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A Systematic Study on the Analysis of the Emission of CO, CO_2 and HC for Four-Wheelers and Its Impact on the Sustainable Ecosystem

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Abstract: The urbanization in Delhi NCR has led to a rapid increase in the vehicle count concerning the rise in population and mobilization. The emissions from the vehicles are currently counted amongst the main sources of air pollution in Delhi. This affects the quality of air. The emission criterion of various pollutants that are emitted from vehicles is evaluated through various International models, which include various vehicles, their modes of pollutants emitted while driving and other factors that are affecting the weather. The approximate emission of pollutants such as Carbon Monoxide (CO) and/or Particulate Matter (PM), from a variety of vehicles and different fuel types, has undergone diurnal variation over the years, depending on the time of the day. This study presents the emission factor of gaseous pollutants Hydrocarbons (HC), Carbon Monoxides (CO) and Carbon Dioxide (CO_2) of 181 four-wheeler cars from different companies containing different types of fuels. The measurement of gaseous pollutants is performed for Delhi, the most polluted city in India. The various facts and data were calculated and analyzed with reference to the standard values set by the national schemes of the Pollution and Environment. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned to overcome emission problems. Therefore, it is important to develop and deploy methods for obtaining real-world measurements of vehicle emissions, to estimate the pollutants. The analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles. This study shows that many old vehicles are used in different regions of the country, regardless of many notifications of banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants. The analysis stated that the diesel engine would emit less CO_2/km than a petrol engine if having an almost similar engine capacity.

Keywords: vehicular emissions; pollutants; Carbon Monoxide; Particulate Matter (PM)

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1. Introduction

India is one of the biggest emitters of pollutants, and vehicle pollution is one of the major sources of these pollutants. Here we present an inventory of vehicle pollution for different car models and companies. This inventory is the study of major pollutants Hydrocarbons (HC), Particulate Matter (PM), Carbon Monoxides (CO) and Carbon Dioxide (CO_2), for the period from 2005 to 2019. These inventories play a very important role when we discuss the input for modeling of atmospheric composition, about the air and other pollution. In this paper, we study the major makers/companies of four-wheelers vehicles that emit the pollutants in the air. The maker/companies considered for this study are Toyota, Maruti Suzuki, Hyundai, Honda, Mahindra, TATA and some other luxury makers.

According to WHO, air pollution kills around seven million people worldwide every year. The data show that approximately 90% of the population breathes air containing high levels of pollution, resulting in around seven million deaths every year due to such exposure. In January 2019, the state-run Central Pollution Control Board's air-quality index shows that the concentration of poisonous Particulate Matter, also known PM 2.5, stood at 440 and about 12 times more than the US-government-recommended level, i.e., the level of 35. Therefore, it becomes imperative for us to deeply understand and analyze the causes of air pollution in our surroundings. Vehicles are one of the major sources of emission of pollutants, especially in urban areas. The major pollutants associated with vehicular emission are Hydrocarbons (HC), Particulate Matter (PM), Carbon Monoxides (CO) and Carbon Dioxide (CO_2). In this paper, we analyze these major pollutants emitted by different fuel vehicles. In the next section, we detail these pollutants in brief. The fuel and air can be the source of different pollutants that can be harmful to human health. Here we discuss some of the major pollutants caused by vehicular emission.

Fuel + Air ←Hydrocarbons + Carbon Dioxide + Carbon Monoxide + Nitrogen Oxide + Sulfur Dioxide + water.

Hydrocarbons (HC) are considered to be specks of molecules of fuel that are not fully burned. These react when sunlight and oxides of Nitrogen are present, and the reaction results in the formation of ground-based ozone. The ozone so formed majorly contributes to smog and irritates the eyes and nose and also damages the lungs. Some exhausts' HCs are harmful, too, with the potential to cause cancer. Carbon Monoxide (CO) is the product of the incomplete burning of Hydrocarbons-based fuels. It is a colorless, odorless and poisonous gas. Mostly, when cars are about to start, and if they are not tuned in a proper way or at higher altitudes, where the fraction of oxygen that is available for combustion decreases, then the CO formed has a low air-to-fuel ratio in the engine. Two-thirds of the CO emissions arise from the sources of transport, cars being the largest contributor. In some areas, the contribution of on-road vehicles to Carbon Monoxide pollution may rise up to 90%. The affinity of CO to hemoglobin is about 250 times more than the oxygen. This may cause mild-to-severe poisoning, depending upon the concentration of CO and its exposed length. The symptoms include headache, dizziness, nausea, vomiting and loss of consciousness. Carbon Dioxide (CO_2), as per the US Environmental Protection Agency (EPA), initially inspected CO_2 as a result of "complete" combustion, but now suspects Carbon Dioxide as the concern of pollution. CO_2 is a greenhouse gas that traps the heat of the earth and contributes to the change in the climate.

We have seen that the new vehicles are comparatively less polluting than before, but the number of vehicles and the overall distances traveled by them has considerably increased, and the people, especially while commuting, are heavily exposed to such pollutants. One such region which has an air-quality level of criticism is the Delhi National Capital Region. Delhi, also being the capital, is undergoing rapid development, with an ever-increasing number of vehicles, reaching more than 10 million now. Delhi NCR has been given the worst position among the 14 major cities of the country, on the basis of vehicular emissions, according to a study conducted by the Centre for Science and Environment (CSE). A survey conducted by IIT-Kanpur has revealed that such emissions from vehicles contribute 9% of the total Particulate Matter 10 (PM10) and 20% of the total PM2.5 in the national capital. Recently there have been some initiatives taken to curb or reduce vehicular pollution, including public-awareness campaigns, registration of only those first-sale four-wheeled petrol-driven vehicles which have catalytic converters installed, the expansion of the rapid public transport system, the phasing out of old commercial vehicles, compliance of tightened emission standards and improvement in fuel quality by completely phasing out leaded petrol, and introduction to low Sulfur diesel. However, despite all of these measures taken, the problem still persists, and there is a large and excessive need for studies and analyses, to understand the problem at a deeper level, and with those results, a more practical approach can be strategized. Hence, our paper analyses the different types of pollutants emitting from distinct vehicles, at different periods of time, and gives an overall view of the most current situation in this region.

Timely differences in vehicle emissions are influenced by many inter-mixing factors in the real world. Post tailpipe emission the particles go through a change as they come into the contact with atmosphere, as observed when we see two times the increase in emission factors from summer to winter [1]. Taking cost-effectiveness into account is one of the major things when it comes to implementing policies for the reduction of vehicular emissions. It was seen that implementing a policy of limited driving was less cost-effective than a policy of elimination of old cars [2]. Pollutants such as SO_2, HC, CO_2, CO and PM are emitted by vehicles in very high quantities [3]. Detailed specifications of the compound of gases where the particles are studied at different stages, such as cooling, equilibrating to current conditions, are needed for the evaluation of vehicular emissions [4–6]. Usually, the estimation of vehicular and engine emissions is done by using a chassis dynamometer and engine, but these are costly and require quite a high amount without the representation of real-life emissions [6]. Tunnel studies and remote sensing aptly represent the road fleet emissions, but traffic flow, road conditions and technology lead to varying real-life emissions [7,8].

Certain studies have been conducted for the evaluation of pollutant emission from Particulate Matter and gaseous pollutants [9].However, mostly, these evaluations are carried out for a few specific developing countries only. Intergovernmental Panel on Climate Change (IPCC) (2007) states that activity data and emission profiles from a regional source are required for the calculation of tier-two emissions. A large dataset is required for the refined estimation of emission from the road transport sector, while encompassing the effects of all the region-specific variables.

The indoor air quality has been measured by the emission evolution of specific indoor sources. This procedure included three typical activities, namely cooking style, biofuels and different levels of toasting bread [10]. In another study [11], three different models were integrated into a hybrid model for the prediction of vehicular emission, at a specific location and time, in Malaysia. A method has been proposed for emission estimation and energy consumption based on the condition of vehicles in different regions such as Spain, Malaysia and Colombia [12]. In another study, the author discussed the delay issues and time complexity on the internet of vehicles [13]. The prediction of boiler performance in terms of mass flow rate and the temperature was performed by using Artificial Neural Networks (ANNs) [14,15].

An inventory was performed for the Bangaluru region at a grid resolution of 1 km [16]. Another study provides the PM10 and PM2.5 concentration data for a populated region in Erongo [17]. The properties of SO_2 adsorption have been explored and evaluated [18]. Another study investigated the combustion and emission characteristics of diesel engines [19].

