

**Air Pollution Control**  
**Professor Bhola Ram Gurjar**  
**Department of Civil Engineering**  
**Indian Institute of Technology Roorkee**  
**Lecture 48**  
**Air Quality Standards**

Hello friends, today we will discuss about air quality standards. You might have heard about ambient air quality standards which every country basically has like in our country, we have national ambient air quality standards. So, they are prescribed by CPCB central pollution control board which is the nodal agency for having environment related regulatory things in entire India and we have then these state pollution control boards also.

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So, in this particular lecture, we will first of all discuss what are the air quality standards, why they are so important? What are different components of the air quality standards? How they are developed? Which are the factors which are taken into account when we develop or set the air quality standards?

And then which are the national air quality standards in India at present which we are following what is their little bit history and then WHO, World Health Organization related air quality guidelines because WHO also prescribes certain guidelines. The reason is because not each country has national air quality standards because it needs a lot of resources to develop ambient air quality standards.

So, WHO prescribed guidelines and those who are under developed countries or who do not have their own ambient air quality standards, they can follow those guidelines basically. Air quality standards for different countries we will compare then some emission standards we will look into which are at present prevalent in India and then the timeline presenting representing the emission standards in India and then we will conclude.

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The slide is titled "Introduction" and contains three bullet points. To the right of the text is a graphic with the text "air pollution" in the center, surrounded by various chemical symbols (SO<sub>2</sub>, O<sub>3</sub>, CO, HF, CO<sub>2</sub>, NO, VOC, H<sub>2</sub>S, NO<sub>2</sub>) and icons of a factory, an airplane, and a car. Below the graphic is a small video inset showing a man in a white shirt speaking. At the bottom of the slide, there is a source citation and a footer with logos and the number 3.

**Introduction**

- The acceptable threshold level of air pollution in terms of its potential impacts on health and environment is defined as the **ambient air quality standard**.
- These standards are adopted and enforced by a **regulatory body or authority**.
- Every standard should have a standalone definition and its threshold values should be justified appropriately.

Source: Gujjar, B.R., 2021, <https://www.terin.org/>; Image: <https://zerde.ie/>

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So, when we talk about this introductory part of ambient air quality standard so basically this is nothing but a kind of threshold level of air pollution which is acceptable and acceptable because of certain scientific reasoning certain rational not just arbitrary.

So, this is an acceptable threshold level or quantity of air pollution in terms of potential health effects that means below that the quantity of ambient air quality standards it will not be very much adversely affecting the health of the people or ecosystem depending upon which kind of air quality standards.

And these standards are adopted and enforced by your regulatory body like, we have central pollution control board for that and every standard that every air quality standard should have a stand-alone definition that means they are exclusive.

It is not like that SO<sub>2</sub> to have certain quantity and we can apply it for NO<sub>2</sub> also no. Every pollutant has certain guidelines or the reasoning behind the definition of their value is of the threshold level which is justified because of certain reasons.


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### Components of Air Quality Standards

Pollutant [links to historical tables of NAAQS reviews]	Primary/ Secondary	Averaging Time	Level	Form
<a href="#">Carbon Monoxide (CO)</a>	primary	8 hours	9 ppm	Not to be exceeded more than once per year
		1 hour	35 ppm	

Indicator

1. The indicator
2. An averaging time
3. The form
4. The level



Source: Phalen, F., and Phalen, N., 2013

Well, when we talk about the components of air quality standards, so there are basically four basic components like the indicator, indicator means some pollutant like SO<sub>2</sub>, NO<sub>2</sub> or carbon monoxide, whatever pollutant we are talking about that is the indicator and we also know whether it is primary pollutant or secondary pollutant.

So, this is the part of the indicator, then the second is averaging time means it is defined whether it is for 8 hour average or 24 hours or 1 hour or annual average. So, that span that duration has to be defined. So, this is another important component of air quality standards. Then the level means how much threshold level is there beyond that it should not exceed in the ambient air otherwise, it will be problematic it will affect our health negatively.



So, that level that threshold level has to be defined like 9 ppm for 8 hours in carbon monoxide 1 hour 35 ppm, shorter duration higher concentration may be. But for larger duration small concentration must be there, ultimately what is important dose? Dose means concentration multiplied by the duration of the exposure.

So, that dose should not be of that extent or level which can affect our health in a very negative way. Then the fourth is this one is this form. Form means what is frequency whether once in a year or three times in a quarter when it can exceed or not exceed those kinds of statistical parameters are related to these components of the air quality standards.

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### Components of Air Quality Standards

- The air quality standards issued by the U.S. EPA have **four major components**, as follows:
  - The indicator** – which defines what is to be measured (e.g.,  $PM_{2.5}$ ,  $SO_2$ ,  $O_3$ , etc.) and how it is to be measured.
  - An averaging time** – e.g., 1-hour, 8-hours, 24-hours (i.e., daily), or 1-year (i.e., annually).
  - The form** – a statistical method for defining compliance (i.e., conformity with the standard), such as the number of exceedances permitted in a year.
  - The level** – the numerical value of an indicator, such as  $15 \mu\text{g}/\text{m}^3$  (as for the  $PM_{2.5}$  annual average) or  $0.075 \text{ ppm}$  (as for the ozone 8-hour average).



Source: Phalen, F., and Phalen, N., 2013

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So, these pollutants are the indicators which are defined in terms of measurements which can be measured properly and the averaging time can vary from 1 hour to 8 hour 24 hour and annually also or monthly also the form is basically statistical method defining their accidents.


