

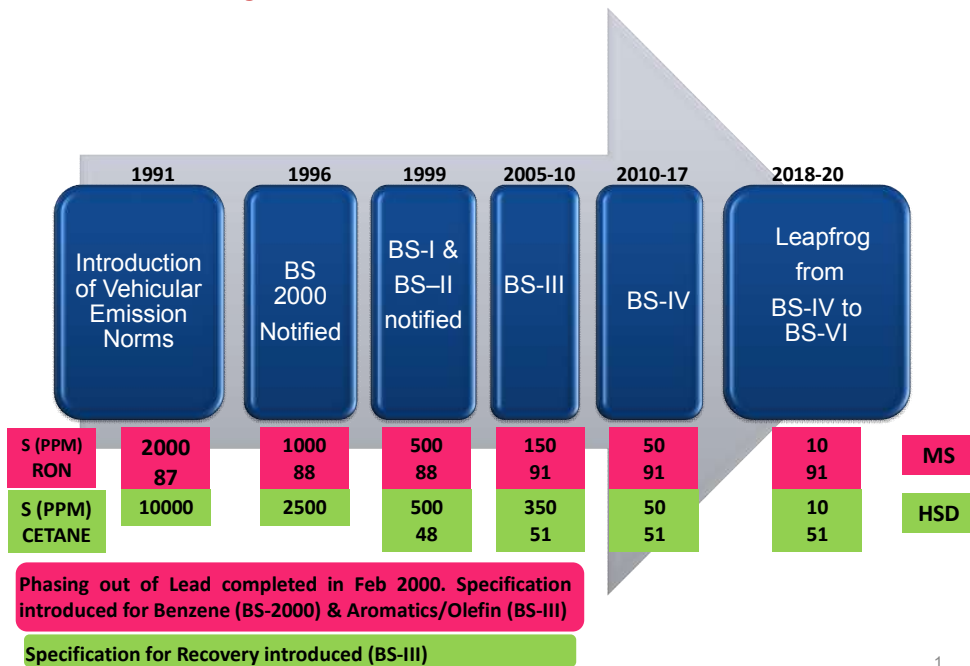
## FUEL QUALITY UPGRDATION PROGRAM IN INDIA- A HISTORICAL PERSPECTIVE

- Across the world, over the last many decades, atmospheric air quality has been adversely impacted by emission from automobile tailpipe exhaust, industrial smoke stacks, thermal power plants, construction dust & debris and the other by-products of a crowded and modernized urban existence. Simultaneously, the rising incidence of a range of health effects has been recorded and there is compelling evidence of a causative link from the former to the latter, some very direct, some somewhat direct and some in an associated sense along with other factors. That cleaning up the air will be good for citizens' well-being is thus not just a gut feeling, but clearly established in the research literature. The World Health Organization (WHO) has consistently red-lined the danger to human health from air pollutants.
- Taking a cue from the research literature about ill effect of air pollution on human health, Indian Fuel upgradation program was taken off with notification of vehicular emission norms for new vehicles in 1991. The emission norms were revised in 1996. India has followed regulatory pathway for fuel quality and vehicle emissions standards termed as Bharat Stage (BS). These requirements have usually been first introduced in Delhi and other major cities, followed by nationwide implementation. India's fuel quality standards have been gradually tightened since mid-1990s. Low lead gasoline was introduced in 1994 in Delhi, Mumbai, Kolkata and Chennai. On Feb 1, 2000, unleaded gasoline was mandated nationwide. Similarly, BS 2000 (Euro 1 equivalent, BS-I) vehicle emission norms were introduced for new vehicles from April 2000. BS-II (Euro-II equivalent) emission norms for new cars were introduced in Delhi from the year 2000 and extended to the other 3 metro cities in the year 2001. The emission norms for CNG and LPG vehicles were notified in the year 2000 and 2001, respectively.
- India's current gasoline standards took effect on 1<sup>st</sup> April 2010. These standards required marked improvements from pre-2010 levels. Benzene limits were reduced progressively from 5% in 2000 to 1% nationwide. The aromatic content limit, which was unregulated under BS-II, was restricted to 42% under BS-III norms and 35% under BS-IV. Olefins, which were also unregulated under BS-II, mandated at 21% and 18% for BS-III regular and premium gasoline, respectively. Sulphur content was lowered to 150 ppm nationwide and 50 ppm in BS-IV compliant cities in 2010. Under BS-II, the octane

number had been increased to 88 and 93 for regular and premium, respectively. It was further increased to 91 and 95 for regular and premium, respectively, under BS-III and beyond. India will meet international best practices with implementation of BS-VI, which will require 10 ppm Sulphur gasoline from 1<sup>st</sup> April, 2020.