Strict vehicle emission regulations make sure that vehicles are efficient during their operation [20]. For major vehicle categories, the emission limits from the late 1990s are given by Euro Path; in 2000, 2004 and 2007, they were given by National-1, N-2 and N-3 standards. However, while implementing N-3 standards, it has been observed that the vehicle degradation occurs as the vehicle emission factors reach their highest values (Zhang et al., 2008). Hence, it was seen that, only after enforcing the N-4 standards, the pollutant emission factor was decreased [20]. Findings from the American Environment Protection Agency showed that NO_x emission was decreased by 5%, HC emission was decreased by 7% and CO emission was decreased by 8% when the Sulfur (S) content in fuel was decreased to

49 mg/kg, which was almost similar to the N-4 fuel standard from 327 mg/kg, which was similar to N-3 fuel standard.

In Delhi, the road traffic increased from 128 to 191 vehicles per kilometer in the time frame from 2003 to 2009 [21]. Due to this, the availability of road space in Delhi increased by 678 lane kilometers between 2003 and 2009. In Delhi, the average annual rate of the vehicle population growth is about 9.150% for commercial and 7.40% for private vehicles. Annual growth in the vehicle population is causing severe environmental problems in Delhi [22]. Delhi occupies the fifth position when it comes to the worst traffic congestion/jams in a major city. Various models, like Spreadsheet, Long-Range Energy Alternative Planning (LEAP) and Vehicle Air Pollution Information System (VAPIS), do not take into consideration many distinguishing factors in the local environment, such as management of traffic and behavior of the driver; along with this, there is also an assumption that vehicles having lower speed increase the pollutant emission. Considering the above discussion, an IVE model which has been applied in various major cities all over the world, including cities such as Shanghai and Beijing in China, can be used for emission estimations [23]. For differently fueled vehicles, features such as meteorological variables, emission factors and different modes of driving are being used in this model, with further related studies in References [24–54].

The study by Reference [55] concentrated on the analysis of CO_2 emission for five NMI subsectors. Authors have studied the CO_2 emission for the time period of 30 years, from 2010 to 2030. In another study, authors have estimated the environmental technical efficiency and shadow prices for SO_2 emissions of China's provinces, from 2001 to 2013 [56]. Authors have highlighted the incompatibility in Carbon neutrality assumptions, system boundaries, methodologies and functional units in LCA studies of paper and pulp making [57]. An analysis has also been carried out which measures the effect of acceleration and speed on the emission of HC, CO and NOX in four-stroke motorcycle exhaust [58]. Another study has discussed the prospect of ethanol as an effective substitute for gasoline and also analyzed its effect on the emissive behavior of SI engines [59].

Some initiatives have been already taken to curb or reduce vehicular pollution: public awareness campaigns, registration of only those first-sale four-wheeled petrol-driven vehicles which have catalytic converters installed, the expansion of the rapid public transport system, the phasing out of old commercial vehicles, the compliance of tightened emission standards and improvement in fuel quality by completely phasing out leaded petrol and introduction of low Sulfur diesel. However, despite all of these measures taken, the problem still persists as a large and excessive need to study this situation, and analyses are required to understand the problem at a deeper level; with those results, a more practical approach can be strategized. This study shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-years-old vehicles. This study shows that many old vehicles are used in different regions after the many notifications regarding banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants.

The urbanization in Delhi NCR has led to a rapid increase in the vehicle count with respect to the rise in population and mobilization. The emissions from the vehicles are currently counted amongst the main sources of air pollution in Delhi, and this affects the quality of air. The emission criterion of various pollutants that are emitted from vehicles is evaluated through various international models that include the different vehicles, their driving modes, pollutants emitted and other meteorological factors. The estimated emissions of pollutants such Carbon Monoxide (CO) and Particulate Matter (PM) from different types of vehicles and different fuel types have undergone diurnal variation over the years, depending upon the time of the day. This paper makes an attempt to study and analyze the pollutants by the emission of gases by vehicles which emit from them. The various facts and data were calculated and analyzed with reference to the standard values set by the national schemes of pollution and the environment. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned, to overcome emission problems.

Therefore, it is important to develop and deploy methods for obtaining real-world measurements of vehicle emissions, to estimate the pollutants. The comprehensive review reveals whether the moving vehicles create a significant impact on air quality on specific locations or not.

The significant contribution of this paper is its presentation of the gaseous pollutants (Hydrocarbons (HC), Carbon Monoxides (CO) and Carbon Dioxide (CO_2)) emission factor of 181 four-wheeler cars from different companies and of different types of fuels. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned, to overcome emission problems. This study shows that many old vehicles are used in different regions, even after the many notifications regarding banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants. The unauthorized installation of compressed natural gas (CNG) kits also has to be banned strictly. Secondly, technological advancement not only targets fuel efficiency but also targets the reduction of CO, CO_2 and HC. It will be helpful to pollution-monitoring authorities for making new and effective policies against the emission of pollutants by vehicles.

The paper is organized as follows: The methodology is discussed in Section 2, which includes the quantification of emissions, studied area, experimental setup and data collection; Section 3 presents the result analysis; and, finally, the study is concluded in Section 4.

2. Methodology

2.1. Quantification of Emissions

The estimation of the emissions from the on-road vehicles is done on the basis of a number of vehicles and distance traveled in a particular year per different vehicle. This can be expressed as follows:

$$Ei = \sum (\mathrm{Vehj} \times \mathrm{Dj}) \times \mathrm{Eijkm} \tag{1}$$

where *Ei* = emission of compound (i); Vehj = number of vehicles per type (j); Dj = distance traveled in a year per different vehicle type (j); and *Ei*,j, and km = emission of compound (i) from bottom-up approach [60] were taken into account so as to estimate gaseous and particulate emission based on annual average utilization for a different vehicle category, number of registered vehicles and the corresponding emission factors vehicle type (j) per driven kilometer. Annual utilization of cars and jeeps and taxi were assumed to be 33,500, 12,600 and 12,600 km, respectively. These values were taken on the basis of five-year planning reports of India. For other sections of vehicles, annual utilization was calculated by taking the average of all the above values. The CO_2 emission [61] is estimated by using the value of the consumption of fuel [24,62] and emission factor, as follows:

$$Ei = \sum (\mathrm{Fuelj,k} \times \mathrm{EFi,j}) \tag{2}$$

where *Ei* = emission of compound (i); Fuel j,k = consumption of fuel (j) for transport type (k); and EFi,j= emission factor for compound (i) emitted from fuel (j).

Emissions of CO and HC were estimated by using the following equation:

$$Emissions\ (kt) = \mathrm{Fuel\ Consumption\ (kt)} \times \mathrm{NCV}\left(\frac{\mathrm{TJ}}{\mathrm{Kt}}\right) \times \mathrm{Gas\ Specific\ Emission\ Co-efficients}\left(\frac{\mathrm{kg}}{\mathrm{TJ}}\right) \tag{3}$$

Stoichiometric air–fuel ratio **and** equivalence air–fuel ratio **or** Lambda(λ) are the important parameters for the analysis of pollution emitted by vehicles. To understand the Stoichiometric air–fuel ratio, we need to look at the fuel combustion process. It is a process in which the mixture of fuel and water produces water, heat and Carbon Dioxide. Activation energy is also required for the occurrence of such an oxidation reaction.

$$\mathrm{Fuel} + \mathrm{Oxygen} \rightarrow (\mathrm{Activation\ Energy}) \frac{Spark\ (\mathrm{SI})}{HighTemperature\ (\mathrm{CI})} \rightarrow CO_2 + H_2O + \mathrm{Energy}$$

With the help of Stoichiometric air–fuel ratio, the value of Lambda can be calculated by using the following equation:

$$\text{Lambda } (\lambda) = \frac{AFR_{actual}}{AFR_{ideal}} \tag{4}$$

Hence, the Lambda factor can be calculated by using the actual and ideal value of air–fuel ratio.

