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Investigation of the Performance and Emission Values of Non-Standard Fuels at Diesel Engines

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Abstract: Diesel engines have very important role at transportation and agriculture. Due to the fuels used in diesel engines being expensive and tendency of increase in its price, consumers have been forced to seek alternative fuels. However, the effects of fuels on environment and engines have been ignored.
In this study, together with diesel fuel oil as a reference, the effects of number 10 mineral oil and waste vegetable neutralized oil on engine performance and exhaust emission were investigated. The engine used in study was diesel with single cylinder, four cycle, direct injection, and rate power of 15 HP engine. Results of the study showed that when both waste vegetable oil and number 10 mineral oil were used, the power and moment values have decreased 9.1% and 2.8%, respectively while the specific fuel consumption has increased.
Key words: Waste vegetable oil, number of 10 mineral oil, kit, engine, performance, emission

INTRODUCTION

The vehicles with diesel engines that are widely used in land transportation and agricultural transportation in our country and the world lead to the prevalence of vehicles using diesel engines. Both the excessive use of diesel fuel and its price increasing recently directed consumers to alternative fuels. Among them vegetable oils and the fuels produced from them comes first.

Oils are classified as mineral, etheric and triglyceride. The mineral oils obtained with petrol refining are paraphinic mixtures. Etheric oils are volatiles oils and natural products which are generally composed of odorous vegetable originated natural products. Triglyceride oils are natural substances which are generally formed in the inner structures of plants and animals and water-insoluble and whose essential component is triglyceride (Güner, 1990).

While waste frying oils were added to animal feed, following from 2002, European Union (EU) forbidden the use of waste oils in this way because many hazardous compositions are formed during frying process and if waste cooking oil for frying is used as additive in animal feed, hazardous compositions can return to people from animal meat, milk and eggs through food chain. Therefore, waste frying oils are to be eliminated in a safe way or to be used in a way which will not be hazardous to people (Uslan et al, 2007), which is achieved by using it in diesel engines after passing oil through some chemical processes (neutralization, esterification).

Although many studies on the use of vegetable oils as fuels in diesel engines have been carried out so far, desired level of success has not been attained in making its use as fuel widespread. To use vegetable oil directly, some properties important for the engine (kinematic viscosity, water content, the number of acid and iodine, total pollution, phosphor, sulphur, oxidation stability) are to be brought to desired level, that is, the oil is to undergo some chemical pretreatments (Öğüt et al., 2007).

Especially since the mid of the year 2007, number 10 mineral oil-which is primarily composed of base oil-started to be sold in cans to be used in vehicles with diesel engines. Majority of producers are licensed mineral oil companies. The use of number 10 mineral oil especially increased as consumers consciously preferred to use economical, non-standard fuels in their vehicles. In this case it is becoming difficult to practice direct legal sanctions on producers and sellers.

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The annual production of number 10 mineral oil is 10-15.000 tons and is a type of mineral oil with low viscosity. As it has comparable technical features and as the market price of base and mineral oil types which can be directly used instead of fuel in some vehicles are lower than taxed diesel oils prices, they were used instead of diesel oil. This application which started with selling and using oils for this purpose become widespread with the use of waste oils and other substances. This activity which started with the availability of these oils as number 10 mineral oil in cans in them market since the second half of 2007 has gradually become common and annual consumption amount all over the country has reached to 300.000-400.000 tons (PETDER; 2008). In Table 1 prices of various fuels are given.

Table 1. Unit Prices of various fuels (EPDK, 2010)

Type of fuel	Price (L/TL) *
Country diesel fuel	3,05
Diesel fuel	3,15
Number of 10 mineral oil	2,12

* Average prices on 15 April 2010 in Konya

In this study, besides reference diesel fuel, the effects of number 10 mineral oil which are used in diesel vehicles in our country and waste vegetable neutral oils on engine performance and exhaust emissions.

