EDITORIAL

The efficacy of biodiesel as an automotive fuel is well recognized. Several countries including U.S.A. are substituting the conventional mineral diesel by biodiesel to address the issues of air quality and energy security. The availability of wastelands, presence of a variety of non-edible oil seeds and plants, prospects of development of rural economy, biodegradability and emission benefits are some of the positive attributes which qualify biodiesel especially its blends to be a prominent contender for substituting petrodiesel in India. Moreover, the technological requirements for process and production of biodiesel being comparatively less cumbersome and its ability to fuel an existing diesel vehicle with no or minor modifications also make it a promising alternate fuel.

In recent years several initiatives are being taken in India to bring this fuel from the fields to the wheels. The Planning Commission, Government of India has constituted a Committee for " Development of biofuels" with experts from organizations like CPCB, IIP, MNES, IOC (R&D), etc.

This report presents a comprehensive view of biodiesel covering attributes like emissions, prospects of the fuel in India and other technological aspects. I am thankful to my colleagues Dr. B. Sengupta, Member Secretary, Dr. S.A. Dutta, Sr. Project Scientist and Shri R. Debroy, AEE for compiling this issue of PARIVESH.

I hope this will serve as a ready reference to the concerned authorities and general public.

(Dilip Biswas)
Chairman, CPCB

CONTENTS

INTRODUCTION

India imported about 2/3rd of its petroleum requirements last year, which involved a cost of approximately Rs. 80,000 crores in foreign exchange. Even 5% replacement of petroleum fuel by bio-fuel can help India save Rs.4000 crores per year in foreign exchange. It is utmost important that the options for substitution of petroleum fuels be explored to control this burgeoning import bill. The degrading air quality in our cities further warrant the quest for alternate cleaner fuels. With the stock of fossil fuels diminishing throughout the world and demand for energy based comforts and mobility ever increasing, time is ripe that we strike a balance between energy security and energy usage. Moreover having uplifted to such a sphere of engineering excellence, reverting back to the ages of the bull carts will prove next to impossible thereby compelling us to search for a basket of alternative fuels to derive energy to cater to our needs. Several sources of energy, especially for driving the automotives are being developed and tested. This report presents detailed information on Biodiesel together with its emission benefits. The prospect of biodiesel as an alternative to conventional fuels like gasoline and diesel and the experience of other countries is also outlined.

1.0 Biodiesel

Biodiesel is the name for a variety of ester-based oxygenated fuels derived from natural, renewable biological sources such as vegetable oils. Biodiesel operates in compression ignition engines like petroleum diesel thereby requiring no essential engine modifications. Moreover it can maintain the payload capacity and range of conventional diesel. Biodiesel fuel can be made from new or used vegetable oils and animal fats. Unlike fossil diesel, pure biodiesel is biodegradable, nontoxic and essentially free of sulphur and aromatics. The concept of using vegitable oil as a fuel dates back to 1895 when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil.

1.1 Production

Vegetable oils can be chemically reacted with an alcohol (methanol is the usual choice) to produce chemical compounds known as esters. Biodiesel is the name given to these esters when they are intended for use as fuel. Currently biodiesel is produced by a process called transesterification where the vegetable oil or animal fat is first filtered, then processed with alkali to remove free faty acids. It is then mixed with an alcohol (usually methanol) and a catalyst (usually sodium or potassium hydroxide). The oil's triglycerides react to form esters and glycerol, which are then separated from each other and purified. Much of the current interest in biodiesel production comes from soybean producers faced with an excess of production capacity, product surpluses and declining prices. Methyl soyate, or soydiesel, made by reacting methanol with soyabean oil, is the main form of biodiesel in the United States. Waste animal fats and used frying oil (known as "fellow grease"), peanuts, cottonseed, sunflower seeds and canola are some of the potential feedstocks for biodiesel. Esters made from all the above feedstocks can be used successfully as automotive fuel, although they may differ slightly in terms of energy content, cetane number and other physical properties.
Oil from rapeseed is also a raw material of choice for biodiesel production and is leading with a share of over 80% as a raw material source with highly suitable properties. Sunflower oil takes second place with over 10% share mostly in Italy and Southern France. Percentage shared of some feedstocks for biodiesel in various countries is given in Table-1.

Table-1: Feedstock for biodiesel in some countries

Feedstock	% Share	Countries
Rape seed	80%	
Sunflower	10%	Italy, Southern France
Soya bean		U.S.A.
Palm Oil		Malaysia
Linseed & Olive oil		Spain
Cotton Seed Oil		Greece
Jatropha Curcas Oil		Nicaragua
Beef Tallow		Ireland
Used frying Oil		Australia

The general process of biodiesel production is depicted in Figure-1. A fat or oil is reacted with an alcohol (methanol) in the presence of a catalyst to produce glycerine and methyl esters or biodiesel. The methanol is charged in excess to assist in quick conversion and recovered for reuse. The catalyst is usually sodium or potassium hydroxide, which has already been mixed with the methanol.

