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BS6 EMISSION NORMS IN AUTOMOBILE INDUSTRY

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Abstract
The Bharat Stage VI (BS-VI) emission standards represent the sixth phase of vehicular emission regulations in India, aiming to combat pollution more effectively. These stringent norms are crucial for a densely populated country like India to mitigate environmental degradation. Compared to the previous BS-IV standards, BS-VI norms impose tighter restrictions, resulting in cleaner air and reduced pollution levels.
Compliance with BS-VI norms necessitates significant advancements and adaptations from both the automotive and oil sectors. Optimal performance and emissions control require vehicles to be powered by BS-VI-compliant fuel. Unlike their predecessors, modern engines, especially those designed for low-quality fuels, emit fewer toxic gases when running on BS-VI fuel. This shift underscores the importance of reducing sulphur content in fuels to maintain engine efficiency.
This journal paper seeks to explore a fresh perspective on the transition from Bharat Stage IV to VI, providing valuable insights for stakeholders across various sectors.

Keywords: Bharat Stage VI emission norms

I. Introduction

Air quality remains a pressing global concern, particularly amidst the rise of vehicular pollution. While pollution can stem from various sources, vehicle emissions stand out as a significant contributor, posing grave health risks. Hence, regulatory measures such as the Bharat Stage emission standards, instituted by the Indian Government through the central pollution control board, are crucial for curbing vehicular pollution.
Derived from European regulations and introduced globally in 2000, these standards primarily target emissions from vehicle exhausts and internal combustion engines. The Bharat Stage IV norms, for instance, aim to mitigate pollutants like carbon monoxide, carbon dioxide ($CO2$), nitrogen oxides, hydrocarbons, and particulate matter (PM), commonly known as carbon soot. Internal combustion engines (ICEs) are notorious for emitting these pollutants, underscoring the need for stringent regulations to safeguard human health.

II. Literature

Transition from BSIV To BSVI Impacting theStakeholders

2.1 Customer

Many cities across India have begun offering and implementing BS-VI fuels allowing owners of older generation cars adhering to Bharat Stage IV standards to opt for this upgraded fuel at petrol stations. The transition to BS-VI fuel has a direct impact on emissions, particularly regarding sulfur content, wherein lower sulfur levels result in reduced particulate matter (PM) emissions, leading to cleaner combustion.Typically, petrol contains lower sulfur content, thereby emitting fewer pollutants like carbon monoxide, nitrogen oxides (NOx), and toxic hydrocarbons. Studies indicate that pairing a BS-IV compatible vehicle with BS-VI fuel can halve PM emissions. However, reducing sulfur content in fuel may compromise its quality and energy content, consequently affecting fuel efficiency. Ultra-low sulfur diesel (ULSD) fuels, while addressing sulfur-related concerns through additives, may diminish fuel efficiency, potentially leading to price hikes at gas stations.

2.2 Effect on The Cost of The Vehicles Once BSVI Is Implemented

India adopted the BSVI emission regulations on April 1, 2020, aligning with Euro-VI norms. Alongside these new emission standards, technological upgrades are imperative to control emissions. While petrol engine vehicles can easily meet BSVI norms with upgraded Electronic Control Units (ECUs), diesel engine vehicles require significant technological overhauls to lower their emissions.

The enhancements to diesel vehicles will inevitably escalate their prices. The price disparity between diesel and petrol cars, considering features like premium hatchbacks, premium sub-compact sedans, or entry-level compact sedans, is estimated to be around 2.5 lakhs. This increase stems from the incorporation of additional components such as the Diesel Particulate Filter (DPF) and the Selective Catalytic Reduction system (SCR).

The SCR system injects Diesel Exhaust Fluid into the exhaust gases, thereby reducing the production of Nitrogen Oxide (NOx) emitted by vehicles. These technological advancements add complexity and cost to diesel cars, contributing to their higher price tags compared to petrol counterparts.

2.3 Manufacturers

Leading car manufacturers such as Tata Motors Maruti Suzuki adopted the BS6 compliance of emission and have made several changes in their model.

