QUALITY IMPROVEMENT IN VEHICULAR FUELS WITH GREEN TECHNOLOGIES

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ABSTRACT

The quality of ambient air has been deteriorating day by day in metro cities like Delhi, Mumbai, Kolkata, Chennai and also major cities like Bangaluru, Hyderabad; etc due to emissions of vehicular exhausts coming into the atmosphere from the large number of vehicles running on the roads of these cities. The motor vehicles run on burning of fossil fuels ;like gasoline and diesel . The burning of these fossil fuels emits various types of air pollutants; CO, HC, NOx, PM10, PM2.5, VOCs; etc. Apart from these air pollutants, some greenhouse gases (GHGs) are also emitted from the vehicles. GHGs are responsible for increasing the temperature of the atmosphere and consequently gives threat of global warming and climate change. These air pollutants cause adverse effects on human health's and help increase the number of mortality. The transport sector in India is the second largest precursor for greenhouse gases emissions including ground level ozone and deteriorating ambient air quality of the cities.

This paper aims to discuss the enhancement of quality of vehicular fuels using green or modern technologies and latest Indian emission standards so that the emission of greenhouse gases may reduced and the air pollutants due to vehicular exhausts may also be minimum. Alternative fuels like CNG , H-CNG , E10, E20, B10 ,B20 and hydrogen alone have been considered as the potential transport fuels for reducing vehicular emissions and improving quality of vehicular fuels.

Keywords: Vehicular emissions, alternative fuels , greenhouse gases , BS Norms

1. INTRODUCTION

The driving of motor vehicles depends on burning of fossil fuels ; such as gasoline , diesel etc. These fossil fuels after combustion either in SI or CI engines emit various types of undesirable substances ; like carbon monoxide (CO) , hydrocarbons (HCs) , nitrogen oxides (NOx) , particulate matters (PMs) , volatile organic compounds (VOCs) ; etc. After oxidation , CO in the atmosphere gets converted into carbon dioxide (CO2) ,which is a strong greenhouse gas . Other greenhouse gases emitted from vehicular exhausts include ; nitrous oxide ,water vapour, ,indirect emissions of ozone ;etc. Compressed natural gas (CNG) is also used as vehicular fuel in most of the heavy duty vehicles and also in passenger cars having bi-fuel facility . The fugitive emission of methane (CH4) , being major component of CNG fuel is also a kind of emission of GHG .Methane is also a strong greenhouse gas .The emissions of such Green House Gases (GHGs) are responsible for increasing the temperature of the earth's atmosphere and as a result cause adverse impact on climate change. Greenhouse gas molecules present in the atmosphere absorb infrared radiations from the sun, and these molecules re-emit the radiations in all directions causing an increase in the temperature of the earth's surface. Due to anthropogenic activities in the country, GHGs emissions are increasing. These emissions are also responsible for deteriorating ambient air quality of the cities like Delhi , Mumbai, Kolkata, Bangalore, Hyderabad, etc. The necessary technologies and practices to mitigate GHG emissions is of paramount importance. The strategies for reducing emissions of GHGs to minimize the effect of global warming and climate change are also necessary by the policy makers . The impacts of implementing energy efficiency and conservation measures, the role of renewable energy, and hydrogen blends in the vehicular fuel CNG are also considered some of the parts of the strategies.

Vehicular emissions are the second largest precursors to generate greenhouse gases (GHGs) and main reason to cause ambient air pollution in India. Around 80% of Indian cities are participating in

violation of National Ambient Air Quality Standards (NAAQS) for respirable suspended particles matter (RSPM) . Concentration of oxides of Nitrogen (NOx) in Indian cities are close to the standards and are expected to exceed in future. In addition to major cities of the country, even smaller cities are also critically polluted; nearly 1.5 times more than prescribed norm for RSPM . Air pollution has been categorised as the fifth biggest cause of mortality in India. Due to bad ambient air quality, people suffer from various types of bronchial diseases and ultimately they succumb to death. Around 6.2 lakh mortalities were reported in 2010 due to ambient air quality. Fine particles coming from diesel vehicles are causing risk of lung cancer as per WHO report 2012.