2.2. Locations

The most appropriate region chosen for the analysis of vehicular emission and its pollutants is the Delhi Northern Central Region. Delhi, a vast metropolitan area in the northern part of the country, is India's capital territory as shown in Figure 1. The city covers the area of 1484 square kilometers (573 sq. mi) bordered by Haryana and Uttar Pradesh. The urban area of Delhi extends afar from the national capital territory border. The National Capital Region (NCR) consists of cities like Gurgaon, Noida, Ghaziabad and Faridabad. The National Capital Region (NCR) also includes Delhi, which is considered to be an"interstate regional planning" area by the National Capital Region Planning Board Act of 1985. A survey conducted by the World Health Organization (WHO) in 2014 shows that Delhi was the most polluted city in the world. Delhi was downgraded to the eleventh-worst city in the urban air-quality database in 2016. The air quality of Delhi is usually Moderate (101–200) level between January to September, and then it becomes Very Poor (301–400), Severe (401–500) or Hazardous (500+) between October and December. There is such deterioration in air quality due to various factors like stubble burning, firecrackers burning during festivals like Diwali and cold weather. The levels of Particulate Matter (PM) in Delhi have increased by about 44%, mainly due to high industrial and vehicular emissions, construction work and crop burning in neighboring states. The level of airborne Particulate Matter is also very high, that is, around PM 2.5, which is considered as most harmful to health. Increasing levels of vehicular pollution have consequently caused diseases such as asthma and lung cancer amongst the population of Delhi. The dense smog results in major air and rail traffic disruptions every year, during the winter season. The Indian meteorologists lately stated that the average peak temperature during winters has decreased in Delhi since 1998 due to rising vehicular emissions and, hence, the air pollution. Some measures have been taken to overcome air pollution in Delhi. Delhi has been ranked third amongst the other Indian cities in the count of trees. The world's largest fleet of eco-friendly compressed natural gas (CNG) buses is controlled by Transport Cooperation of Delhi. The CSE began public interest litigation that ordered the Delhi's transport system to switch on CNG and not to use the leaded petrol in 1998. The Department of Energy of the United States declared Delhi as its first "Clean Cities International Partner of the Year" in 2003 for its efforts to overcome air pollution by choosing eco-friendly fuel initiatives. The air pollutants in the city are also reduced by choosing Delhi metro cooperation as the main transport source in the city.

Therefore, as per various studies, many of the gains are lost. There's a significant decrement in bus ridership due to an increment in the market share of diesel cars. The city remains assessed at basic sustainability due to the Carbon emissions of its poorer neighborhoods.

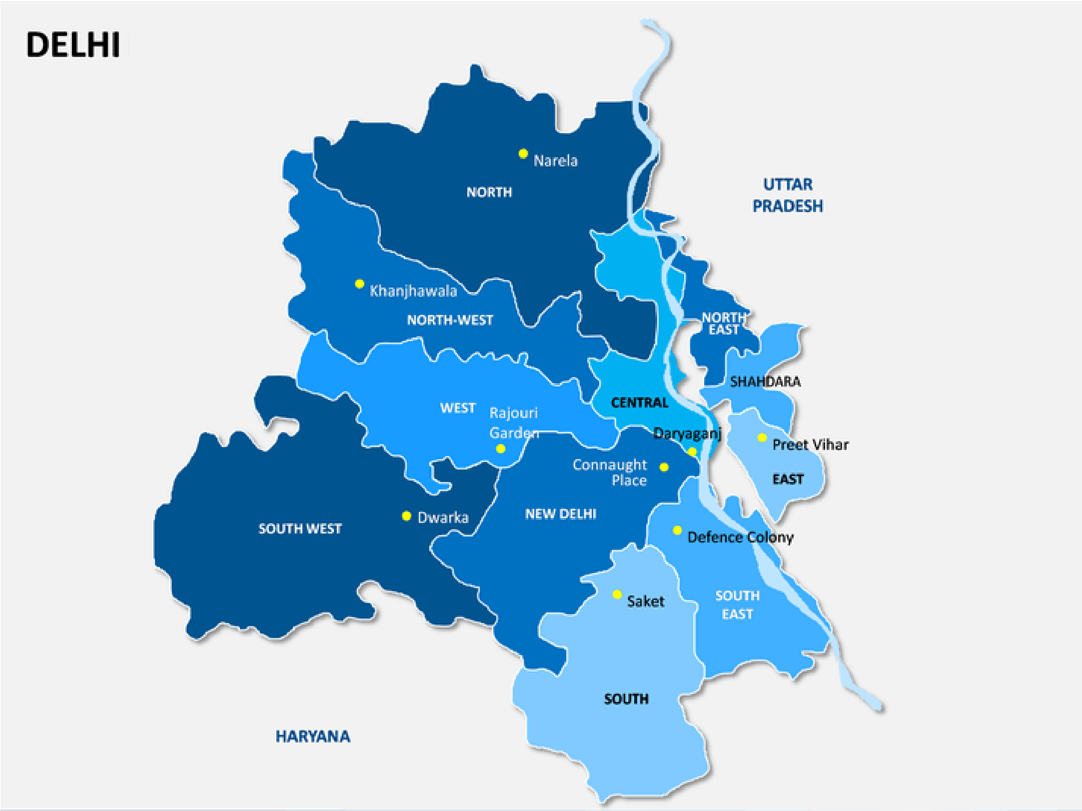


Figure 1. Selected area for on-road emission estimation in Delhi National Capital Region (NCR). Source: https://www.sketchbubble.com/en/presentation-delhi-map.html.

2.3. Experimental Setup

In this section, we discuss the test procedure used for analyzer gasses. Some of the compulsory steps needed to be performed for the analysis of gas. For the gas analyzer, as per the specifications of the fabricator, the power supply is checked, and earthing also needs to be proper, in order to perform a test on vehicles. The electrical calibration should be checked. The availability and the functionality of all the components as per the fabricator need to be checked. With the help of the sample gas of suitable value for Carbon Monoxide (CO) and Hydrocarbons (HC), the span and zero calibrations are checked. We also need to check if the sampling system is leak-proof or not. Finally, it is checked if the printer is working efficiently and the print-out information is correct.

We also discuss the test procedure used for smoke meters. Some of the necessary steps needed to be carried out on smoke meters. It is checked that if the calibration of the meter is at zero and midscale point while the neutral density filter is available, after the warm-up of the meter. The ideal value must lie within 0.1 m^{-1}. The components, such as the sample hose, internal pipes, etc., are checked if they are deteriorated or have damages, to ensure that there are no leakages. The functionality of the heating system for the optical chamber is checked. The purge air system and visual displays should also be checked, to see if they are working correctly. The functioning of the oil temperature and Revolutions Per Minute (RPM) sensor also needs to be checked. Finally, it is checked if the printer is working efficiently and the print out information is correct, and the instrument casing should be proper, with a proper electrical earthling.

The prescribed standard for different fuel-type vehicles consists of the appropriate values of Carbon monoxide (CO), Hydrocarbon (HC) and Lambda in the different Bharat stage norms as shown in Table 1. Here, CO and HC have emitted pollutants, and Lambda indicates the optimum condition needed for the proper functioning of catalytic converters. The estimation of the pollutants emitted is also based on the prescribed Hartridge Smoke Unit (HSU) and measured HSU. HSU (Hartridge

Smoke Unit) is a unit of measurement used to measure the capacity of exhaust gases of emissions, especially in diesel engines. The HSU limit for pre-Bharat Stage 4 norms was 65. The prescribed values for petrol vehicles consisting of pollutants and Lambda are stated as follows:

Prescribed Standard for Petrol Vehicles in Bharat Stage 4 norms:
Carbon Monoxide (CO): −0.3 ppm.
Hydrocarbon (HC): −200 ppm.
Lambda (λ): Should be in the range of 0.97–1.03.
Prescribed Standard for Petrol Vehicles in Bharat Stage 3 norms:
Carbon Monoxide (CO): −0.5 ppm.
Hydrocarbon (HC): −750 ppm.

Table 1. Air-quality standards for national ambient [24–54].

S. No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		
			Industrial, Residential, Rural and Other Areas	Ecologically Sensitive Area (Notified by Central Government)	Methods of Measurement
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulfur Dioxide(SO_2), μg/m^3	Annual * 24 h **	50 80	20 80	Improved West and Gaeke Ultraviolet Fluorescence
2	Nitrogen Dioxide(NO_2), μg/m^3	Annual * 24 h **	40 80	30 80	Modified Jacob and Hochheiser (Na-Arsenite) Chemiluminescence
3	Particulate Matter(size less than 10μm) or PM10 μg/m^3	Annual* 24 h **	60 100	60 100	Gravimetric TOEM Beta attenuation
4	Particulate Matter(size less than 2.5μm) or PM2.5 μg/m^3	Annual * 24 h **	40 60	40 60	Gravimetric TOEM Beta attenuation
5	Ozone(O^3) μg/m^3	8 h ** 1 h **	100 180	100 180	UV Photometric Chemiluminescence Chemical Method
6	Lead(Pb) μg/m^3	Annual * 24 h **	0.50 1.0	0.50 1.0	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper ED-XRF using Teflon filter
7	Carbon Monoxide(CO) mg/m^3	8 h ** 1 h **	0.2 0.4	0.2 0.4	Non-Dispersive Infrared (NDIR) spectroscopy
8	Ammonia(NH3) μg/m^3	Annual * 24 h **	100 400	100 400	Chemiluminescence Indophenol blue method

* Annual arithmetic mean of minimum 104 measurements in a year, ** 24 hourly monitored values shall be complied with 98% of the time.

