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Environmental Impacts of Production of Biodiesel and Its Use in Transportation Sector

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1. Introduction

The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present context. The fuels of bio-origin can provide a feasible solution to this worldwide petroleum crisis. Gasoline and diesel-driven automobiles are the major sources of greenhouse gases (GHG) emission [3 - 5]. Scientists around the world have explored several alternative energy resources like biomass, biogas [6] primary alcohols, vegetable oils and biodiesel. These alternative energy resources are highly environment-friendly but need to be evaluated on case-to-case basis for their advantages, disadvantages and specific applications. Some of these fuels can be used directly, while some others need to be formulated to bring the relevant properties closer to conventional fuels.

Environmental concerns have increased significantly in the world over the past decade, particularly after the Earth Summit-92. Excessive use of fossil fuels has led to global environmental degradation effects such as greenhouse effect, acid rain, ozone depletion and climate change. So there is need to develop or find alternative ways to power the world's motor vehicles.

There are two global biorenewable liquid transportation fuels that might replace gasoline and diesel fuel. These are bioethanol and biodiesel. Bioethanol is good alternate fuel that is produced almost entirely from food crops. Biodiesel has become more attractive recently because of its environmental benefits.

Transport is one of the main energy consuming sectors. It is assumed that biodiesel is used as a fossil diesel replacement and that bioethanol is used as a gasoline replacement. Biomass based energy sources for heat; electricity and transportation fuels are potentially carbon dioxide neutral recycle the same carbon atoms. Due to its widespread availability, biorenewable fuel technology will potentially employ more people than fossil fuel based technology [7].

The term biofuel is referred to as solid, liquid or gaseous fuels that are predominantly produced from biorenewable or combustible renewable feedstocks [8]. Liquid biofuels are important for the future because they replace petroleum fuels. Biofuels are generally

considered as offering many priorities, including sustainability, reduction of greenhouse gas emissions, regional developments, social structure and agriculture, security of supply [9].

The biggest difference between biofuels and petroleum feedstocks is oxygen content. Biofuels are non polluting, locally available, accessible, sustainable and are a reliable fuel obtained from renewable sources. Electricity generation from biofuel has been found to be a promising method in near future. The future of biomass electricity generation lies in biomass integration gasification / gas turbine technology, which offers high energy conversion efficiencies.

First generation biofuels refers to biofuels made from starch, sugar, vegetable oils or animal fats using conventional technology. The basic feedstocks for the production of first generation biofuels are often seeds or grains such as wheat, which yields starch that is fermented into bioethanol, or sunflower seeds, which are pressed to yield vegetable oil that can be used in biodiesel. Table 01 shows the classification of renewable biofuels based on their production technologies [10].

Generation	Feedstock	Example
First Generation biofuels	Sugar, Starch, vegetable oils, or animal fats	Bioalcohols, vegetable oil, biodiesel, biogas
Second Generation biofuels	Non food crops, wheat straw, corn, wood, solid waste, energy crops	Bioalcohols, bio – oil, bio – DMF, wood diesel
Third Generation biofuels	Algae	Vegetable oil, biodiesel
Fourth Generation biofuels	Vegetable oil, biodiesel	Biogasoline

Table 1. Classification of renewable biofuels based on their production technologies

Second and third generation bio fuels are also called advanced bio fuels. Second generation bio fuels are mainly made from non – food crops like wheat straw, corn, wood etc. On the other hand appearing the fourth generation is based in the conversion of vegoil and biodiesel into bio gasoline using the most advanced technology.

Renewable liquids bio fuels for transportation have recently attracted huge attention in different countries all over the world because of its renewability, sustainability, common availability, regional development, rural manufacturing, jobs, reduction of greenhouse gas emissions and its biodegradability. Table 02 shows the availability of modern transportation fuels. There are several reasons for biodiesel to be considered as relevant technologies by both developing and industrialized countries [7]. They include energy security reasons, environmental concerns, foreign exchange savings and socioeconomic issues related to rural sector.

Due to its environmental merits, the share of bio fuel in the automotive fuel market will grow fast in the next decade [11, 12]. The advantages of bio fuels are the following –

- a. They are easily available from biomass sources
- b. They represent a carbon dioxide cycle in combustion

- c. They have a considerable environmentally friendly potential
- d. They have many benefits for the environment, economy and consumer and
- e. They are biodegradable and contribute to sustainability [13].