Some of the air pollutants like ground level ozone (GLO) which are formed by the complex interactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) that are emitted from vehicles, power plants and other combustion sources and undergo cyclic reactions in the presence of sunlight . Due to increase of temperature ,particularly in the summer when temperature is around 40 degree celsius , more ozone is produced . The toxicity of ozone is more than particulate matter and the health impact is immediate. When ozone limit exceeds 50 ppb ,the pulmonary disease , asthma, respiratory conditions aggravate . There is damage of agriculture crops due to exposure of ground level ozone . Due to increasing trend of vehicles particularly in metro cities, the level of pollution in those cities are increasing considerably day by day. In view of all these above, there is an urgent need of improving transport fuel quality to reduce vehicular emissions. Fuel quality and modern technology in vehicles may play an important role in reducing emissions from transport sector.

1.1. Auto Fuel Policy 2003 in India

Auto fuel policy 2003 laid down a road map for introduction of cleaner fuels and vehicles in the country up to 2010.

Based on this road map, India has now introduced BS-VI norms in major cities. However, some of the cities are still on BS-IV. India had to leapfrog BS-V due to delay implementation with the introduction of BS-VI norms in India, the gasoline and diesel fuel quality have been upgraded by fixing 10 ppm sulphur in place of 50 ppm in BS-IV & BS-III.

Auto Fuel Vision Committee was set up in 2013 to recommend the future roadmap on advancement of fuel quality and vehicular emission standards up to 2025. India has been 10 years behind the US and the European countries in view of vehicular fuel quality as per recommendation of Auto Fuel Vision Committee. It has also been envisaged that to upgrade the quality of refineries to produce 10 ppm sulphur containing fuel ,an investment cost of Rs 25000/- crore may be incurred. The effect of GHGs on the cause of global warming primary depends on three factors (i) degree of concentration, (ii) retentivity (how long it stays in the atmosphere), and (iii) its global warming potential (GWP), for example, water vapor is the most abundant greenhouse gas, but CO_2 has a more significant impact on global warming due to its abundance in the atmosphere and also due to its longevity of 300 to 1000 years. However, water vapor has an atmospheric lifetime of not more than ten days (Journal of the atmosphere Science, 2020). Methane has about 21 times more absorbing capacity than CO_2, with a higher rating of GWP. Methane is produced through agricultural processes, whereas CO_2 is produced from natural processes like respiration and; the burning of fossil fuels such as; Coal, Oil, and Gas [1,2].

The entire world, including India, is facing the challenges of climate change. Climate change is due to various adverse environmental effects. Due to the increased temperature of the atmosphere, there has been adverse impacts on agriculture, water resources, forest and biodiversity, health. Due to rapid industrialization, urbanization and economic development, vehicular emissions are increasing day by day . Climate change affects human well-being in many ways like capital, ecosystem, disease; etc.

Nowadays, several latest technologies, such as Solar Thermal and Photovoltaic Energy Systems have come up.

Some of the critical impacts of climate change may include:

- Food Security
  Since the agriculture output will be adversely affected, food security will be a big challenge.
- Water Security
  Melting of glacier may have more adverse effects on the productivity of agriculture yields. It may cause more damage to the infrastructures and habitats.
- Energy Security

Developing countries including India are vulnerable to the adverse effects of climate change and are already facing tremendous effects, such as; drought and extreme weather events, sea level rise, coastal erosion and acidification of oceans. These adverse effects pose a threat to the food security and sustainable development. The global average temperature increases daily exceeding 400 ppm due to the increase of GHGs. The increasing number of cars and the household comfort appliances are responsible for increasing greenhouse gas emissions.

Due to environmental degradation, land's quality is also degraded. Soil degradation is due to climate change effect. The statistics of the International Commission on climate change show that the average global temperature may increase by 6°C by the next century if the current trends of the use of fossil fuels are not controlled [19]. From the present trends of population growth in India, there will be more demand of natural resources and, therefore, more depletion of natural resources, more emissions of greenhouse gases, etc.

The greenhouse effect is an increase of the Earth's surface temperature due to the heating of the lower layers of the atmosphere by the accumulation of greenhouse gases. As a result, the air temperature is more significant than it should be, leading to irreversible consequences such as climate change and global warming [6]. Table 1 gives details of greenhouse gas concentration in the atmosphere.

