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Role of Biofuels on IC Engines Emission Reduction

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Abstract

Vehicles are the main sources for environmental pollution especially those associated with diesel engines. It causes a number of health diseases and harm to the ecosystem. It is very urgent to find alternative fuel for vehicles. Biofuel is an alternative for vehicles which have potential to reduce engine emissions and maintain the air quality better. In recent years, worldwide biofuel production and use raised drastically. Some developed countries have put their target and mandate to use biofuel. The aim of this review is to discuss the impact of biofuel on diesel engines emission. From this review it is found that biofuel significantly reduces engine emissions and it has potential to reduce more than 80% of GHG emission. Finally, biofuel can be a viable alternative to be used as a transportation fuel.

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Keywords: *Biofuel development; emission reduction;ethanol; transportation sector*

1. Introduction

Rapid growth of a number of automotive industries in the world has resulted in increase of exhaust emissions to the environment. Vehicular emissions such as particulate matter, hydro carbon, carbon dioxides, carbon monoxides and nitrogen oxides are hugely responsible for the air quality deterioration [1]. Two main internal combustion engine types such as petrol engine and diesel engine contribute to degrade the air quality in the urban environment. There are about 22% of global GHG (greenhouse gas) emissions comes only from the transportation sector due the increasing demand of vehicles. **Figure 1** shows the CO_2 emission by transportation sector [2]. The fast emission growth was driven by emissions from road transport sector which increased by 52% since 1990 and accounted for three quarters of transport emission in 2011 [2]. The International Energy Agency (IEA) forecasts that the emissions of carbon dioxide (CO_2) from transport sector will increase by 92% between 1990 and 2020 and it is estimated that 8.6 billion metric tons of carbon dioxide will be released to the atmosphere from 2020 to 2035 [3]. It has been also reported that, an increase in average global temperature by 2^o C will result in death of hundreds of millions of people [4]. It is very urgent to find out alternative fuels for transportation

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sector as this sector is emitting higher GHG emission and contribute to the rapid growth of global oil demand. Recently, attention has been drawn to develop cleaner alternative fuels from renewable sources to reduce the harmful emission to the air and to reduce the dependency on the petro-diesel fuel [5]. The most feasible alternative for vehicles being considered globally are biofuel such as biodiesel and ethanol due to their renewable property and reduction of fossil CO_2 discharge which most probably contributes to the global climate changes. Ethanol is produced from a number of crops such as potatoes, sugarcane, grains, corn and sorghum etc [6] whereas, biodiesel can be produced from vegetable oils, recycled waste oil and animal fats [7]. Thus this review aims to investigate the potential of reduction of exhaust emission using biofuel in IC engines either pure or blend form along with the key factor of biofuel development and policies set by government of different countries around the world to use biofuel.

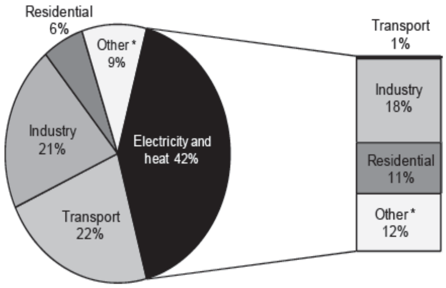

Figure 1: CO_2 emission by sectors [2]

2. Environmental and Health Hazards of Fossil Fuel Emission

Transportation sector is one of the main sources of greenhouse gases such as CO_2. This GHG emission is responsible for worldwide climate change. Worldwide vast number of health problems and respiratory diseases are caused by air pollution. Irritation of lungs and pneumonia, oedema and bronchitis are caused by NOx emission. Also, NOx emission results in increased sensitivity to dust and pollen in asthmatics. Tissue development of young children and fetal growth in pregnant women are caused by CO emission. HC emission promotes morbidity in people who have circulatory or respiratory problems. Drowsiness, eye irritation, sneezing and coughing and symptoms akin to drunkenness are caused by PAHs. Lung diseases are caused by some hydrocarbons which have close affinity for diesel particulates [1, 8]. Ozone negatively affects health and also causes harm to ecosystems. Acidification is caused by emissions of nitrogen oxides and sulphur emissions [13]. On the basis of damage of human body, fine particulate matter, lead and ozone are the most hazardous elements. Today, in developing countries, on the basis of exposure, toxicity, and ambient concentrations, fine particulate matter has become the pollutant of greatest concern.