Fuel Type	Availability	
	Current	Future
Gasoline	Excellent	Moderate poor
Bioethanol	Moderate	Excellent
Biodiesel	Moderate	Excellent
Compressed natural gas (CNG)	Excellent	Moderate
Hydrogen for fuel cells	Poor	Excellent

Table 2. Availability of modern transportation fuels

Various scenarios have resulted in high estimates of bio fuels in the future energy system. The availability of resources is an important factor. The rationale is to facilitate the transition from the hydrocarbon economy to the carbohydrate economy by using biomass to produce bio ethanol and bio methanol as replacements for traditional oil based fuels and feed stocks.

The refining, transport and combustion of bio fuels can result in significant environmental costs, particularly on local water and air quality. Generally, these effects pale in comparison to those generated by the use of fossil fuels, where the main detrimental environmental effects originate from the vehicle exhaust pipe. Even so, these impacts could expand considerably as bio fuel production increases to meet rapidly rising global demand. However, more sustainable practices and new technologies offer the potential for environmental improvements.

This chapter elaborates the main environmental impacts associated with bio fuels processing, transport and use. In order to provide comparison, it first describes some of the environmental costs resulting from processing and the use of petroleum transport fuels.

2. Environmental costs of petroleum refining and use

While the use of oil has brought incalculable benefits to modern industrialised society, it has also extracted great costs, particularly to the local and global environments. Most of these things occur during oil refining and fuel consumption. Delucchi[14] estimated that in the US the costs of environmental externalities associated with oil and motor vehicle use totally between US \$ 54 to \$234 billion in 1991 alone. Human mortality and disease due to air pollution accounted for more than three quarters of these costs. In Germany it estimated that the quantifiable costs of air pollution and carbon dioxide emissions associated with the transport sector in 1998 totalled about US \$ 14.5 billion.

3. Oil refining

Refining of petroleum is an energy intensive, water hungry and very highly polluting process. Everyday, average US refinery releases 41, 640 litres of oil and other chemicals into the air, soil and water [15]. Population lives around that location may feel higher incidences of respiratory problems, skin irritation, nausea, eye problems, headaches, birth defects, cancers etc.

Crude oil, chemical inputs and refined products leak from storage tank and spill during transfer points. Numerous toxins are likely to enter the groundwater, including benzene, toluene, ethyl benzene and xylene [16]. Other chemical may split into the air. Gases such as methane and slightly heavier hydrocarbons such as those in gasoline evaporate. Other chemicals enter in the air as combustion products; the most significant of these are sulphur dioxide (SO₂), Nitrogen dioxide (NO₂), carbon dioxide (CO₂), carbon monoxide (CO), dioxins, hydrogen flouride, chlorine, benzene, large and small particulates and lead [17]. It is well established that oil refineries are the largest industrial source of volatile organic compounds and carbon dioxide, which leads to ozone and smog formation in troposphere. The second known source of sulphur dioxide which contributes to particulate matter and acid rain and the third largest source of nitrogen oxide, all these are known as ozone precursors [18].

4. Oil transport

Most of the world's crude oil comes from field far from where it is refined and transported big distances from field to refinery and from refinery to fuel station. Large tanker vessels account for 68% of crude delivery to refineries covering an average of 6600 Km per trip. Oil pipelines, used mainly in places where deliveries can be land based, account for 30% while trucks and train transport the remainder [17].

Invariably oil spills occur along the journey. Although most tanker spillage is relatively minor, while during loading or unloading, even small amounts can damage ecosystems. Pipelines spills, although typically smaller, can also be ecologically disruptive, polluting soil and seeping into ground water. Such spills can be fairly common in region where pipelines are not maintained adequately [19].

Oil is shipped over distances to refineries and from refineries, gasoline and diesel fuels travel via pipelines and trucks to fuel depots. Upon leaving the refinery 59% of refined petroleum fuels enter pipelines before loading to trucks [17]. Gasoline and diesel are lighter hydrocarbons that tend to evaporate, participating in complex reactions that form ozone in the atmosphere. Benzene is another pollutant and is also evaporative and is well known for its carcinogenicity. The most significant hydrological pollutant is methyl tertiary - butyl ether (MTBE), fuel additive derived from petroleum that seeps quickly into nearby groundwater and is a likely carcinogen [20].

5. Combustion of petroleum fuels

Compared to bio fuels, petroleum contains a much wider variety of chemical molecules, including far more sulphur. Most of these have been sequestered in the earth for ten and even hundred years of millions years. The burning of gasoline and diesel fuels releases host

pollutants and heavy metals that affect local and regional air quality and these are well linked with global warming issues.