Table 1: Greenhouse gas concentration in the atmosphere

Greenhouse Gas	**Chemical Formula**	**Concentration in the atmosphere (ppm)**	**% Contribution**
Water Vapour & Clouds	H_2O	10 – 50000	36 – 72
Carbon Dioxide	CO_2	400	9 – 26
Methane	CH_4	1.8	4 – 9
Ozone	O_3	2 – 8	3 – 7

Source: European Environment Agency

1.2. Paris Protocol (Dec. 2015-16)

To reduce GHGs, an international protocol agreement was signed by 73 countries in April 2016 termed as Paris Agreement, according to UNFCCC. According to that agreement, India was mandated to reduce its GHGs emissions by 33-35% by 2030. The Paris Agreement also set to limit global warming to 1.5°C; for the same, the world needs to cut its CO_2 emissions by 7.6% for the next decade (UNEP).

The Paris protocol passes several significant challenges for all countries to achieve the goal. These goals include; the end of the fossil fuel era, the development of low carbon technologies and the countries' adaptation to climate change.

The total GHGs emissions reduced by 2.2 times in 2017 as against of 1990 and the same decreased from 853 to 393 Mt of carbon equivalent, methane decreased by 2 times (i.e., from 151 to 73 Mt of carbon equivalent), nitrous oxide emissions dropped by 2.5 times (from 59 Mt to 24 Mt of carbon equivalent).Table 2 gives details about global warming potential of GHGs.

Table 2: Major greenhouse gases and their global warming potential

Greenhouse Gas	**Chemical Formula**	**GWP,100**
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
HFCs	-	124 – 14800

Source: IPCC report, 2007

1.3. Various Alarming Effects on the Eco-systems

The country may face the following challenges in the future :

- If the rate of glacier melt increases, a flood is possible; it may result in scarcity of drinking water and agricultural irrigation.
- Warming of 0.5°C is likely in India by 2030, and warming of 2°- 4°C is expected by the end of this century.
- Increased warming will likely lead to higher troposphere ozone pollution and other air pollution levels in India's major cities.
- Growing emissions of aerosols from energy production and other sources may suppress rainfall. Leading to drier conditions with mere dust and smoke from the burning of drier vegetation, affecting regional and global hydrological cycles and agricultural production.

Due to both its greenhouse gas emissions and its vulnerability to climate change, India is one of the most powerful countries in the world. With a large and growing population, India's emissions of greenhouse gases are increasing. Due to all these above, the potential climate impacts in India may include rising earth's surface temperature, rising sea level, frequent floods, scarcity of drinking water and agricultural irrigation, etc.

Recently, climate variability in the form of floods and cyclones has destroyed crops, property, and infrastructure and negatively impacted human health and well-being. All of these impacts are responsible for affecting socio-economic development.

2. Strategies to reduce Effect of Climate Change in India

Greenhouse gas emissions (GHGs) is one of the most severe global warming and climate change concerns. To reduce the emissions of GHGs, the consideration of fuel characteristics is the need of the hour . Hydrogen resources are vast and considered one of the most promising vehicular fuels. Since it has still been challenging to use hydrogen alone as transport fuel, it may also continue shortly. However, optimum percentage of hydrogen blend with CNG i.e. methane improves the combustion

performance of methane and thus reduces the demand of pure hydrogen. Many researchers are working on this for the last few years . The optimisation of percentage of hydrogen blends with CNG has already been established [7,8].

2.1 Adoption of Green Technologies to improve Fuel Quality

It is imperative that emissions from vehicular sources need to be controlled. To achieve this purpose, stringent emissions and fuel quality norms are to be put in place. By the year 2030, ***P M 2.5,*** NOx, CO & VOC emissions will grow manifolds. These emissions will make the air quality further worse . With the deterioration of ambient air quality by the emissions of various types of air pollutants ,there will be severe impact on human health .Reduction of emissions could be achieved through adoption of alternative fuels with multiple quality using modern technologies and promoting renewable energy sources .

India has also been mandated by Conference of Party (COP) .Paris Agreement held in December 2016 to reduce its GHGs emissions by 30-35% by 2030 . The recent COP Agreement held in Egypt enhanced the target of GHGs reduction by 45% instead of 30-35 % .

