POSITION PAPER

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OPPORTUNITIES TO ADDRESS AIR POLLUTION WITH TRANSPORT BIOFUEL – A CASE STUDY

Tampere University

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BACKGROUND

India is the fifth largest economy of the world with gross domestic production (nominal GDP) of $3.16 trillion during 2019 according to the International Monetary Fund report. The country is expected to continue its economic growth for a few decades. Energy is a critical input towards raising the standard of living of citizens. In addition, the conventional fossil fuel-based energy is limited in India and generates pollutions at different levels. Renewable energy resources are non-polluting. These can support the economic growth of the country directly and indirectly.

Crude oil and natural gas account for nearly 36% of the total primary energy consumption (809.2 MToE) in the country.[1] India is the third largest consumer of crude oil in the world (254.40 MMT in 2017–18).[2] However, the domestic crude oil production can meet only about 17.9% of the total demand. Thus, the country is highly dependent on crude oil import to support the energy demand for economic growth. The Government of India has prepared a road map to reduce the import dependency of primary energy by adopting different strategies. Adopting biofuels and renewables is one of these strategies. The Government of India also has an ambitious target of reducing the emissions intensity from energy by 33%–35% by 2030. In India, biofuels is of strategic importance as it augers well with the initiatives of the government, such as Make in India and Swachh Bharat Abhiyan, and offers great opportunity to integrate with the ambitious targets of doubling of farmers income, import reduction, employment generation, waste to wealth creation, etc. Development of new feedstock and new technologies for conversion of biofuels are two important visions of the National Policy on Biofuel (2018) of the government.

The road transport sector accounts for 6.7% of GDP and 28% of overall energy demand of the country. Diesel alone meets an estimated 72% of transportation fuel demand (about 92 billion litre during 2016–17[3]) followed by petrol (23%) and other fuels such as CNG and LPG. The diesel demand in the transport sector of India will be an estimated 158 billion litre during 2026. Under the National Policy on Biofuel, 'biodiesel' is defined as a 'methyl or ethyl ester of fatty acids produced from non-edible vegetable oils, acid oil, used cooking oil or animal fat and bio-oil'. An indicative target of 5% blending of biodiesel in diesel is proposed by 2030 in the policy. Earlier, under the National Biodiesel Mission (2009), the Government of India proposed a target of 20% biofuel blending with crude oil by 2017 identifying *Jatropha curcas* and *Pongamia glabra* as the most suitable tree-borne oil seeds for biodiesel production. However, the government could not achieve the target due to lack of availability of these oil seeds and lack of R&D to evolve high-yielding drought- tolerant seeds. In addition, competition with food crop land, ownership issues with government or community-owned wastelands for the plantation of these oil seed plants, and high production cost of biodiesel were also the hurdles towards production of the feedstocks. The government has revamped the path to produce biodiesel under the National Biofuel Policy, 2018 by incorporating biodiesel production from used cooking oil (UCO), animal tallow, agricultural waste residue, acid oil, algal feedstock, etc. apart from the non-edible oilseeds.

The study suggests that biodiesel can reduce the tail-pipe emissions of CO, PM, NOx, and SO2 while reducing the emissions of carcinogenic compound compared to conventional diesel (Figure 1). Again, higher blends of biodiesel can reduce much higher tail-pipe emissions compared to that of petroleum diesel.[5]

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[1] BP-Statistical Review of World Energy 2019, details available at https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf

[2] MoPNG 2017-18 PNGStat, pp 6. Details available at http://petroleum.nic.in/sites/default/files/ipngstat.pdf

[3] MoSPI (2018) Energy Statistics, pp46. Details available at http://mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2018.pdf

[4] IEA[international Energy Agency], 2017 World Energy Outlook

[5] US-EPA (2002) A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions. EPA420-P-02-001

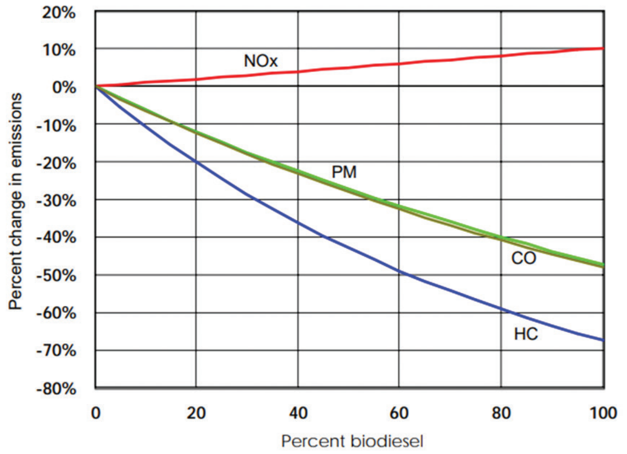

Figure 1: Percent reduction in tail-pipe emissions from heavy duty vehicle with biodiesel blends compared to petroleum diesel. PM – Particulate matter; CO – Carbon monoxide; HC – Hydrocarbon Source: USEPA (2002)[5]