Transport related air pollution leads to reduce visibility, damage to vegetation and buildings and increased incidence of human illness and premature death [21]. Road transport is also growing contributor to air pollution in many developing countries / cities particularly where diesel remains the predominant fuel [22]. Table 03 is summarized below shows the main environmental and health impacts associated with the petroleum primary combustion products including CO₂, CO, unburned hydrocarbons, NO_x, SO_x, particulates and in some countries lead [23].

Combustion product	Impacts
CO ₂	Contributes to global warming and climate change
CO	Results from incomplete combustion or burning. In the atmosphere, CO reacts with oxygen to form ozone, a highly reactive molecule that damages plant leaves and human and animal lungs
Benzene	The smallest aromatic hydrocarbon and a highly toxic carcinogen.
NO & NO _x	Ozone precursor, they also react with atmospheric water and create acid rain
SO ₂ & SO ₃	Acid rain precursors,
Lead	Has been phased out from gasoline in most of the countries, but is still used as an octane enhancer
Particulate matter	Formed from SO _x , NO _x and hydrocarbons, particulates contribute to ozone formation and affect visibility and hence global warming.

Table 3. Environmental and health impacts of emissions from petroleum combustion

6. Environmental impacts of biofuel

Same as like petroleum fuels, bio fuels can have environmental impacts at all stages of their production and use. Relative to fossil fuels, however, the impacts resulting from refining, transporting and using bio fuels are generally significantly smaller. Moreover, there are ways to improve the resource efficiency and impacts of these activities.

7. Water use

Large quantities of water can be utilise for the processing the bio fuel feedstock into fuel. The primary uses of water for biodiesel refining are to wash plants and seeds for processing and then to remove the soap and catalysts from the oils before and final product is shipped out. A typical US Soybean crushing system requires just over 19 Kg water per tonne of oil produced [24]. For each tonne of soybeans that go into the refining process, 170 kg come out

as crude de-gummed soybeans oil, 760 kg are soy meal and remaining 70 kg include air and solid and liquid waste [24]. The primary contaminant in wastewater is soybean oil [24]. Production of ethanol, in particular, requires a tremendous amount of water for processing and for evaporative cooling to keep fermentation temperatures at the required level [25]. But some feed stocks are more water intensive than other; each tonne of sugar cane in Brazil, for example, requires as much as 3900 litres for processing [26]. Ethanol processing also results in large volumes of nutrient rich wastewater that, if not cleaned and recycled can speed eutrophication of local rivers and streams by affecting the water's dissolved oxygen content [27]. In addition, sugar mills must be flushed every year, putting huge amount of organic matter into local waterways [28]. In Brazil, 1 litre of ethanol produces about 10 to 15 litres of vinasse which is very hot and corrosive, with a low pH and high mineral content [22]. Today, however, wastewater and vinasse are recycled and used for irrigation and fertilization of Brazil's sugarcane crops, with varying quantities of vinasse used under different conditions as regulated by law [29]. However, some experts caution that vinasse cannot be used where water tables are high, such as in India [30]. Also, if used excessively, vinasse can cause eutrophication of surface water due to the increased load [31]. Filter cake another waste stream from ethanol processing is also recycled as a fertilizer. As a result Brazil has been able to significantly reduce its use of petroleum fertilizers, saving money while creating value from waste products [22].

8. Air pollution

Among the pollutant that bio refineries emit in to the air are SO_x, NO_x, VOCs and particulate matter. Emission from corn ethanol plants, for example include SO_x, NO_x, CO, mercury, particulates and CO [32]. Corn ethanol plants in Iowa have polluted both water and air, emitting cancer causing chemicals such as formaldehyde and toluene [33].

Biodiesel production require methanol, which has the same environmental cost as those associated with petroleum production. In addition, direct emission from biodiesel processing plants can include air, steam and hexane, which can be used to extract oil from plants and seeds. Hexane is air pollution, and through as much as possible is recovered and recycled, some is emitted into air as well. Sheehan et al (in 1998) estimate that the average US soybean crushing system releases just over 10 Kg of hexane per tonne of oil produced. Alternatives have been found so that hexane is no longer needed; but these options are more costly [34]. In addition, where renewable sources are not used to produce process energy, pollutants associated with the use for natural gas and the generation of steam and electricity are released into air. An estimated 3.6 Kilowatt hours of electricity are required per ton of soybeans entering in a soy biodiesel plant [35]. On the other hand, Fischer-Tropsch [F-T] biodiesel in gasification based and therefore has minimal local air pollution problem [36].