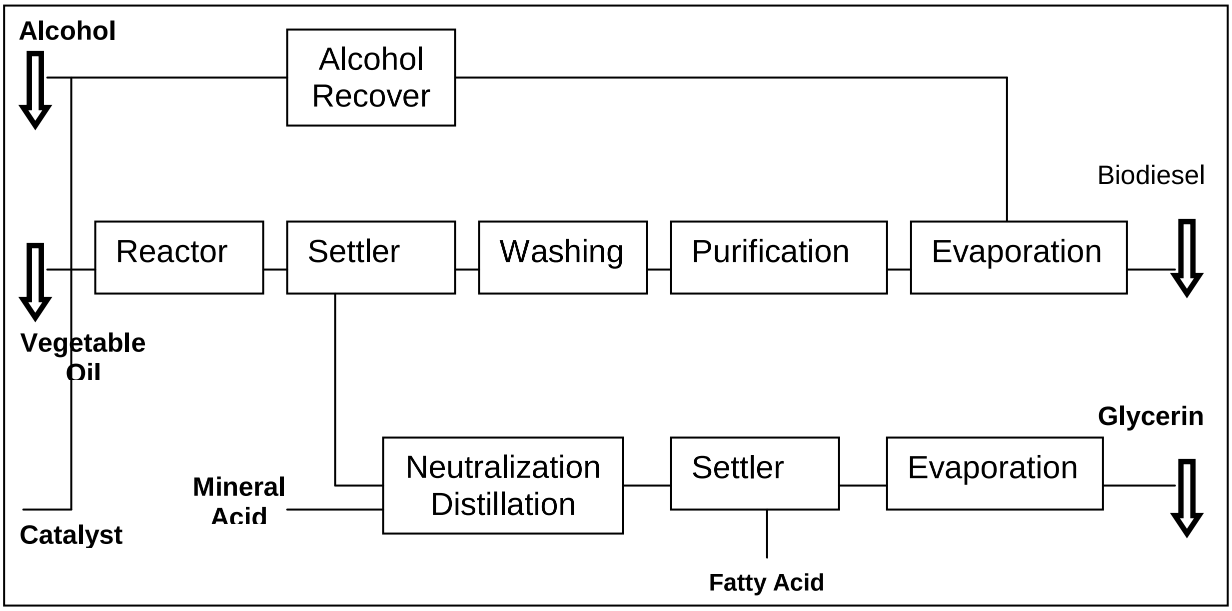


Fig-1: General Process of Biodiesel Production

2.0 Characteristics of Biodiesel

Biodiesel as automotive fuel has similar properties to petrodiesel and as such can be directly used in existing diesel engines with no or minor modifications. It can be used alone or mixed in any ratio with petrodiesel. The most common blend is B20, a mix of 20% biodiesel with 80% petroleum diesel. Biodiesel has 11% oxygen by weight and essentially contains no sulphur or aromatics.

2.1 Physical Properties

Some of the physical characteristics of biodiesel are given in Table-2.

Table-2: Physical properties of Biodiesel

Properties	Values
Specific gravity	0.88
Viscosity @ 20 Ċ (centistokes)	7.5
Cetane Index	49
Cold filter Plugging Point (Ċ)	-12
Net Heating Value (Kilojoules/Liter)	33,300

3.0 Emission Characteristics

Biodiesel is the only alternative fuel to have a complete evaluation of emission results and potential health effects submitted to the U.S.EPA under the Clean Air Act Section

211(b). These programs include the most stringent emissions testing protocols ever required by EPA for certification of fuels in the U.S. Emission results for pure biodiesel (B100) and mixed biodiesel (B20-20% biodiesel and 80% petrodiesel) compared to conventional diesel are given in Table-3.

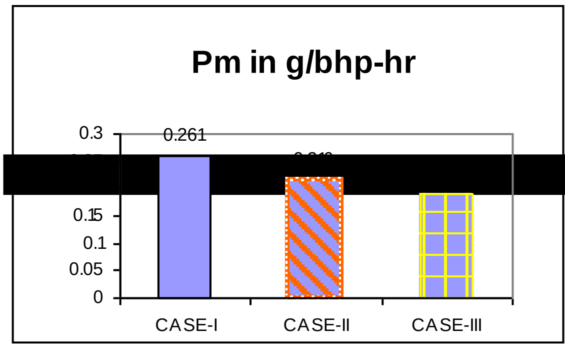
Table-3: Biodiesel Emissions Compared to Conventional Diesel

Emissions	B100	B20
Regulated Emissions		
Total Unburned Hydrocarbons	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
NOx	+13%	+2%
Non-Regulated Emissions		
Sulphates	-100%	-20%*
Polyciclic Aromatic Hydrocarbons (PAH)**	-80%	-13%
NPAH (Nitrated PAHs)**	-90%	-50%***
Ozone Potential of Speciated HC	-50%	-10%
Life-Cycle Emissions		
Carbon Dioxide (LCA)	-80%	
Sulphur Dioxide (LCA)	-100%	

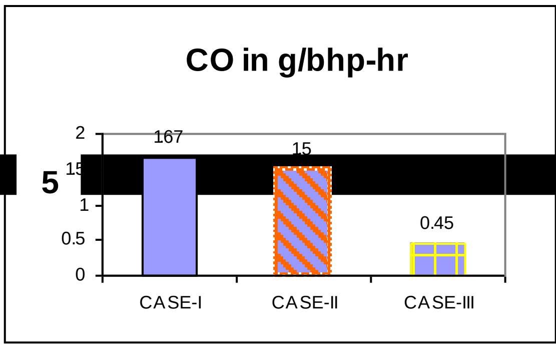
*Estimated from B100 results. **Average reduction across all compounds measured. ***2-nitroflourine results were within test method variability.