2.2. Advanced Emission Control Technologies

BS VI regulation allows maximum 10 PPM of sulphur content in gasoline and diesel ,diesel particulate filters (DPF) and selective catalyst reduction (SCR) systems to meet BS VI emission standards .With the introduction of various BS emissions norms in India since 2000 to 2020 and also by implementing Auto Fuel Policy 2003 ,India has upgraded the quality of vehicular fuels like gasoline and diesel to reduce the emissions after burning in the vehicle engines . It has also been witnessed that approximately 28ooo/- crore rupees has been invested to implement the BS-VI emissions norms across the country .

2.2.1. Fuel Quality Improvement

(I) Gasoline

It is a mixture of hydrocarbons containing 5-12 carbon atoms .It contains mainly alkanes (paraffins) , alkenes(olefins) and aromatics ; like benzene, butane ,toluene ;etc . Earlier gasoline was containing lead also which was a harmful element . Now the gasoline is available from refineries free from lead .

Benzene Removal

It is a natural constituent of crude oil .Benzene is a carcinogenic product and advised to be away from its exposure and hence to control benzene in gasoline . Before 2000 , there was no specification or standard limit for benzene . In 2000, the then MoEFCC notified a limit of benzene of 3% by vol max for four Metros and 5% vol max for rest of the country .It was further reduced to 1% vol max.

Reduction of Sulphur Content

As per BS -VI emissions norms introduced in 2020 , sulphur content in gasoline has been reduced to 10 ppm max from earlier 50 ppm in BS-IV .

Enhancement of Octane Number

Octane number in the gasoline is the measure of anti- knocking property in the Spark Ignition (SI) Engine. The higher is the octane number , the higher is the quality of gasoline engine .Earlier the research octane number (RON) of gasoline was 87 in 1999,which was enhanced to 91 in 2020 .

Reduction of Olefin and Aromatic Contents

In normal gasoline , olefin content was limited to 21% by vol max in 2020 , Earlier there was no limit for this. Aromatics in gasoline was limited to 35% vol in 2020 as per BS -VI Norms as against of 42 % in 2005.

Blending of Ethanol with Gasoline

Ethanol being a kind of renewable energy source and has potential to improve performance of the SI engines as vehicular fuels . Government of India has already implemented 10 % ethanol blend with 90% gasoline or petrol for vehicles . Research findings reveal that 10% ethanol blend with gasoline (E10) and 20 % ethanol blend with gasoline (E20) have better fuel economy for petrol driven four

wheeler cars . With the addition of E10 and E20 with the remaining portion of petrol or gasoline ;respectively , the emissions of GHGs , CO ,HC get reduced as compared to neat gasoline ,if burnt in SI engine vehicles . However , there is some additional cost involved in developing such alternative fuels .

(II) Diesel

Diesel is a petroleum product of oil refineries . It contains 12 to 20 carbon atoms . It contains mainly of paraffins , aromatics and naphthene's .It is used widely in heavy -duty vehicles ,commercial vehicles , passenger cars ;etc. The diesel fuelled vehicles do emit hydrocarbons , CO ,NOx , PMs ,VOCs ;etc .

Enhancement of Cetane Number of Diesel

The cetane number is a measure of compression ignition (CI) quality of diesel fuel and affect cold start ability ,exhaust emissions and combustion noise. Below 45 of cetane number of diesel fuel gives more smoke . It was increased further up to 51 in BS-VI effective from 2020.

Restricting Polycyclic Aromatic Hydrogen (PAH)

This aromatic organic compounds are very harmful to human lives .Its presence in diesel may cause several fatal health hazards . It produces due to incomplete combustion of diesel .Its presence in diesel has been limited to 8% as per BS -VI in 2020.

Reduction of Sulphur Content in the Diesel

After introduction of BS-VI in India in 2020, the sulphur content in the Diesel has been reduced to 10 PPM from the earlier limit of 50 PPM as per BS -IV Emission Norms .

