioned otherwise)								
AQI Category (Range)	PM ₁₀ 24-hr	PM _{2.5} 24-hr	NO ₂ 24-hr	O ₃ 8-hr	CO 8-hr (mg/m ³)	SO ₂ 24-hr	NH ₃ 24-hr	Pb 24-hr
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.6-1.0
Moderate (101-200)	101-250	61-90	81-180	101-168	2.1-10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-248*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430+	250+	400+	248+*	34+	1600+	1800+	3.5+

Breakpoints for AQI Scale for India.




Source: (AQI Report, CPCB)


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IND-AQI: Health Impacts

Health Statements for AQI Categories	
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. Effect 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

Health Statements for AQI Categories for India.



Source: (AQI Report, CPCB)


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So, you can see this coloured representation of Indian Air Quality Index breakpoint, AQI scale 0 to 500 so, PM 10, 24 hour, good. 0 to 50, PM 2.5 0 to 30, NO2 to 24 hour, 0 to 40. So, different value ranges there. These AQI related breakpoints.

(Refer Slide Time: 26:40)

IND-AQI: Health Impacts

Health Statements for AQI Categories	
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. Effect 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

Health Statements for AQI Categories for India.



Source: (AQI Report, CPCB)


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Then there are health impacts also because good means minimal impact, satisfactory it may cause little minor breathing related issues discomfort to sensitive people, we have seen. Poor air quality, it can cause breathing discomfort to people for prolonged exposure. When it is severe, then it is very dangerous. When we are exposed to this severe Air Quality means highly polluted.

(Refer Slide Time: 27:08)

AQI: Applications (1/2)

- AQI data can help govt. to take quick decisions and form rules and regulations as per the requirement.
- ❖ **In Beijing, China:** On red alert days (when AQI falls to very poor or severe category)
 - KG, primary and middle schools get closed
 - 80% of Govt. owned cars are taken off the roads.
 - Private cars allowed on alternated days
 - At construction sites excavation and demolition operations are halted.



Source: (<https://www.cseindia.org/cse-welcomes-release-of-national-air-quality-index-5762>) accessed on Nov. 15, 2021

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Then what is the application? So, application are many as I briefly discussed initially also. This can give to policymakers a way of quick decision making in the form of rules and regulations as per the requirement. You might be, in these days when winters are there and in Delhi, this poor air quality is becoming very big issue. So, you might have read in newspapers that the

judiciary is asking the government that even if you have to do the lockdown, reduce this air quality index, it is very high now.

So, what are the different ways which can be implemented? So, these air quality indices help in decision making for these kinds of interventions like in Beijing in China, on red alert days when AQI falls to very poor or severe category, they stop school functioning. Even in Delhi like for few days schools, colleges have been shut down, because air quality is very poor. This AQI is giving this range that it is very very poor or kind of severe kind of thing.

Then 80 percent of government owned cars are taken off the roads in Beijing when this red alert is there for severe category of air quality. Private cars allowed on alternate dates like odd and even we did last time in Delhi, if you recall. At construction sites, excavation and demolition related operations are stopped because they emit a lot of particulate matter and that contributes to the poor air quality in winter, it is very problematic because of inversion etc.

(Refer Slide Time: 28:55)

AQI: Applications (2/2)

- ❖ In Paris: In March 2015, to control the air problem
 - Made public transport free and removed 50% of the vehicle off the road.
 - Private cars allowed on alternated days
 - No diesel cars on road on smoggy days
 - Minimizes combustion of high Sulphur fuels in industry and curtails industrial operations
- ❖ Similar measures are also implemented in cities of the US, UK, and Mexico.

India can also draft such contingencies rules and measures to implement to high pollution days.

Source: (<https://www.cseindia.org/cse-welcomes-release-of-national-air-quality-index5762>) accessed on Nov 15, 2021

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In Paris, this AQI related application have been made, like in March 2015 to control the air problem they made public transport free and removed 50% of the vehicle of the road, those privately owned. So, that people can go for public transportation if it is not costing. Then private cars allowed on alternate days and no diesel cars on the road, on the smoky days were allowed.

And then this minimizes combustion of high sulphur fuels in industry and curtails industrial operations. Similar measures have been implemented in different cities of the US, UK and Mexico.