- India has reduced its diesel Sulphur content from 10,000 ppm in most of the country in 1996 to a maximum of 50 ppm in 2017. Another factor that has improved over this period is cetane number, which increased from 45 to 48 in 1998 and 51 in 2005. The proposed BS-VI regulation will reduce diesel Sulphur content to a maximum of 10 ppm, enabling the introduction of advanced emission control technologies, including diesel particulate filters (DPF) and selective catalyst reduction (SCR) systems, which will be needed to meet BS-VI emission standards.

## Fuel Quality Improvement



Date	Diesel	Gasoline
1995	10,000 ppm (nationwide)	-
1996	5,000 ppm (Delhi + select cities)	-
1998	2,500 ppm (Delhi)	-
2000	2,500 ppm (nationwide)	1,000 ppm (nationwide)

	500 ppm in NCR and gradually extended to Metros	500 ppm in NCR
2005	500 ppm (BS II, nationwide) 350 ppm (BS III, select cities)	500 ppm (BS II, nationwide) 150 ppm (BS III, selected cities)
2010	350 ppm (BS III; nationwide) 50 ppm (BS IV; select cities)	150 ppm (BS III, nationwide) 50 ppm (BS IV, selected cities)
2017	50 ppm (BS IV; nationwide)	50 ppm (BS IV; nationwide)
2018	10 ppm (BS VI; NCT)	10 ppm (BS VI; NCT)
2020	10 ppm (BS VI; nationwide)	10 ppm (BS VI; nationwide)

Chronology of fuel upgradation in India		
Year	Standard	Remarks
1991	Vehicle emission norms introduced in India	
1995	Diesel: Cetane Number: 45; Sulphur: 1%	
1996	Diesel Sulphur: 0.5% (Metros and TTZ)	
1998	Diesel Sulphur: 0.25% (Metros and TTZ) and Cetane No 48	
1999	SC orders Government to introduce BS-2000/II vehicle emission norms	
2000	Diesel Sulphur: 0.05% (NCR and gradually extended to other Metros) Diesel Sulphur- 0.25 % rest of the country Unleaded Gasoline introduced Nationwide	
2000	Sulphur in Gasoline reduced from 0.2% to 0.1% wt max and 500 ppm for NCR	
2000	Benzene in Gasoline <ul style="list-style-type: none"> <li>• 1% vol max</li> <li>• 3% vol max</li> <li>• 5% vol max</li> </ul>	NCR/ Mumbai Other Metros Rest of country
2000	<b>BS 2000 emission standard implemented</b>	Nationwide
2000-2003	<b>BS II</b> (Reference Euro 2)	NCR, select Cities
2003	Dr R A Mashelkar Committee report 'Auto Fuel Policy 2003' approved adopting BS-III and IV fuel standards	
04-2005	<b>Auto fuel policy 2003 implemented, BS III</b> (Reference Euro 3)	NCR, 13 Cities#
10-2005	<b>BS II</b> (Reference Euro 2)	Nationwide
04-2010	<b>BS-IV implemented</b> (Reference Euro 4)	NCR, 13 Cities#
09-2010	<b>BS III</b> (Reference Euro 3)	Nationwide
	<b>MoP&amp;NG Decided to go beyond Auto Fuel Policy-2003 and introduced BS-IV in 50 more cities by 31.03.2015</b>	50 Cities*
Dec 2012	Petroleum Ministry set up Saumitra Chaudhuri Committee for <b>Auto Fuel Vision &amp; Policy 2025</b>	
05- 2014	Saumitra Chaudhuri Committee recommendations ' <b>Auto Fuel Vision &amp; Policy 2025</b> '	

<b>04-2017</b>	<b>BS IV introduced in 3 phases</b>	Nationwide
	<b>Phase-1</b>	
<b>01.04.2015</b>	<p><b>North India w.e.f. 01.04.2015</b> covering areas whole of Northern India covering J&amp;K (#Except Leh/ Kargil and 7 district of J&amp;K), Punjab, Haryana, Himachal Pradesh, Uttarakhand, Chandigarh, Delhi and the bordering districts of Rajasthan (Bharatpur, Alwar, Hanumangarh and Sriganganagar) and Western Uttar Pradesh (Saharanpur, Muzaffarnagar, Baghpat, Meerut, Bijnor, Ghaziabad, Gautam Buddh nagar, Bulandshar, Jyotiba Phule Nagar, Rampur, Moradabad, Aligarh, Budaun, Bareilly, Mathura, Mahamaya Nagar, Etah, Agra, Ferozabad, Etawah and Mainpuri).</p> <p>The districts of Pilibhit, Shamli, Sambhal, Farrukhabad, Kannauj, Auraiya and Kasganj were added on 15.4 2015.</p> <p>The 7 districts of J&amp;K (Pulwama, Baramullah, Badgam, Srinagar, Kudwara, Bandipura and Gandarbal) were added on 1.5.2015.</p> <p>Leh/Kargil were supplied BS-IV w.e.f. 01.09.2015.</p>	
	<b>Phase-2</b>	
<b>01.04.2016</b>	<p><b>Western India w.e.f 01.04.2016 covering areas</b> Whole of Goa, Kerala, Karnataka, Telangana, Odisha, and the Union Territories of Daman &amp; Diu, Dadra-Nagar-Haveli and Andaman and Nicobar Islands, parts of Maharashtra and Gujarat. Retail Outlets situated on the identified National Highways No. NH 8, NH 14, NH 15 and NH 8AE passing through Gujarat and Rajasthan linking Northern India to the ports on the West Coast.</p>	
	<b>Phase-3</b>	
<b>01.04.2017</b>	<b>Rest of India</b>	Madhya Pradesh, Maharashtra, Bihar, Jharkhand, Uttar Pradesh, Rajasthan, West Bengal, North East States, Tamilnadu, Andhra Pradesh, Gujarat etc.
<b>01.04.2018</b>	<b>BS VI</b> (Reference Euro 6)	NCT
<b>01.04.2020</b>	<b>BS VI</b> (Reference Euro 6)	Nationwide