The emission estimation rate for petrol vehicles is evaluated using the prescribed values and the measured values of various pollutants and other different factors. The values of Carbon Monoxide (CO), Hydrocarbon (HC) and Carbon Dioxide (CO_2) ppm. These measured values are then compared with the prescribed values based on various factors such as Bharat Stage norms, Manufacturer of the vehicle, Model of the vehicle, Year of Registration of the vehicle.

Similar to the emission evaluation of petrol vehicles is the emission estimation of petrol/CNG fuel type vehicles. It consists of the estimation of emission of pollutants from petrol/CNG vehicles by collecting the appropriate values of pollutants emitted with reference to the prescribed values as per the Bharat Stage norms. Here, we consider the prescribed standards of the petrol fuel type vehicles in Bharat Stage Norm 3 and Norm 4. Moreover for the CNG/petrol fuel type vehicles, the Carbon Monoxide (CO) and Hydrocarbon (HC) are considered only (in ppm) and not Carbon Dioxide and Lambda. The values of CO and HC are measured from vehicles which are then compared with the prescribed values of the petrol type vehicles based on various factors such as Bharat Stage norms, Manufacturer of the vehicle, Model of the vehicle, Year of Registration of the vehicle.

The estimation of the emission of various pollutants in diesel type vehicles is done by comparing the prescribed and measured values of HSU. HSU is the unit of estimation to evaluate the capacity of exhaust gases of emissions in diesel engines. HSU stands for Hartridge Smoke Unit. The prescribed standard of HSU (Hartridge Smoke Unit) for diesel vehicles in Bharat Stage 3 norm and Bharat Stage 4 norm is 65 and 50, respectively. The HSU values of different diesel vehicles are collected. The comparison is then made between diesel vehicles with respect to different comparable factors, such as Bharat stage norms, a manufacturer of the vehicle, vehicle model number, year of registration of the vehicle, prescribed values of HSU and measured values of HSU.

2.4. Data Collection

The following data were collected from pollution certificate centers of Delhi NCR. A total data of 181 vehicles were used and analyzed collectively, to reach the following outcomes. Table 2 showcases the characteristics of the different vehicles which were analyzed by displaying varying vehicle maker/companies having different models and registration dates. It also shows the varying or similar engine capacities between two fuel types (diesel and petrol) from different vehicle models. Engine capacity of a vehicle simply depicts the area in which any engine's pistons work/operate; hence, a larger amount of fuel and air is being processed when a vehicle is moving with a larger engine capacity. The average engine capacity calculated from the given table is 1778 cm^3 (approximately) for diesel engines and 1295 cm^3 (approximately) for petrol engines; hence, we can observe that vehicles having a diesel engine have a larger engine capacity, on average, than vehicles having a petrol engine, meaning that it is processing more fuel than its counterpart. A major difference between diesel and petrol engines is that the diesel engine uses more air and less fuel than the petrol engine to operate at the same level, hence emitting less CO_2 despite having a larger concentration of Carbon in it than petrol. The analysis stated that the diesel engine would emit less CO_2/km than a petrol engine if having an almost-similar engine capacity.

Table 2. Characteristics of selected cars [24–54].

Maker/Company	Model	Registration Date	Fuel Type	Engine Capacity (cm^3) *
Toyota	Innova	2009	Diesel	2494
Toyota	Fortuner	2010	Diesel	2982
Toyota	Altis	2014	Diesel	1364
Maruti Suzuki	Dzire	2009	Diesel	1248
Maruti Suzuki	Sx4	2011	Diesel	1248
Maruti Suzuki	Swift	2012	Diesel	1248
Maruti Suzuki	Ciaz	2015	Diesel	1248
Maruti Suzuki	Ritz	2016	Diesel	1248
Honda	Amaze	2014	Diesel	1498
Honda	Mobilio	2015	Diesel	1498
Honda	City	2018	Diesel	1498
Mahindra	Scorpio	2010	Diesel	2179
Mahindra	XUV	2014	Diesel	2179
Mahindra	Thar	2017	Diesel	2523
BMW	X1	2011	Diesel	1995
BMW	520D	2013	Diesel	1995
Maruti Suzuki	Zen	2004	Petrol	993
Maruti Suzuki	Wagonr	2005	Petrol	1061
Maruti Suzuki	Alto	2006	Petrol	796
Maruti Suzuki	Esteem	2007	Petrol	1298
Maruti Suzuki	Ritz	2009	Petrol	1197
Maruti Suzuki	Swift	2010	Petrol	1298
Maruti Suzuki	EECO	2011	Petrol	1196
Maruti Suzuki	Ertiga	2013	Petrol	1373
Maruti Suzuki	Dzire	2014	Petrol	1197

Table 2. *Cont.*

Maker/Company	Model	Registration Date	Fuel Type	Engine Capacity (cm^3) *
Maruti Suzuki	Ciaz	2015	Petrol	1373
Maruti Suzuki	Celerio	2017	Petrol	998
Maruti Suzuki	Ignis	2018	Petrol	1197
Hyundai	Santro	2006	Petrol	1086
Hyundai	I10	2009	Petrol	1086
Hyundai	EON	2013	Petrol	814
Hyundai	Xcent	2015	Petrol	1186
Hyundai	Creta	2017	Petrol	1591
Hyundai	Grand i10	2018	Petrol	1197
Honda	Accord	2006	Petrol	2354
Honda	Civic	2007	Petrol	1799
Honda	City	2009	Petrol	1497
Honda	Amaze	2013	Petrol	1198
Toyota	Innova	2010	Petrol	1998
Toyota	Etios	2014	Petrol	1496
Tata	Indica	2007	Petrol	1193
Tata	Tiago	2016	Petrol	1199

* Inventory shows the characteristics for petrol and diesel cars registered in 2004–2019. Engine capacity also affects the environment, as high-capacity engines emit high amounts of pollutants in the air.

Tables 3–5 display the value/level of pollutants emitted by each vehicle, with its prescribed value. It also shows the Bharat stage norms each car is following, and their registration dates are in the chronological order.

Table 3. Measured Hartridge Smoke Unit (HSU) values for diesel vehicles [24–54].

S No.	Bharat Stage	Maker/Model	Registration Date	Prescribed HSU	Measured HSU
1	3	Toyota/Innova	June 2009	65	42.21.27
2	3	Toyota/Innova	July 2009	65	45.41.41
3	3	Maruti Suzuki/Dzire	Sept 2009	65	44.31.36
4	3	Mahindra/Scorpio	Jan 2010	65	31.70.89
5	3	Toyota/Innova	Jan 2010	65	39.81.18
6	3	Toyota/Fortuner	May 2010	65	39.81.18
7	4	Toyota/Innova	Oct 2011	50	42.51.29
8	4	BMW X1	July 2011	50	39.91.07
9	4	Maruti Suzuki/Swift	Sept 2011	50	42.51.28
10	4	Hyundai/Verna	Feb 2012	50	42.71.29
11	4	Maruti Suzuki/Sx4	Aug 2012	50	38.61.13
12	4	Maruti Suzuki/Dzire	July 2013	50	39.21.15
13	4	BMW 520D	Aug 2013	50	38.31.12
14	4	Volkswagen/Vento	Oct 2013	50	40.01.19
15	4	Ford/ EcoSport	Nov 2013	50	44.61.37
16	4	Volvo/XC60	Jan 2014	50	41.41.24
17	4	Maruti Suzuki/Sx4	Feb 2014	50	44.01.35
18	4	Mahindra/XUV	April 2014	50	38.81.14
19	4	Toyota/Etios	July 2014	50	43.01.30
20	4	Maruti Suzuki/Swift	Aug 2014	50	41.51.24
21	4	Toyota/Altis	Sept 2014	50	43.81.34
22	3	TATA/Indigo	Oct 2014	65	46.01.43
23	1	Audi/A6	Oct 2014	65	42.11.27
24	4	Honda/Amaze	Nov 2014	50	31.50.88
25	4	Toyota/Etios	March 2015	50	42.31.28
26	4	BMW	March 2015	50	39.91.18
27	4	Honda/Mobilio	April 2015	50	37.71.10
28	4	Renault/Duster	June 2015	50	39.21.15
29	4	Maruti Suzuki/Swift	July 2015	50	39.81.18
30	4	Mahindra/Scorpio	July 2015	50	44.61.37