The major thrust of the National Biofuel Policy, 2018 is to ensure availability of biofuels from indigenous feedstock. However, to address the energy security it is not feasible to prepare biodiesel from the first-generation edible oil. The Government of India emphasized on producing biodiesel using feedstock, such as non-edible oilseeds, used cooking oil (UCO), animal tallow, acid oil, algal feedstock. Different types of biodiesels can be derived from the same feedstock following technological modifications. First, esterification/ transesterification of vegetable oil or used cooking oil can derive fatty acid methyl esters (FAME) of long-chain fatty acids (see Figure 2). Second, hydro-decarboxylation of the same feedstock produces oxygen and aromatic free hydrocarbons known as renewable diesel (refer to Figure 3). Third, the hydrocarbon reaches cellulosic diesel derived from the pyrolysis of cellulosic feedstock (Garpen and He 2014).

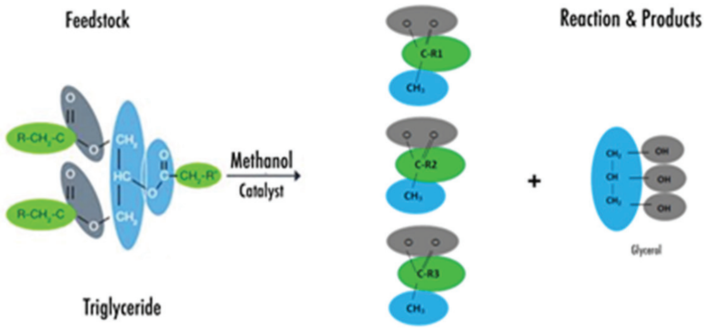

Figure 2: FAME biodiesel production process

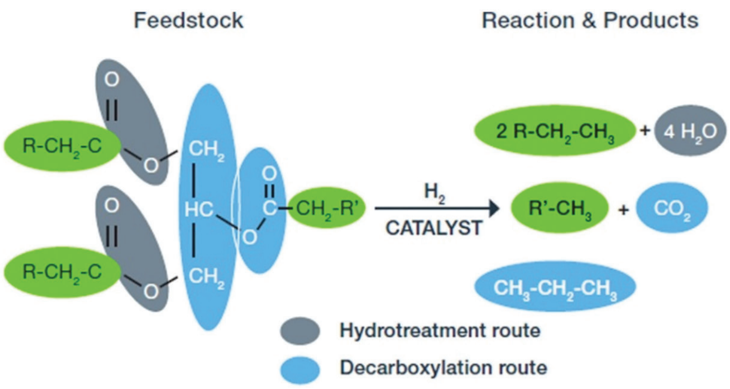

Figure 3: Hydrodecarboxylation process to prepare renewable diesel Source DoE (2016)[7]

[5] US-EPA (2002) A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions. EPA420-P-02-001

[6] Advances in Biorefineries (2011) , pp. 441-475. Amsterdam: Woodhead Publishing

[7] DoE (Department of Energy, United States) Biodiesel handing and use guide. Number DOE/GO-102016-4875

FAME biodiesel contains about 11% oxygen by weight as esters which on blending upgradation can react with the plastic and rubber parts in fuel system or carbon built up in engine motor and, thus, creates damage to these components. Renewable diesel is produced through hydrotreatment and, thus, does not contain oxygen/esters that can create damage to the above components. Although, US-EPA (2002) and other reported literatures (Robbins, Hoekman, Ceniceros, *et al.* 2011)[8] have confirmed that FAME biodiesel blends with petroleum diesel reduces the emissions of PM, CO and HC; however, such data with the use of renewable diesel is sparse. Again, particulate emissions (<200 nm) with the use of biodiesel blends or renewable diesel are not so well reported, while particulate numbers at these diameter range are more harmful to human being compared to PM2.5. , [9,10]