# 13 Cities (NCR- National Capital Region (Delhi), Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Lucknow, Sholapur and Agra)

\* 50 Cities (Puducherry, Mathura, Vapi, Jamnagar, Ankleshwar, Hissar ,Bharatpur, Silvassa, Daman, Diu, Aligarh, Rae Bareilly, Unnao, Karnal, Kurukshetra, Yamunanagar, Valsad, Medak, Nizamabad, Mehbub Nagar, Vrindavan, KosiKalan, Hindaun city, Dholpur, Ahmednagar, Mahabaleshwer, Lonawala, Palgarh, Dahanu, Talasari, Boisar, Panchagani, Mahad, Nagothana, Indapur (Maharashtra), Vizag (AP), Kochi, Trivendram (Kerala), Kavarratti (Lakshdeep), Nagar, Dig, Nadbai (Rajasthan), Bhiwani, Jind, Mahendragarh, Hansi, Charkhi Dadri, Narnaul (Haryana), Kiruli, Fatehpur Sikri (UP))

Estimated Investment by Refineries	Rs Crore
Up to BS-III	35,000
BS-III to BS-IV	25,500
BS-IV to BS-VI	28,000

### Fuel Quality Improvement

The fuel quality transition in the country has been in phases, given the order of changes that were required at the refinery end and in terms of vehicle production. Further, given the link of fuel standards to emission outcomes, priority was accorded to metropolitan centres where vehicle density and emission standards are the highest. In India, auto fuels are produced in refineries as per BIS standards. These standards are amended from time to time to meet environmental as well as other quality aspects and are mandatory.

### Gasoline

#### Phasing out of Lead

Health effects associated with the use of lead alkyl additive in gasoline have led to elimination of leaded gasoline in several countries.

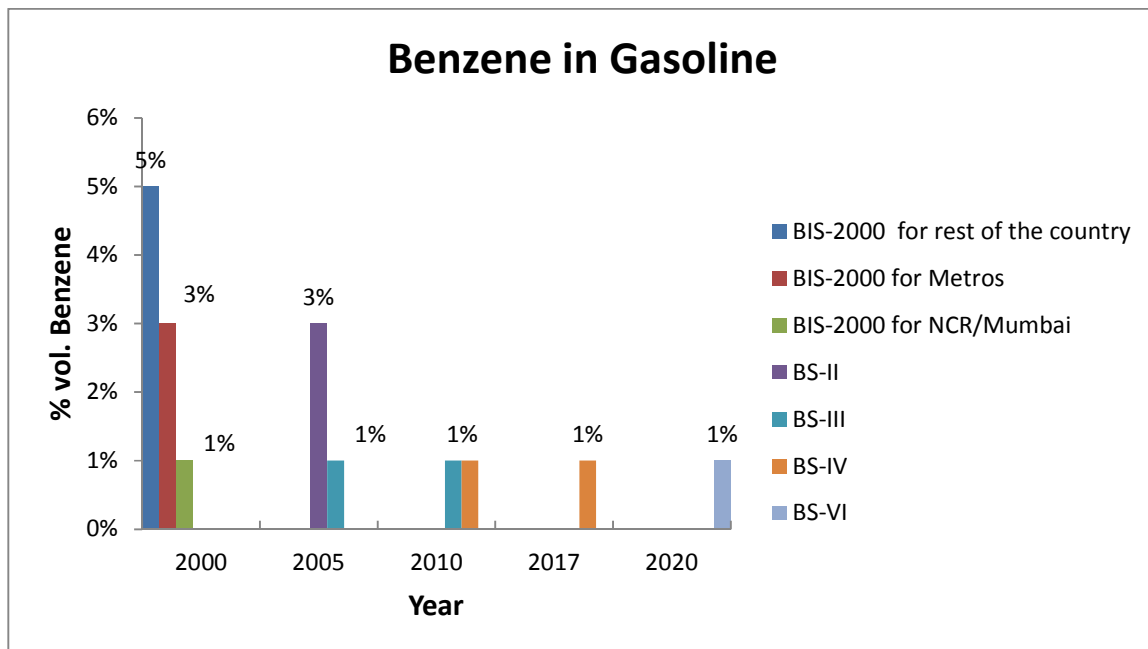
Lead content in gasoline in India was removed in 6 years in phases and only unleaded gasoline is being produced and sold from 01.02.2000. Initial lead limit of 0.56 g/litre for leaded gasoline was reduced to 0.15 g/litre for low lead gasoline, then to 0.013 g/litre for unleaded gasoline. Present lead limit in gasoline across the country is 0.005 g/litre.