3. Potential of Biofuel as a Renewable Energy Sources

3.1 Biofuel development

The key factors for biofuel development are: (a) Renewable (b) Net Energy Output (c) GHG reduction, (d) Job Creation, (e) Rural development, (f) Conversion technology, (g) Food security (h) Biodiversity (i) Water Resource, (j) Nutrient and pesticides (k) Feedstock and soil, (l) Change in land use, (m) Contamination and air quality.

3.2 Biodiesel

Biodiesel is an ester based oxygenated fuels consisting long chain fatty acids derived from vegetable oils (both edible and non-edible) or animal fats and it is non explosive, biodegradable, non flammable, renewable, non-toxic. It can be used in diesel engine as alternative of diesel fuel without major modification of the engine with same or better performance in comparison to ordinary diesel fuel [9]. Currently, the sources of biodiesel include soybean oil, sunflower oil, corn oil, used fried oil, olive oil, rapeseed oil, castor oil, lesquerella oil, milkweed (Asclepias) seed oil, *Jatropha curcas*, *Pongamia glabra* (karanja), *Madhuca indica* (Mahua) and *Salvadora oleoides* (Pilu), *Calophyllum inophyllum*, palm oil, linseed oil, algae etc. Biodiesel can be produced from vegetables oils in four different ways namely pyrolysis/cracking, dilution with hydrocarbons blending, emulsification, and transesterification [10].

3.3 Ethanol

Ethanol is a low cost oxygenates which contains 34% higher oxygen content by weight [11]. Using fermentation process ethanol can be made biologically from a variety of biomass sources such as sugarcane, corn, sugar beet, molasses, cassava root, etc [6]. Ethanol can be produced from a variety of feedstocks such as sugarcane, bagasse, miscanthus, sugar beet, sorghum, rain, switch grass, barely, hemp, kenaf, potatoes, cassava, sunflower, fruit, molasses, corn, stover, grain, wheat, straw, cotton, other biomass, as well as many types of cellulose waste and harvesting, whichever has the best well-to-wheel assessment. The basic steps for large-scale production of ethanol are: microbial (yeast) fermentation of sugars, distillation, dehydration and denaturing. Prior to fermentation, some crops require saccharification or hydrolysis of carbohydrates such as cellulose and starch into sugars. Saccharification of cellulose is called cellulolysis. Enzymes are used to convert starch into sugar. Figure 2 shows the production process of biofuel [12].

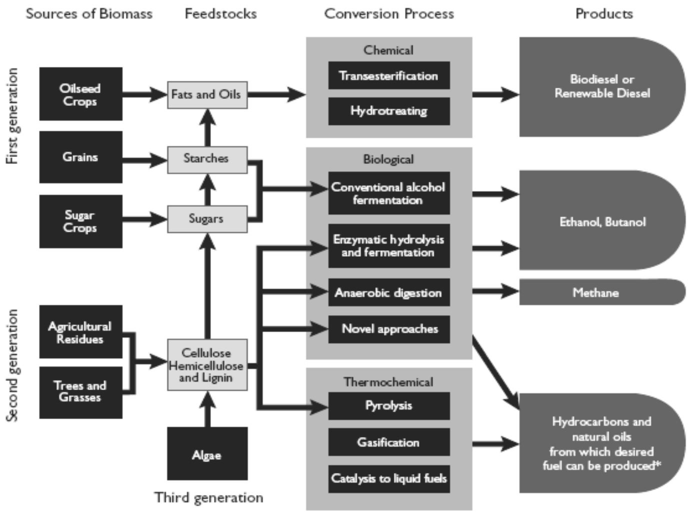

Figure 2: Production process of biofuel [12]

3.4 Biofuel Production and Use Target in Some Countries around the World

In recent years, production of biofuel around the world raised drastically. For example, in 2010, increasing by 17% from 2009, worldwide biofuel production reached 105 billion liters (28 billion gallons US), and 2.7% of world′s fuels for road transport are largely contributed from ethanol and biodiesel. This is driven primarily by the government's pursuit of energy security, economic development (particularly, improvement of trade balances and expansion of the agriculture sector), and poverty alleviation. Biofuel strategies of the most Asian countries are focused around the country's main agricultural product and new business opportunities. All these countries pay heavy subsidies on petroleum transport fuel which are imported. Contrary, in order to influence the commercialization of self-produced biofuel, the countries need to pay more subsidies as price of biofuels still a bit higher [12]. **Table 1** shows biofuel target of some countries in the world.