MATERIAL and METHOD

Material

Number 10 mineral oil used as material in this study is obtained from Konya industry zone and ALBİYOBİR (Alternative Energy and Biodiesel Producers Association), which has a license to collect waste vegetable oil. Waste vegetable oil was passed through physical cleaning. For neutralization process was achieved Biodiesel Production Facility at Department of Agricultural Machines, Agricultural Faculty, Selçuk University. The properties of these oils and diesel fuel as reference fuel are examined. The properties of fuel are determined in Biodiesel Laboratory at Department of Agricultural Machines, Agricultural Faculty, Selçuk University which was founded within the scope of DPT 2004/7 project. In Figure 1 the fuels used in trials are given.

Figure 1. Fuels used in trials

Engine tests were carried out in Engine Test Unit at Department of Agricultural Machines, Agricultural Faculty, Selçuk University which was founded within the scope of TÜBİTAK 108 O 419 project. To carry out trials under controlled conditions, hydraulic dynamometer placed in cooling room and the kit designed on it were mounted (according to TSE 1231) (Figure 2). Exhaust emissions were made with Mobydic brand exhaust emission device.

Figure 2. Engine test unit used in trials

The technical properties of diesel engine are given in Table 2.

Table 2. Technical properties of engine used in trials

Type	Unit	4 cycled, Direct Injection, Diesel
Number of Cylinders		1
Diameter of Cylinder	mm	108
Stroke of Cylinder	mm	100
Volume of Cylinder	liter	0.92
Compression Rate		17:1
Max. Power	BG	15
Max. Torque	Nm	60
Fuel Injection Pump		Bosch Type
Cooling system		Water-cooled

High level of viscosity of vegetable oils leads to contamination of atomization and burning (Altun and Gür, 2005). One of the methods used to solve high viscosity problem is to heat the oil to decrease its viscosity. With achieve this in this study, a kit designed in the scope of TÜBİTAK 108 O 419 project was mounted on the engine to make use the temperature of engine cooling water. In Figure 3, fuel equipments are shown with the Kit mounted on them.

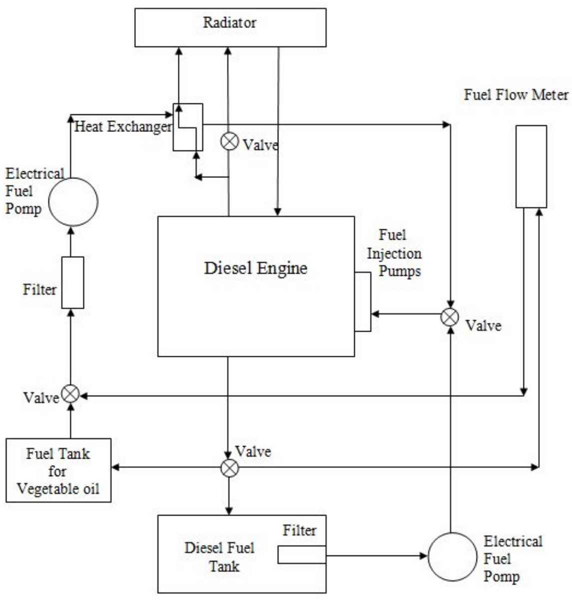

Figure 3. Fuel equipment scheme with the Kit mounted

Method

This study was carried out in two stages. In the first stage, to change the properties of waste vegetable oil according to DIN V 51605 standard properties, neutralization, blanching and filtration processes were carried out. The details of these processes are given below.

With physical cleaning of waste oil, the waste frying particles were removed and the oil was taken to settling tank in production facility.

In this tank, waste vegetable oil was heated up to 100ºC and it was kept in vacuum for 2 hours at this temperature and the water formed in it because of usage was removed.

After the water in waste oil was removed, it was taken to reactor tank and kept there till heat decreases to 85 ºC. This temperature was kept constant reactor mixer was started and phosphoric acid of 0.2% of the oil was applied and mixed for 10 minutes for neutralization process. While mixing was ongoing, 1/3 sodium hydroxide/pure mixture was added to the oil at 5% and mixed for 5 minutes more. The mixer was turned off, 3 hours were waited for phosphor compositions to sinks and phosphor compositions were taken.

Waste vegetable oil was again heated up to 85 ºC and washed with douching method with 20% water at the same temperature. Three hours were waited for waste water to sink and then waste water was removed.

The mixture was dried at 100 ºC for 2 hours under vacuum for the water in waste vegetable oil to be removed.