How Will This Impact on The Performance and Fuel Efficiency Of The Car?Transitioning to stricter emission norms poses a substantial challenge for automakers on multiple fronts. Achieving lower exhaust emissions typically comes at the expense of fuel efficiency and performance. The car manufacturers have to make sure that they not only have to minimize the amount of pollution caused by the exhaust of the cars, but the car manufacturers also have to It's essential to maintain the overall performance and efficiency of BSVI cars amidst stricter emission standards. The new BSVI engine technology typically involves a slower combustion process. Additionally, the vehicle's exhaust system post-treatment increases back pressure on the engine, requiring regeneration processes for components like particulate filters and Nitrogen Oxide (NOx) traps, which involve combusting exhaust material buildup using fuel.Reducing sulfur content in diesel engines can impact fuel quality and performance, thereby affecting vehicle efficiency. Automakers are employing various strategies to address these challenges. For instance, Tata Motors has focused on enhancing torque and power features to ensure optimal performance. Similarly, Mahindra has adjusted the powertrains of their cars to maintain drivability. The powertrain, responsible for converting engine power into car movement, encompasses components like the engine, transmission, driveshaft, and axles. Mahindra also claims to have achieved a decrease in the friction of the engine to around 30 per cent thus improving the fuel efficiency and the tweaking the performance of the car in the process.

2.4 Government

The Ministry of Petroleum and Natural Gas informed the court that vehicles not compliant with BSVI standards would be prohibited from operating on Indian roads. Additionally, the court ruled that car manufacturers would be unable to register BSIV-compliant vehicles after March 31, 2020.

2.5 Environment

Our natural habitat, where we reside, is becoming increasingly inhospitable for our daily activities due to rising air pollution. Recognizing this pressing issue, the Indian government has taken steps to implement more stringent emission standards, transitioning from BSIV norms to BSVI emission standards. Aligned with Euro-VI norms prevalent in many European countries, these standards aim to develop vehicles with advanced technology to minimize air pollutants and enhance air quality, especially in metropolitan areas.

The government set a deadline of April 2020 for automobile manufacturers to adapt their products to comply with BS-VI norms. This involves modifying the vehicles' exhaust systems to reduce the emission of harmful gases such as hazardous NOx and particulate matter generated during combustion. The overarching goal of BSVI norms is to mitigate the release of NOx and particulate matter from both petrol and diesel vehicles, fostering a cleaner and greener environment.

2.6 BS-VI Fuel Grade-Major Changes Made on Gasoline and Diesel Fuel Specifications-

With the introduction of BSVI vehicular norms, major oil companies such as the Indian oil corporation have beenadvised by the government of India to develop high quality of fuel which is clean and free from harmful pollutants [13]. Many oil companies have invested significant resources in upgrading to the BSVI standard, aligning with Euro-VI standards prevalent in most European countries. One of the primary changes made to BS-VI fuel involves reducing the total sulfur content from approximately 50 to 10 parts per million (ppm). The sulfur content in fuel directly correlates with the release of sulfur dioxide, a hazardous gas harmful to human health. Therefore, fuel with simpler chemical compositions combusts more naturally and contributes less to air pollution.The introduced BSVI fuel specifications largely mirror European-VI standards regulations, although prospective limits for various gasoline and diesel fuels in India may differ from European standards. The criteria mainly include the Octane number and the olefin content in the fuel for Gasoline and the density, Polycyclic aromatic hydrocarbon (PAH) and 95% distillation point content for diesel. The main difference in fuel specifications between diesel fuels, commercial gasoline in India and the European standards fuel has been determined below.

2.7 Gasoline Specification

The BS-VI norm outlines requirements for two types of gasoline: regular and premium. Table 1 illustrates a comparison between the recently introduced Indian gasoline standards specifications and those of other countries, which often have more stringent exhaust emission norms than India. The main parameters discussed here are the Olefin content and Octane number requirements for premium grade BS-VI Gasoline matches the quality of that of European-VI values and standards. For a regular grade, BS-VI gasoline a higher Olefin content and lower Octane number is permitted

Fuel parameter	Euro-VI	BS-VI	EPA conventional gasoline average -2005	EPA RFG AVG -2005	SOUTH KOREA	JAPAN	Worldwide Fuel Charter (Category IV)
Sulphur, ppm, max.	10	10	30ppm (Tier2) 10ppm (Tier 3)	30ppm (Tier2) 10ppm (Tier3)	10	10	10
Research Octane (RON), min.	95a	91/95	NS	NS	91/94	86/96	91/95/98
Motor Octane (MON), min.	85a	81/85	NS	NS	NS	NS	82.5/85/88
Anti-Knock Index (AKI), min.	NS	NS	87/87/91	87/87/91	NS	NS	NS
Olefins, vol%,	18	21/1	11.6-12.0	11.2-	16-19b	NS	10