As plant size increases, concerns about pollution – including air emissions, odour releases during the drying of distillers grain in corn ethanol plants and waste water recharges- have risen as well [22]. However, with appropriate regulation and pollution control technologies, emission associated with bio fuels refining can be minimised significantly [37, 38]. For example NO_x emission from boiler can be reduced by installing new NO_x burner system [39]. VOCs emission, which results primarily from the blending of ethanol with gasoline, can be reduced by mixing fuels at locations where pollutants can be collected and treated [40]. In some cases, new and larger plants are incorporating such emission control system and are finding alternative options that are enable them to reduce such emissions [36].

In addition, much of the air pollution associated with bio fuels refining results from burning of fossil fuels for process heat and power – which in the US, Germany, China and many other countries is mainly coal. Thus, emission can be reduced through traditional power plant control technology or the use of renewably generated power [36].

In Brazil, today, mills and distilleries meet most if not all of their own energy needs with bagasse (a by product of sugar cane crushing), which can generate thermal, mechanical and electrical energy. Some plants even sell surplus electricity into the grid [22]. Elsewhere, agricultural and forestry residues can be used to produce required power and heat; however it is important to ensure that enough residues remain to maintain soil organic matter and nutrient levels [40].

9. Biofuel transport and storage

9.1 Water pollution

Pure ethanol and biodiesel fuels offer significant environmental benefits compared to petroleum fuels, making them highly suitable for marine and farm uses, among others. They result in dramatically reduced emission of VOCs and are less toxic to handle the petroleum fuels [41]. One other significant advantage relates specifically to water: both ethanol and biodiesel are biodegradable and break down readily, reducing their potential impact on soil and water [42].

Biodiesel is far more soluble than petroleum diesel, enabling marine animals survive in far higher concentrations of it than petroleum if fuel spills occur (due to lower risk of suffocation) [43]. Such benefits are helping to drive biofuel promotion policies in China, where vehicles have polluted water bodies and gasoline and diesel leakage pipelines have polluted ground water – affecting biodiversity, drinking water and soil resources [25].

At least one study has shown that biodiesel made with rapeseed oil can biodegrade in half the time required for petroleum diesel. Biodiesel also speeds the rate at which biodiesel petroleum blends can biodegrade, which is not the case of ethanol [43]. There is evidence that ethanol's rapid break down depletes the oxygen available in water and soil, actually slowing the breakdown of gasoline. This can increase gasoline's impact on the environment in two ways. First, the harmful chemicals in gasoline persist longer in environment than they otherwise would; benzene, in particular, can last 10 – 150 % longer when gasoline is blended with ethanol. Second, because gasoline breaks down more slowly, it can travel further (up to 2.5 times) in the marine environment, affecting a greater area [44].

Additionally, if ethanol is spilled, it can remobilize gasoline in previously contaminated soils, intensifying the impact of the initial spill. Since up to 85% of such spills occur at gasoline terminals. This is where such a problem is most likely to happen [45]. The transition of high level of ethanol needs to be planned with such impact in mind and should include regulations for the handling of fuels.

9.2 Air pollution

Most biomass is carried to processing plants by truck and most bio fuels are transported by truck as well, although some travel by train or, in Brazil, via pipelines. The environmental impacts associated with transport include the air emission and other pollutants associated with the life cycle of the fuel used – in most cases, petroleum diesel. As demand of bio fuel increases and as consumption exceeds, production in some countries, it is likely that a

raising amount of feed stocks and bio fuel will be transported by ship. By shipping is a relatively energy-efficient means of transport, it is also a major source of pollution due primarily to a lack of regulations governing maritime emissions. Pollutants include NO_x, SO₂, CO₂, particulate matter and a number of highly toxic substance, such a formaldehyde and poly aromatic hydrocarbons [46]. Emissions from diesel from marine engines represent an ever increasing share of air pollution, and most of these pollutants are released near coastlines, where they can easily be transported over land [46].

The over potential concern associated with bio fuels transport is possibility for spills and evaporation. Bio fuels can leak at the production facility, spill while being transported and leak from above and below ground tanks. They can also evaporate during fuelling and storage and from a vehicle's fuelling system.

In general, 'neat' bio fuels are distinctly less toxic than spills of petroleum fuels. For biodiesel, evaporative emissions are not a particular concern since biodiesel fuel does not have a higher vapour pressure. Neat ethanol has a low rigid vapour pressure (RVP), and when stored as a pure fuels (or even as an E-85 blends), it has a lower vapour pressure than gasoline and thus will have fewer evaporative emissions [36].