We waited till waste vegetable oil decrease to 85 ºC', and started the reactor mixer and 2% of blanching soil was added and mixed fro 45 minutes. Later on, reactor mixer was turned off and 3 hours were waited for blanching soil to sink and the blanching soil was removed.

After neutralization process, waste oil was passed through plate filter so that the fuel was ready to be used.

The fuel properties of waste vegetable neutral oil, number 10 mineral oil and reference diesel fuel are determined according to methods mentioned in DIN V 51605 and TS 3082 EN 590.

In the second stage, the engine performance of fuels (according to TS 1231) and exhaust gas emissions were determined. Engine was tried at full load and at different engine loads.

RESULTS and DISCUSSION

Analysis results of the fuels used in the study are given in Table 3.

According to analysis results, the viscosity of both vegetable oil and number 10 mineral oil values are almost 15 times more than diesel fuel. At engine working temperature, this rate decreases up to 5 times.

The values obtained from tests are given as graphics by comparing power, moment, fuel consumption and specific fuel consumption in terms of engine speed. The graphics obtained are given in Figure 2,3,4 and 5.

As it can be seen in Figure 4, although the power values of waste vegetable oil and number 10 mineral oil coincide, it is 9.1 % lower than diesel fuel at average.

In Figure 5, the moment changes of fuels according to engine speed are given. According to results, the maximum moment values of vegetable oil and number 10 mineral oil are 2.8 % lower than diesel fuel.

Table 3. Properties of fuels used in trials

Property	Diesel fuel	Number 10 Mineral Oil	TS 3082 EN 590		Waste vegetable Neutral Oil	DIN V 51605	
			Min.	Max.		Min.	Max.
Density at 15°C (kg/m^3)	826.4	879.0	820	845	920.9	900	930
Viscosity at 40 ° (mm^2/s)	2.738	40.926	2	4.5	43.221	-	36
Viscosity at 70 °C (mm^2/s)	1.668	13.254			15.439		
Viscosity at 100 °C (mm^2/s)	1.171	6.351			8.215		
Flash point (°C)	60	200	<55		<320	220	-
The number of Cetane	58.4	54.3	51		50.9	39	-
Water content (mg/kg)	29.528	58.140		200	435.531	-	750
Copper Strip Corrosion (at 50 °C for 3 hours)	1a	1a		1	1a		-
pH	5.5	5.5		-	5.5		-
Heat of Combustion (MJ/kg)	46.581	48.541		-	37.695	36	
ASTM Color (0.5 - 8 units)	>0.5	2.1		-	0.7		-