## Reduction of Benzene Content

Benzene is a natural constituent of crude oil besides its production during catalytic reforming operation for making high octane gasoline component. It is known to be a human carcinogen. An effective way to reduce human exposure to benzene is to control benzene in gasoline.

There was no benzene specification in gasoline in India till MOE&F notified a benzene limit of 3% vol. max for 4 Metros and 5% vol. max for rest of the country from the year 2000.

Benzene in gasoline supplied to NCR of Delhi and Mumbai was further reduced to 1% vol. max since Oct/Nov, 2000. Presently, nation-wide benzene limit for gasoline is 1% vol. max.

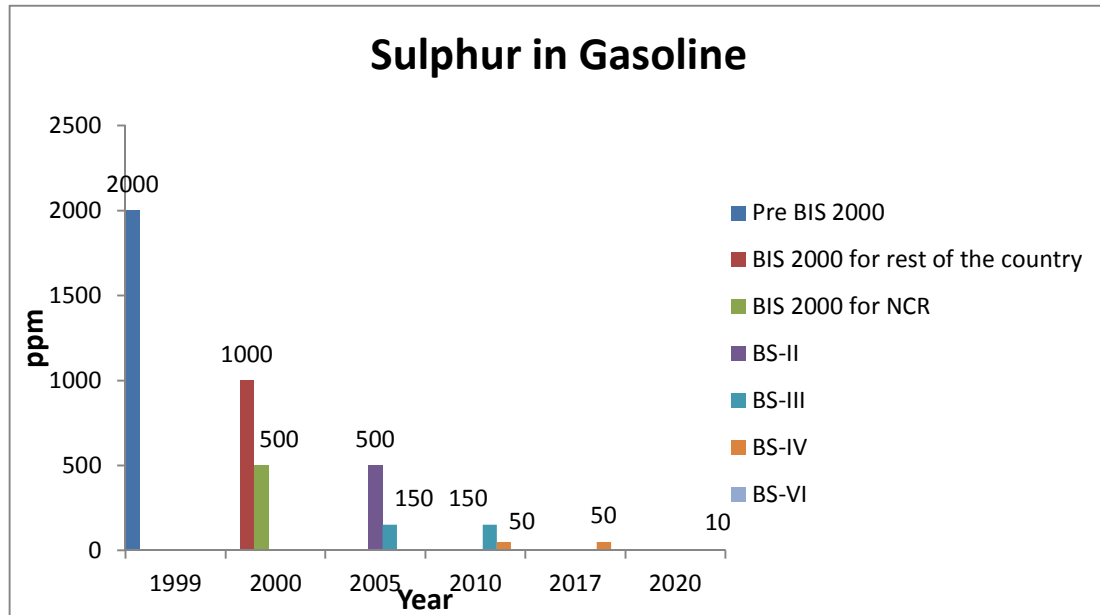


## Reduction of Sulphur Content

For BS 2000 specification, sulphur in gasoline was reduced from 0.2% to 0.1% wt max from the year 2000. Further, in line with the Ministry of Surface Transport (MOST) Gazette notification, sulphur in gasoline was further reduced to 0.05% wt. max to meet Euro-II equivalent BS-II emission norms in NCR from April, 2000 and expanded to 11 cities by 1<sup>st</sup> April 2003.

Sulphur content in gasoline was further reduced to 150 and 50 ppm respectively for BS-III and BS-IV gasoline supplied in the country and major cities as per Auto Fuel Policy, 2003. From 1<sup>st</sup> April 2017, entire country is being supplied with BS-IV gasoline having 50 ppm sulphur.