The primary concern regarding emission from bio fuel transport has to do with lower- level blends of ethanol in gasoline, which tend to raise vapour pressure of the base gasoline to which ethanol is added. When ethanol is blended up about 40% with gasoline, the two fuel combined have higher evaporative emission than either does on its own. The fuels are mixed via splash blending at the petroleum supply 'rack', so there is a potential for increased evaporative emission from these lower - level blends at the point in the distribution chain and 'downstream'- mainly during vehicles refuelling and from use in the vehicles. These evaporative emissions from a vehicle's fuelling system can increase ozone pollution.

Adding the first few per cent of ethanol generally causes the biggest increase in volatility so increasing the blend level to 2.5 or even 10 per cent will have similar results [47]. Evaporative emissions peak at the blend level between 5 to 10 percent and then start to decline. Once ethanol's share exceeds 40 percent, evaporative VOC emission from the blend are lower than those from gasoline alone [48].

Most international energy agencies (IEA) countries have emission standards requiring the VOC emissions and thus RVP, be controlled [47]. Emission resulting from higher vapour pressure can be controlled by requiring refiners to use base gasoline stock with a lower vapour pressure when blending with ethanol, although this increases cost and reduces production levels. The US state of California and US federal reformulated gasoline programmes have set caps on vapour pressure that take effect during high ozone seasons in areas that do not meet ambient air quality standard of ozone. As a result, the addition of ethanol does not increase the vapour pressure of the gasoline available during summer months [49]. Emission from permeation are more difficult to control in the on-road fleet, although expert believes that most can be controlled in new vehicles that much meet stricter evaporative emission control standard (such as California LEV 2 and US Federal Tier II), with higher-quality tubes, hoses and other connectors [49].

10. Biofuel combustion

The level of exhaust emissions that results from the burning of ethanol and biodiesel depends upon the fuel (e.g. feedstock and blend), vehicles technology, vehicle tuning and

driving cycles [22]. Most studies agree that using bio fuels can significantly reduced most pollutants compared to petroleum fuels, including reductions in controlled pollutant as well as toxic emissions [47]. NO_x emissions have been found to increase slightly as blend level rise, although the levels of emissions differ from study to study.

10.1 Ethanol

Ethanol contains no sulphur, olefins, benzene and other aromatics [22]. All of which are component of gasoline that can affect air quality and threaten human health [22]. Benzene is carcinogen, while olefins and some other aromatics are precursor to ground-level Ozone (smog) [47]. Ethanol-gasoline blends also reduce toxic emissions of 1,3-butadiene, toluene, xylene, while few studies have a looked at the impacts on the pollution levels from high blends.

With ethanol fuel combustion, emission of the toxic air pollutants acetaldehyde, formaldehyde, peroxyacetyl nitrate (PAN) increase relative to straight gasoline [47]. Most is emitted as acetaldehyde, a less reactive and less toxic pollutant than formaldehyde. Neither pollutant present in fuel; they are created as by product of incomplete combustion. PAN is an eye irritant that is harmful to plants, is also formed as by product [47]. A US auto-oil industry study determined that combustion of E85 resulted in a slight increase in hydrocarbon emission relative to California reformulated gasoline. It is also found that toxic emission rose as much as two to three folds compared to conventional gasoline, due mainly to an increase in aldehyde emission.

There is concern that aldehydes might be carcinogenic; but the pollutant that are reduced by blending with ethanol (including benzene, 1,3 - butadiene, toluene and xylene) are considered more dangerous for human health. A study done in California determined that acetaldehyde and PAN concentrations increases only slightly with ethanol blends, and a Canadian study concluded the risks of increased aldehyde pollutants are negligible [90]. Because of reactivity of aldehydes, emissions can generally be managed with emission controls [36]. For example, three way catalysts can efficiently minimize aldehyde emissions [50].

Ethanol blended gasoline increase fuel oxygen content, making hydrocarbons in the fuel burn more completely in older vehicles, in particular, thus reducing emission of CO and hydrocarbon emissions [22]. Ethanol used an additive or oxygenate (e.g. 10 percent blend) has been found to achieve CO reductions of 25 percent or more in older vehicles [22]. In fact, one of the goals driving the use of ethanol in US during the 1990s was to reduce hydrocarbons and CO emissions particularly in winter when emission of these pollutants tend to be higher. Ethanol in higher blend will be positively affecting the efficiency of catalytic convertors because of the dilution of Sulphur [51]. Ethanol can be used to make ethyl tertiary butyl ether (ETBE), which is less volatile than ethanol and widely used in the European Union (EU) [51].