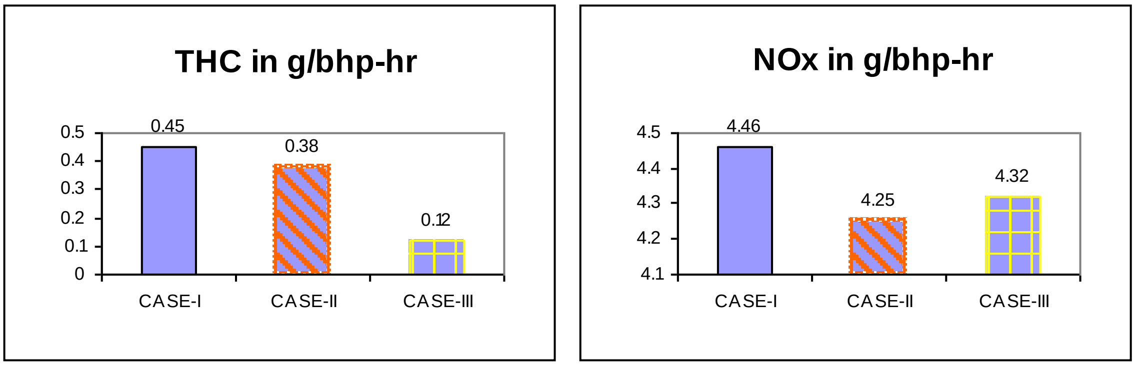
The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. Emissions of nitrogen dioxides are either slightly reduced or slightly increased depending on the duty cycle or testing methods. Biodiesel decreases the solid carbon fraction of particulate matter (since the oxygen in the fuel enables more complete combustion to CO2), eliminates the sulphur fraction (as there is no sulphur in the fuel), while the soluble or hydrogen fraction stays the same or is increased.

The life-cycle production and use of biodiesel produces approximately 80% less carbon dioxide and almost 100% less sulphur dioxide compared to conventional diesel. From Table-3 it is clear that biodiesel gives a distinct emission benefit almost for all regulated and non-regulated pollutants when compared to conventional diesel fuel but emissions of Nox appear to increase from biodiesel. Nox increases with the increase in concentration of biodiesel in the mixture of biodiesel and petrodiesel. This increase in Nox may be due to the high temperature generated in the fairly complete combustion process on account of adequate presence of oxygen in the fuel. This increase in Nox emissions may be neutralized by the efficient use of Nox control technologies, which fits better with almost nil sulphur biodiesel then conventional diesel containing sulphur. A comparative emission scenario with petrodiesel, biodiesel and biodiesel blends evolved from a real-life fleet study is presented in Figure-2.



[redacted]





CASE-I: Petrodiesel with 0.05% sulphur. CASE-II: 20% biodiesel with 3-degree injection timing adjustment. CASE-III: CASE-II + Catalytic Converter (Source: Twin Rivers Technologies, USA).

Fig-2: Comparative Emissions from petrodiesel & biodiesel

3.1 Nox and Biodiesel

Opinion regarding emissions of nitrogen dioxides varies from one study to another study. Some fleet tests concluded Nox emissions to have increased with the use of biodiesel as fuel while other studies proved that emissions of Nox can be controlled, if not decreased, by adjustments like retarding the injection timing or by adding heavy alkylate replacing 20% of the fuel of B20% blend biodiesel. Conclusions from different scientific studies are compiled below.

- "Adjustment of injection timing and engine operation temperature will result in reduction of Nox emission levels from biodiesel below that of petrodiesel levels"-Dr. Kerr Walker, Scottish Agricultural College (Journal of Royal Society of England).

- " Nitrous Oxides (Nox) are reported by several researchers to be increased with biodiesel. However, our own data shows a reduction in Nox, very consistently, throughout all our dynamometer tests. Nox started at 6.2 gm/mile for diesel and goes down to around 5.6 gm/mile with 100% biodiesel, with slightly more reduction with REE (rapeseed ethyl ester) than RME (rapeseed methyl ester)"-Toxicology, biodegradability and environmental benefits of Biodiesel; Charles L. Peterson and Daryl Reece, University of Idaho.

- " Fueling with biodiesel/diesel fuel blends reduced PM, THC and CO, while increasing Nox. Retarding the fuel injection timing reduced Nox emissions while maintaining the other emissions reductions"-DDC engine emission tests using methyl ester; L.G. Schumacher, W.G. Hires; University of Missouri.

- “ As the concentration of biodiesel increased, Nox emissions decreased. The B20A20 fuel blend effectively reduced the oxides of nitrogen emissions below that of baseline diesel fuel. Retarding the timing was an effective way of reducing Nox. Moreover, Nox emissions from biodiesel can be successfully reduced below that of baseline diesel fuel either retarding injection timing or replacing 20% of the baseline diesel fuel of B20 blend with heavy alkylate”-Engine exhaust emissions evaluation of a Cummins L10E with biodiesel; William Marshall, Leon G. Schumacher; Society of Automotive Engineers, SAE paper # 952363.

- “ Nitrogen Oxides (Nox) emissions from biodiesel increase or decrease depending on the engine family and testing procedures. Nox from pure biodiesel (100%) increased in this test by 13%. However, biodiesel’s lack of sulphur allows use of Nox control technologies that cannot be used with conventional diesel. So, biodiesel Nox emissions can be effectively managed and efficiently eliminated as a concern of the fuel’s use”- U.S. National Biodiesel Board, Biodiesel Report.

- “ There are reliable proven methods for baselining or even reducing Nox produced when using biodiesel. I have certified emissions for the urban bus retrofit program with EPA using this technology. This package included use of an

3.2 Comparison of particulate composition: Diesel Vs. Biodiesel

Table-4 gives a comparison of particulate emissions of all forms (insoluble, fuel soluble, lube soluble and inorganic soluble) from petrodiesel and RSME (biodiesel from rapeseed methyl ester).