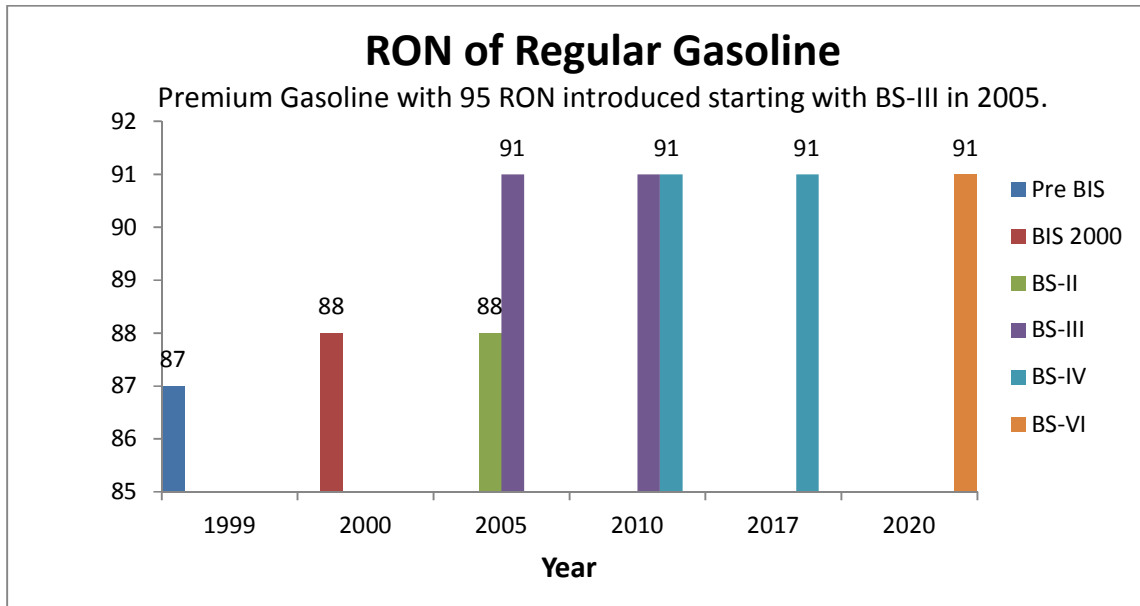
Further, Euro-VI equivalent BS-VI gasoline having 10 ppm max sulphur has been introduced in NCT w.e.f. 1<sup>st</sup> April 2018 and has been decided to introduce w.e.f. 1<sup>st</sup> April 2020 across the country.



### Octane Number Enhancement

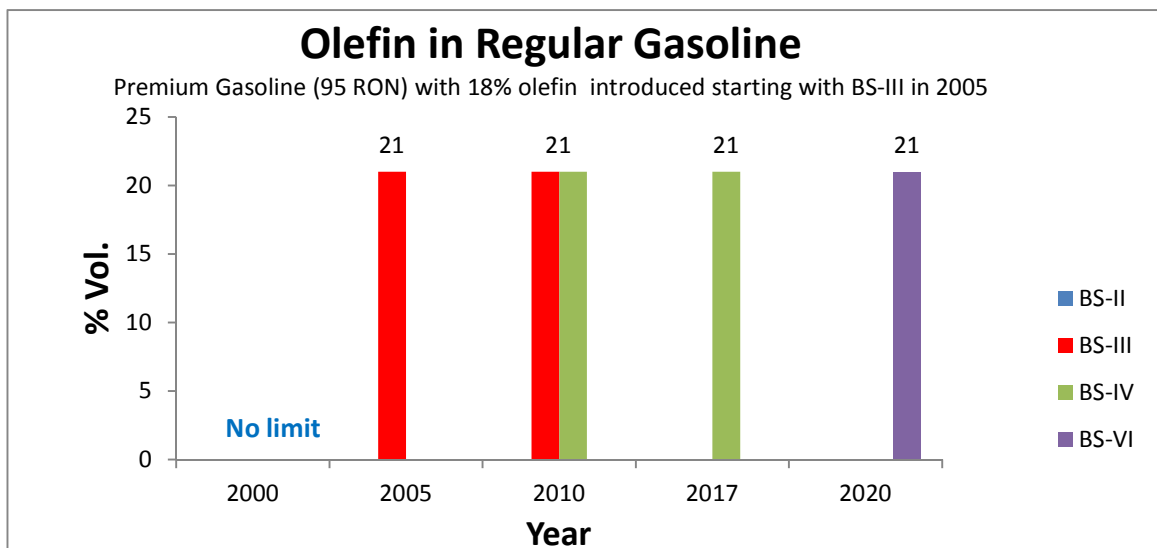
Octane number of gasoline signifies the improved performance of engine. Loss in octane number due to phasing out of lead was made up by installing new facilities in the refinery and changes in refinery operation. RON (Research Octane Number) of gasoline for BS-2000 spec was increased to 88 (93 for premium grade gasoline supplied in major cities). Anti-Knock Index (AKI) was added as the new criterion for BS-2000 as 84 (88 for premium grade gasoline supplied in major cities).

RON was further increased to 91 for regular grade gasoline and 95 for premium grade gasoline meeting BS-III & IV specification respectively.