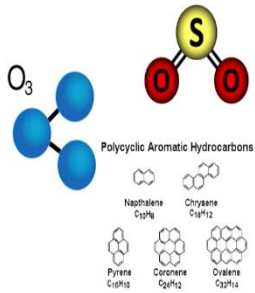
And the frequency and the level is basically that threshold quantity that threshold level which should not exceed or below that this pollutants concentration will not affect us very negatively it will be reversible if something happens otherwise, we are means adaptable to that particular quantity.

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### Components of Air Quality Standards

#### Indicator

- The *indicator* is typically a pollutant characterized by their chemical composition (e.g.,  $O_3$ ,  $SO_2$ ,  $NO_x$ , polycyclic aromatic hydrocarbons, or oxidants).
- An exception is particulate matter (PM), which is mass-based (e.g., particle size fractions,  $PM_{2.5}$  or  $PM_{10}$ ) without regard for their chemical composition.



Source: Phalen, F., and Phalen, N., 2013; Image: <https://users.physics.unc.edu>

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So, when we talk about in detail to the about the indicator let us say so like ozone or sulfur dioxide or NO<sub>x</sub>. So, these indicators are basically pollutants and these pollutants have characteristic of some chemical composition. Some chemical characterization is there, like ozone had some kind of chemical characterization.

SO<sub>2</sub> has or NO<sub>x</sub>, has they are having some particular chemical composition or characterization but PM particulate matter it says that which is defined by mass by their mass per unit of volume concentration or size and say physical parameters irrespective of their chemical composition.

Although these days people also talk about some presence of the chemical coating on the particulate matter because then it will further cause very negative consequences to the health basically otherwise, this mass concentration or they are even nowadays number concentration, that is also very important because very small particles which may have very less mass concentration but their number is very high.

And they can go into our respiratory system they can go into our body and they can damage our health in terms of some diseases. Well, when we talk about averaging time, so this is basically the exposure time. It depends upon the exposure and the intensity like for very acute effect very small duration also can cause very acute effect if concentration is very high but if a span is more, then a small concentration can also be tolerated.

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### Components of Air Quality Standards

**The averaging time (2/2)**

- Particulate matter can have both short-term and long-term effects, hence 24-hour and annual averaging time are typically used.
- The averaging time vary extensively, and a given air pollutant can have more than one averaging time.

Pollutant <small>(links to historical tables of NAAQS reviews)</small>	Primary/ Secondary	Averaging Time
<a href="#">Carbon Monoxide (CO)</a>	primary	8 hours ✓ 1 hour ✓

Source: Phalen, F., and Phalen, N., 2013; Image: <https://www.mynli.life/>

So, these averaging times are 8 hours or 1 hour or 24 hours something like that.


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### Components of Air Quality Standards

**The level**

- The level of an air pollutant is the numerical value that represents the allowable or permissible concentration of a pollutants in the ambient air.
- For example, the level for Carbon Monoxide is 9 ppm for an average time of 8 hours and 35 ppm for 1 hour average time.

Pollutant (links to historical tables of NAAQS reviews)	Primary/ Secondary	Averaging Time	Level
<a href="#">Carbon Monoxide (CO)</a>	primary	8 hours	9 ppm ✓
		1 hour	35 ppm ✓



Source: Phalen, F., and Phalen, N., 2013


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Level we have seen these values like 9 ppm 35 ppm or in case of SO<sub>2</sub> or NO<sub>2</sub> different values are there. So, those levels are basically depending upon several studies of health-related lab-based studies which scientists conduct and then they come to these values that this is the threshold value. So, below that, there is no problem if we can have if we have that pollutant in the atmosphere.

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### Factors considered for setting Air Quality Standards

- ✓ Adverse effects on health
- ✓ Special populations at risk
- ✓ Dose Response Curves
- ✓ Exposure characterization
- ✓ Risk assessment
- ✓ Acceptability of risk



Source: Guidance for Setting Air Quality Standards, WHO, 1997

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When we consider several other factors for setting these air quality standards, then like adverse health effects are taken into account and then these special populations at risk means, like, some are diseased people, old age people or children, those kinds of things, maybe they are so

if they are at risk, so in that sensitive area, we should have different kinds of air quality standards. So, that is taken into account, dose response curve.

So, these are the scientific reasoning how they are taken into account when we want to set some air quality standards. Exposure characterization, again that duration and some people can get exposed to very high concentration depending upon their occupation, like if somebody is working in hazardous pollutant related scenario like some or mining area or where extraction of some heavy metals are there.

So, those kinds of issues may be there. Risk assessment so again, we have to assess the risk, what is even concentration high, but risk is not there, because of certain meteorological parameters when we calculate the risk, then it's fine in that particular area, but if a location is such that even small concentrations are emitted and then they build up over the period of time because of some peculiar metrological conditions or topographical conditions, then, in those locations, we should have different kind of air quality standards.

It is not that the same standard we should have although, to begin with, we are having uniform standards across country, but several researchers, several policymakers also argue that we should have air quality standards as per the context as per the atmosphere or the environment where people are working and of course in these industrial areas, people have different kind of air quality standards.

Like indoor air quality standards are nowadays being developed, then acceptability of the risk. Risk factor is very important to consider because, we get exposed to several kinds of risk like traffic accidents or we also have health risks due to some consumption of other material or there are issues people talk about like people get exposed to occupational risk people get exposed to other kinds of risks which are not in our control like earthquake.

And so the estimate how much risk is there in the background, whether that is acceptable or not, if some industry is coming and some emissions will be added and that will add some risk in that particular environment. So, whether that risk is acceptable or not because trade-off is there, we get some benefit like economic growth will be there, we may have better health facilities, education facilities because of some industrial developments.

So, those risk benefit analysis is to be done and what is acceptable that is also considered for setting the air quality standards.