Table 3. *Cont.*

S No.	Bharat Stage	Maker/Model	Registration Date	Prescribed HSU	Measured HSU
31	4	Hyundai/Creta	Aug 2015	50	41.21.39
32	4	Mercedes Ml250	Aug 2015	50	31.50.88
33	4	Maruti Suzuki/Ciaz	Sept 2015	50	30.90.86
34	4	Mahindra/XUV	Sept 2015	50	39.41.16
35	4	Toyota/Fortuner	Nov 2015	50	42.41.28
36	4	Maruti Suzuki/Dzire	Dec 2015	50	43.41.33
37	4	Hyundai/Creta	June 2016	50	43.51.33
38	4	Honda/Mobilio	July 2016	50	37.91.10
39	4	Maruti Suzuki/Ritz	July 2016	50	43.91.34
40	4	FCA/Aventura	Aug 2016	50	38.21.12
41	4	Maruti Suzuki/Ciaz	Nov 2016	50	41.31.24
42	3	Toyota/Innova	Dec 2016	65	38.91.14
43	4	Toyota/Innova	Jan 2017	50	42.61.29
44	4	Maruti Suzuki/Dzire	Feb 2017	50	44.21.36
45	4	Honda/City	March 2017	50	39.11.15
46	4	Mahindra/THAR	May 2017	50	44.71.37
47	4	Maruti Suzuki/Ciaz	June 2017	50	39.01.15
48	4	Toyota/Innova	Dec 2017	50	40.01.19
49	4	Honda/Amaze	Dec 2017	50	39.31.16
50	4	Ford/Endeavour	Jan 2018	50	39.01.15
51	4	Maruti Suzuki/Ciaz	Sept 2018	50	43.11.31
52	4	Honda/City	Nov 2018	50	42.11.27

Table 4. Measurement of CO, CO_2 and λ for petrol vehicles [24–54].

S No.	Bharat Stage	Maker/Model	Registration Date	CO (ppm)	HC (ppm)	CO_2 (ppm)	Λ
1	3	Maruti/M800	March 2004	0.036	46		
2	3	Maruti Suzuki/Zen	July 2004	0.050	8		
3	3	Maruti Suzuki/Versa	Sept 2004	0.036	11		
4	3	Maruti Suzuki/Zen	Dec 2004	0.020	17		
5	3	Maruti Suzuki/Wagonr	Feb 2005	0.130	21		
6	3	Hyundai/Santro	Jan 2006	0.040	21		
7	3	Maruti/Maruti	Nov 2006	0.009	23		
8	3	Honda/Accord	Dec 2006	0.003	7		
9	3	Maruti Suzuki/Alto	Dec 2006	0.036	20		
10	3	Maruti Suzuki/Wagonr	Dec 2006	0.020	129		
11	3	Hyundai/Santro	Jan 2007	0.090	39		
12	3	Honda/City	Feb 2007	0.010	22		
13	3	Maruti/Maruti	April 2007	0.027	44		
14	3	TATA/Indica	April 2007	0.010	20		
15	3	Honda/Civic	June 2007	0.020	29		
16	3	Honda/City	Sept 2007	0.001	75		
17	3	Maruti Suzuki/ Esteem	Sept 2007	0.100	107	Pre-Bharat Stage 4 norms *	
18	3	Maruti Suzuki/Alto	April 2008	0.040	6		
19	3	Hyundai/Santro	May 2008	0.040	39		
20	3	Maruti Suzuki/Zen	July 2008	0.003	19		
21	3	Hyundai/Santro	July 2008	0.110	60		
22	3	Honda/Accord	Aug 2008	0.017	23		
23	3	Honda/City	Dec 2008	0.020	162		
24	3	Maruti Suzuki/Wagonr	Feb 2009	0.036	16		
25	3	Hyundai/i10	April 2009	0.140	24		
26	3	Maruti Suzuki/Swift	June 2009	0.160	34		
27	3	Maruti Suzuki/Alto	Aug 2009	0.070	185		
28	3	Hyundai/i10	Sept 2009	0.100	17		
29	3	Ford/IKON	Sept 2009	0.020	25		
30	3	Hyundai/i10	Sept 2009	0.110	31		
31	3	Honda/City	Aug 2009	0.043	29		
32	3	Maruti Suzuki/Ritz	Nov 2009	0.020	0		
33	3	Hyundai/i10	Nov 2009	0.003	88		
34	3	Maruti Suzuki/Swift	March 2010	0.020	0		
35	4	Hyundai/i10	March 2010	0.035	10	17.20	0.999
36	3	Maruti Suzuki/Wagonr	May 2010	0.380	197		
37	4	Toyota/Innova	May 2010	0.004	3	15.4	1.005
38	4	Maruti Suzuki/Dzire	Oct 2010	0.041	27	17.20	1.003
39	4	Maruti Suzuki/EECO	Feb 2011	0.033	27	16.70	1.009
40	4	Maruti Suzuki/AStar	May 2011	0.020	24	17.30	1.003

Table 4. *Cont.*

S No.	Bharat Stage	Maker/Model	Registration Date	CO (ppm)	HC (ppm)	CO_2 (ppm)	Λ
41	4	Mitsubishi/Outlander	Aug 2011	0.003	2	17.10	1.004
42	4	Maruti Suzuki/Dzire	Oct 2011	0.026	7	16.80	1.009
43	4	Volkswagen/Polo	Feb 2012	0.019	73	16.70	1.000
44	4	Maruti Suzuki/Wagonr	Sept 2013	0.034	26	16.80	1.000
45	4	Maruti Suzuki/Ertiga	Oct 2013	0.020	18	16.60	1.003
46	4	Honda/Amaze	Nov 2013	0.032	22	15.70	1.001
47	4	Hyundai/EON	Dec 2013	0.032	14	15.70	1.003
48	4	Hyundai/Verna	April 2014	0.010	28	17	1.007
49	4	Maruti Suzuki/Dzire	July 2014	0.003	5	15.30	1.009
50	4	Maruti Suzuki/Ciaz	Nov 2014	0.030	16	16.70	0.998
51	4	Toyota/Etios	Dec 2014	0.025	17	17.10	1.003
52	4	Ford/Eco	March 2015	0.003	66	16.60	1.011
53	4	Honda/Amaze	April 2015	0.034	8	17.10	1.004
54	4	Maruti Suzuki/Ciaz	June 2015	0.36	36	17	1.001
55	4	Honda/City	June 2015	0.042	13	16.60	1.002
56	3	Hyundai/Xcent	Oct 2015	0.018	149		
57	4	Maruti Suzuki/Dzire	Jan 2016	0.035	13	15.50	1.003
58	3	Honda/Amaze	March 2016	0.043	22		
59	4	Maruti Suzuki/Swift	July 2016	0.027	18	16.90	1.003
60	4	Renault/Kwid	Aug 2016	0.012	8	15.40	1.003
61	4	TATA/Tiago	Oct 2016	0.027	12	16.80	1.004
62	4	Honda/City	Oct 2016	0.003	20	16.90	1.002
63	4	Honda/City	Feb 2017	0.11	7	16.90	1.004
64	4	Hyundai/Grand i10	Feb 2017	0.028	19	17	1.003
65	4	Maruti Suzuki/Swift	June 2017	0.003	8	17.30	1.003
66	4	Maruti Suzuki/Dzire	July 2017	0.043	38	17.30	1.002
67	4	Hyundai/Creta	Aug 2017	0.043	9	16.80	1.004
68	4	Maruti Suzuki/Celerio	Oct 2017	0.033	22	17	1.003
69	4	Maruti Suzuki/EECO	Sept 2017	0.017	24	16.50	1.029
70	4	Maruti Suzuki/Dzire	Nov 2017	0.042	42	16.90	1.002
71	4	Renault/Kwid	Jan 2018	0.003	5	16	1.003
72	4	Maruti Suzuki/Dzire	Jan2018	0.003	4	17.10	1.003
73	4	Maruti Suzuki/Ertiga	Feb 2018	0.036	21	16.4	1.003
74	3	Hyundai/ Grand i10	April 2018	0.080	26		
75	4	Maruti Suzuki/Dzire	April 2018	0.026	18	16.6	1.003
76	4	Maruti Suzuki/Ignis	May 2018	0.042	13	15.7	1.002
77	4	Maruti Suzuki/Ignis	Aug 2018	0.024	35	17	1.003
78	4	TATA/Tiago	Jan 2019	0.004	46	17	1.001
79	4	Maruti Suzuki/EECO	Jan 2019	0.002	10	12.9	1.004

* Pre-Bharat Stage 4 norms cars do not have the CO_2 and λ values.

Table 5. Petrol/compressed natural gas (CNG) vehicles [24–54].