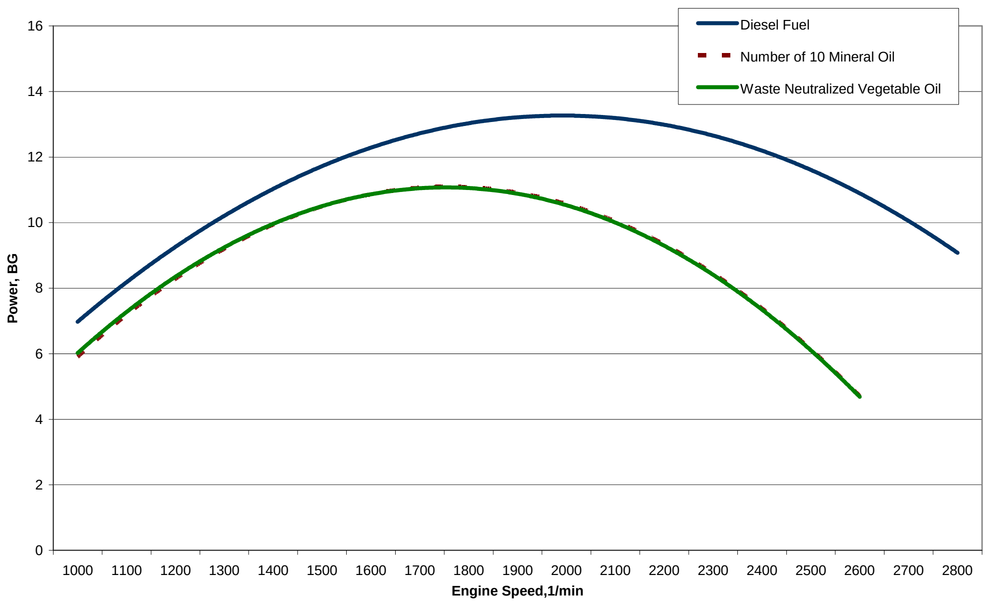

Figure 4. Power change of fuels according to engine speed

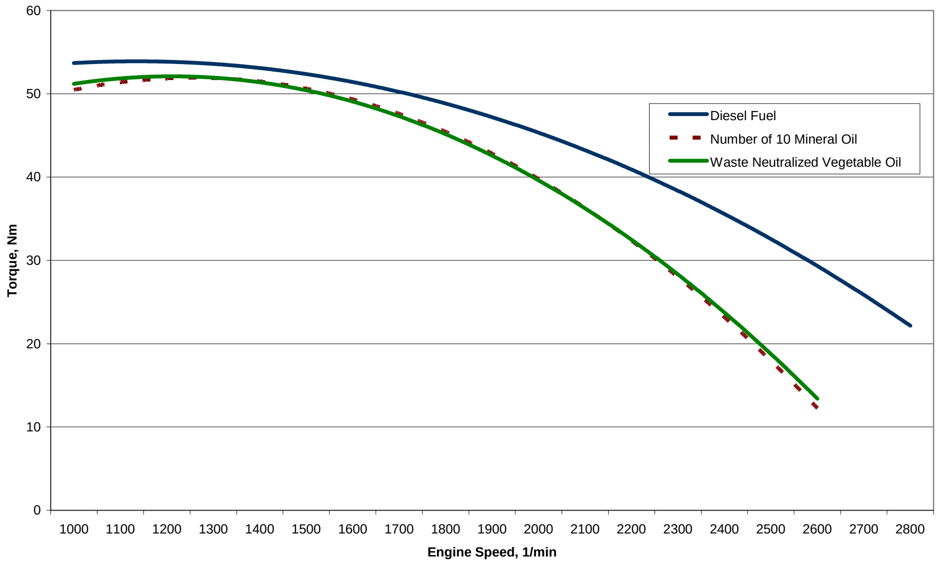

Figure 5. The turning torque changes in fuels according to engine speed

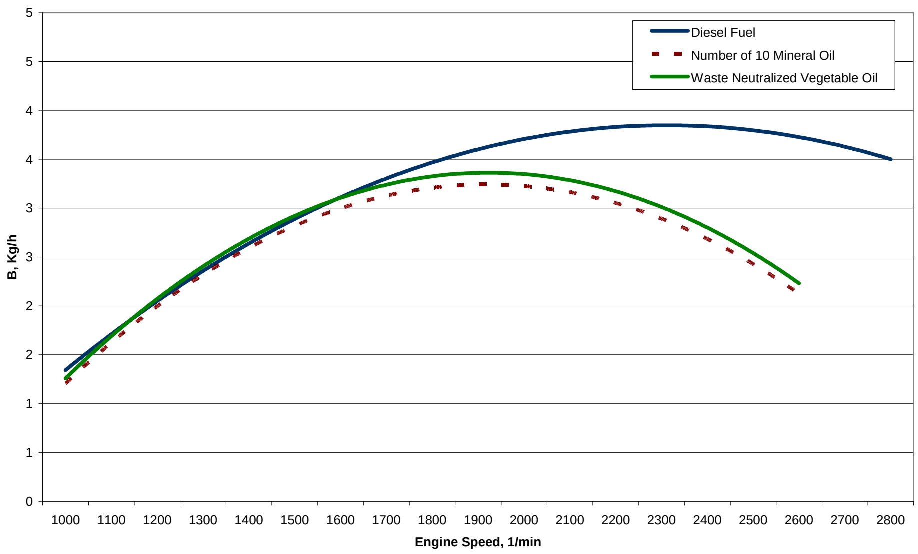

Figure 6. Change in fuel consumption values of fuels according to engine speed

In Figure 6, fuel consumption values of fuels according to engine speed are given. According to results, the values of vegetable oil, number 10 mineral oil and diesel fuel coincide up to 1600 speeds.