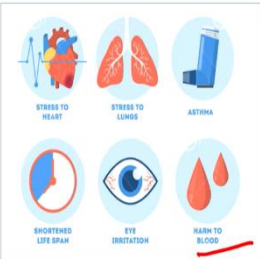


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### Factors considered for setting Air Quality Standards

**Adverse health effects**

- In setting a standard for the control of an environmental pollutant, the effects that the population is to be protected against need to be defined.
- A hierarchy of health effects can be identified ranging from acute illness and chronic diseases, to temporary physiological or psychological changes.



Source: Guidance for Setting Air Quality Standards, WHO, 1997

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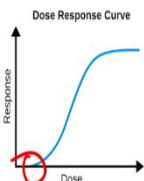
So, adverse health effects that can be we have already discussed at several locations, like they can have respiratory related problems, they can have eye irritation, because of certain pollutants, and you can go into blood, they can cause asthma also. So, there are several ways air pollutants can affect our health. So, we have to see those health effects and we have to consider which is important and which particular pollutant is causing a peculiar kind of health effects. So, accordingly we have to take those considerations into account.

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### Factors considered for setting Air Quality Standards

**Dose Response Curves**

- Dose-response relationships are used to compare the toxicity of various substances, and they are also used by regulators to establish **criteria for air quality**.
- The **potentially susceptible** sub-populations (with respect to the effects of air pollution responses) are sometimes classified into two general groups:
  - *more sensitive (including the ill, elderly, very young, undernourished, etc.)*
  - *greater exposures (including the poor, uneducated, exercising school children, exercising outdoor workers)*



Source: Phalen, F., and Phalen, N., 2013

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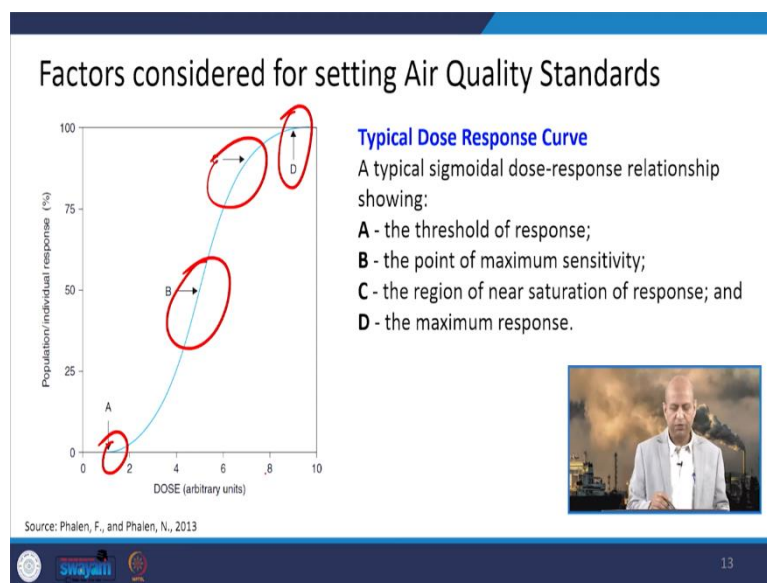
When we talk about dose response curve some dose is there, so dose means duration and the concentration both these. So, this is the relationship, dose increases and response also increases



some relationship is there and we can get but there is some threshold quantity also below that, there is no effect and another way of looking at this problem is like potentially susceptible as people are ill or they are elderly or very young, they are more sensitive even to small concentrations of pollutants.

Then there may be occupational related exposures like and like somebody working outdoors. So, higher concentration of pollutants can get exposed to that person, some occupational related issues may be there, some people may be unaware of some issues of pollutants hazards and they might be working in hazardous situations like landfill emissions maybe there, there may be different kinds of waste material and people are not aware of those harmful effects which they carry because of exposure. So, those reasons may also be there. So, that thing has to be taken into account.

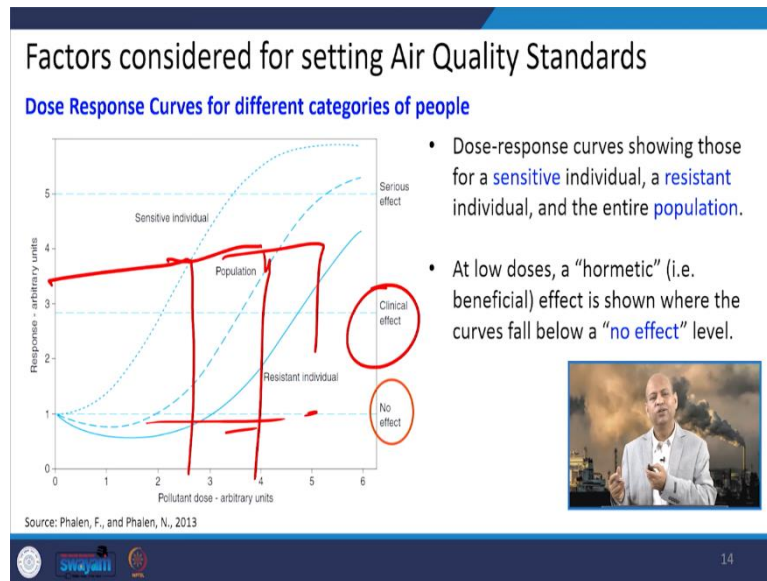
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This is the sigmoidal dose response relationship as we have also seen earlier. So, this A is the threshold of the response below that there is no problem means below this level, there is no problem. When this increases, then of course, problems start to occur some responses there in terms of health effects.

So the point of maximum sensitivity at this most of the people have problem related issues, health related issues, C is the region near saturation response means kind of it has exposed to most of the population and maximum response is occurred at this particular level. So, these are the based on the studies scaling up those dose response curves.