Blending of Bio-diesel with Diesel

Bio-diesel is a source of renewable energy produced from esterification of fatty acids . Its combustion performance as fuel is better than neat diesel . When even 10 % of bio-diesel is blended with neat diesel ,the performance of diesel as vehicular fuel gets enhanced . Government of India has already promulgated that 10% bio-diesel blended diesel is mandatory in diesel run vehicles so that the vehicular emissions due to diesel burning may reduce to improve the ambient air quality of the Indian cities.

With the addition of B10 or B20 fuel with neat diesel , the fuel economy for passenger car increases in addition to the reduction of vehicular emissions e.g particulate matters, CO ,NOx , HCs ;etc . However, there is a need of further development of alternative fuels to reduce emissions of volatile organic compounds (VOCs) .

(III) CNG Fuel

In 2000 CNG was introduced in India as transport fuel particularly in heavy -duty vehicles . Later passenger cars were also designed to combust compressed natural gas (CNG) . The vehicle engines suitable for petrol- CNG bi-fuel were manufactured in rapid pace to reduce the number of diesel vehicles for commercial purposes . The CNG fuel after combustion in the SI engines gives less percentage of CO, HCs, particulate matters as compared to diesel vehicles ,however NOx emissions are more due to burning of CNG .CNG is having major component as CH4 which is a greenhouse gas . But its diffusivity coefficient is higher and disperses quickly in the atmosphere while fugitive emissions .It is cheaper also as compared to gasoline and diesel. Since it is containing single carbon atom and hence gives less CO ,HCs ,CO2 ;etc as compared to gasoline and diesel while their combustion in the vehicle engines .

(IV) H-CNG

The combustion performance of CNG can be further improved with the addition of hydrogen with neat CNG. Hydrogen is a potential source of energy and it is renewable . It has higher energy content ,when optimum percentage of hydrogen is blended with CNG , the combustion performance of CNG increases and emission due to burning of this bi-fuel reduces . Hydrogen is the only transport fuel

which does not have even a single carbon atom and hence if burnt alone ,it will emit water vapour only .Research findings reveal that 18% hydrogen has been considered as the optimum value to be blended with 82 % CNG to perform better as vehicular fuel . There is further reduction of various vehicular pollutants ;such as CO, HCs , NOx, PMs , CO2 , CH4 ,VOCs ;etc as compared to CNG alone and also as compared to gasoline and diesel fuels. In this way , the vehicular fuel quality can be upgraded.

When hydrogen is added to CNG, the physical and chemical properties of CNG fuel gets changed, and the combustion performance of CNG improves. Due to the blend of hydrogen with CNG, the laminar velocity of the mix fuel gets enhanced since hydrogen has a higher laminar velocity. There is faster ignition, and the rate of combustion enhances. The lower heating value of hydrogen is also higher; when blended with CHG, the lower heating value (MJ/kg) also becomes higher than CNG alone. The diffusivity coefficient is also higher in the case of H-CNG fuel. Table 3 gives the composition of H-CNG and CNG fuels .

Table 3: Composition of H-CNG Blends

S.No.	Type of Compounds, %	CNG	18 HCNG
1	Hydrogen	0.2	17.8
2	Methane	90.1	73.4
3	CO_2	2.9	3.2
4	Nitrogen	2.2	1.3
5	Oxygen	0.1	0.1
6	Ethane	3.2	3.1
7	Propane	1.0	0.9
8	i-butane	0.1	0.1
9	N-Butane	0.2	0.1

Source: CPCB Handbook 2007

Characteristics of H-CNG Blend Fuels

The addition of hydrogen in CNG allows the mixture to burn leaner. Blends of HCNG ranging from 5-25% extend the lean operating limit allowing complete combustion, and reducing H.C. and C.O. emissions. The laminar burning velocity of hydrogen is nearly eight times higher than that of CNG ,so the addition of hydrogen can increase the burning velocity of the mix fuel, as a result, the mix fuel brings some advantages; such as shorter combustion duration, enhanced thermal efficiency, a greater degree of constant volume combustion; etc.

3. Results and Discussion

3.1 Emission Performance

- It is evident from Figure 1 that there is around 80% reduction in C O emissions at idle (1000 rpm) and 95% reduction at 5000 rpm with CNG as compared to gasoline. The excess air ratio in the cylinder makes C O emission lower for HCNG blends. There is a slightly 3% reduction in C O with 18HCNG compared to CNG at 1000 rpm [1].