Brief Description of Study

The consortium of Indian and Finnish research institutes undertook a study to measure the tail-pipe emissions from in use heavy duty vehicle under specific driving cycle (DBDC) (Figure 4) using different quality of petroleum diesel, biodiesel, and renewable diesel blends (Table 1). FAME biodiesel and renewable diesel (NesteMY) used in this study were blended (20%) with BS-IV diesel. The heavy duty vehicle used in the study was BS-IV compliant and the same lubricant oil was used with all fuel types to avoid the interference of emission due to lubricant oil

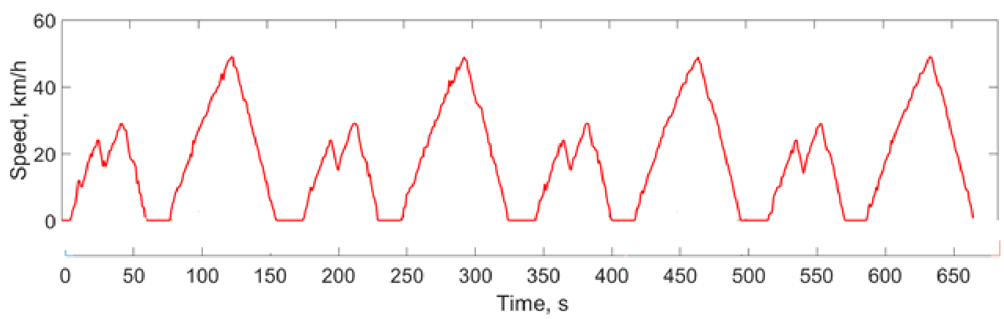

Figure 4: The DBDC cycle

Table 1: Basic properties of different diesels used in the study

Parametrs	BS-IV	BS-VI	FAME biodiesel	Renewable Diesel
Density (kg/m3)	820–845	820–860	882	770–790
Viscosity (cSt at 40°C)	2–4.5	2–4.5	4.9	2
Flash point(°C)	35	35	>61	>61
Cetane number	51	51	56	>70
Total sulphur (mg/kg)	50	10	120	<5
Aromatics (% m/m)	11	11	0.7	<1
FAME content (% v/v)	-	-	1.02	0
Ash (%)	0.01	0.01	<0.001	<0.001

[8] SAE Technical Paper 2011-01-1943

[9] Environmental Science and Technology 2010) 44(1): 476–482

[10] Particle and Fibre Toxicology(2009) 6 (19): 16 pp

Tail-pipe emissions (g/Km) of PM followed the order; BS-IV > BS-VI > BS-IV + FAME > BS-IV + Renewable diesel (Table 2), which is in accordance with earlier report by USEPA (Figure 1).

which has a lower cut-off diameter of 2.5 nm, and can detect particles up to 3 μm in diameter. We measured the particle size distribution with an Electrical Low Pressure Impactor (ELPI+, Dekati, detects particles between 10 nm

Table 2: Average Tail-pipe emissions (g/Km) of different pollutants during hot start study

Fuel Used	CO	HC	NOx	CO_2	PM
BS-IV	2.19 ± 0.074	0.059± 0.009	4.975± 0.004	330.6± 5.71	0.046
BS-VI	2.06± 0.13	0.041± 0.002	4.785± 0.008	332.133± 3.32	0.025
BS-IV+ FAME	2.15± 0.25	0.102± 0.014	4.763± 0.022	339.133± 7.41	0.017
BS-IV + RD	1.71± 0.139	0.076± 0.007	4.686± 0.041	331.033± 0.25	0.029

Average of three tests ± Standard Error, RD – Renewable diesel, FAME– Fatty Acid Methyl Ester

During the study, the measurement of SO2 was not considered as the focus of the study was on tail-pipe particulate emissions; however, high concentration of sulfur (Table 1) present in the FAME biodiesel may increase the tail-pipe emission of SO_2.

The particle number concentration was measured with a Condensation Particle Counter (CPC, TSI model 3776), and 10 μm), and the particles were mostly below 200 nm in diameter. Emission of particles remained significantly higher throughout the driving cycle with the BS-IV+FAME compared to other fuels and there is no significant difference in the number of particles emitted with BS-IV and BS-VI fuels (Figure 5). Again, with all fuel types the emissions of particles increases with increase in vehicle speed.

