Asian J. Exp. Sci., Vol. 19, No. 2, 2005, 13-22

Biodiesel as an Alternative Fuel for Pollution Control in Diesel Engine

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Abstract : Diesel vehicles are the major source for air pollution; there is great potential for global warming due to discharge of greenhouse gases like CO_2 from vehicles. Many lung problems are connected with particulate matter emitted by diesel vehicle including dust, soot and smoke. People are exposed to pollution even as they talk or when stir up the dust when they walk. Biodiesel is a non-toxic, biodegradable and renewable fuel. Compared to diesel fuel, biodiesel produces no sulfur, no net carbon dioxide, less carbon monoxide and more oxygen. More free oxygen leads to the complete combustion and reduced emission. Overall biodiesel emissions are very less compared to diesel fuel emissions which is promising pollution free environment.

Abundant source of vegetable oil in India and its ease of conversion to biodiesel help to save large expenditure done on import of petroleum products and economic growth of country. Bio-diesel also generate huge rural employment and degraded lands can be restored due to plantation of oil plants which helps in reducing pollution. Lot of work is going on in different countries on different types of vegetable oils like sunflower oil, karanji oil, linseed oil, soya bean oil, palm oil and many more, which can be used in those countries as per availability, our research is in progress on jatropha oil, jatropha oil methyl ester (biodiesel) and its blends with diesel. Research is going on in right direction and likely to get surprising results.

Key words : Biodiesel, vegetable oil, methyl ester, diesel engine performance, emissions.

Introduction :

With increasing power consumption and an increase in number of transport vehicle the coal pits are going to empty within short period. The world at present is heavily depends upon petroleum fuels for transportation and for operating agriculture machinery. Diesel engines dominates the field of transportation and agriculture machinery on account of its superior fuel efficiency, the consumption of fuel in India is several times higher than that

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of petrol consumption. Roughly estimate of petrol and diesel consumption is 30 and 70%, respectively.

The diesel engine is a major contributor to air pollution especially within cities and along urban traffic routes. In addition to air pollution that causes ground level ozone and smog in the atmosphere, diesel exhaust also contains particulate and hydrocarbon toxic air contaminants (TAC). Now society has become more aware of harmful effects of the various exhaust emission coming out of the engines and there is tremendous pressure on researchers to reduce exhaust emissions. Various harmful effect of exhaust emission are already established and known to today's society. Carbon monoxide, if inhaled, enters the blood stream and causes hypoxia, which leads to further health problems. Hydrocarbon emissions are irritant and odorants and some of them carcinogenic. Oxides of nitrogen are found to be responsible for many of the pulmonary diseases.

Diesel particulate matter (PM) is made up of very small particles that are inhaled deep into the human lung. Since there is no effective natural removal process from this area of the lung, the particles are increasingly urgent health concern (Mooney, 2000). Therefore, it has become very essential to develop the technology of IC engines, which will reduce the consumption of petroleum fuels and exhaust gas emissions.

Irrecoverable rapid depletion of petroleum reserves, high price fluctuations, uncertainty in supply to consuming nations, high expenditure on fuel import, harmful effects of various exhaust emission on the human being and environment forces to search for alternative fuels that they themselves can produce. These alternative fuels should be preferably available from renewable sources. Therefore, attention is mainly focused towards biomass- based fuels. Alternative considered are ethanol, methanol, biogas and vegetable oil, methyl or ethyl ester of vegetable oil (biodiesel). Biodiesel is a vegetable oil-based fuel that runs in diesel engines - cars, buses, trucks, construction equipment, boats, generators, and oil home heating units. It's usually made from soy or canola oil, and can also be made from recycled fryer oil. One can blend it with regular diesel or run 100% biodiesel. The different benefits are : 1) National security. Since it's made domestically, it reduces our dependence on foreign oil. 2) National economy.