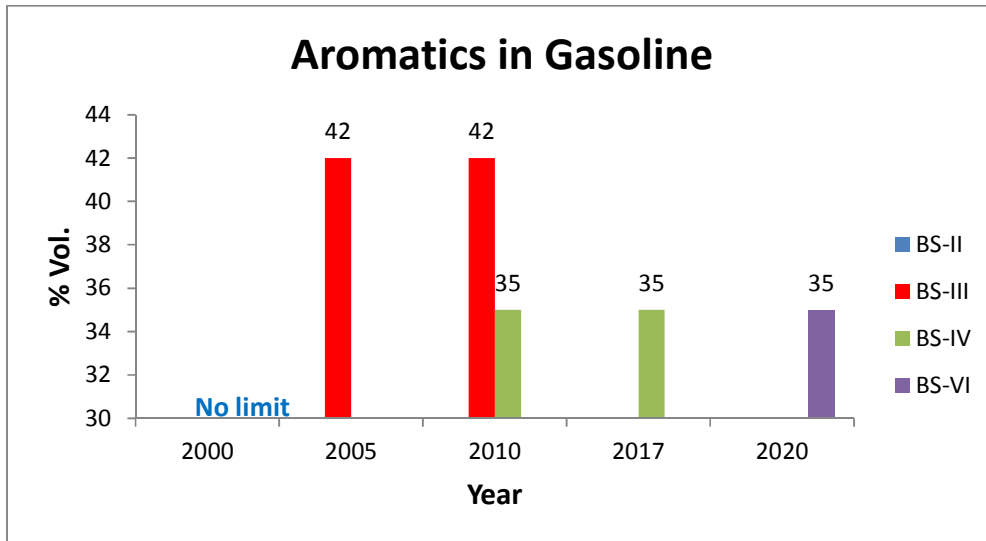


### Limiting Olefin and Aromatics Content

Olefin and aromatic content limit was for the first time introduced in BS-III gasoline specification as 21% and 42% vol. max respectively (18% and 42% vol. max for premium gasoline). Aromatics were further brought down from 42% to 35% vol. in BS-IV gasoline. This was done with the objective to reduce deposit formation and reduced tailpipe emission of reactive hydrocarbons, undesirable compounds and CO<sub>2</sub>.







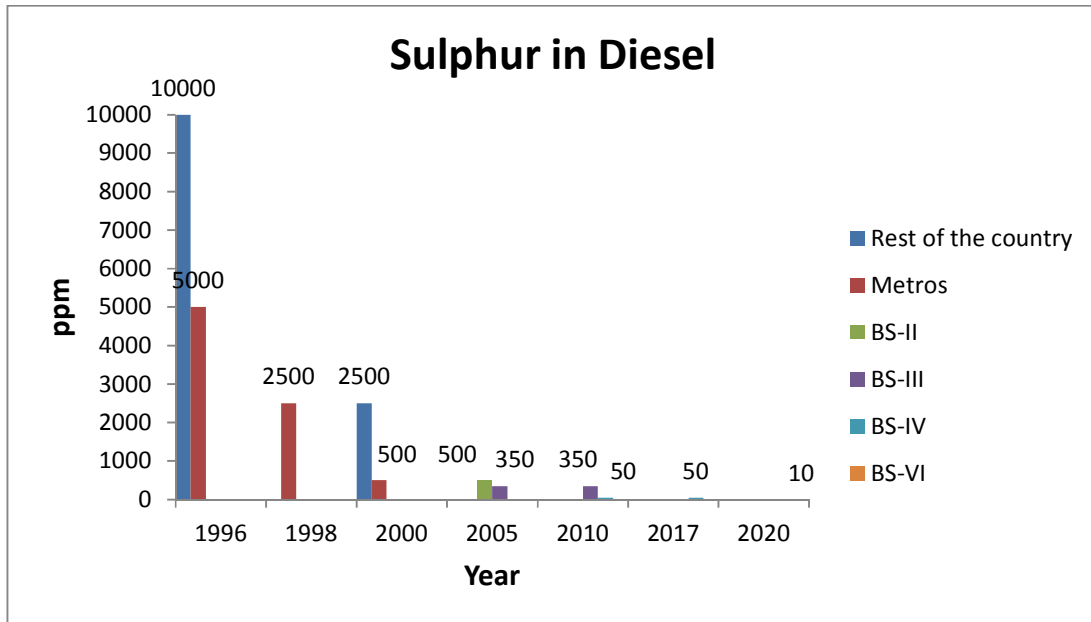
## Diesel

### Reduction of Sulphur Content

Sulphur in diesel fuel contributes to fine Particulate Matter (PM) emissions through the formation of sulphates both in exhaust and in the atmosphere. It can also lead to corrosion and wear of engine. Efficiency of some of the after treatment devices is severely affected at higher sulphur levels and these work well only with fuel having 50 ppm or less sulphur.