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And also there are certain levels, there is no effect after this below this level. Then clinical effect have been observed at this particular level, but, the same concentration will have different effects on different kind of segment of population like sensitive people, even smaller concentration will have some response, whereas, high concentration of this population means average population can expose to higher concentration.



And resistant individual who have good immunity, good health, they can even get exposed to higher concentrations. So, depending upon the segment of the population, again different standards may be there but we have to take here worst case scenario. So, we go for sensitive population, we have to protect them.

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### Factors considered for setting Air Quality Standards

**Exposure characterization**

- The air quality estimates from **monitoring networks or models** corresponding to personal exposure in the population should also be considered in standard-setting.
- These estimates depend on the pollutant as well as on a number of local characteristics, climatic conditions, spatial distribution of pollution sources and local determinants of pollution dispersion



Source: Guidance for Setting Air Quality Standards, WHO, 1997

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Then exposure characterization because of monitoring like air quality monitoring must be there. Otherwise, how can we implement our air quality standards if we do not have monitor data? So, we have to have monitor data or modelled data of the concentrations at several locations. So, monitoring capability also restrict air quality standards.

Suppose some country or some particular organization start arguing that we should have very stringent air quality standards fine but what is the huge with they do not have any instrument to monitor to compare whether the concentration is there of that nature or not. So, those air quality monitoring capabilities, skilled manpower, then resources to support that particular monitoring network, all these issues economic factors are also there.

Means whatever policy can be implemented, those air quality standards can be properly implemented, regulated only then it is making sense otherwise having those regulations or these air quality standards and not having infrastructure to support those guidelines, then there is no fun. So, that is why this monitor network related issues are also important.

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## Factors considered for setting Air Quality Standards

### Risk assessment

- The first two steps in risk assessment, namely **hazard identification** and, in some cases, **development of exposure–response relationships**.
- The third step, **exposure analysis**, may predict changes in exposure associated with reductions in emissions from a specific source.
- The final step in a **regulatory risk assessment** is the risk characterization stage, where exposure estimates are combined with exposure–response relationships to generate quantitative estimates of risk

- Hazard identification
- Development of exposure–response relationships
- Exposure analysis
- Regulatory risk assessment

Source: Guidance for Setting Air Quality Standards, WHO, 1997

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And in risk assessment, there are various issues like hazardous components identification, development of exposure and response related relationships, then we analyse the exposure assessment and the regulatory risk assessment is also taken into account and it is carried out. In New Zealand, Canada, Australia, those countries, they basically have this risk based related processes to set these air quality standards.

Other countries have other ways to go for threshold quantities for criteria pollutants. So, several countries have different kinds of methodologies.

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## Factors considered for setting Air Quality Standards

### Acceptability of risk

- The standard selected will depend on the **severity** of the potential effects, the size of the **population at risk**, and the degree of scientific certainty that the effects will occur at any given level of pollution.
- For example, if a suspected but uncertain **health effect** is **severe** and the size of the population at risk is **large**, a more **cautious approach** would be appropriate.

Source: Guidance for Setting Air Quality Standards, WHO, 1997

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And as earlier also I said that acceptability of risk is very important, how much risk we can accept by trading with the benefits or by trading with other kinds of risks which are every day we face like traffic accidents are there and there are several kinds of risk basically, so you have to compare which kind of risk is more and already if we are having some more risk in terms of background concentration, then we should not allow other industries to come up.

Like emissions adding there to exceed those standards but the standards when we set the acceptability of the risk is also primary factor because if you can afford more risk in terms of exposure, then you can have higher level of standards. Otherwise, if some situations are there where you do not want to get exposed to even very small concentrations because of certain regions like in that area maybe school children are there or maybe hospitals are there in that case in that particular area, we cannot go for normal standards.

So, we have to specify sensitive standards air quality standards as per sensitive zones sensitive areas, we will see those kinds of situations.

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**National Ambient Air Quality Standards: India**

- 1970 • Interest in air quality management policies began in India during the 1970s.
- 1972 • After the 1972 Stockholm Conference on the Human Environment, it became clear that the nation was in need of a uniform environmental law.
- 1981 • As a result, the Air (Prevention and Control of Pollution) Act was passed by Parliament in 1981.
- 1994 • With the goal of providing for the prevention, control, and abatement of air pollution, the first ambient air quality standards were adopted in 1982 by the Central Pollution Control Board (CPCB) and revised in 1994 and again in 2009.
- 2009

Source: Bhawe and Kulkarni, 2015


Well, if we look into timeline for the setting of national ambient air quality standards for India, so in 1970 basically this interest grew in management policies, spheres or circles and then in 1972 after this Stockholm Conference on the Human Environment, it became very clear that we need, uniform environmental law and then as a result or as a consequence of that year prevention and control of pollution that was passed by Parliament in 1981.

And with the goal of providing for the prevention, control and abatement of air pollution, the first ambient air quality standards were adopted in 1982 by the CPCB central pollution control board and they were revised in 1994 and 2009, we will see how much values are changing according to that.