- Figure 2 shows that there is around 20% reduction in CO_2 at 1000 rpm,10% reduction at 3000 rpm and around 15% at 5000 rpm with 18 HCNG as compared to gasoline. CO_2 emissions are lower at all speeds with 18HCNG as against of CNG [1].
- Nearly 30% increase in NOx emission at idle 1000 rpm and nearly 60% increase at 5000 rpm with CNG are envisaged (Figure 3) . 40% increase in NOx emission at 1000 rpm whereas 70% increase at 5000 rpm with 18 HCNG are indicated [1].
- Figure 4 shows that THC reduced by 10% with CNG and reduced by 70% with 18HCNG even at 1000 rpm as compared to gasoline . This happens since C/H ration decreases with increase of hydrogen fraction[1].

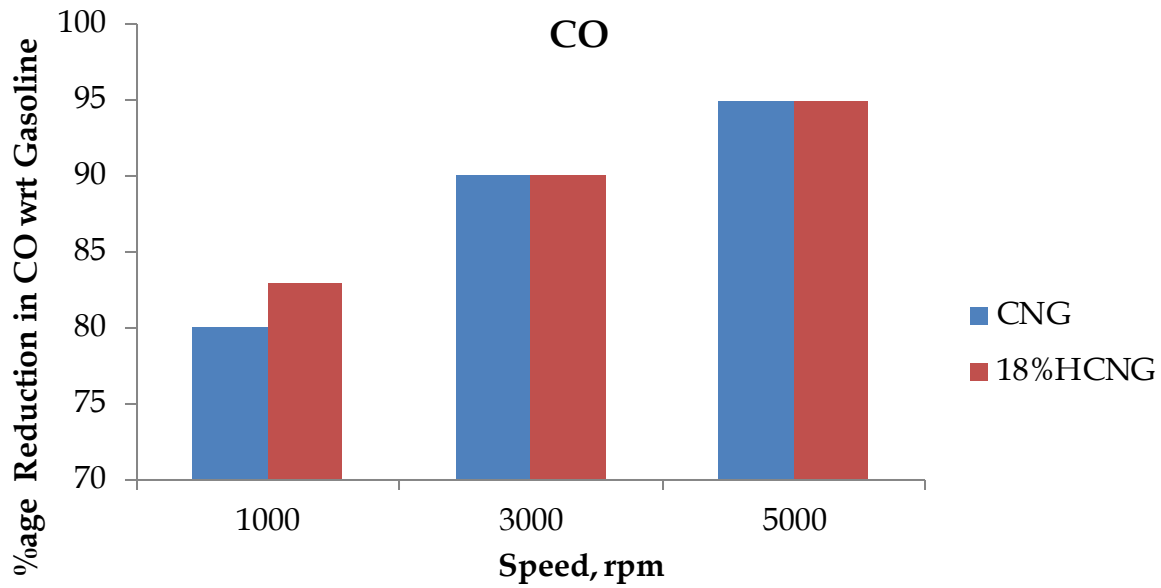

Figure:1 CO variations with CNG and 18 HCNG as compared to gasoline at different speeds