Using biodiesel keeps our fuel buying dollars at home instead of sending it to foreign countries. This reduces our trade deficit and creates jobs. 3) It's sustainable and non-toxic. Biodiesel is 100% renewable there will be no paucity of fuel never run out of it. Besides this, if it gets into water supply, it causes no problem. 4) Emissions. Biodiesel is nearly carbon-neutral, meaning it contributes almost zero emissions to global warming as well as also dramatically reduces other emissions. 5) Engine life. Studies have shown it reduces engine wear by as much as one half, primarily because it provides excellent lubrication. Even a 2% biodiesel/98% diesel blend may be of great use. 6) Drivability. An immediate smoothing of the engine with biodiesel is also claimed. It just runs quieter, and produces less smoke.

Suitability of vegetable oil as diesel engine fuel

Biomass derived oils are quite promising alternative fuels for diesel engines. A diesel engine was run on peanut oil at the Paris exposition of 1900 (Stewart *et al.,* 1981). The vegetable oils include soyabean oil, cottonseed oil, sunflower oil, rapeseed oil, palm oil, linseed oil, jatropha oil, neem oil and mahua oil. There are more than 350 oil bearing crops identified whose cetane number and calorific value are comparable with those of diesel fuels and are compatible with material vehicle fuel system. Vegetable oil is of special interest because it has shown to significantly reduce particulate emission relative to petroleum diesel. Recent studies indicates that cetane number, aromatic content and type, sulpher content, density are important factor for emission control (Giannelos *et al.,* 2002) use of vegetable oils in diesel engines leads to slightly inferior performance and higher smoke emissions due to their high viscosity and carbon residue (Senthil Kumar *et al.,* 2000). Filter plugging and cold starting along with higher specific consumption observed. It is due to the higher viscosity and lower calorific value of vegetable oils (Stewart *et al.,* 1981). The performance of vegetable oil can be improved by modifying vegetable oil by transesterification process.

Suitability of biodiesel and its effect on environment and health

Biodiesel is methyl or ethyl ester of fatty acid made from vegetable oils (both edible and non-edible). India having great demand of edible oil for cooking purpose and it is expensive too. The main source for biodiesel in India can be non-edible oil. Non-edible oil can be obtained from plant species such as *Jatropha carcus* (ratanjyot), karanja, mahua, and neem.

A number of researchers have shown biodiesel has fuel properties and provides similar engine performance as that of diesel fuel. It is non-toxic, biodegradable, renewable fuel. Further advantage over petroleum – based diesel fuel include a high cetane number, low sulpher, low aromatics, low volatility and presence of oxygen atom in the molecule (Suryawanshi and Deshpande, 2004). The use of biodiesel in conventional diesel engines results in substantial reduction of unburned hydrocarbon, carbon monoxide and particulate matter. Biodiesel reduces carbon dioxide emission, the primary cause of the green house effect up to by 100%. Since biodiesel comes from plants and plants breathe carbon dioxide so there is no net gain in carbon dioxide by using biodiesel.

Biodiesel is considered clean fuel, since it has almost no sulpher, no aromatics and has 10% built in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in petroleum diesel.

TABLE 1 : Properties of different Methyl esters compared to diesel fuel.

Fuel property	**Soya bean methyl ester**	**Rapeseed methyl ester**	**Diesel fuel**
Formula	C_{18} to C_{19}	C_{18} to C_{19}	C_8 to C_{25}
Carbon (% wt)	78	81	84-87
Hydrogen (% wt)	11	12	12-16
Oxygen (% wt)	11	7	0
Specific Gravity	0.87	0.88	0.81
Pour point (ºC)	-3	-15	-23
Viscosity mPa-s at 20ºC	3.6	3.6	2.6-4.1
Lower heating value KJ/lit	32	37	35-37
Flash point ºC	–	179	74
Cetane number	52	62	40-55

Biodiesel preparation

The vegetable oil /animal oils /fats can be converted into biodiesel by a process called transesterification or alcoholysis. This process reduces the viscosity of triglycerides. The reaction represented by the general equation (Lele, 2002).

$$RCOOR' + ROOR'' \rightleftharpoons RCOOR'' + ROOR'$$

Oilseed production

India being an agriculture-based country, it will not big problem of cultivating crops for vegetable oil.

Jatropha carcus oil known as ratanjyot can be used as diesel substitute in India. It can be cultivated in arid and semiarid area conditions. About 1500 l of oil can be extracted from the yield per acre of 5000 kg of *Jatropha carcus* in irrigated area and 400 l of oil from 2000 kg yield per acre in arid area

It is estimated that 7 million acres plantation is required to produce 10% replacement petrodiesel need of India. The residual oil cake after extraction of oil from *Jatropha* can be used as fertilizer (Patel and Mishra, 2004).