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Pollutant	Time weighted average	Concentration in ambient air		
		Industrial Area	Residential, rural and others area	Sensitive area
Sulphur dioxide ( $\mu\text{g}/\text{m}^3$ )	Annual	80	60	15
	24 hours	120	80	30
Nitrogen dioxide ( $\mu\text{g}/\text{m}^3$ )	Annual	80	60	15
	24 hours	120	80	30
Suspended particulate matter ( $\mu\text{g}/\text{m}^3$ )	Annual	360	140	70
	24 hours	500	200	100
Respirable particulate matter ( $\mu\text{g}/\text{m}^3$ )	Annual	120	60	50
	24 hours	150	100	75
Lead ( $\mu\text{g}/\text{m}^3$ )	Annual	1	0.75	0.50
	24 hours	1.5	1	0.75
Carbon Monoxide ( $\text{mg}/\text{m}^3$ )	8 hour	5	2	1
	1 hour	10	4	2
Ammonia ( $\text{mg}/\text{m}^3$ )	Annual	--	0.1	--
	24 hours	--	0.4	--

National Ambient Air Quality Standards: India  
Revised in 1994



Source: Guidelines NAAQS, CPCB, 2013

Like in 1994 this was basically the national ambient air quality standards. So, concentration defined in industrial area, residential, rural and other areas and sensitive areas. So, three particular categories were defined and then as per pollutant, the time weighted average like annual average or 24 hours average depending upon the pollutant like for carbon monoxide it was only 8 hour and 1 hour because of the toxicity level.

Ammonia annual at 24 hour. So, mostly those were suspended particulate matters, these were around 100 this micrometre respiratory particulate matter RSPM that is basically  $\text{PM}_{10}$ . So, for that annual and 24 hours are there and different values are there. For industrial area it was higher like 80 annual and residential area 60 and sensitive area 15 very less.

Similarly, 24 hours for industrial area of sulphur dioxide it was 120, for residential area it was 80 and for sensitive area it was 30. So, different areas have as per the time exposure or average time different values but then researchers had better perspective over the years.

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Pollutant	Time weighted average	Concentration in ambient air	
		Industrial, Residential, rural and others area	Ecologically Sensitive area (notified by Central Government)
Sulphur dioxide ( $\mu\text{g}/\text{m}^3$ )	Annual	50	20
	24 hours	80	80
Nitrogen dioxide ( $\mu\text{g}/\text{m}^3$ )	Annual	40	30
	24 hours	80	80
Particulate Matter, $\text{PM}_{10}$ ( $\mu\text{g}/\text{m}^3$ )	Annual	60	60
	24 hours	100	100
Particulate Matter, $\text{PM}_{2.5}$ ( $\mu\text{g}/\text{m}^3$ )	Annual	40	40
	24 hours	60	60
Lead ( $\mu\text{g}/\text{m}^3$ )	Annual	0.5	0.5
	24 hours	1.0	1.0
Carbon Monoxide ( $\text{mg}/\text{m}^3$ )	8 hour	2	2
	1 hour	4	4
Ammonia ( $\text{mg}/\text{m}^3$ )	Annual	100	100
	24 hours	400	400
	8 hour	100	100
Ozone, $\text{O}_3$ ( $\mu\text{g}/\text{m}^3$ )	1 hour	180	180
	Annual	5	5
Benzo Pyrene ( $\text{ng}/\text{m}^3$ )	Annual	1	1
Arsenic ( $\text{ng}/\text{m}^3$ )	Annual	6	6
Nickel ( $\text{ng}/\text{m}^3$ )	Annual	20	20

## National Ambient Air Quality Standards: India

Revised in 2009



Source: Guidelines NAAQS, CPCB, 2013

And in 2009, then they were revised. People argued that even if people are living in industrial area, they have equal to clean air. So, industrial areas, residential areas, rural areas, all these areas were clubbed and the standards were defined uniformly for those areas but of course, ecologically sensitive areas which are notified by central government of India.

So, those were taken as a separate entity and standards were prescribed differently. Sulphur dioxide annual 50 earlier it was 60, residential area 80 was in industrial area, then 24 hours 80 ecologically sensitive 20 and 80. So, 24 hours, almost say exactly same but for annual average because of, regular exposure and their harmful effect. So, it was taken as 20. Different values like  $\text{PM}_{10}$  then  $\text{PM}_{2.5}$  was also added in 2009 and then this benzene and arsenic nickel all other additional pollutants were added in the list.



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### NAAQS (Comparison 1994 and 2009)

Some of the salient features include (1/6):

- Area classification is based on land-use so that industrial areas have to conform to the same standards as residential areas.

1994		Concentration in ambient air		
Pollutant	Time weighted average	Industrial Area	Residential, rural and others area	Sensitive area
		↓		
2009		Concentration in ambient air		Ecologically Sensitive area (notified by Central Government)
Pollutant	Time weighted average	Industrial, Residential, rural and others area		

Source: Bhave and Kulkarni, 2015



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So, if we compare 1994 and 2009 air quality standards, so like concentrations were divided into three categories earlier industrial, residential, rural other and then sensitive area and in 2009 only two categories, this industrial, residential rural in one and ecologically sensitive in the second.

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### NAAQS (Comparison 1994 and 2009)

Some of the salient features include (2/6):


- The standards shall be applicable uniformly with the exception of stringent standards for NO<sub>2</sub> and SO<sub>2</sub> in the Ecologically Sensitive Areas.

1994		Concentration in ambient air		
Pollutant	Time weighted average	Industrial Area	Residential, rural and others area	Sensitive area
Sulphur dioxide (µg/m <sup>3</sup> )	Annual	80	60	15
	24 hours	120	80	30
Nitrogen dioxide (µg/m <sup>3</sup> )	Annual	80	60	15
	24 hours	120	80	30

2009		Concentration in ambient air	
Pollutant	Time weighted average	Industrial, Residential, rural and others area	Ecologically Sensitive area (notified by Central Government)
Sulphur dioxide (µg/m <sup>3</sup> )	Annual	50	20
	24 hours	80	80
Nitrogen dioxide (µg/m <sup>3</sup> )	Annual	40	30
	24 hours	80	80

Source: Bhave and Kulkarni, 2015



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Different values who have different variations are there earlier, like for annual, this is 80 and 60 and it was fixed as 50 then when these were club, so little bit more stringent we have become. Sensitive area, it was earlier 15 for sulfur dioxide now, it is 20.