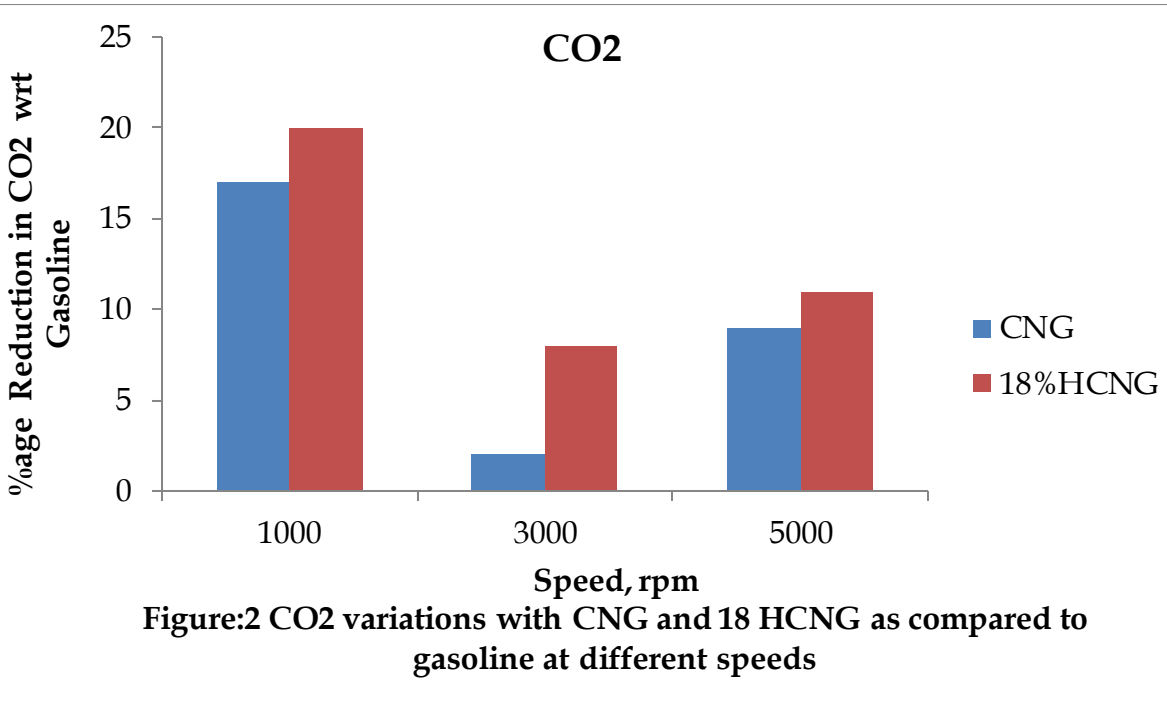

Figure:2 CO2 variations with CNG and 18 HCNG as compared to gasoline at different speeds

(iii) There is around 80% reduction in C.O. emissions at idle (1000 rpm) and 95% reduction at 5000 rpm with CNG compared to gasoline. However, with 18HCNG blends, there is a further reduction of C.O.

(iv) CO_2 emissions are lower at all speeds with 18HCNG against CNG[1].

(v) There is around a 30% increase in NOx emissions at idle 1000 rpm and nearly 60% increase at 5000 rpm with CNG compared to gasoline. There is a nearly 40% increase in NOx emissions at 1000 rpm, whereas there is a 70% increase at 5000 rpm with 18HCNG concerning gasoline fuel [1].

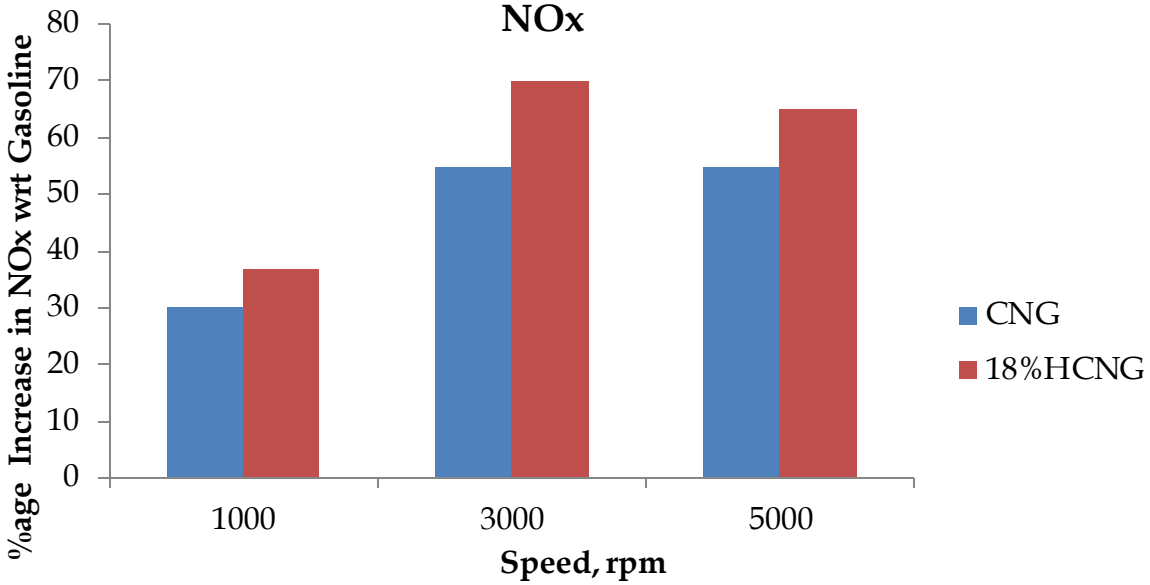

Figure:3 NOx variations with CNG and 18 HCNG as compared to gasoline at different speeds