max.		8		11.9			

Table 1. Comparison of fuel specifications for select gasoline parameters

2.8 Octane Number

The octane number of gasoline fuel serves as a measure of its ability to resist auto-ignition, a process that can potentially damage engines. This number is typically determined through laboratory testing and can be expressed as either Research Octane Number (RON) or Motor Octane Number (MON), depending on the specific testing methods employed. In certain regions, the octane rating is denoted by an Anti-Knock Index (AKI), which represents the average of RON and MON values for the fuel. The octane number is more critical to engine efficiency than air pollutant emissions. A higher octane number allows for higher compression ratios in engines, facilitating the design of engines capable of achieving greater thermal efficiency.Recent research has indicated that the Research Octane Number (RON) of fuel and its associated

compositional changes do not significantly affect pollutant emissions from gasoline engines. This is because engines are engineered to operate efficiently with fuel of a specified octane rating. As shown in Table 1, the Motor Octane Number (MON) and Research Octane Number (RON) specifications for regular-grade BSVI gasoline—81 and 91, respectively—are notably lower than those of Euro-VI, which stand at 85 and 95. While these differences may impact the fuel efficiency of Indian vehicles, the calculated Anti-Knock Index (AKI) derived from MON and RON specifications for regular-grade BS-VI gasoline is 86, closely aligning with the AKI for regular gasoline in the United States at 87.
Furthermore, both South Korea and Japan, which have adopted Euro-VI level emission standards, maintain RON specifications for regular-grade gasoline at or below the levels proposed in the BS-VI emission norms. This indicates that with respect to octane number, the requirements in India are on par with those of other countries with world-class emission standards.

2.9 Olefin Content in the Fuel

Olefins represent a distinct class of hydrocarbon compounds characterized by the presence of at least one carbon-carbon double bond. This double bond renders olefins more reactive than other gasoline components, such as aromatic compounds. These reactions have various implications for air pollutant emissions.
Typically, an increase in olefin content in fuel enhances combustion efficiency, potentially reducing hydrocarbon emissions (HC) while increasing nitrogen oxide emissions (NOx) due to reaction effects. Olefins also tend to exhibit higher ozone formation potentials compared to other hydrocarbon components in gasoline fuels.
Studies have shown that increasing the olefin content from around 3 percent to 15 percent results in no change in emissions of primary pollutants such as hydrocarbons, nitrogen oxide, and carbon monoxide. Theresearchers have also noticed an increase of 26 per cent in 1,3-butadiene emissions with the increase in the olefin content in the fuel. One major takeaway from the study is that emissions from modern age vehicles which are integrating advanced exhaust after-treatment systems andcombustion control usually tend to be more reactive to olefin content than vehicles working on obsolete technology. The olefin content for regular-grade gasoline is limited to 21 per cent in BSVI specification for regular- grade gasoline. This is greater than the 18 per cent which is specified for the Euro-VI gasoline. As determined above the difference will not be expected to impact the emissions of pollutants such as Hydrocarbons (HC), Carbon oxide (CO) and Nitrogen Oxide (NOx).

Fuel parameter	**Euro-VI**	**BS-VI**	**CARB**	**EPA**	**CARB**	**SOUTH**	**JAPAN**	**Worldwide**
			DESIGNATED	**Conventional**	**designated**	**KOREA**		**Fuel Charter**

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			EQUIVALENT LIMIT	Diesel	equivalent limit			(Category IV)
Sulphur, ppm, max.	10	10	15	15	15	10	10	10
Cetane Number (CN), min	51	51	53	Cetane Index≥40 Or aromatics ≤35 percent	Cetane index ≥ 60 or aromatics ≤ 35%	52a	45	55
Density @ 15°C, kg/m3	865(max)	820-860	NS	NS	NS	815-835	NS	820-860
95% Distillation Boiling Point (T95), °C, max.	360	370	NS	NS	NS	360b	360b	340
Polycyclic Aromatic hydrocarbons (PAH), mass %, max.	8	11	35	NS	NS	5	NS	2
Flash Point, Abel, °C, min.	55	35	NS	NS	NS	40	45	55

Table 2. Comparison of fuel specifications for select diesel parameters

Density is a property of diesel fuel which is closely related to both the Cetane number and the aromatic content as well. The fuel injection is controlled in diesel engines. The fuel density imparts the volume of thefuel that is needed to maintain constant power output in the engine.

2.10 95 Per Cent Distillation point

The 95 percent distillation point signifies the temperature at which 95 percent of a particular diesel fuel will distill during a distillation test. This parameter is employed to characterize the back-end volatility of the fuel. According to a recent study it was distinguished that while reducing T95 may lead to slight increase in Hydrocarbon and Carbon Oxide emissions from the exhaust of heavy-duty vehicle engines the overall effect of the variations on the back-end volatility on emissions of regulated pollutants is very small . Hochhauser also found that reducing back-end volatility had little to no effect on emissions from light-duty vehicles (LDV) and tended to decrease particulate matter (PM) and increase hydrocarbons and carbon oxide emissions from heavy-duty diesel engines. In the case of commercial diesel fuel, the BSVI norm specifies a maximum T95 value of 370 degrees Celsius, which exceeds the European specification of 360 degrees Celsius.