Table-4: Particulate Composition-Diesel Vs. Biodiesel

Test	Fuel	Total PM (g/mile)	Insolubles (g/mile)	Fuel Solubles (g/mile)	Lube Solubles (g/mile)	Soluble Inorganic (g/mile)
Cold FTP	Diesel	0.311	0.259	0.021	0.031	17
	RSME	0.258	0.118	0.104	0.036	54
Difference %		-17%	-54%	+49%	+16%	+318%
Hot FTP	Diesel	0.239	0.206	0.012	0.021	14
	RSME	0.190	0.101	0.068	0.021	47
Difference %		-21%	-51%	+567%	0%	+335

(Source: Concawe Report No. 2/95).

The study on mechanism of soot formation from diesel as well asbiodiesel (RSME) indicates reduction in total particulate matter. When the engine is operated on RSME, soot emissions (insolubles) are dramatically reduced, but the proportion of emissions composed of fuel derived hydrocarbons (fuel solubles), condensed on the soot, is much higher as can be seen from the Table given below. This implies that the RSME may not burn to completion as readily as diesel fuel. It should, however, be noted that gaseous HC emissions were reduced with RSME in the above tests. Since concern over particulates arises partly from the potential harmful effects of the soluble fraction, it might be suspected that emissions from RSME would be more harmful however data shows no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on 20% RSME and 80% diesel blends.

3.3 Emissions of Greenhouse gas

Comparative emissions of greenhouse gases for diesel and biodiesel in various stagers of life cycle is depicted in Table-5. Life cycle analysis for various fuels including biofuels is diagrammatically represented in Figure-3, which shows that biodiesel (RSME) has the lowest Greenhouse emissions followed by ethanol from wood. Emissions of greenhouse gases during the production of diesel are about 32 g/km (Fig-5). These are hardly a half of the emissions from producing biodiesel even when straw rather than electricity is used to fire the processing. However, this difference is far outweighed by the emissions of CO2 during the combustion of the diesel itself (245 g/km).

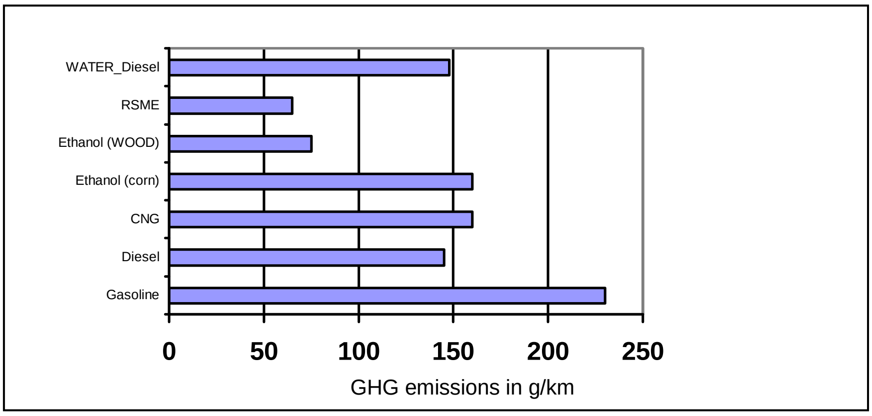


Fig-2: Life Cycle Analysis-GreenHouse Gas Emissions of Different Fuels
(CO_2+CO_2 Equivalent of the other pollutants CH_4 and N_20)
Table-5: Emissions of Greenhouse Gases (g/km)

	Diesel		Biodiesel
Extraction	15.84	Fertiliser Production	15
Transport	2.74	Fertiliser Application	10
Refining	13.63	Agricultural Machinery*	25
Distribution	0.95	Oil Production	3
Vehicle Operation	245	Processing Straw**	1
		Processing Gas	17
		Transport	5
		Vehicle Operation	0
Total	278.16	Total (Straw Processing)	59
		Total (Gas Processing)	75

*Assumed mineral diesel oil used.
**Emissions of straw include those from transporting straw.

4.0 Biodiesel Specifications

The key components, which determine the quality of biodiesel are monoalyl esters, dialkyl esters, residual vegetable oil, free glycerin, reactant alcohol, free fatty acids and the residual catalyst. In December 2001, American Society of Testing & Materials (ASTM) issued a specification (D6751) for biodiesel (B100) which is presented in Table-6. A provisional specification for B20 biodiesel is also notified by the ASTM known as ASTM PS121 (Table-7). Table-8 summarizes standards for biodiesel in various countries and Table-9 shows a comparison of selected properties of biodiesel and petrodiesel.

Table-6: ASTM Specification (D6751) for B100

Property	ASTM Method	Limits	Units
Flash Point	D93	130 min.	Degrees C
Water & Sediment	D2709	0.050 max.	% Volume
Kinematic Viscosity (40 C)	D445	1.9-6.0	mm^2/sec
Sulfated Ash	D874	0.020 max.	% mass
Sulphur	D5453	0.05 max.	% mass
CopperStrip Corrosion	D130	No.3 max.	
Cetane	D613	47 min.	
Cloud Point	D2500	Report	Degrees C
Carbon Residue (100% Sample)	D4530*	0.050 max.	% mass
Acid Number	D664	0.80 max.	Mg KOH/gm
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass
Phosphorous Content	D4951	0.001 max.	% mass
Distillation Temperature (90% Recovered)	D1160	360 max.	Degrees C

*The carbon residue shall be run out on the 100% sample.