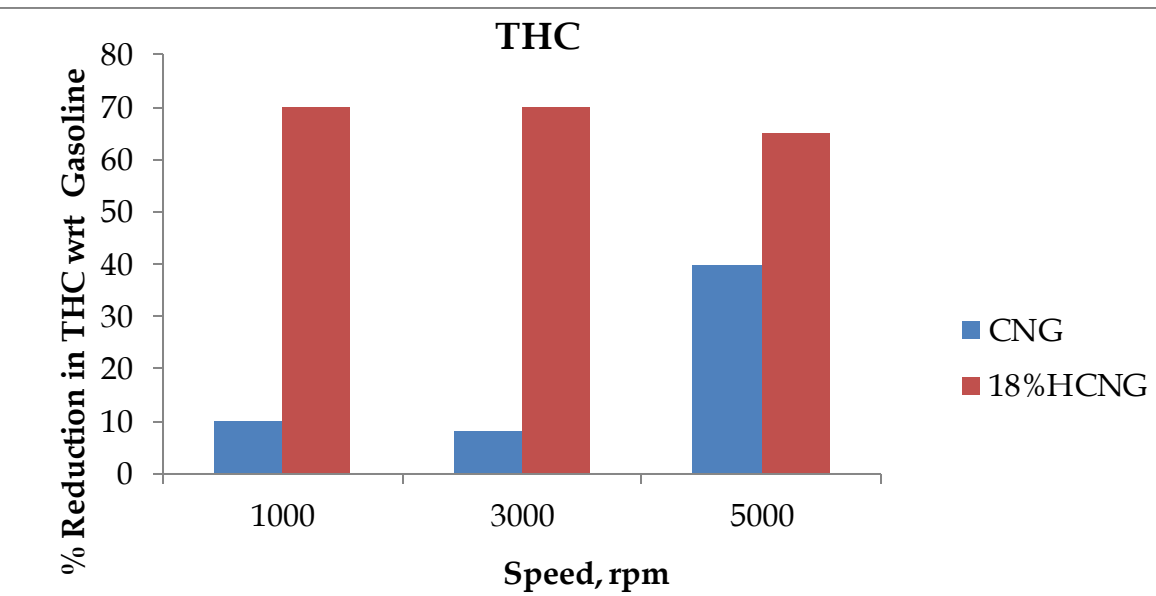

Figure:4 THC variations with CNG and 18 HCNG as compared to gasoline at different speeds

(vi) The THC reduces by 10% with CNG and further reduces by 70% with HCNG even at 1000 rpm compared to gasoline.

(vii) After upgrading the quality of CNG by blending with hydrogen ,the emission performance of CNG as compared to CNG alone improves . Such a combination of fuel mix reduces greenhouse gas emissions, paves the way to protect the climate, and reduces the threat of global warming.

Conclusions

((i) E10 , E20 fuels give better emission performance as compared to gasoline alone for petrol engine vehicles .Blending of 10% ethanol with rest of gasoline increases the oxidising properties of the blended fuel.

(ii) Similarly, B10 and B20 blended fuels reduce the emissions of diesel engine vehicles as compared to diesel alone.

(iii) For CO emission measurement with different blends of HCNG and also at different speeds at rpm, there is no significant change in the emissions.

(iv) There is variation in the emissions of total hydrocarbons with variations of percentage of HCNG blends. With 18HCNG fuel, the overall THC seems to be optimized at all speeds (1000, 3000 and 5000 rpm).

(v) NOx emissions increase with 18HCNG at all speeds as compared to other blends of HCNG. This happens due to better combustion performance of the fuel with 18% hydrogen mix with 82% CNG.

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