As a result of its national ethanol programme *proalcool*, Brazil was one of the first countries in the world to eliminate lead entirely from gasoline. According to Sao Paulo State Environmental Agencies (CETESB), ambient lead concentrations in the Sao Paulo metropolitan region declined from 1.4 gram per cubic meter in 1978 to less than 0.1 gram per cubic meter in 1991 [52]. Most of the countries however have been able to eliminate lead through other means, including a reduction in unnecessarily high octane grades and the development of the chapter refining alternatives (e.g. reforming and isomerisation) [22].

Ethanol use has resulted in significant reductions in other air pollutants as well. Emission of toxic hydrocarbons such as benzene has declined in Brazil, in addition to the emission of sulphur and CO. For Example, Brazil transport related CO emission declined from more than 50grams per kilometre in 1980 to less than 1gram per kilometre in 2000 due to ethanol use. CETESB estimates that urban air pollution in Brazil could be reduced in additional 20-40 percent if the entire vehicle fleet were fuelled by alcohol [22]. In 1998 Denver, Colorado, became the first US city to require blending of gasoline with ethanol; it is used in winter to improve fuel combustion and to reduce CO emissions. As a result, it is estimated that CO level have declined by 50 percent [53].

There is some evidence that emission reductions associated with using ethanol blends, compared to straight gasoline, are not as significant in the cleanest vehicles available today. Durbin et al (2006) tested vehicles that qualified as low emission and ultra low emission in California, and found that emission of non methane hydrocarbons increased as engine temperature rose and that benzene emission increased with higher concentrations of ethanol, while fuel efficiency declined. However, CO emission decreased somewhat with ethanol use [54]. Some of the findings were inconsistent with those of the studies, highlighting the need for further research [54].

As discussed earlier, ethanol used as an oxygenate can reduce emission of several pollutants particularly in older vehicles. However the use of oxygenates such as ethanol (and biodiesel), to alter the fuel to oxygen ratio will not necessarily have a positive effect on emission if a vehicle's air-to-fuel ratio is set low or if too much ethanol is added to gasoline in a vehicle with a fixed air-to-fuel ratio. If that is the case, oxygenate can increase NOx emissions and cause 'lean misfire' increasing hydrocarbon emissions [22]. In fact, Tyson et al (1993) argue that ethanol has no emission related advantages over reformulated gasoline other than the reduction of CO₂ [55].

Ethanol blended with diesel can provide substantial air quality benefits, Blends of 10-15 per cent ethanol (combined with performance additive) result in significantly lower emission compared with pure diesel fuel; exhaust emissions of PM, CO, and NOx decline. For high blends, the results are mixed. Some studies have found higher average CO and hydrocarbon emissions and other have seen reductions in these pollutants. However, all studies, to date, have seen significant decrease in both PM and NOx [47].

Flexible-fuel vehicles (FFV)- which can take virtually any ethanol- gasoline blend up to 85 percent in the US and up to 100 percent in Brazil- are widely used in the Brazil and are becoming increasingly available in the US. However, tests to date have found that the use of FFVs results in higher air emission than new gasoline vehicles [36]. Because it is not possible to tune the combustion controls of vehicles so that it is optimized for all conditions, controls are compromised somewhat to allow for different mixes [56,57]. It is possible that vehicles dedicated to specific blends, operated on those blends level, would achieve lower emissions than conventional vehicles.

10.2 Biodiesel

Biodiesel – whether pure or blended- results in lower emissions of most pollutants relative to diesel, including significantly lower emission of particulates, sulphur, hydrocarbons, CO, toxins [57]. Emissions vary with engine design, condition of vehicles and quality of fuel. In biodiesel- diesel blends, potential reductions of most pollutants increase almost linearly as the share of biodiesel increases, with the exception of NOx emission [47].

In one of the most comprehensive analyses to date, a US Environmental Protection Agency (EPA) study of biodiesel determined that the impacts on emissions vary depending upon type (feedstock) of biodiesel and the type of petroleum diesel that it is mixed with. Overall animal based biodiesel did better in the study than plant based biodiesel with regard to reducing emission of NO_x, CO and particulates. On average, the EPA determined that B20 (made with soybeans) increase NO_x emission the least, followed by rapeseed biodiesel and that soybean based biodiesel; the same relationship held true for CO reduction, as well. Reductions in particulate emissions were also greatest for animal based biodiesel [58].