According to economic survey of government of India, out of cultivated land area, about 175 million hectares are classified as waste and degraded land which can be easily used for plantation of oil seed plants. And, thus help in accelerating the economic growth of India as well as reducing the pollution.

However, biodiesel is not the same thing as raw vegetable oil. Fuel-grade biodiesel must be produced to strict industry specifications in order to insure proper performance. Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act Amendments. Raw vegetable oil cannot meet biodiesel fuel specifications, it is not registered with the EPA, and it is not a legal motor fuel.

The official definition consistent with other federal and state laws and Original Equipment Manufacturer (OEM) guidelines is as follows :

Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to ASTM D6751 specifications for use in diesel engines. Biodiesel refers to the pure fuel before blending with diesel fuel. Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (*i.e.,* B20 is 20% biodiesel, 80% petroleum diesel).

Oilseed meals

Oilseed is a source of high quality protein for animal production. Soya beans meal has the highest crude protein content. Rapeseed has high lysine content, and all of the meals are rich in sulpher containing amino acids, cystine and methionine.

Biodiesel manufactured from canola oil was blended with diesel and used as fuel in two diesel vehicles. This study aimed to test the emissions of diesel engines using blends of 100%, 80%, 60%, 40% , 20% biodiesel and 100% petroleum diesel, and characterise the particulate matter and gaseous emissions, with particular attention to levels of polycyclic aromatic hydrocarbons (PAHs) which are harmful to humans. A real time dust monitor was also used to monitor the continuous dust emissions during the entire testing cycle. The ECE (Euro 2) drive cycle was used for all emission tests. It was found that the particle concentration was up to 33% less when the engine burnt 100% biodiesel, compared to 100% diesel. Particle emission reduced with increased percentages of biodiesel in the fuel blends. Reductions of NOx, HC and CO were limited to about 10% when biodiesel was burned. Levels of CO_2 emissions from the use of biodiesel and diesel were similar. Eighteen EPA priority PAHs were targeted, with only 6 species detected in the gaseous phase from the samples. 9 PAHs were detected in particulate phases at much lower levels than gaseous PAHs. Some marked reductions were observed for less toxic gaseous PAHs such as naphthalene when burning 100% biodiesel, but the particulate PAH emissions, which have more implications to adverse health effects, were virtually unchanged and did not show a statistically significant reduction. These findings are useful to gain an understanding of the emissions and environmental impacts of biodiesel (Zou and Atkinson, 2003).

Enzymatic transesterification of soybean oil with methanol and ethanol was studied. Of the nine lipases that were tested in the initial screening, lipase PS from Pseudomonas cepacia resulted in the highest yield of alkyl esters. Lipase from *Pseudomonas cepacia* was further investigated in immobilized form within a chemically inert, hydrophobic sol-gel support. The gel-entrapped lipase was prepared by polycondensation of hydrolyzed tetramethoxysilane and iso-butyltrimethoxysilane. Using the immobilized lipase PS, the effects of water and alcohol concentration, enzyme loading, enzyme thermal stability, and temperature in the transesterification reaction were investigated. The optimal conditions for processing 10 g of soybean oil were: 35^{o} C, 1:7.5 oil/methanol molar ratio, 0.5 g water and 475 mg lipase for the reactions with methanol, and 35^{o} C, 1:15.2 oil/ethanol molar ratio, 0.3 g water, 475 mg lipase for the reactions with ethanol. Subject to the optimal conditions, methyl and ethyl esters formation of 67 and 65 mol% in 1h of reaction were obtained for the immobilized enzyme reactions. Upon the reaction with the immobilized lipase, the triglycerides reached negligible levels after the first 30 min of the reaction and the immobilized lipase was consistently more active than the free enzyme. The immobilized lipase also proved to be stable and lost little activity when was subjected to repeated uses (Noureddini *et al.*, 2005).