S No.	Bharat Stage	Maker/Model	Registration Date	CO (ppm)	HC (ppm)
1	3	Honda/City	Dec 2004	0.026	10
2	3	Honda/City	Jan 2005	0.170	9
3	3	Maruti Suzuki/Wagonr	March 2005	0.050	34
4	3	Maruti Suzuki/Esteem	March 2005	0.020	7
5	3	Maruti Suzuki/Esteem	Oct 2005	0.034	7
6	3	Ford/Ikon	Feb 2007	0.310	35
7	3	Maruti Suzuki/Esteem	Oct 2007	0.020	12
8	3	Maruti Suzuki/Esteem	Dec 2007	0.020	16
9	3	Maruti Suzuki/Swift	March 2008	0.100	9
10	3	Maruti Suzuki/Alto	April 2008	0.020	0
11	3	Maruti Suzuki/Wagonr	May 2008	0.040	9
12	3	Maruti Suzuki/Wagonr	May 2008	0.020	3
13	3	Maruti Suzuki/Wagonr	Aug 2008	0.010	14
14	3	Maruti Suzuki/Omni	Aug 2008	0.001	5
15	3	Hyundai/Santro	Oct 2008	0.016	4
16	3	Toyota/Altis	December 2008	0.040	27
17	3	Chevrolet/Aveo	Feb 2009	0.010	6
18	3	Hyundai/Accent	April 2009	0.040	7
19	3	Maruti Suzuki	May 2009	0.004	8
20	3	Maruti Suzuki/Alto	May 2009	0.100	44

Table 5. *Cont.*

S No.	Bharat Stage	Maker/Model	Registration Date	CO (ppm)	HC (ppm)
21	3	Hyundai/i10	Nov 2009	0.050	0
22	3	Maruti Suzuki/Wagonr	Sept 2009	0.041	9
23	3	Maruti Suzuki/Sx4	March 2010	0.040	7
24	3	Maruti Suzuki/Sx4	March 2010	0.040	16
25	3	Maruti Suzuki/Dzire	May2010	0.001	31
26	4	Maruti Suzuki/Swift	Sept 2010	0.003	132
27	4	Maruti Suzuki	April 2011	0.027	77
28	4	Maruti Suzuki/EECO	June 2011	0.019	18
29	4	Hyundai/i20	July 2011	0.010	93
30	4	Hyundai/Santro	Oct 2011	0.030	19
31	4	Maruti Suzuki/Wagonr	Nov 2011	0.040	18
32	4	Maruti Suzuki/Alto	Aug 2012	0.004	58
33	4	Maruti Suzuki/Alto	Dec 2012	0.027	42
34	4	Hyundai/i10	June 2013	0.018	12
35	4	Maruti Suzuki/Sx4	Oct 2013	0.041	88
36	4	Maruti Suzuki/Wagonr	Oct 2013	0.003	85
37	4	Maruti Suzuki/Dzire	Nov 2015	0.020	161
38	4	Maruti Suzuki/Dzire	Dec 2015	0.010	7
39	4	Maruti Suzuki/EECO	Jan 2016	0.030	29
40	4	Honda/Amaze	Jan 2016	0.028	69
41	4	Maruti Suzuki/Wagonr	April 2016	0.043	62
42	4	Hyundai/Xcent	Feb 2017	0.027	128
43	4	Maruti Suzuki/EECO	March 2017	0.020	22
44	4	Maruti Suzuki/Celerio	April 2017	0.027	58
45	4	Maruti Suzuki/Tour	Sept 2017	0.050	22
46	4	Maruti Suzuki/Dzire	Oct 2017	0.020	41
47	-	Bajaj Auto/Compact	Oct 2018	0.026	21
48	4	Maruti Suzuki/Tour	Nov 2018	0.025	24
49	4	TATA/Truck LPT	Jan 2019	0.050	27
50	-	Bajaj Auto/Compact	Jan 2019	0.001	187

Table 3 displays the value/level for vehicles using diesel as a fuel type. Emission from diesel vehicles is measured on the basis of HSU (Hartridge Smoke Unit), which is a unit of measurement used to measure the capacity of exhaust gases during emission. The HSU limit for pre-Bharat Stage 4 norms was 65, and for Bharat Stage 4 norms, it has been reduced to 50. Some of the major maker/companies being showcased through the table are Toyota, Maruti Suzuki, Hyundai, Honda, Mahindra, TATA and some luxury makers. As can be seen from the information mentioned above, we used vehicles from both indigenous and foreign makers/companies, thus adding another dimension to the analysis. The given data of HSU range from the value of 30.90.86 to 46.01.43, leading to the conclusion that most of the diesel vehicles are well below the current prescribed limits of HSU emission, yet the pollution levels are increasing at an alarming rate. Here we can also conclude that some of the old cars are well maintained and not emitting a large number of pollutants; it may be because the regular maintenance and service by car owner. Many old-car owners followed the pollution-under-control norms introduced by the Government of India. They always adopt new steps for reducing the pollution emission, while driving their cars. The following are the steps that can be helpful for someone for reducing the maintenance cost of vehicles, as well as the emission of pollution, too. Everyone needs to keep vehicles well-tuned and inflate the tires regularly, use biofuels such as CNG for regular derive, kept regular maintenance and test vehicles every 3 months by nearby installed pollution-under-control-norms center.

Details about the petrol type fuel are presented in Table 4, in which emissions are measured from three different pollutants which are CO (Carbon Monoxide), HC (Hydrocarbons) and CO_2 (Carbon Dioxide). Another parameter that is being measured for petrol driven vehicles is Lambda (λ), indicating the optimum conditioning needed for the proper functioning of catalytic converters. The vehicles registered during the pre-Bharat Stage 4 norms are only tested for CO and HC, having a prescribed limit of 0.5 and 750 ppm. For Bharat Stage 4 norms which were adopted in 2010 the prescribed limit for CO and HC are 0.3 and 200 ppm; Lambda should be in the range of 0.97 to 1.03. The given data of CO ranges from 0.001 to 0.380 ppm, and for HC, the data range from 0 to 197 ppm. The given data for both the pollutants have a large range, which shows that there are many parameters which give any vehicle its emission results, e.g., the distance traveled and the terrain on which the vehicle has been driven, the maintenance of the vehicle and the maker/company of the vehicle.

Table 5 showcases the details about vehicles that operate/run on petrol/CNG. For such vehicles, only CO and HC are measured with the same prescribed limit as according to pre-BS4 and BS4 norms; Lambda (λ), as a parameter, is not measured for such vehicles. In the data collected for petrol/CNG, the value of CO ranges from 0.001 to 0.310 ppm, and the value of HC ranges from 0 to 187 ppm. We can also notice that the data for petrol and petrol/CNG driven vehicles almost have the same range.

Tables 6–8 displays the average emissions over different years of HSU for diesel-driven vehicles and CO, HC and CO_2 for petrol and for petrol/CNG-driven vehicles. Calculating the average emission over different years helps in realizing how a change in technology over the year can affect vehicular emissions. The average emissions in chronological order for vehicles operating from a diesel engine are given by Table 6. The average HSU emission is calculated from the year of 2009 to 2018. The lowest HSU emission average (38.53.36) is calculated from the year 2015, and the highest average (43.31.35) is calculated from the year 2009. Table 7 displays the average emissions of three pollutants (CO, HC and CO_2) for vehicles operating on a petrol engine. The average values of pollutants are calculated from the year of 2010 to 2019.

Table 6. Average emissions over different years of HSU for diesel-driven vehicles [24–54].

Year	**HSU**		**HSU**		**HSU**		**HSU**
2009	42.21.27 45.41.41 44.31.36	2010	31.70.89 39.81.18 39.81.18	2011	42.51.29 39.91.07 42.51.28	2012	42.71.29 38.61.13
Average *	43.31.35	Average *	36.77.41	Average *	41.64.21	Average *	40.66.21
	HSU		HSU		HSU		HSU
2013	39.21.15 38.31.12 40.01.19 44.61.37	2014	41.41.24 44.01.35 38.81.14 43.01.30 41.51.24 43.81.34 46.01.43 42.11.27 31.50.88	2015	42.31.28 39.91.28 37.71.10 39.21.15 39.81.18 44.61.37 41.21.39 31.50.88 30.90.86 39.41.16 42.41.28 43.41.33	2016	43.51.33 37.91.10 43.91.34 38.21.12 41.31.24 38.91.14
Average *	40.29.21	Average *	41.35.35	Average *	38.53.36	Average *	40.63.21
	HSU		HSU		HSU		HSU
2017	42.61.29 44.21.36 39.11.15 44.71.37 39.01.15 40.01.19 39.31.16	2018	39.01.15 43.11.31 42.11.27				
Average *	41.28.24	Average *	41.08.24				

* The average values are calculated by using data collected for diesel cars. * The results demonstrate that the new advancement in automobile industries is not very concerned about maintaining the HSU level for vehicles.

Table 7. Average emissions over different years of CO, HC and CO_2 for petrol-driven vehicles [24–54].