The test carried out by the EPA showed that, when compared with conventional diesel, pure diesel (produced with Soybean oil) resulted an average reduction of particulate matter by 40 percent, CO by 44 per cent, unburned hydrocarbons by 68 percent, polycyclic hydrocarbons (PAHs) by 80 percent, carcinogenic nitrate by 90 percent, sulphate by 100 percent [59].

During 2000, biodiesel become the first alternative of fuel to successfully complete testing for tier 1 and 2 for health effect under the US Clean Air Act. Test determined that, with the exception of minor damage to the lung tissue at high level of exposure, animal observed in the study suffered non biological significant short term effect associated with biodiesel [22].

A 1999 Swedish study by Pedersen et al found that biodiesel (rapeseed methyl ester, or RME) led to an up to tenfold increase in emission of benzene and Ozone precursors compared with Swedish low sulphur diesel fuel, called MKI [60]. However, this study was conducted using a very small reactor; many US and European researches were sceptical about transferring results from this study to the real world for combustion in a diesel engine. Since then, other studies have produced results. For example, Krahel et al (2000) compared 100 percent RME to MKI, fossil diesel fuel and another low sulphur diesel fuel (with high aromatic compounds content and flatter boiling characteristics, known as DF05), using modern DaimlerChrysler diesel engine such as those generally installed in light duty transport vehicles. They concluded that RME lead to significant reduction in CO, hydrocarbons, (HCs), aromatics HCs (including Benzene) and aldehydes, ketones (which contribute to the formation of summer smog) compared with the other fuels [61].

11. Impact of NO_x emissions

Most studies conclude that ethanol and biodiesel emit higher amounts of nitrogen oxides (NO_x) than do conventional fuels, even as other emissions decline [47] there are exceptions, however. When ethanol is blended with diesel, NO_x, emissions decline relative to pure diesel fuel; and some tropical oils are saturated enough- thus have a high enough cetane value – that they increase NO_x less (and in the case of highly saturated oils such as coconut, actually decrease NO_x) relative to diesel [62]. NO_x are precursor to ground level ozone (smog). In addition, NO_x emission increase acid rain and are precursor to fine particulate emissions; associated with health impact include lung tissue damage, reduction in lung function and premature health [63].

The level of NO_x emissions found varies significantly from study to study. Some cities, particularly in the US state of California, have complained that ethanol has increased local problems with NO_x and ozone [22]. California is using ethanol as an oxygenate meet

requirements under US Clean Air Act because concern about water contamination led to the state to ban MTBE. More recently concern about evaporative VOCs emission and combustion emissions of NO_x led California to sue the US EPA twice for a waiver; both times the waiver was denied [58]. But both the EPA and California Air Resources Board agreed during the process that ethanol increases NO_x slightly in the on-road fleet [64].

Fulton et al (2004), on the other hand, report that the impact of bio fuels on NO_x emissions level are relatively minor and can actually be higher or lower than conventional fuel, depending upon the conditions. In fact, there is evidence that NO_x level from low ethanol blends range from a 10 percent decrease to a 5 percent increase relative to pure gasoline emission [47].

Studies by US National Renewable Energy Laboratory (NREL) show inconsistent results with regard to biodiesel and NO_x, depending upon whether vehicle is driven on the road or in the laboratory. According to McCormick (2005), they have seen 'Nox reductions for testing of vehicles (chassis dyno) and Nox increases for testing of engines (engine dyno). The former, which involves driving an entire car on rollers rather than testing emissions directly from an engine removed from the vehicle, is considered more realistic than the latter [65].

NREL studies of in-use diesel buses have found a statistical significant reduction in NO_x emissions with biodiesel. A US auto-oil industry six year collaborative study examined the impact of E85 on exhaust emissions and found that NO_x emission were reduced by upto 50 percent relative to conventional gasoline [66]. But India's Central Pollution Control Board has determined that burning biodiesel in a conventional diesel engine increases NO_x emissions by about 13 % [57].

Fortunately, newer vehicles designed to meet strict air standards, such as those in California, have very efficient catalyst system that can reduce VOC, NO_x and CO emissions from ethanol-gasoline blends to very low levels [36]. With biodiesel, NO_x increases can be minimized by optimizing the vehicle engine for the specific blend that will be used [47]. Emission can also be reduced with additives that enhance the cetane value or by using biodiesel made from feedstock with more saturated fats (e.g. tallow is better than canola, which is better than soy) [65].