(Refer Slide Time: 29:40)

IND-AQI: Calculation (1/5)


E.g.: Calculate the AQI for the given air pollutant concentration data:

PM_{2.5} = 33 µg/m³
PM₁₀ = 63 µg/m³
O₃ = 49.4 µg/m³
NO₂ = 15.7 µg/m³
SO₂ = 4.1 µg/m³
CO = 650 µg/m³

Sol:
Individual Air Quality Index is calculated from

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

And the overall AQI = Max (I_p)



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So similarly, if we go for this demonstration or example, how to calculate when different pollutant related concentrations are available. So, this is one example. You can see, calculate the AQI for given air pollutant concentrations, different values are there, like PM 2.5 33 micrograms per cubic meter, PM 10 is 63 micrograms per cubic meter, ozone is around 49 microgram per cubic meter, NO₂ 15, SO₂ four, CO is 650.

So, we use this particular relationship to calculate the individual pollutant related sub-indices and then we will go for its aggregation.

(Refer Slide Time: 30:18)

IND-AQI: Calculation (2/5)

For $PM_{2.5} = 33 \mu\text{g}/\text{m}^3$
 So, the range we consider will be Satisfactory (50-100) w.r.t. $PM_{2.5}$ concentration ($30-60 \mu\text{g}/\text{m}^3$)
 Individual Air Quality Index for $PM_{2.5}$ is


$$I_{PM_{2.5}} = \left[\left\{ \frac{I_{HI} - I_{LO}}{B_{HI} - B_{LO}} \right\} * (C_p - B_{LO}) \right] + I_{LO} = \left[\left\{ \frac{100 - 50}{60 - 30} \right\} * (33 - 30) \right] + 50 = 55$$

AQI Category (Range)	$PM_{2.5}$ 24-hr $\mu\text{g}/\text{m}^3$
Good (0-50)	0-35
Satisfactory (51-100)	31-60
Moderate (101-200)	61-90
Poor (201-300)	91-120
Very poor (301-400)	121-150
Severe (401-500)	151+

For $PM_{10} = 63 \mu\text{g}/\text{m}^3$
 So, the range we consider will be Satisfactory (50-100) w.r.t. PM_{10} concentration ($50-100 \mu\text{g}/\text{m}^3$)
 Individual Air Quality Index for PM_{10} is

$$I_{PM_{10}} = \left[\left\{ \frac{I_{HI} - I_{LO}}{B_{HI} - B_{LO}} \right\} * (C_p - B_{LO}) \right] + I_{LO} = \left[\left\{ \frac{100 - 50}{100 - 50} \right\} * (63 - 50) \right] + 50 = 63$$

AQI Category (Range)	PM_{10} 24-hr $\mu\text{g}/\text{m}^3$
Good (0-50)	0-54
Satisfactory (51-100)	51-100
Moderate (101-200)	101-250
Poor (201-300)	251-350
Very poor (301-400)	351-450
Severe (401-500)	451+



So, here you can see, for an example for PM 2.5 33 micrograms per cubic meter. So, where it lies? 33 here, 31 to 60, within this range. So, 51 100 is the basically this range of the AQI and 30 will be the minimum, 60 will be high. So, 60 is BHI and BLO is 30. And 150 is because this range, IHI, ILO this 50 is the lowest. This ILO and IHI is 100 so these values are here.

So, you can use concentration is 33, BLO is 30 because the lower concentration value in the range of 60 and 30. So, you can go for this ILO is 50 again as I said. So, you calculate the 55, this IPM 2.5. This is the sub-index of PM 2.5.

(Refer Slide Time: 31:20)

IND-AQI: Calculation (3/5)

For $O_3 = 49.4 \mu\text{g}/\text{m}^3$
 So, the range we consider will be Good (0-50) w.r.t. Ozone concentration ($0-50 \mu\text{g}/\text{m}^3$)
 Individual Air Quality Index for O_3 is


$$I_{O_3} = \left[\left\{ \frac{I_{HI} - I_{LO}}{B_{HI} - B_{LO}} \right\} * (C_p - B_{LO}) \right] + I_{LO} = \left[\left\{ \frac{50 - 0}{50 - 0} \right\} * (49.4 - 0) \right] + 0 = 49.4 \approx 50$$

AQI Category (Range)	O_3 8-hr $\mu\text{g}/\text{m}^3$
Good (0-50)	0-50
Satisfactory (51-100)	51-100
Moderate (101-200)	101-168
Poor (201-300)	169-208
Very poor (301-400)	209-249
Severe (401-500)	250+

For $NO_2 = 15.7 \mu\text{g}/\text{m}^3$
 So, the range we consider will be Good (0-50) w.r.t. NO_2 concentration ($0-40 \mu\text{g}/\text{m}^3$)
 Individual Air Quality Index for NO_2 is

$$I_{NO_2} = \left[\left\{ \frac{I_{HI} - I_{LO}}{B_{HI} - B_{LO}} \right\} * (C_p - B_{LO}) \right] + I_{LO} = \left[\left\{ \frac{50 - 0}{40 - 0} \right\} * (15.7 - 0) \right] + 0 = 19.625 \approx 20$$