Year	CO (ppm)	HC (ppm)	CO_2 (ppm)		CO (ppm)	HC (ppm)	CO_2 (ppm)		CO (ppm)	HC (ppm)	CO_2 (ppm)
2010	0.035 0.004 0.041	10 3 27	17.20 15.4 17.20	2011	0.033 0.020 0.003 0.026	27 24 2 7	16.70 17.30 17.10 16.80	2013	0.034 0.020 0.032 0.032	26 18 22 14	16.80 16.60 15.70 15.70
Average *	0.026	13.33	16.6	Average *	0.0205	15	16.975	Average *	0.0295	20	16.20
2014	0.010 0.003 0.030 0.025	28 5 16 17	17 15.30 16.70 17.10	2015	0.003 0.034 0.36 0.042	66 8 36 18	16.60 17.10 17 16.60	2016	0.035 0.027 0.012 0.027 0.003	13 18 8 12 20	15.50 16.90 15.40 16.80 16.90
Average *	0.017	16.5	16.525	Average *	0.10975	32	16.825	Average *	0.0694	14.20	16.3
2017	0.11 0.028 0.003 0.043 0.043 0.033 0.017 0.042	7 19 8 38 9 22 24 42	16.9 17 17.30 17.30 16.80 17 16.50 16.90	2018	0.003 0.003 0.036 0.026 0.042 0.024	5 4 21 18 13 35	16 17.10 16.40 16.60 15.70 17	2019	0.004 0.002	46 10	17 12.9
Average *	0.0398	21.125	16.9625	Average *	0.022	16	16.46	Average *	0.003	28	14.95

* The average values are calculated by using data collected for petrol cars. * The table demonstrates the emission of CO, HC and CO_2. * The average values for HC are rapidly growing every year. This is a matter of concern. New advancement in automobile industries do not take this into consideration to maintain these values.

Table 8. Average emissions over different years of CO and HC for petrol/CNG-driven vehicles [24–54]

Year	**CO (ppm)**	**HC (ppm)**	**Year**	**CO (ppm)**	**HC (ppm)**	**Year**	**CO (ppm)**	**HC (ppm)**
2005	0.026	10	2007	0.31	35	2008	0.1	9
	0.17	9		0.02	12		0.02	0
	0.05	34		0.02	16		0.04	9
	0.02	7					0.02	3
	0.034	7					0.01	14
							0.001	5
							0.016	4
							0.04	27
Average *	0.06	13.4	Average *	0.116	21	Average *	0.0308	8.875
Year	CO (ppm)	HC (ppm)	Year	CO (ppm)	HC (ppm)	Year	CO (ppm)	HC (ppm)
2009	0.01	6	2010	0.04	7	2011	0.027	77
	0.04	7		0.04	16		0.019	18
	0.004	8		0.001	31		0.01	93
	0.1	44		0.003	132		0.03	19
	0.05	0					0.04	18
	0.041	9						
Average *	0.0408	12.33	Average *	0.021	46.5	Average *	0.0252	45
Year	CO (ppm)	HC (ppm)	Year	CO (ppm)	HC (ppm)	Year	CO (ppm)	HC (ppm)
2012	0.004	58	2013	0.018	12	2015	0.02	161
	0.027	42		0.041	88		0.01	7
				0.003	85			
Average *	0.0155	50	Average *	0.0206	61.66	Average *	0.015	84
Year	CO (ppm)	HC (ppm)	Year	CO (ppm)	HC (ppm)			
2016	0.03	29	2017	0.027	58			
	0.028	69		0.05	22			
	0.043	62		0.02	41			
Average *	0.0336	53.33	Average *	0.0323	40.33			

* The average values are calculated by using data collected for diesel cars. * The average values are calculated by using data collected for petrol/CNG cars. * The cars registered in 2017 are emitting higher pollutants compare to the cars registered in 2005. * This is due to the easy availability of unauthorized installation of CNG kits in the Delhi NCR region.

The lowest average of CO (0.003 ppm) is derived from the year 2019, and the highest average (0.10975 ppm) is derived from the year 2015. The lowest average of HC (13.33ppm) is derived from the year 2010, and the highest average (32 ppm) is derived from the year 2015. The lowest average of CO_2 (14.95 ppm) is from the year 2019, and the highest average (19.975 ppm) is from the year 2011.Table 8 displays the average emissions of just two pollutants (CO and HC) for vehicles operating on petrol/CNG. The average values of pollutants are calculated from the year 2005 to 2017. The lowest average of CO (0.0150 ppm) is from the year 2015, and the highest average (0.116 ppm) is from the year 2007. The lowest average of HC (8.875 ppm) is from the year 2008, and the highest average (84 ppm) is from the year 2015.

3. Result Analysis

Our analysis is based on the data collected from the different pollution tracker nodes installed across the different locations in Delhi NCR. The analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles. In Table 2, we can track out that a large number of old vehicles are used in different regions after the various notifications in regard to banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants (Figures 2–4).

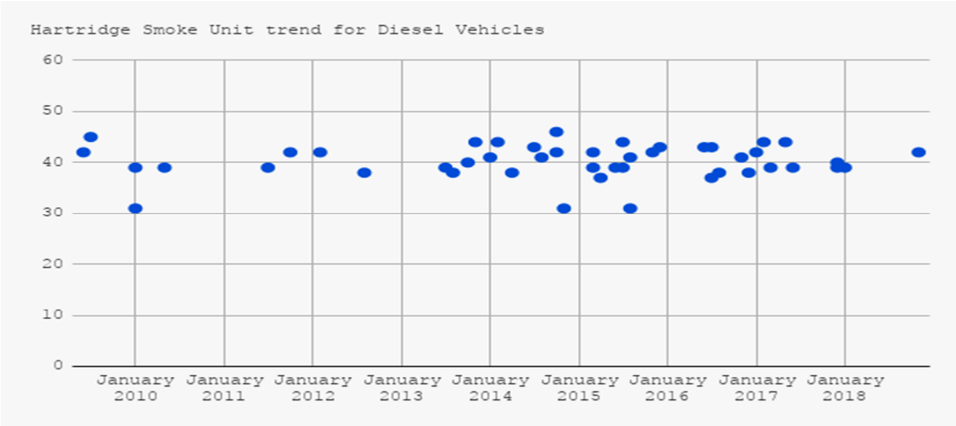
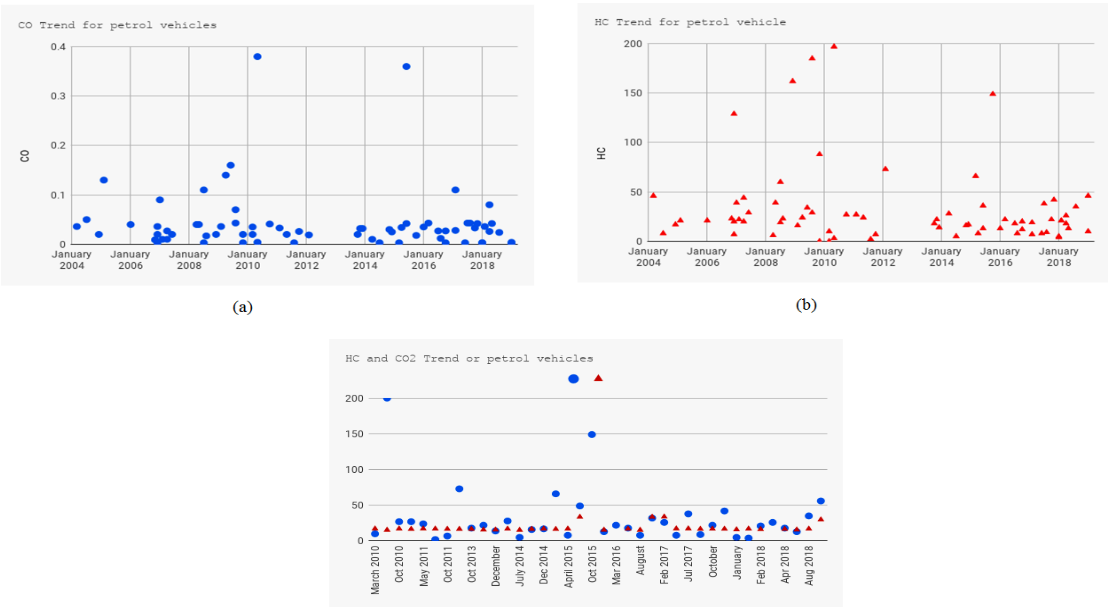


Figure 2. Trend of HSU over an eight-year period for diesel vehicles [24–54].