Table 1: Biofuel targets in some countries around the world [12]

Countries	Years	Target	Feedstocks
U. S. A	2012	28 Billion ethanol	Corn, soybean oil, sorghum and cellulosic sources in the future
	2013	1 Billion liters of cellulosic ethanol	
	2020	25% Ethanol	
	2005	2% Biodiesel	
Brazil	2012	25% Ethanol and B2	Soybean, sugarcane, palm oil
	2013	B5 (2.4 billion biodiesel)	
	2020	B20	
EU	2005	2%	Rapeseed, sunflower, wheat sugar beet, barley
	2010	5.75%	
	2020	10%	
	2025	30%	
China	2010	1.5–2 Million biodiesel	Corn, cassava, sweet potato, rice, jatropha
	2020	10% Ethanol (=8.5 million tons)	
		10.6–12 million biodiesel	
Canada	2010	5% Ethanol	Corn, wheat
	2012	2% Biodiesel	
India	2012	5% Biofuel	Molasses, sugarcane in the future, jatropha
	2017	10% Biofuel	
Australia	2010	350 Million liters of biofuel	Wheat, sugarcane, molasses, palm oil, cotton oil
	2012	10% Ethanol and 10% biodiesel	
	2017	20% Ethanol and 20% biodiesel	
Japan	2010	360 Million liters biofuel	Imported ethanol, rice bran and
	2020	6 billion liters biofuel	
	2030	10% Biofuel	

4. Impact of Biofuel on IC Engines Emission Characteristics

The increasing industrialization and modernization of the world has to a step up for the demand of petroleum derived fuel which is viable to human health as well as environment due to emitting green house gases. **Figure 3** [12, 13] show the reduction of engine emission using biofuel. Ekrem [14] found that the use of biodiesel in diesel engines produces lower CO and smoke opacity and NO_x emissions compared to diesel fuel at full load condition. He suggested that only low concentration blends in terms of performance efficiency and environmentally friendly emissions could be recognized as the potential candidates to be certified for full scale usage in unmodified diesel engines. Saleh [15] found that Jojoba methyl ester (JME) increase 14% and 16% NO_x emission at 1600 rpm and 1200 rpm respectively compared to fossil diesel fuel. At lower engine speed JME produce higher HC and CO emissions but at higher engine speed, there is no significant difference between HC and diesel fuel while CO is lower than diesel. The results also showed that when the exhaust gas recirculation (EGR) rate is increased, the NO_x emissions decreased. However, CO and HC emissions increased. They recommended that the optimum EGR level is 5-15% for all engine speeds and loads and that may be favorable in a trade-off between HC, CO and NO_x emissions with little economy penalty. Study conducted by Zhihao et al. [16] depicts that Pistacia Chinensis Bunge biodiesel blended fuel emits lower HC, CO and exhaust smoke emissions. B10 and B20 reduces NO_x emission, however, B30 slightly increases NOx emission due to having higher oxygen contents which results in higher cylinder temperature. The emission analysis by Selvam and

Vadivel [17] shows a radical reduction (34.7-63%) in carbon monoxide (CO), unburned hydrocarbon (UHC) and smoke density for all beef tallow biodiesel blended fuel. However, in the case of oxides of nitrogen, there is a slight increase for all the blended fuels and with neat biodiesel (6.35%) compared to diesel fuel. Nurun Nabi et al. [18] reported that Pongamia biodiesel reduces CO, smoke and engine noise by 50%, 43% and 2.5dB respectively but increased NOx emission by 15% at high load conditions. The reason can be attributed to the presence of oxygen in karanja biodiesel molecular structure. Raheman and Phadatare [19] found Karanja biodiesel blend (B20-B100) in a diesel engine reduce CO emission (73-94%), smoke density (20-80%) and 26% in average NO_x emission than diesel fuel due to the complete combustion of the biodiesel blend fuel. There was no significant variation in exhaust temperatures.