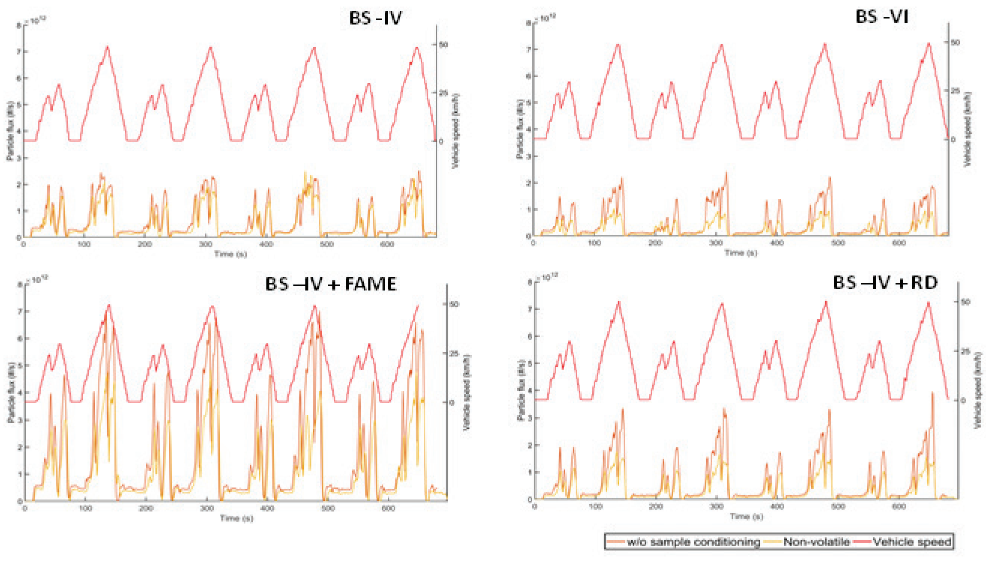

Figure 5 Time series of nano particle (0-200 nm) number emissions during the driving cycle, measured with the CPC

The number of the non-volatile particles emissions was also significantly higher with BS-IV+FAME compared to others (Figure 6). However, the tail-pipe emission of volatile particles with BS-IV +RD was at par with that with BS-VI fuel.

Further, Pirjola, Kuuluvainen, Timonen *et al.* (2019)[11] have studied the tail-pipe nanoparticle emissions from passenger car in Finland using the BS-IV, EN590 diesel and RD (100%). They have reported significant lower emissions of nanoparticles with RD (2.92×10^{13}/Km) compared to EN590 (2.96×10^{13}/Km) and BS-IV (3.55×10^{13}/Km).

- Hydrodecarboxylation process of producing biodiesel from vegetable oil, used cooking oil, etc. needs to be endorsed over esterification/transesterification.
- The process requires hydrogen and catalyst. Hence, research on the development of bio-hydrogen and suitable catalyst needs to be promoted.
- This study need to be undertaken with minute detail following standardized protocol for tail-pipe emission measurement to further establish the endorsement of hydrodecarboxylation over esterification/trans esterification process.

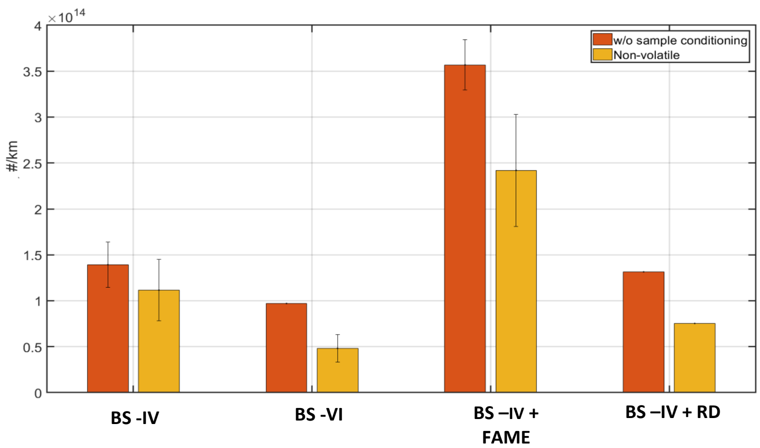

Figure 6 Nano particle (0-200 nm) number emissions with different fuels used in the study, measured with CPC

Study Outcome – in a Nutshell

This study suggests that the hydrodecarboxylation process of vegetable oil, used cooking oil, etc. can produce a better quality of biofuel from the tail-pipe emission perspective than the esterification/transesterification process of the above feedstocks to produce FAME biodiesel.

Recommendation

- The biodiesel proposed to be used for blending with the transport fuel should be ester free to reduce the tail-pipe emission of air pollutants, particularly most unhealthy nanoparticles (10–200 nm) for human health.

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[11] Applied Energy (2019) 254: 113636

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