In Figure 7, the changes in the specific fuel consumption values of fuels according to engine speed are given. According to results, the specific fuel consumption results of diesel fuel are lower than vegetable oil and number 10 mineral oil.

CO restriction is one the basic parameters of emission standards. The basic reason for the existence of CO among burning products is the low air-fuel rate. CO emission is also an important parameter as it indicates loss chemical energy not used in engine. As it significantly affect fuel properties, injection characteristics, engine load, air-fuel rate CO formation changes as a function of these parameters. (Özsezen and Çanakçı, 2008).

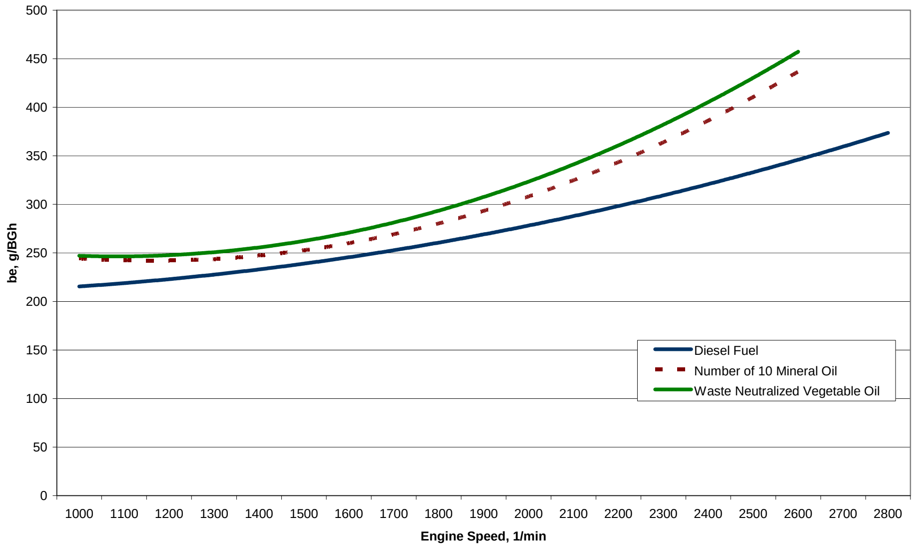

Figure 7. Change in specific fuel consumptions of fuels according to engine speed

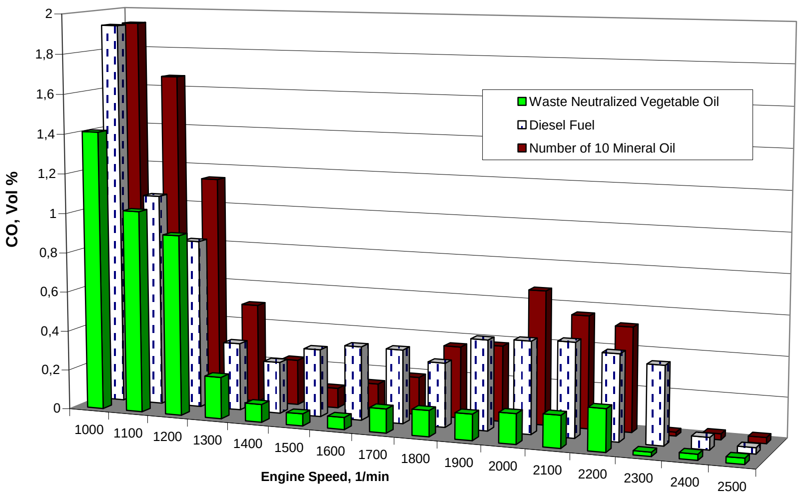

Figure 8. CO change in fuels according to engine speed

In Figure 8 CO values of fuel according to engine speed are given. According to results, CO values of waste vegetable oil are lower than number 10 mineral oil and diesel fuel because of full combustion. The effects of CO on human health are exhaustion, decrease performance at work, headache, dizziness, difficulty in breathing, blackout (when it reaches to limit values 0.3% in the air, it is fatal) (Öğüt, 2007).