Table-7: ASTM PS121 for B20

Property	ASTM Method	Limits	Units
Flash Point	D93	100 min.	Degrees C
Water & Sediment	D2709	0.050 max.	% Volume
Kinematic Viscosity (40 C)	D445	1.9-6.0	mm^2/sec
Sulfated Ash	D874	0.020 max.	% mass
Sulphur	D5453	0.0015 max.	% mass
Copper Strip Corrosion	D130	No. 3 max.	
Cetane Number	D613	46 min.	
Cloud Point	D2500	Report	Degrees C
Carbon Residue (100% Sample)	D4530	0.050 max.	% mass
Carbon Residue (Ramsbottom)	D524	0.090 max.	% mass
Acid Number	D664	0.80 max.	Mg KOH/gm
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass

Table-8: Biodiesel Standards of Different Countries

Specifications	Units	Australia	France	Germany	Italy	Sweden	USA	Draft EU
Standard/Specification		ONC1191	-	DINE51606	UNI10635	SS155436	ASTMD6751	EN14214
Introduction Date		Jly 1997	Spt1997	Spt1997	Apr1997	Nov1996	Dec2001	2001
Density @15ċ	g/cm^3	0.85-0.89	0.87-.89	.875-0.90	0.86-0.90	0.87-0.90	-	0.86-0.90
Viscosity@40ċ	mm^2/s	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	1.9-6.0	3.5-5.0
Flash Point	ċ	≥100	≥100	≥110	≥100	≥100	≥130	≥130
CFPP	ċ	0/-15	-	0-10/-20	-	-5	-	0/-15
Pour Point	ċ	-	-10	-	0/-15	-	-	-
Sulphur	%max	0.02	0.02	0.01	0.01	0.01	0.05	0.01
CCR 100%max		0.05	-	0.05	-	-	0.05	-
10%disti.residue	%max	-	0.3	-	0.5	-	-	0.3
SulphatedAshx	%max	0.02	-	0.03	-	-	0.02	0.01
(Oxid).Ash ,mx	%mass	-	-	-	0.01	0.01	-	-
Water max.	mg/kg	-	200	300	700	300	≤0.05	500
TotalContaminants	mg/kg	-	-	20	-	20	-	-
Cu Corrosion	3h/50ċ	-	-	1	-	-	NO.3	1
Cetane No.		≥49	≥49	≥49	-	≥48	≥47	≤≥49
Neutral No.		≤0.8	≤0.5	≤0.5	≤0.5	≤0.6	≤0.8	≤0.02
Methanol	%mass	≤0.20	≤0.01	≤0.3	≤0.02	≤0.02	-	≤0.02
Ester Content	%mass	-	≥96.5	-	≥98	≥98	-	≥96.5
Monoglyceride	%mass	-	≤0.8	≤0.8	≤0.8	≤0.8	-	≤0.8
Diglyceride	%mass	-	≤0.2	≤0.4	≤0.2	≤0.1	-	≤0.20
Triglyceride	%mass	-	≤0.2	≤0.4	≤0.1	≤0.1	-	≤0.03
Free Glycerol	%mass	≤0.02	≤0.02	≤0.02	≤0.05	≤0.02	≤0.02	0.25
Total Glycerol	%mass	0.24	0.25	0.25	-	-	0.24	≤115
Iodine No.		≤120	≤115	≤115	-	≤125	-	-
C18:3 & higher acids		≤15	-	-	-	-	-	10
Phosphorous	ppm	≤20	≤10	≤10	≤10	≤10	≤10	10
Alkaline Matter	(Na,K)	-	≤5	≤5	≤10	≤10	-	≤360
Distillation 95%	ċ	-	≤360	-	-	-	≤360	*
IBP min.	ċ	-	-	-	-		-	*
Bound Glycerin		-	-	-	-		-	Max 0.8
Oxidation Stability	Hrs.	-	-	-	-		-	6 min.
Sediment		-	-	-	-		-	≤0.05
Cloud Point		-	-	-	-		*	-

*Report

Table-9: Selected Fuel Properties for Petrodiesel & Biodiesel

Fuel Property	Petrodiesel	Biodiesel
Fuel Standard	ASTM D975	ASTM PS121
Fuel Composition	C10-C21 HC	C12-C22 FAME
Lower Heating Value, Btu/gal	131,295	117,093
Kin. Viscosity, @40 C	1.3-4.1	1.9-6.0
Specific Gravity, kg/l @ 60 F	0.85	0.88
Density, lb/gal @ 15 C	7.079	7.328
Water, ppm by wt.	161	0.05% max.
Carbon, wt%	87	77
Hydrogen, wt%	13	12
Oxygen by dif. Wt%	0	11
Sulphur, wt%	0.05 max.	0.00-0.0024
Boiling Point, Degrees C	188-343	182-338
Flash Point, Degrees C	60-80	100-170
Cloud Point, Degrees C	-15 to 5	-3 to 12
Pour Point, Degrees C	-35 to -15	-15 to 10

Cetane Number	40-55	48-65
Stoichometric Air/Fuel Ratio	15	13.8
BOCLE Scuff, gm	3,600	>7,000
HFRR, microns	685	314