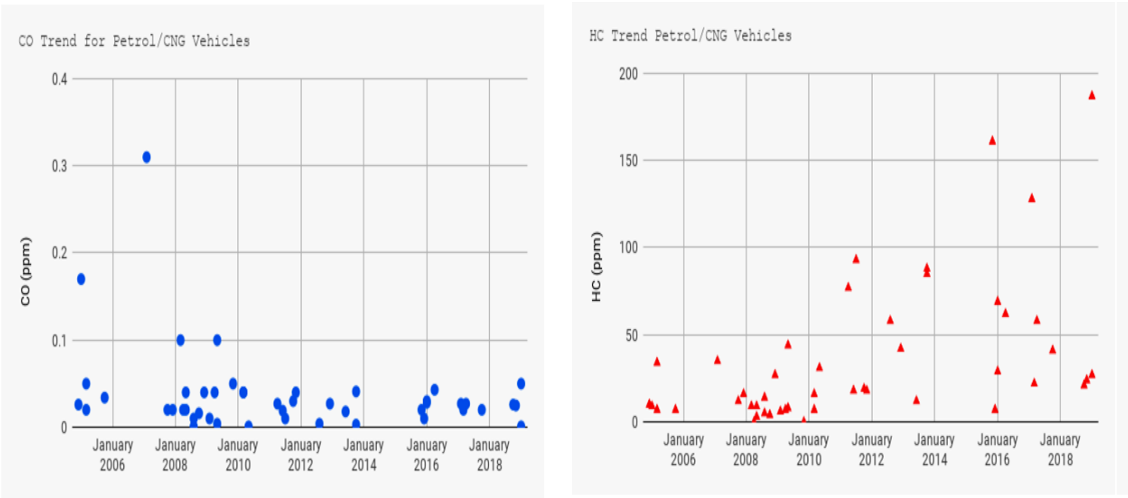
(a) (b)

(c)

Figure 3. Different emission trend for petrol vehicles: (**a**) CO trend for petrol vehicles, (**b**) HC trend for petrol vehicles and (**c**) HC and CO_2 combined trend for petrol vehicles. [24–54].

This situation can be handled by introducing the low survival rate for vehicles. It would correspond to easy replacement or breakdown of old vehicles. Thus, after introducing this, the pollutants share of old vehicles would be low. Lowering the survival rate will down the percentage of pollutants emission by old vehicles.

Lowering the mileage can also result in low fuel consumption and reduce emissions, too. The vehicles can be categorized in different mileage levels. For new vehicles, the mileage should be high, and for old vehicles, those having a high emission, the mileage level should be low. Major enforcement is also needed for reducing vehicle pollution. Time to time, vehicle services and enforcement are very important to reduce the pollutants emission by vehicles (Figure 5). The current study can make significant correlations with the impact of emission components toward sustainable development. We can further investigate in terms of green ICT and pollution, as well. In the future, based on several available studies found from the work done by several researchers, we may try to further explore the solutions for reducing pollutants. We can find some IoT sensor-enabled technologies to raise alarms if the pollution level or emission of specific gases, such as CO, CO_2 and HC, go beyond the acceptable limits [63–68].



(a) (b)

Figure 4. Different emission trends for petrol/CNG vehicles: (**a**) CO trend for petrol/CNG vehicles and (**b**) HC trend for petrol/CNG [24–54].

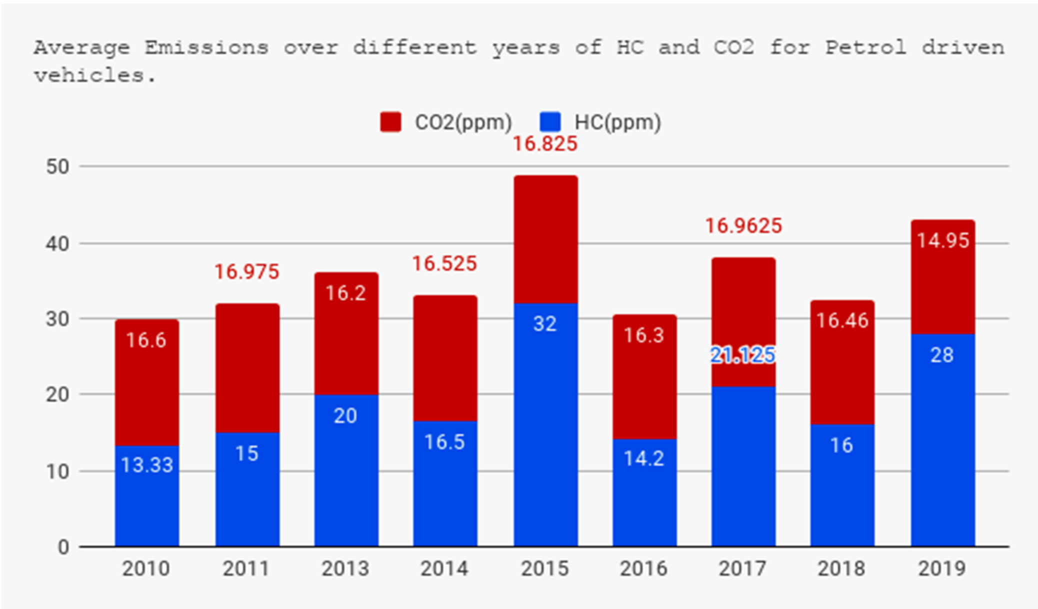


Figure 5. Average emissions for petrol vehicles over nine years [24–54].

4. Conclusions

This study presents the gaseous pollutants (181) emission factors of 181four-wheeler cars from different companies and of different types of fuels. The measurement of gaseous pollutants was done for Delhi, the most polluted city in India. Table 3 displays the value/level for vehicles using diesel as a fuel type. Emission from diesel vehicles is measured based on HSU (Hartridge Smoke Unit), which is a unit of measurement used to measure the capacity of exhaust gases during emission. Some of the major makers/companies being showcased through the table are Toyota, Maruti Suzuki, Hyundai, Honda, Mahindra, TATA and some luxury makers. The given data of HSU range from the value of 30.90.86 to 46.01.43, leading to the conclusion that most of the diesel vehicles are well below the currently prescribed limits of HSU emission, yet the pollution levels are increasing at an alarming rate. Here we can also conclude that some of the old cars are well maintained and not emitting a large number of pollutants; it may be because of the regular maintenance and service by the car owner. This study is also demonstrating the different HSU values emitted by the different companies' cars. The results also demonstrate that the new advancement in automobile industries is not very much concerned about maintaining the HSU level for vehicles.

Details about the petrol-type fuel show that the cars registered in 2015 emit higher amounts of pollutants as compared to those emitted by the cars registered in 2004. However, in the cars registered after 2015, the CO and HC values come down rapidly. On the other side, if we will look at the emission of CO_2 by the vehicles registered in 2010, 2015 and 2019, we see the same value of CO_2 emitted by the old and new cars. The results also demonstrate that the new advancement in automobile industries is not very much concerned about maintaining the CO_2 level for vehicles. The outcome for petrol/CNG cars indicates that few petrol/CNG cars are emitting a large number of pollutants. The cars registered in 2019 are emitting higher pollutants compared to the cars registered in 2005. This is due to the easy availability of unauthorized installation of CNG kits in the Delhi NCR region. Yes, to reduce the expenses on travel, everyone is now adopting the easy installation of CNT kits from an unauthorized dealer. No one cares about the effect of unauthorized installation on pollutant emission.

Overall, the analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles. The unauthorized installation of CNG kits also has to be banned strictly. Secondly, technological advancement not only targets fuel efficiency but also targets to reduce CO, CO_2 and HC. This study shows that many old vehicles are used in different regions after the various notifications regarding banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants. These old vehicles need to be banned immediately. This study will also help pollution-monitoring authorities make new and effective policies against the emission of pollutants by the vehicles. The significant contributions that were made by the work in this paper are summarized below:

1. Presents the gaseous pollutants (Hydrocarbons (HC), Carbon Monoxides (CO) and Carbon Dioxide (CO_2)) emission factor of 181 four-wheeler cars from different companies and of different type of fuels.
2. Based on this statistical data obtained and analyzed, the scenarios regarding future vehicle growth rate and its impact on air quality are mentioned, to overcome emission problems.
3. The analysis shows that few parameters need to be a concern for reducing the pollutants emission by vehicles. These major parameters are the high survival rates, decrease in annual mileage and major enforcement for three-to-five-year-old vehicles.
4. This study shows that many old vehicles are used in different regions after the many notification regards to banning old vehicles by the Government of India. These old vehicles are the major source of vehicle pollutants.
5. The unauthorized installation of CNG kits also has to be banned strictly. Secondly, technological advancement not only targets fuel efficiency but also targets the reduction of CO, CO_2 and HC.
6. It will be helpful to pollution-monitoring authorities for making new and effective policies against the emission of pollutants by the vehicles.

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