So, means more evidence based literature was there to afford get to getting exposed for higher concentrations annually while other this 80-80 values are same for 24 hours earlier it was 120 and 80 in residential areas. And it was 30 sensitive areas. So, that way a lot of difference means in residential industrial areas values were reduced, it became a little bit stringent and for sensitive areas depending upon the definition more concentrations were allowed.


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### NAAQS (Comparison 1994 and 2009)

1994	Pollutant	Time weighted average	Concentration in ambient air		
			Industrial Area	Residential, rural and others area	Sensitive area
Sulphur dioxide ( $\mu\text{g}/\text{m}^3$ )	Annual		80	60	15
	24 hours		120	80	30
Nitrogen dioxide ( $\mu\text{g}/\text{m}^3$ )	Annual		80	60	15
	24 hours		120	80	30
Lead ( $\mu\text{g}/\text{m}^3$ )	Annual		1	0.75	0.50
	24 hours		1.5	1	0.75

**Some of the salient features include (3/6):**

The previous standards for residential area have been uniformly applied for fine particulate matter ( $\text{PM}_{10}$ ), Carbon Monoxide and Ammonia. More stringent limits for Lead,  $\text{SO}_2$  and  $\text{NO}_2$  have been prescribed even for residential areas.



Source: Bhave and Kulkarni, 2015

So, everywhere whether it is nitrogen dioxide, lead, you will see that kind of variation.

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### NAAQS (Comparison 1994 and 2009)

**Some of the salient features include (4/6):**

1994	Pollutant	Time weighted average	Concentration in ambient air		
			Industrial Area	Residential, rural and others area	Sensitive area
Suspended particulate matter ( $\mu\text{g}/\text{m}^3$ )	Annual		360	140	70
	24 hours		500	200	100

Suspended Particulate Matter (SPM) as parameter has been replaced by fine particulate matter ( $\text{PM}_{2.5}$ ).

2009	Pollutant	Time weighted average	Concentration in ambient air	
			Industrial, Residential, rural and others area	Ecologically Sensitive area (notified by Central Government)
Particulate Matter, $\text{PM}_{2.5}$ ( $\mu\text{g}/\text{m}^3$ )	Annual		40	40
	24 hours		60	60



Source: Bhave and Kulkarni, 2015

Suspended particulate matter was there then PM<sub>2.5</sub> was added. So, that is also again new addition the reason is because it was found that PM<sub>2.5</sub> is more dangerous because it can go up to our lungs and it can result into several kind of problems basically.

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### NAAQS (Comparison 1994 and 2009)

**Some of the salient features include (5/6):**

- Other new parameters like, Ozone, Arsenic, Nickel, Benzene and Benzo(a)Pyrene have been included.

2009 Pollutant	Time weighted average	Concentration in ambient air	
		Industrial, Residential, rural and others area	Ecologically Sensitive area (notified by Central Government)
Ozone, O <sub>3</sub> (µg/m <sup>3</sup> )	8 hour	100	100
	1 hour	180	180
Benzene (µg/m <sup>3</sup> )	Annual	5	5
Benzo Pyrene (ng/m <sup>3</sup> )	Annual	1	1
Arsenic (ng/m <sup>3</sup> )	Annual	6	6
Nickel (ng/m <sup>3</sup> )	Annual	20	20

Source: Bhawe and Kulkarni, 2015



Then, if we talk about other parameters like ozone, arsenic, nickel, these benzo pyrene all these have been added and their standards have been defined.

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### NAAQS (Comparison 1994 and 2009)


**Some of the salient features include (6/6):**

1994 Pollutant	Time weighted average	Concentration in ambient air		
		Industrial Area	Residential, rural and others area	Sensitive area
Carbon Monoxide (mg/m <sup>3</sup> )	8 hour	5	2	1
	1 hour	10	4	2

Standards for short duration, just one to few hours, have been set to reduce peak exposure to some deadly gases like Ozone and Carbon Monoxide.

2009 Pollutant	Time weighted average	Concentration in ambient air	
		Industrial, Residential, rural and others area	Ecologically Sensitive area (notified by Central Government)
Carbon Monoxide (mg/m <sup>3</sup> )	8 hour	2	2
	1 hour	4	4
Ozone, O <sub>3</sub> (µg/m <sup>3</sup> )	8 hour	100	100
	1 hour	180	180

Source: Bhawe and Kulkarni, 2015





Well, then carbon monoxide, ozone there this time weighted average is 8 hour and 1 hour because of their toxicity.

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### WHO air quality guidelines 2021

- The World Health Organization (WHO) released revised air quality guidelines on **September 22, 2021**, the first major update to the standards in 15 years.
- The revised recommendations, produced from evidence-based data and information and a growing awareness, resulted in nearly all pollutant standards being strengthened in comparison to the air quality guidelines established in 2005 (published in 2006).



Source: <https://www.igair.com/blog/air-quality/2021a-WHO-air-quality-guidelines>

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Then as I said, because not every country has that much resources to develop their own air quality standards. So, better they go for WHO air quality guidelines and they try to follow them.