The transesterification of vegetable oil with short-chain alcohols, in the presence of base-catalyst, by means of low frequency ultrasound (28 and 40 kHz) in order to obtain biodiesel fuel was studied. By using ultrasounds the reaction time is much shorter (10-40 min) than for mechanical stirring. The quantity of required catalyst is 2 or 3 times lower. The molar ratio of alcohol/oil used is only 6:1. Normal chain alcohols react fast, while secondary and tertiary alcohols show some or no conversion after 60 min of reaction. Surprisingly, 40 kHz ultrasounds are much more effective in the reduction of the reaction time (10-20 min). Twenty eight kilohertz give slightly better yields (98-99%), but longer reaction time, while higher frequencies are not useful at all for the transesterification of fatty acids (Stavarache *et al*., 2005).

The chemical and toxicological characteristics of emissions from an urban bus engine fueled with diesel and biodiesel blend showed that exhaust gases produced by a turbocharged EURO 2 heavy-duty diesel engine, operating in steady-state conditions on the European test 13 mode cycle (ECE R49) were having regulated and unregulated pollutants, such as carcinogenic polycyclic aromatic hydrocarbons (PAHs) and nitrated derivatives (nitro-PAHs), carbonyl compounds and light aromatic hydrocarbons. Mutagenicity of the emissions was evaluated by the *Salmonella typhimurium*/mammalian microsome assay. The effect of the fuels under study on the size distribution of particulate matter (PM) was also evaluated. The use of biodiesel blend seems to result in small reductions of emissions of most of the aromatic and polyaromatic compounds, though these differences, however, have no statistical significance at 95% confidence level. Formaldehyde, on the other hand, has a statistically significant increase of 18% with biodiesel blend. *In vitro* toxicological assays show an overall similar mutagenic potency and genotoxic profile for diesel and biodiesel blend emissions. The electron microscopy analysis indicates that PM for both fuels has the same chemical composition, morphology and shape (Turrio-Baldassarri *et al.,* 2004).

Biodiesel was prepared in various supercritical alcohol treatments with methanol, ethanol, 1-propanol, 1-butanol, or 1-octanol to study transesterification of rapeseed oil and alkyl esterification of fatty acid at temperatures of 300 and 350^{o} C. The results showed that in transesterification, the reactivity was greatly correlated to the alcohol: the longer the alkyl chain of alcohol, the longer the reaction treatment. In alkyl esterification of fatty acids, the conversion did not depend on the alcohol type because they had a similar reactivity. Therefore, the selection of alcohol in biodiesel production may be taken on the basis of consideration of its performance of properties and economics (Warabi *et al*., 2004).

Benefits of biodiesel

- Biodiesel reduces CO_2 emission by 100%.
- Biodiesel reduces smoke due to soot free and complete combustion.

- Biodiesel reduces hydrocarbon emission.
- Biodiesel reduces carbon monoxide emission.
- Biodiesel is safe for transport due to high flash point.
- Biodiesel is safe for handle as it is biodegradable and non-toxic.
- Biodiesel is renewable energy source.
- Biodiesel promotes rural development.
- Biofuel plantation reduces soil erosion.

However, some shortcomings should not be ignored as no oil is perfect. With an old diesel vehicle, there's a chance that your first tank or two of BD could free up all the accumulated crude and clog the fuel filter. It has a higher gel point. B100 (100% biodiesel) gets slushy a little under 32 °F. But, B20 (20% biodiesel, 80% regular diesel is more commonly available than B100) has a gel point of -15 °F. However, like regular diesel, the gel point can be lowered further with additives, such as kerosene (blended into winter diesel in cold-weather areas). Old vehicles (older than mid-90s) might require upgrades of fuel lines (a cheap, easy upgrade), as BD can eat, through certain types of rubber. Almost all new vehicles should have no problem with BD. Finally, the one emission that goes up with biodiesel is NOx. NOx contributes to smog. We feel that a slight increase (up to 15%) in NOx is greatly offset by the reduction in all other emissions and the major reduction in greenhouse gasses.

Conclusion :

1) Biodiesel is renewable energy source; can be used without change in existing engine.
2) Biodiesel reduces the exhaust emission, thus helps in reducing pollution.
3) Biodiesel increases rural income; provide employment and leads towards economic growth of India.

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