AQI Category (Range)	NO_2 24-hr $\mu\text{g}/\text{m}^3$
Good (0-50)	0-40
Satisfactory (51-100)	41-80
Moderate (101-200)	81-150
Poor (201-300)	151-280
Very poor (301-400)	281-360
Severe (401-500)	361+



IND-AQI: Calculation (4/5)

For $SO_2 = 4.1 \mu\text{g}/\text{m}^3$
 So, the range we consider will be Good (0-50) w.r.t. SO_2 concentration (0-40 $\mu\text{g}/\text{m}^3$)
 Individual Air Quality Index for SO_2 is


$$I_{SO_2} = \left[\frac{I_H - I_{LO}}{B_H - B_{LO}} \right] * (C_p - B_{LO}) + I_{LO} = \left[\frac{50 - 0}{40 - 0} \right] * (4.1 - 0) + 0 = 5.125 \approx 6$$

AQI Category (Range)	SO_2 24-hr $\mu\text{g}/\text{m}^3$
Good (0-50)	0-40
Satisfactory (51-100)	41-80
Moderate (101-200)	81-180
Poor (201-300)	181-300
Very poor (301-400)	301-400
Severe (401-500)	401-500

For $CO = 650 \mu\text{g}/\text{m}^3$
 So, the range we consider will be Good (0-50) w.r.t. CO concentration (0-1000 $\mu\text{g}/\text{m}^3$)
 Individual Air Quality Index for CO is

$$I_{CO} = \left[\frac{I_H - I_{LO}}{B_H - B_{LO}} \right] * (C_p - B_{LO}) + I_{LO} = \left[\frac{50 - 0}{1000 - 0} \right] * (650 - 0) + 0 = 32.5 \approx 33$$

AQI Category (Range)	CO 8-hr (mg/m^3)
Good (0-50)	0.1-0.4
Satisfactory (51-100)	1.1-2.0
Moderate (101-200)	2.1-10
Poor (201-300)	10.1-17
Very poor (301-400)	17.1-30
Severe (401-500)	34+



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Similarly, you can go for PM 10 and then NO_2 , ozone and then SO_2 , CO , all different values are there SO_2 , came only 6, CO , it came 33. You go for this ozone it came 50, NO_2 it came 20. So, different pollutant different sub-indices.

(Refer Slide Time: 31:40)

IND-AQI: Calculation (5/5)

The overall AQI = $\text{Max}(I_{PM_{2.5}}, I_{PM_{10}}, I_{O_3}, I_{NO_2}, I_{SO_2}, I_{CO})$
 $= \text{Max}(53, 63, 50, 20, 6, 33)$
 $= 63$ (Satisfactory)

- Here, $PM_{2.5}$ and PM_{10} fall in the "Satisfactory" category, and Ozone, NO_2 , SO_2 and CO fall in the "Good" category and so the overall AQI is determined as "Satisfactory" because of PM_{10} .
- From this, we can infer that the particulate matter in the region is high and in order to improve the air quality, sources of particulate matter emission are regulated.



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Then we go for overall AQI, so, maximum of these. What is the maximum value? We go for $PM_{2.5}$, PM_{10} , IO_3 , NO_2 , all those. So, 63 is the maximum value. So, we go for this particular method, the last method where we choose the maximum value. Otherwise, you have seen those issues with when we go for these statistical problems like ambiguity, etc that happens when we go for aggregation.

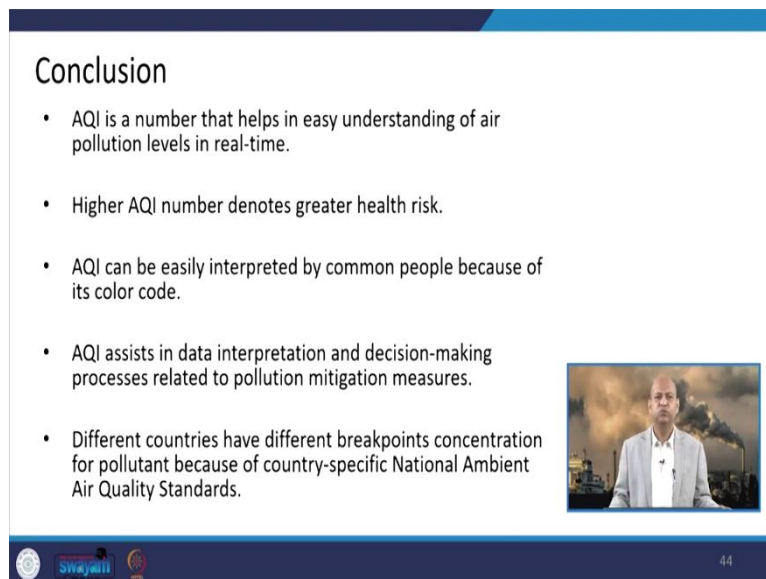
So, to avoid that we go for this highest value approach. So, 63 is satisfactory, why satisfactory? You can see the overall value, this is 51 to 100, in between this range. So, this is satisfactory.