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### WHO air quality guidelines 2021

Pollutant	Averaging Time	2005 AQGs	2021 AQGs
PM <sub>2.5</sub> $\mu\text{g}/\text{m}^3$	Annual	10	5
	24-hour	25	15
PM <sub>10</sub> $\mu\text{g}/\text{m}^3$	Annual	20	15
	24-hour	50	45
Ozone (O <sub>3</sub> ) $\mu\text{g}/\text{m}^3$	Peak Season*+ 8-hour**	-	60
		100	100
Nitrogen dioxide (NO <sub>2</sub> ) $\mu\text{g}/\text{m}^3$	Annual	40	10
	24-hour*	-	25
Sulfur dioxide (SO <sub>2</sub> ) $\mu\text{g}/\text{m}^3$	24-hour	20	40
Carbon monoxide (CO) $\text{mg}/\text{m}^3$	24-hour*	-	4

\*new averaging time for 2021

- Peak season refers to the six consecutive months with the highest running-average of ozone concentration.
- 24-hour AQG level for sulfur dioxide of  $40 \mu\text{g}/\text{m}^3$  was recommended based on a new evaluation of the effects of short-term sulfur dioxide concentrations on all-cause mortality and respiratory mortality.



Source: <https://www.igair.com/blog/air-quality/2021a-WHO-air-quality-guidelines>

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So, WHO has produced certain guidelines like in 2005 there were some values in 2021 they have given more stringent values like from PM<sub>2.5</sub> annual this was 10 this is a microgram per cubic meter and this is 5, then in PM<sub>10</sub> annual it was 20 earlier, now it is 15. Sulphur dioxide it was 20 earlier, now it is 40.

So, means, when we have like new evaluation methodology, new values new scientific data, so change can be on either side, but mostly we go for more stringent depending upon the situation, but in this particular case concentration rather than reduce it increased means air quality standards increase.

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### Air Quality Standards in different countries

- The air quality standards may vary for different countries due to various factors, such as economic conditions, technological know-how, and indigenous air pollution-related epidemiological studies.
- These are known as the National Ambient Air Quality Standards (NAAQS) in countries, such as India, China, and the US. However, in Canada and the European countries, the limit values are predefined (WHO 2005).



Source: Gujjar, B.R., 2021, <https://www.terin.org/>

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When we talk about of different countries air quality standards, so they vary as I said because of their technological capabilities because of their economic status, all these things influence how much a standard they can afford to apply or implement.

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### Air Quality Standards in different countries

Pollutant	Time	WHO	European Union	United States	California	Japan	Brazil	Mexico	South Africa	India (i <sub>1</sub> /i <sub>2</sub> /i <sub>3</sub> ) <sup>a</sup>	China (I/II/III) <sup>d</sup>
Sulphur dioxide (µg/m <sup>3</sup> )	1 year	-	-	78	-	-	80	78	50	15/60/80	20/60/100
	24 hr	20	125	366	105 <sup>b</sup>	105	365	341	125	30/80/120	50/150/250
	1 hr	-	350	-	655	262	-	-	-	-	150/500/700
	10 min	500	-	-	-	-	-	-	500	-	-
Nitrogen dioxide (µg/m <sup>3</sup> )	1 year	40	40	100	-	-	100	-	94	15/60/80	40/40/80
	24 hr	-	-	-	-	113	-	-	188	30/80/120	80/80/120
	1 hr	200	200	-	470 <sup>c</sup>	-	320	395	376	-	120/120/240
PM <sub>10</sub> (µg/m <sup>3</sup> )	1 year	20	40	50	20	-	50	50	60	50/60/120	40/100/150
	24 hr	50 <sup>a</sup>	50 <sup>a</sup>	150	50	100	150	120	180	-	50/150/250
PM <sub>2.5</sub> (µg/m <sup>3</sup> )	1 year	10	-	15	12	-	15	-	15	-	-
	24 hr	25 <sup>a</sup>	-	65	65	-	65	-	65	-	-
Ozone (µg/m <sup>3</sup> )	8 hr	100	120	157	137	-	157 <sup>e</sup>	-	-	-	-
	1 hr	-	-	-	180 <sup>c</sup>	118 <sup>c</sup>	160	216	235	-	120/160/200
Carbon Monoxide (mg/m <sup>3</sup> )	1 hr	30	-	40	23	11	40	-	30	4	10
	8 hr	10	10	10	10	23	10	11	10	2	-

a: Not to be exceeded more than 3 days per year. b: Not to be exceeded more than 35 days per year. c: Photochemical oxidants. d: i<sub>1</sub>: Sensitive population; i<sub>2</sub>: Residential population; i<sub>3</sub>: Industrial population. Class I: tourist, historical and conservation areas; Class II: residential urban and rural areas; Class III: industrial and heavy traffic areas.



Source: Gujjar, B.R., 2021, <https://www.terin.org/>

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So, we have taken from different sources and compiled this data. So, WHO, European Union, United States, California they have different set of standards. Japan, Brazil, Mexico, South Africa, India, China all these different for different pollutants, we have tried to compile and compare air quality standards.

Different values are there for different countries and the reason is means if some country is capable to monitor in a big way they can have stringent standards they can apply they can execute those standards, some other countries which do not have that much capability so accordingly their standards are a little bit different like Brazil 80 is there. South Africa having 50, India 15, 60, 80 depending upon different situations, like sensitive and those residential areas.

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**Emission Standards**

- *Emission standards* define release limits, which are usually measured directly at their sources.
- The sources include *tailpipe emissions* from cars and trucks, *stack emissions* from factories and power plants, and *general air emissions* from domestic sources.

Source: Govindraj et al., 2019

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The slide features three images: 'Tailpipe Emissions' showing a car with exhaust, 'Stack emissions' showing a factory chimney, and a speaker in a white shirt pointing towards the camera.



Now, we come to emission standards. So, basically air quality standards are the concentration of air pollutants into the ambient air, indoor air quality standards are also nowadays people are talking and they are in the process of development but as such ambient air quality standards are very popular till now, then where these concentrations come to the air because of certain emissions.

So, there must be some emission standards also so that we can prevent to build up more concentration. So, like from tailpipe emissions or from stack emissions. So, all those emissions are also regulated.