5.0 Toxicity of Biodiesel

Impacts on human health represent a significant criteria as to the suitability of the fuel for commercial applications. Health effects can be measured in terms of fuel toxicity to the human body as well as health impacts due to exhaust emissions. Tests conducted by the Wil Research Laboratories investigated the acute oral toxicity of pure biodiesel fuel as well as B20 in a single dose study on rats, which concluded that biodiesel is not a toxic and there is no hazards anticipated from ingestion incidental to industrial exposure. The acute oral LD50 (lethal dose) is greater than 17.4-g/kg-body weight, which by comparison is far safer then even table salt. According to NIOSH (National Institute for Occupational Safety & Human Health), a 96-hr. lethal concentration of biodiesel for bluegills was greater than 1000 mg/l and this aquatic toxicity is deemed as insignificant. Other related effects of biodiesel are given below:

- Very mild human skin irritation. It is less than the irritation produced by 4% soap and water solution.
- It is biodegradable. It degrades at least 4 to 5 times faster then conventional diesel fuel.
- Biodiesel has a flash point of about 300 F well above conventional diesel fuel.
- Spills of biodiesel can decolorize any painted surface if left for long.
- There is no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on biodiesel (20%RSME80% diesel).

5.1 Storage & Infrastructure

In general, the standard storage and handling procedures used for petroleum diesel may be used for biodiesel. It is preferable to store the fuel in clean, dry and dark environment. Biodiesel may gel at low temperatures and care needs to be taken to avoid temperature extremes. Acceptable storage tank materials include mild steel, stainless steel, fluorinated polyethylene and fluorinated polypropylene. Biodiesel has a solvent effect, which releases the deposits accumulated on tanks and pipes, which previously have been used for diesel. These deposits can be expected to clog filters initially and precautions should be taken for this.

5.2 Materials Compatibility

Biodiesel over time will soften and degrade certain types of elastomers and natural rubber compounds. Materials like bronze, brass, copper, lead, tin and zinc may oxidize the diesel or biodiesel fuels and create sediments. Moreover, lead solders and zinc linings should be avoided, as should copper pipes, brass regulators and copper fittings. It is desirable to change all components, which are not biodiesel compatible to aluminum or stainless steel. The effect of B20 on vulnerable materials is diluted compared to higher blends. It may also be noted that most of the new generation vehicles can take biodiesel without any materials compatibility problems as they are already tuned to using low sulphur diesel, biodiesel etc. Compatibility of some materials with biodiesel is given in Table-9.

Table-9: Material Compatibility with Biodiesel Fuels

Material	Biodiesel Type	Effect compared to petrodiesel
Teflon	B100	Little change
Nylon 6/6	B100	Little change
Nitrile	B100	Hardness reduced 20%
	B100	Swell increased 18%
Viton A401-C	B100	Little change
Viton GFLT	B100	Little change
Fluorosilicon	B100	Little change in hardness
	B100	Swell increased 7%
Fluoroethane	B100	Little change in hardness
	B100	Swell increased 6%
Polypropylene	B100	Hardness reduced 10%
	B100	Swell increased 8-15%
Polyvinyl	B100	Much worse
	B50	Worse
	B40	Worse
	B30	Worse
	B20	Comparable
	B10	Comparable
Tygon	B100	Worse

Source: National Renewable Energy Laboratory (NREL).

5.3 Solvency of Biodiesel

Biodiesel is a mild solvent. On prolonged contact with painted surfaces, it may deface some paints. Always wipe up spills and dispose of rags in a safe manner. Biodiesel soaked rags may self-combust if not handled properly. The most commonly encountered problem with solvency is biodiesel’s tendency to “clean out” storage tanks, including the vehicle fuel tanks and systems. Some type of diesel tends to form sediments that stick to and accumulate in storage tanks, forming layers of sludge or slime in the fuel systems. The older the system, and the poorer the maintenance, the thicker the accumulated sediments become. Biodiesel will dissolve these sediments and carry the dissolved solids into the fuel systems of the vehicles. Fuel filters will catch most of it, but in severe cases, the dissolved sediments have caused fuel injector failure. Few problems have been encountered with B20 in typical diesel storage situations. However, the solvency effect of the biodiesel in B20 is sufficiently diluted so that most problems encountered are minor and in general the problem goes away after the first few tanks of fuel.

5.4 Lubricity of Biodiesel

Biodiesel blends offer superior lubricating properties, which may reduce engine wear and extend the life of fuel injection systems. Tests with two leading lubricity measuring systems-the BOCLE machnine and the HFRR machine-show biodiesel blends offer better lubricating properties then conventional petroleum diesel. Lubricity is especially important for rotary/distributor type fuel injection pumps in which parts are lubricated by the fuel itself and not by the engine oil. The result of a lubricity test done by Exxon with petrodiesel and biodiesel blends is given in Table-10.

Table-10: Lubricity Results (HFRR Machine)

Fuel Type	Scar	Friction	Film %
Conventional low sulphur diesel	492	0.24	32
Blend (80% petrodiesel + 20% biodiesel)	193	0.13	93
Blend (70% petrodiesel + 30% biodiesel)	206	0.13	93
Petrodiesel + 1000 ppm lubricity additive	192	0.13	82
Petrodiesel + 500 ppm lubricity additive	215	0.14	94
Petrodiesel + 300 ppm lubricity additive	188	0.13	93

Source: Exxon & Interchem Environmental Inc.