Sulphur in diesel was reduced from 1% max to 0.5% max by weight from April 1996 in 4 metros and Taj Trapezium, and then to 0.25% max from September 1996 for Taj Trapezium. Supply of diesel having 0.25% max sulphur was started in entire Delhi, Mumbai, Kolkata and Chennai w.e.f. April 1998. The same in the entire country was started from January 2000. Supply of extra low sulphur diesel with 500 ppm sulphur was started from NCR in April 2000 and then gradually extended to other metros. Sulphur in diesel was reduced in phases from 2500 ppm for BS-I to 500, 350 and 50 ppm respectively for BS-II, III and IV diesel supplied in the country and major cities as per Auto Fuel Policy, 2003. From 1<sup>st</sup> April 2017, entire country is being supplied with BS-IV diesel having 50 ppm sulphur max.

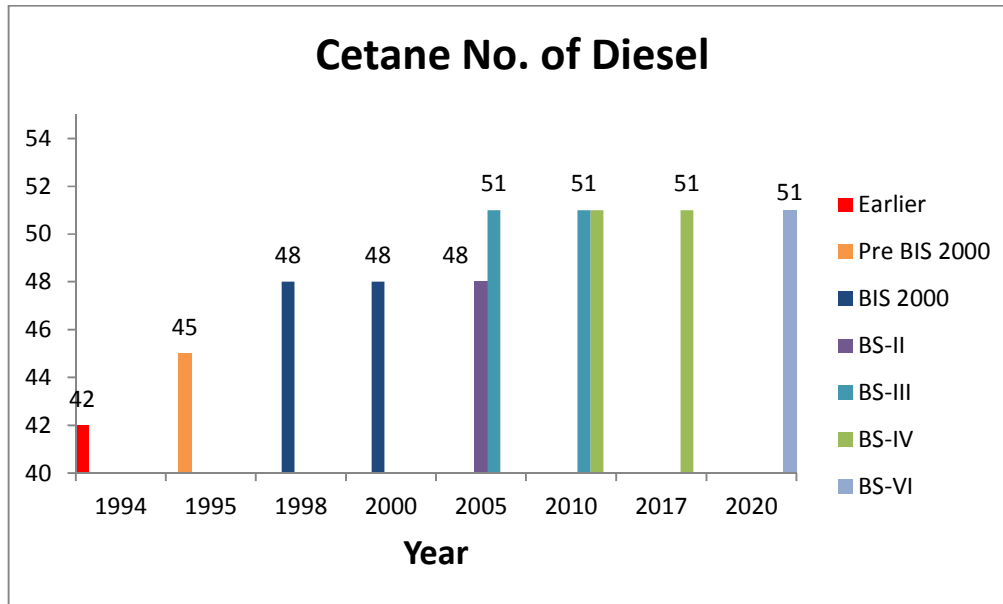
Further, Euro-VI equivalent BS-VI diesel having 10 ppm max sulphur has been introduced in NCT w.e.f. 1<sup>st</sup> April 2018 and has been decided to introduce w.e.f. 1<sup>st</sup> April 2020 across the country.



### Increasing Cetane Number

The Cetane number is a measure of compression ignition quality of diesel fuel and influences cold start-ability, exhaust emissions and combustion noise. Some increase in smoke is generally seen at Cetane number at levels of below 45. However, little improvement in performance is seen at Cetane number above levels of 50.

Cetane number was increased from 42 to 45 in 1995 and further increased to 48 by the end of December 1998 as per MOE&F Gazette notification. The Cetane number was further increased from 48 to 51 for diesel in BS-III specifications.



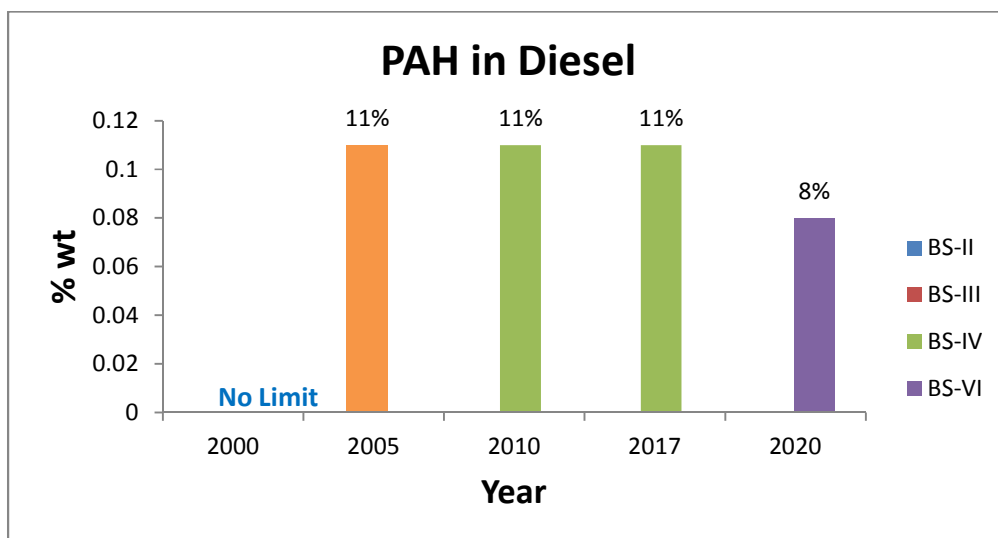
### Changes in Distillation Recovery and Density