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### Emission Standards in India

- Emission standards are governmentally promulgated limits on the emission of a pollutant from a process.
- India have initiated to follow emission standards through the Motor vehicles act of 1988, which allows the government to implement the emission standards.
- Emission standards for petrol vehicles from 1991 and for diesel vehicles from 1992 and started to follow EURO emission standards as a reference from the year 2000.



Source: Govindraj et al., 2019; image: <https://inhabitat.com/>


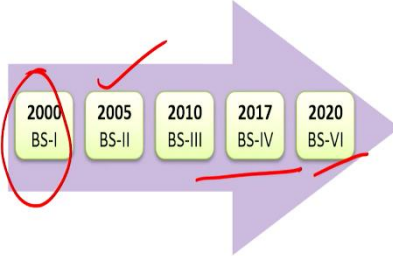
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And some standards are given by the government, like Motor Vehicle Act 1988 was there. So, for petrol for diesel, different cars or different vehicles are there and different standards are there.

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### Emission Standards in India

- Timeline for the nationwide implementation of the various stages of emission standards in all over India.
- The Indian emission standard "BHARAT STAGE" (BS) for India 2000 (BS I) is taken from EURO 1 emission standards as a reference, BS II from EURO II, BS III from EURO III, BS IV from EURO IV, BS V from EURO V and BS VI from EURO VI.



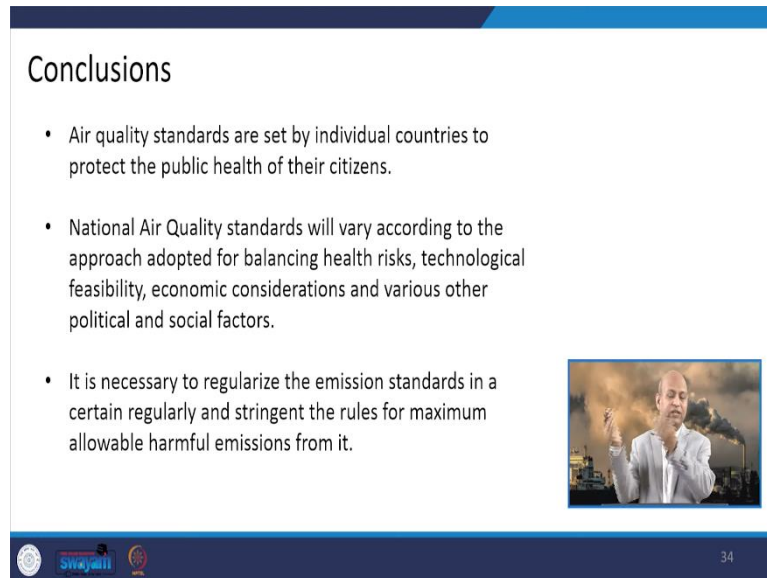
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Like 2000; BS-I, Bharat Stage-I, so they were borrowed from European Union standards like Euro-1, Euro-2. 2005; we implemented BS-II that is Bharat Stage-2. And similarly, like we came to BS-IV in 2017. But then we did like leap frogging. And in 2020; we went directly to BS-VI Bharat Stage VI that is equivalent to Euro-6. So, we did not go for BS-V and that way




big jump or big leap has been achieved. And that is a great contribution to reduce emissions because as we grow in this term, the emissions become very less.

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**Conclusions**

- Air quality standards are set by individual countries to protect the public health of their citizens.
- National Air Quality standards will vary according to the approach adopted for balancing health risks, technological feasibility, economic considerations and various other political and social factors.
- It is necessary to regularize the emission standards in a certain regularly and stringent the rules for maximum allowable harmful emissions from it.

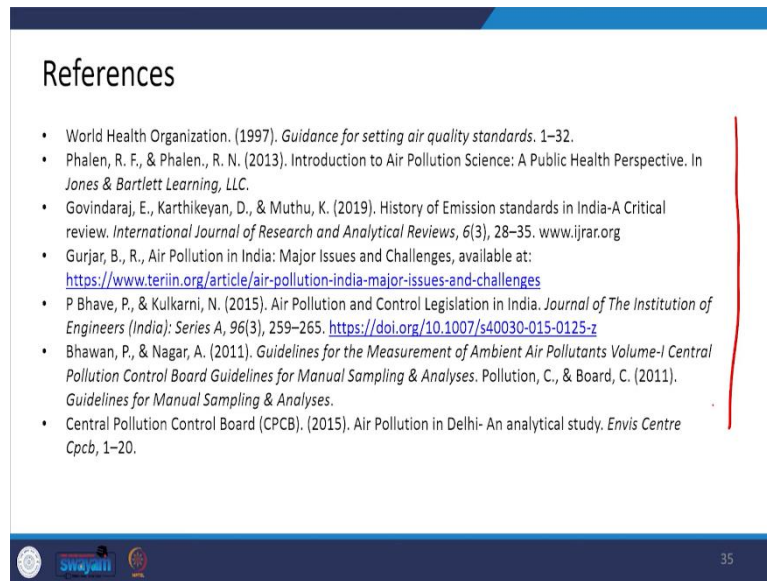


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So, in conclusion, we can say that the air quality standards are very important and individual countries develop their own air quality standards depending upon the scientific evidences as well as their capabilities in terms of economy, technology, etc.

And these are important because of health risk related issues or other like sensitive areas production those kinds of things. And emission standards are also needed, so that we can meet those air quality standards, we can curb the emissions at the source itself. So, emission standards for that purpose is very important to set to achieve the ambient air quality standards.

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So, this is all for today. Thank you for your kind attention. And these are the references for additional information. See you in the next lecture. Thanks again.