2.11 Polycyclic Aromatic Hydrocarbon Content (PAH)

Polycyclic aromatic hydrocarbons (PAHs) are a group of hydrocarbons containing two or more aromatic rings. If PAHs are not completely converted to oxides during combustion, unburned fuel PAHs can be emitted into the gaseous phase, contributing to the toxicity of diesel exhaust. Additionally, unburned fuel PAHs can act as precursors for soot formation.

Studies have demonstrated that reducing the PAH content of diesel fuels leads to a decrease in particulate matter and nitrogen oxide emissions from diesel engines. For example, the European Program on Emissions, Fuels, and Engine Technologies (EPEFE) found that reducing diesel fuel PAH content from 8 percent to 1 percent resulted in a 5 percent reduction in particulate matter emissions from light-duty vehicles and a 4 percent reduction from heavy-duty vehicles.

In line with this, BSVI fuel specifications set a maximum PAH content of around 11 percent for commercial diesel fuel, while the Euro-VI limit is 8 percent. Given that PAH content in fuel contributes to diesel exhaust toxicity, fuel policies in both India and Europe should prioritize reducing the PAH content of diesel fuels. According to worldwide fuel charter it recommends a maximum PAH limit in the fuel at 2 per cent.

2.12 Summary of The Fuel Specification

The prevailing understanding regarding fuel specifications suggests that recent advancements in engine after-treatment technologies have mitigated the impact of fuel characteristics on controlled air pollutant emissions. Modern engines, equipped with sophisticated exhaust after-treatment and advanced combustion control systems, have effectively minimized or nullified the effects of minor changes in fuel parameters. Contemporary engine designs typically necessitate low sulfur content in fuel to ensure optimal performance over their lifespan.One of the primary drivers for this requirement is the introduction of BS-VI regulations, which mandate limiting sulfur content in gasoline and diesel fuels to 10 parts per million (PPM).

Result and Analysis for BSVI Gasoline Specifications

FUEL PARAMETER	ANALYSIS
OCTANE NUMBER	1)Higher the Octane number in Gasoline fuel it will allow for higher compression ratios and the engines can be designed in such a way that it can achieve thermal efficiency. 2)Research Octane number (RON) and the changes in the composition of fuel which is associated with RON do not have a direct impact on pollutant emissions from Gasoline engines the main reason for this is that engines have been designed in such a way to operate on fuels which have specified octane rating. 3)Regarding, The Octane number of Gasoline fuel it will have the same requirement as compared to that of other developed countries which have world class emission standards.
OLEFIN CONTENT	1)Increase in the Olefin content in the fuel will help to improve the combustion efficiency which will help to reduce the overall hydrocarbon emissions (HC) and increase the nitrogen oxide emissions. Because, of this Olefins tend to have high ozone formation potentials than Hydrocarbons in Gasoline fuels. 2)It is also found that increasing the Olefin from 3 percent to 15 percent resulted in no change in emissions of pollutants such as Hydrocarbons, Nitrogen Oxide and CO. 3)It has also been found that there has been an increase of 26 percent in 1,3-butadiene emissions with the increase in the Olefin content in the fuel. The major takeaway from the study is that emissions from modern age vehicles which are integrating advanced after-treatment systems and combustion control are more reactive to Olefin content than vehicles

	operating on old technology.

III. Conclusion

The introduction of BS-VI norms is poised to revolutionize the Indian automobile sector. With this transition, India will witness the emergence of low-emission and more fuel-efficient vehicles. However, diesel engines are likely to incur higher costs compared to petrol engines due to the need for additional adjustments and after-treatments to ensure cleanliness.

This shift is expected to attract original equipment manufacturers (OEMs) towards hybrid fuels, while companies offering environmentally friendly alternative technology solutions stand to benefit greatly from the transition. Regarding fuel specifications under BS-VI, recent advancements in engine after-treatment technologies have diminished the impact of fuel characteristics on controlled air pollutant emissions. Modern engines typically require very low sulphur content in fuel to maintain optimal performance.Overall, this transition is expected to significantly improve the air quality in densely populated cities, where vehicle exhaust emissions constitute the primary source of air pollution.

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