6.0 Advantages of biodiesel

The benefits of biodiesel are:

- The lifecycle production and use of biodiesel produces approximately 80% less carbon dioxide emissions, and almost 100% less sulphur dioxide. Combustion of biodiesel alone produces over a 90% reduction in total unburned hydrocarbons, and a 75-90% reduction in aromatic hydrocarbons. Biodiesel further provides significant reductions in particulates and carbon monoxide than conventional diesel fuel.
- Biodiesel is the only alternative fuel that runs in any conventional, unmodified diesel engine.
- Needs no change in refueling infrastructures and spare part inventories.
- Maintains the payload capacity and range of conventional diesel engines.
- Diesel skilled mechanics can easily attend to biodiesel engines.
- 100% domestic fuel.
- Neat biodiesel fuel is non-toxic and biodegradable. Based on Ames Mutagenicity tests, biodiesel provides a 90% reduction in cancer risks.
- Cetane number is significantly higher than that of conventional diesel fuel.
- Lubricity is improved over that of conventional diesel fuel.
- Has a high flash point of about 300 F compared to that of conventional diesel, which has a flash point of 125 F.

6.1 Disadvantages of biodiesel

Some of the disadvantages of biodiesel are:

- Quality of biodiesel depends on the blend thus quality can be tampered.
- Biodiesel has excellent solvent properties. Any deposits in the filters and in the delivery systems may be dissolved by biodiesel and result in need for replacement of the filters.
- There may be problems of winter operatibility.
- Spills of biodiesel can decolorize any painted surface if left for long.
- Neat biodiesel demands compatible elastomers (hoses, guskets, etc.).

6.2 Operation & Performance

- Horsepower, fuel economy and torque are similar to those of conventional diesel fuel engines.
- Cetane number is higher than that of conventional diesel fuel.
- Improved lubricity.
- No engine modification required when used in compression ignition engines.
- Range of vehicle akin to that of conventional diesel vehicles.

7.0 Prospective feedstock in India

Oil can be extracted from a variety of plants and oilseeds. Under Indian condition only such plant sources can be considered for biodiesel production which are not edible oil in appreciable quantity and which can be grown on large-scale on wastelands. Moreover, some plants and seeds in India have tremendous medicinal value, considering these plants for biodiesel production may not be a viable and wise option. Considering all the above options, probable biodiesel yielding trees in India are:

- *Jatropha curcas* or Ratanjot
- *Pongamia pinnata* or Karanj
- *Calophyllum inophyllum* or Nagchampa
- *Hevea brasiliensis* or Rubber seeds
- *Calotropis gigantia* or Ark
- *Euphorbia tirucalli* or Sher; and
- *Boswellia ovalifololata.*

Of all the above prospective plant candidates as biodiesel yielding sources, Jatropha curcas stands at the top and sufficient information on this plant is already available. One hectare Jatropha plantation with 4400 plants per hectare under rain fed conditions can yield about 1500 literes of oil. It is estimated that about 3 million hectares plantation is required to produce oil for 10% replacement of petrodiesel. The residue oil cake after extraction of oil from Jatropha can be used as organic fertilizers. It is also estimated that one acre of Jatropha plantation could produce oil sufficient to meet the energy requirement of a family of 5 members and the oil cake left out when used as fertilizer could cater to one acre. The fact that Jatropha can be grown in any wastelands with less irrigation gives it a distinct advantage for consideration as the prime biodiesel feedstock in Indian conditions.

7.1 Biodiesel Initiatives in India

India has great potential for production of bio-fuels like bio-ethanol and biodiesel from non-edible oil seeds. From about 100 varieties of oil seeds, only 10-12 varieties have been tapped so far. The annual estimated potential is about 20 million tones per annum. Wild crops cultivated in the westland also form a source of biodiesel production in India and according to the Economic Survey of Government of India, out of the cultivated land area, about 175 million hectares are classified as waste and degraded land. Thus, given a demand-based market, India can easily tap its potential and produce biodiesel in a large scale. Table-11 depicts the annual production of non-edible oil seeds in India. Production trends of vegetable oils in India (both edible and nonedible oils) from 1990 to 2000 are given in Table-12.

During 1995, CPCB had interactions with one of the biodiesel expert company of USA called Twin Rivers Technologies for examining the efficacy of biodiesel blends in reducing emissions from diesel vehicles. The task of conducting the tests was lined up with IOC (R&D) and sample of biodiesel was imported from USA for the tests. However, this initiative did not materialize at the end.

In recent years trials on automobiles using biodiesel have been conducted by institutes like IOC (R&D), SIAM, IIT, Delhi, ICAR etc. IOC (R&D) has already set up a biodiesel production facility of 60 kg/day at Faridabad. Mahindra & Mahindra Ltd. has a pilot plant utilizing Karanj for biodiesel in Mumbai. This plant has carried out successful trails on tractors using this fuel. Parameters such as power, torque, fuel consumption, emissions, etc. have been found quite satisfactory on tractors operating on this biodiesel. Field trials for about 30000 kms have also been carried out on the tractors. Production of biodiesel unlike petrodiesel, is relatively a less cumbersome process and therefore large scale production can be undertaken with a short lead time.

7.2 Constitution of Committee for Bio-fuels in India:

On 18th July 2002, the Planning Commission, Government of India constituted a Committee on "Development of Bio-fuels". This committee under the chairmanship of Dr. D.N. Tewari (Member, Planning Commission) has members from various ministries and organizations including CPCB. The " Committee on development of biofuels" will discuss and recommend the followings:

1. The current level of use of bio-fuels and their prospects for commercial utilization.
2. The various aspects connected with blending of biofuels with mineral oils.
3. The storage, handling and distribution aspects.
4. The commercial scale development of bio-fuels based on costs & benefits.
5. Development of specifications and quality standards for bio-fuels.
6. Identification of prospective plant sources for bio-ethanol, biodiesel and hydrocarbons and determine their R&D needs.
7. To frame a plan for development of plantations, development of demo scale and large-scale plantation and strategies for collection of seeds.
8. Suggest strategies for marketing.