It is possible to control diesel exhaust using catalysts and particulate filters. High efficiency Diesel Particulate Filter (DPF) remove particulate matter (PM) by filtering engine exhaust; such system can reduce PM emissions by 80 percent or more. However, because of concern about increased oil film dilution during the post- injections. German car manufactures do not accept neat biodiesel in DPF equipped vehicles [67]. There is also concern that the extra injection used to increase emission temperatures for regeneration of the particulate trap result in a dilution of engine oil when RME is used as a fuel, and this dilution can increase engine wear [68]. Rust particles filters, which are available in many new diesel automobiles and significantly reduce emissions of fine particulates, cannot operate with biodiesel [69].

According to some sources, biodiesel do not meet European air emissions standards that went into effect in January 2006 [69], although the Association of German Biofuel Industry noted that biodiesel can meet updated European standards for trucks and commercial vehicles.

Several groups are in the process of developing additives to address the issue of NO_x, emissions associated with biodiesel blends, including NREL, the US National Biodiesel Board, the US Department of Agriculture and World Energy Alternatives [65].

12. Advanced technologies

In general, the air quality benefits of biofuel are greater in developing countries, where vehicle emission standards are non-existent or less stringent and where older more polluting cars are more common [70]. For example, the use of ethanol can effectively reduce emissions from CO and hydrocarbons in old technology vehicle today [22]. Less understood, however, are the impacts that biodiesel might have on exhaust emission from vehicles that are underpowered, over-fuelled, overloaded and not well maintained- vehicles that are most prevalent in the world's developing nation [22].

Advances in pollution control technologies for petroleum-fuelled vehicles will reduce. If not eliminate, the relative benefits of biofuels. Greene et al (2004) note that the main benefit of biofuels in such advanced vehicles may be to make it easier to comply with emission standard in the future, thus reducing the cost emission control technologies [36].

At the same time, new technologies are on the horizon. For example, Volkswagen and Daimler Chrysler have invested in biomass-to-liquid (BTL) technologies that convert lignocellulosic fibers into synthetic biodiesel. This process enables them to produce a cleaner burning biofuel. In the future, they hope to optimize fuels and vehicle engines in parallel.

13. Conclusion

The refining, transport and combustion of biofuels have environmental costs, particularly on local water and air quality, and these impacts could rise considerably as biofuel production increases to meet rapidly rising global demand. At the same time, more sustainable practices and new technologies offer the potential for environmental improvements.

Increasing efficiencies in water and energy use at refineries can help to reduce both air and water pollution. The UK-based biodiesel producer D1 Oils now recycles both water and methanol used in its refineries and uses biodiesel to run its facilities [71]. Standards and regulations are also needed to minimize pollutants. In addition, encouraging smaller scale distributed facilities will make it easier for communities to manage wastes, while possibly relying on local and more varied feed stocks for bio fuel production and thereby benefiting local economies and farmers.

The combustion of bio fuels- whether blended with conventional fuels or pure-generally results in far local emissions of CO, hydrocarbons, SO₂ and particulate matter (and, in some instances lead) than does the combustion of petroleum fuels. Thus, the use of bio fuels, particularly in order vehicles, can significantly reduce local and regional air pollution, acid deposition and associated health problems; such as asthma, heart and lung disease and cancer [72].

However, the air quality benefits of bio fuels relative to petroleum fuels will diminish as fuel standards and vehicle technologies continue to improve in the industrialised and developing worlds. Even today, the newest vehicle technologies continue to improve in the industrialised and developing worlds. Even today, the newest vehicles available for purchase largely eliminate the release of air pollutants (aside from CO₂) [73]. At the same time, concern about level of NO_x and VOC emissions from bio fuels will probably diminish with improvements in vehicles and changes in fuel blends and additives. A combination of next generation bio fuels can make a major contribution to reducing air pollution in the transport sector.

In the developing world, ethanol should be used to replace lead, benzene and other harmful additives required for older cars and because of high blends or pure bio fuels pose minimal air emissions problems and are less harmful to water bodies than petroleum fuels, for all countries it is important to transition these high blends as rapidly as possible, particularly for road transport in highly polluted urban areas and few water transport, wherever feasible.

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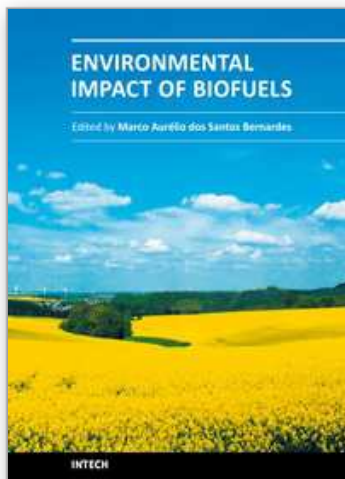
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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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