Changes in distillation recovery were to improve performance and life of diesel engines and reduced emission. Distillation recovery spec for BS-I & II diesel was changed to 85% vol. (min) ( $T_{85}$ ) and 95% vol. (min) ( $T_{95}$ ) at 350°C and 370°C respectively against 90% vol. (min) ( $T_{90}$ ) at 366°C earlier. Subsequently, distillation recovery for BS-III & IV diesel was further changed to 360°C max for 95% vol. recovery.

Density ranges for BS-I & II diesel was reduced to 820–860 kg/m<sup>3</sup> as against 820–880 kg/m<sup>3</sup> earlier. Density range of B-III & IV diesel was further reduced to 820–845 kg/m<sup>3</sup>. Density specification for BS-VI diesel will be 815–845 kg/m<sup>3</sup>.

### Limiting Polycyclic Aromatic Hydrocarbon (PAH) Content

Polycyclic Aromatic Hydrocarbons (PAH) are harmful to human beings. One of the reasons for presence of PAH in the air is due to burning and incomplete combustion of diesel.



Criterion for limiting PAH was for the first time introduced for BS-III diesel as 11% wt. max and has further been reduced to 8% in BS-VI specification in line with Euro-VI norms.

Indian Diesel Specification					
Characteristics	Unit	BS-II	BS-III	BS-IV	BS-VI
Implementation date		2001 (select cities), 2005 (nationwide)	2005 (select cities) 2010 (nationwide)	2010 (select cities) 2017 (nationwide)	2018 (NCT) 2020 (nationwide)
Ash, max	% mass	0.01	0.01	0.01	0.01
Carbon Residue (Ramsbottom) on 10% residue, max <sup>†</sup>	% mass	0.3	0.3	0.3	0.3
Cetane Number (CN), min	-	48	51	51	51
Cetane Index (CI), min	-	46	46	46	46
Distillation 95% vol. Recovery at °C, max	°C	85% at 350C and 95% at 370C	360	360	360
Flash point Abel, min	°C	35	35	35	35
Kinematic Viscosity @ 40 °C	cSt	2.0-5.0	2.0-4.5	2.0-4.5	2.0-4.5
Density @ 15 °C	Kg/m <sup>3</sup>	820-860	820-845	820-845	815-845
Total Sulfur, max	ppm	500	350	50	10
Water content, max	mg/kg	0.05%	200	200	200
Cold filter plugging point (CFPP)					
a) Summer, max	°C	18	18	18	18
b) Winter, max	°C	6	6	6	6
Total contamination, max	mg/kg	-	24	24	24
Oxidation stability, max	g/m <sup>3</sup>	-	25	25	25
Polycyclic Aromatic Hydrocarbon (PAH), max	% mass	-	11	11	8
Lubricity, corrected wear scar diameter (wsd 1.4) @ 60 °C, max	µm (microns)	460	460	460	460
Copper Strip corrosion	Rating	Not worse than No. 1			

## Indian Gasoline Specification

Characteristics	Unit	BS-II	BS-III	BS-IV	BS-VI
Implementation date		2001 (select cities) 2005 (nationwide)	2005 (select cities) 2010 (nationwide)	2010 (select cities) 2017 (nationwide)	2018 (NCT) 2020 (nationwide)
Density 15°C	Kg/m <sup>3</sup>	710-770	720-775	720-775	720-775
Research Octane Number (RON)	min	88/93 <sup>†</sup>	91/95 <sup>†</sup>	91/95 <sup>†</sup>	91/95 <sup>†</sup>
Anti-Knock Index (AKI) or Motor Octane Number (MON)	min	84	81/85 <sup>†</sup>	81/85 <sup>†</sup>	81/85 <sup>†</sup>
Sulphur, max	ppm	500	150	50	10
Lead, max	g/L	0.013	0.005	0.005	0.005
Benzene, max	% volume	3 (metro) 5 (nationwide)	1	1	1
Aromatics, max	% volume	-	42	35	35
Olefin, max	% volume	-	21/18 <sup>†</sup>	21/18 <sup>†</sup>	21/18 <sup>†</sup>
Oxygen Content, max	% mass	-	2.7	2.7	3.7/4.5 <sup>†</sup>
Reid Vapor Pressure (RVP) @ 37.8°C, max	kPa	35-60	60/67	60/67	67
<sup>†</sup> Fuel quality specification for premium gasoline					