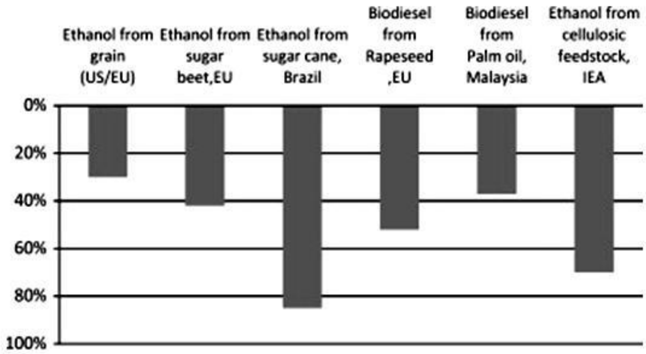

Figure 3: GHG emission reduction of biofuel compared to fossil fuel [13]

Shi et al. [20] found that the use of biodiesel-diesel-ethanol blends helps to reduce particulate matter emissions by 30% and a general reduction in total hydrocarbon but slightly (5.6–11.4%) increase the NO_x emissions in average. In case of unregulated emission such as acetaldehyde and acetone increased a bit when biodiesel-diesel-ethanol blended fuel used. Banapurmath and Tewari [21] operated a diesel engine with 0%, 5%, 10%, 15% ethanol blends and found reduction in HC and increase in NOx emission with ethanol-biodiesel blends compared to diesel and biodiesel fuels. Zhu et al. [22] tested Euro V diesel fuel and ethanol-biodiesel blends in a four-cylinder direct injection diesel engine. It was found that the addition of 5% ethanol in biodiesel improves engine performance slightly. It also could reduce NOx, PM, CO and HC emissions compared to diesel fuel. In exception, higher concentration of ethanol in blend could increase CO and HC emissions, while significantly reduces NOx and PM emissions. Yilmaz et al. [23] found at full load condition the blended fuel increased CO and HC emissions but reduced NO emissions. They concluded that adding ethanol in the blends would be the perfect choice to reduce NO emissions for the concentrations presented in this study. Fang et al. [24] reported that ethanol–diesel–biodiesel blended fuel produce lower NO*x* emissions and higher HC and CO emissions due to higher latent heat of vaporization which causes lower combustion temperature. In case of smoke emission, blended fuel (ethanol–diesel–biodiesel) lowered it compared to that of diesel and biodiesel–diesel fuel. The peaks of smoke emissions were reduced in a large extent with the increase of percentage of ethanol in blended fuels. Finally, they concluded that ethanol–diesel–biodiesel is suitable alternative to reduce NO*x* and smoke emissions in premixed lower temperature condition. Yilmaz et al. [25] investigated the emission of biodiesel-diesel-ethanol (BDE3, BDE5, BDE15 and BDE25) blends in a diesel engine at different engine load condition. Experimental results indicate that emissions are strongly depended on engine operating conditions and biofuel concentration in the blend. Ethanol blended fuels increased CO emissions compared to that of diesel fuel for all operating conditions but the blended fuels reduced NO emissions for all concentrations. Overall, lower percentages of ethanol in the blend, decreased HC emissions and vice versa. But ethanol blended fuel reduced HC emissions at over 50% load conditions.

5. Conclusion

From this review it is found that vehicular emission is largely responsible for GHG emission and health hazards. This problem could be addressed by using biofuel in diesel engines in a blended form as biofuel have potential to reduce engine emission to the environment. This review indicates that biofuel have potential to reduce GHG emission more than 80%. Some developed countries have put their target and mandate to use biofuel. For example, the United States wants to use 25% ethanol within 2020, Brazil targets to implement B20 within 2020 and India targets to use B10 country wide within 2017. Some developing countries are exporting biofuel but not using as they are not conscious enough about the environment pollution. Government of those developing countries can take initiative to introduce biofuel as a fuel in their transportation sector to reduce global IC engine emissions.

Future work

The authors of this paper will study the impact of biofuel such as ethanol and biodiesel from Beautyleaf (Australian native crop) with diesel fuel on IC engine emissions to find out the emission reduction potential of Australian native crops.

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Biography

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