9. Suggest measures for effective coordination between ministries and institutions engaged in R&D of bio-fuels.
10. Suggest strategies and approaches for mobilizing financial resources.
11. Any other aspect that the Committee may consider important.

This main Committee has further constituted seven sub-Committees to recommend for several aspects of biofuels. The seven sub-committees are:

i) Committee on Products/blending aspects of bio-fuels.

ii) Committee on engine development & modifications.

iii) Committee on standards & quality aspects of bio-fuels.

iv) Committee on Legal Regulations on bio-fuels.

v) Committee on role of NGOs, Financial Institutions, etc.

vi) Committee on Institutional Arrangement for bio-fuels.

vii) Committee on Environmental issues pertaining to bio-fuels.

The Committee on " Environmental effects pertaining to use of biofuels" is headed by Prof. D.K. Biswas, Chairman, CPCB. This committee has also co-opted various experts from different organizations. The Terms of Reference (TOR) of this committee are as follows:

1. Study the effect of using bio-fuels on environment and human health; and
2. Study the various measures that can be undertaken to control emissions or its adverse toxic behavior, if any.

Table-11: Annual Production of Non-edible Oil Seeds in India

Type	Production (MT)	Oil %
Neem	500	30
Karanja	200	27-39
Kusum	80	34
Pilu	50	33
Ratanjot	-	30-40
Jaoba	-	50
Bhikal	-	37
Wild Walnut	-	60-70
Undi	04	50-73
Thumba	100	21

Source: Interim Report of " Auto Fuel Policy".

Table-12: Production Trends of Edible & Nonedible oils in India

Years	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00

Edible Oils										
Groundnut	1730	1633	1971	1802	1856	1744	1989	1697	2067	1222
Mustard	1600	1793	1470	1630	1761	1835	2037	1439	1733	1823
Seasamum	260	220	236	176	182	165	199	177	167	161
Sufflower	63	40	68	102	83	75	88	24	47	54
Nigerseed	39	38	34	41	40	40	32	30	30	32
Soyabean	234	224	305	427	354	459	484	582	643	611
Sunflower	314	430	426	485	438	453	450	319	340	288
Cottonseed	349	346	405	380	424	457	505	397	217	412
Cocunut	288	298	332	354	393	383	386	376	441	441
Total	4877	5022	5247	5397	5531	5611	6170	5041	5685	4603
Non-edible oils										
Linseed	96	85	81	96	93	85	90	69	77	84
Castor	250	201	217	222	295	271	314	289	293	271
Total	346	286	298	318	388	356	404	358	370	355

Source: agricoop.nic.in

7.3 Recommandations

Biodiesel has distinct advantage as an automotive fuel. Initial cost may be higher but feedstock diversity and multi-feedstock production technologies will play a critical role in reductions in production cost and making the fuel economically viable. The following points may be considered before introducing the fuel in India:

1. Pilot projects and R&D work on biodiesel needs to be encouraged and supported to establish techno-economic viability of large-scale production.
2. Specifications for biodiesel should be established along with test methods and should be independent of any specific feedstock.
3. Biodiesel may be introduced as a diesel fuel extender or blends (B5, B20) and not as a sole diesel engine fuel (B100).
4. The process and production stage for biodiesel may become very decentralized and uncontrolled down the line. It may be produced by various local units in small scale using different feedstocks, different technologies and different practice of housekeeping thereby increasing the chance of getting tampered and adulterated. Therefore, proper planning, streamlining, quality control logistics and institutional arrangements need to be worked out before introduction of the fuel.
5. Government may consider providing support to the activities related to collection of seeds, production of oil from non-edible sources, production of bio-fuels and its utilization for cleaner environment.
6. Legal framework should be there to enforce regulations on bio-fuels.
7. Energy education on biodiesel programme and storing information and database for wider information dissemination among the public at large should be taken up at a larger scale.

8.0 References

1. CPCB correspondences with Twin Rivers Technologies, USA.
2. Alternate Fuel News, Vol.4, US Department of Energy.
3. Biodiesel Handling & Use Guidelines, September 2001, NREL/TP-580-30004.

4. Concawe Report on Alternative Fuels, No. 2/95.
5. Setting the ethanol limits in petrol-Environment Australia, 2002.
6. ECOTECH Report-2002, UK.
7. Website of agricoop.nic.in
8. Website of National Biodiesel Board, USA.
9. Website of Alternate Fuels Data center.
10. On going work on use of ethanol blending in petrol and bio-fuels by the group set up by MoPNG and MNES.
11. Website of biodiesel.org.
12. Deliberations of the meetings of the expert committee on "Development of Bio-fuels" set up by the Planning Commission, Government of India.

Published By : Dr. B. Sengupta, Member Secretary, Central Pollution Control Board, Delhi – 32
Printing Supervision & Layout : P.K. Mahendru, Anamika Sagar and Mohd. Javed
Fax : 91-11-2217079/2204948 EPABX : 2225792, 2222073, 2222856 TELEX : 031-66440 PCON IN
e-mail : cpcb@alpha.nic.in; Website : http://www.cpcb.nic.in/
Printed at : National Institute of Science Communication
Dr. K.S. Krishnan Marg, New Delhi - 12