So, that is why we call, even overall value is satisfactory but ozone, NO₂, SO₂, CO, all these values fall in good category if you compare individually. For example, let me tell you, the CO is 33 so 33 is in good, 0 to 50 within this range. This is good quality, but overall, it is satisfactory.

So, individual pollutants maybe bad quality or good quality and overall concept is dependent upon the highest value of a particular index. And then we see in the overall scheme, where does it lie. So, overall, it is satisfactory although individual pollutants, it may vary good or satisfactory or something like that.


So, that way you can see particulate matter in the region is high and in order to improve the air quality sources of particulate matter emission are to be regulated. Because this value is related to PM 10. This 63 is PM 10. So, those particulate emissions, if we can reduce then the Air Quality Index can improve.

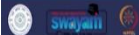
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Conclusion

- AQI is a number that helps in easy understanding of air pollution levels in real-time.
- Higher AQI number denotes greater health risk.
- AQI can be easily interpreted by common people because of its color code.
- AQI assists in data interpretation and decision-making processes related to pollution mitigation measures.
- Different countries have different breakpoints concentration for pollutant because of country-specific National Ambient Air Quality Standards.



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So, in conclusion we can say, that Air Quality Index helps in easy understanding of air pollution levels in real time. It can really help us whether to visit a place or not. If the air quality is poor then we can refrain from going to that particular place. Particularly the sensitive people or old people those who are already unhealthy, they should not get exposed to the poor air quality. So, Air Quality Index gives quick information about that.

And, higher AQI, we know that it has higher health risk and AQI can easily be interpreted by common people because it can also be colour coded. So, it is very easy to understand and it can assist in data interpretation for decision making. Like, whether we should stop private cars, we

should stop diesel cars, depending upon, what kind of pollutant is in high concentration. Then different countries have different break point concentrations depending upon their national ambient air qualifiers and health risk related issues.

So, they can have different Air Quality Indices also. So, this is all for today related to air quality management through Air Quality Index. So, the larger part is basically, air quality management, how to improve the air quality and how to know whether it is polluted or not and Air Quality Index is very easy and simple and quick way to know whether Air Quality is good or bad or satisfactory or unsatisfactory, those kinds of things. So, this is all for today and thank you for your kind attention.

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References

- National Air Quality Index Final Report, (2014-15), CPCB, CUPS/82/2014-15, www.cpcb.nic.in
- Beig G., Ghude S. D., Deshpande A., (2010a) Scientific Evaluation of Air Quality Standards and Defining Air Quality Index for India, Indian Institute of Tropical Meteorology-Pune; ISSN 0252-1075.
- G. Kumar, S. Kumar and Suman, (2021), Air quality index – A comparative study for assessing the status of air quality before and after lockdown for Meerut, Materials Today: Proceedings, <https://doi.org/10.1016/j.matpr.2021.05.575>
- Hemavani, B., Rao, G.V.R.S., (2020), A Comparative Study on Seasonal Variations of Air Quality Index (AQI) in Sanathnagar area of Hyderabad City, India, International Research Journal of Engineering and Technology (IRJET)
- Lingan, B.A., Poyyamoli, G., Boss, U.J.C., (2014), Assessment of Air Pollution and its Impacts near Municipal Solid Waste Dumping Site Kammyampet, Cuddalore, India, International Journal of Innovative Research in Science, Engineering and Technology
- Kanchan, Gorai, A.K., Goyal, P., (2015), A Review on Air Quality Indexing System, Asian Journal of Atmospheric Environment, Vol. 9-2, pp. 101-113, doi: <http://dx.doi.org/10.5572/ajae.2015.9.2.101>
- <https://www.cseindia.org/cse-welcomes-release-of-national-air-quality-index-5762> accessed on Nov. 15, 2021

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These are the references that you can go through to have more information about Air Quality Index, their calculations, their uses, applications, etc. So, see you in the next lecture, thank you till then. Thanks a lot.