The carbon balance of renewable fuels is positive. The CO_2 which result from renewable energy originated fuels are kept by plants. Plants divide CO_2 into carbon and oxygen. Oxygen is released back to atmosphere. Thus, using renewable energy enables natural balance in CO_2 emission. In Figure 9, CO_2 values of fuels according to engine speed are given. According to the results, CO_2 values of the waste vegetable oil are higher compared to number 10 mineral oil and diesel oil.

The reason why hydrocarbons are formed among unburned products is that the fuel is not oxidized or half oxidized as fuel does not react to flammability temperature or fuel is insufficient (Çanakçı and Özsezen 2007; Oğuz et al., 2008).

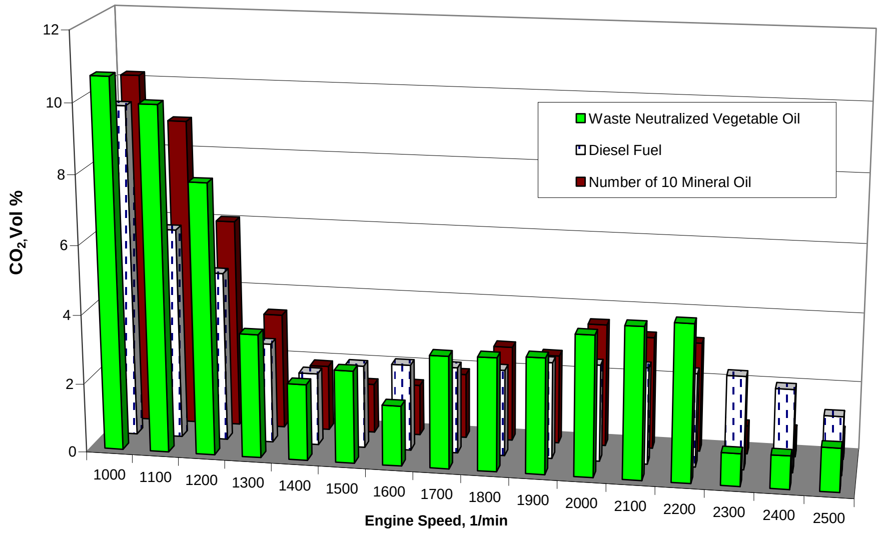

Figure 9. The CO_2 changes in fuels according to engine speed

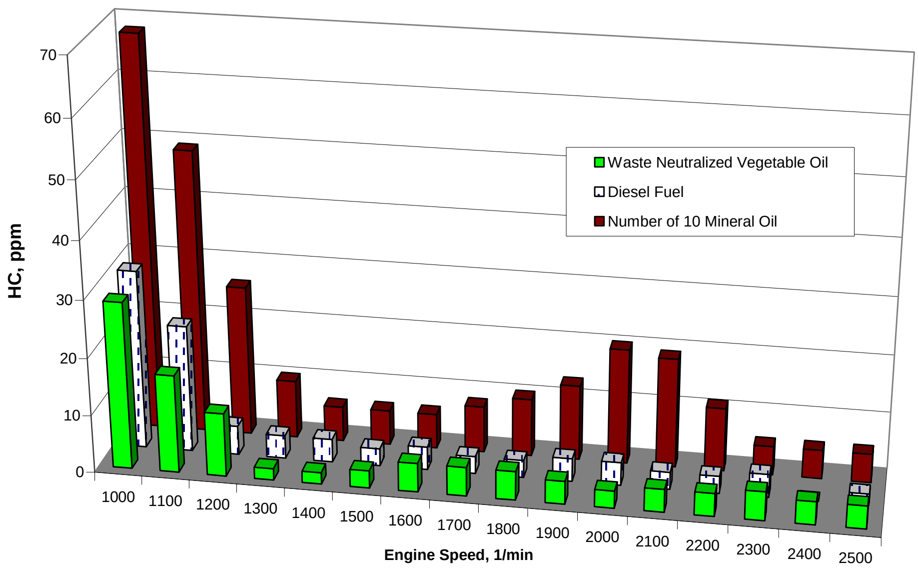

Figure 10. HC change of fuels according to engine speed

In Figure 10, the HC values of fuels according to engine speed are given. According to results, the HC values of number 10 mineral oil are higher compared to waste vegetable oil and diesel fuel. The most important effect of HC on human health is its carcinogenic effect (Öğüt, 2007). Therefore, the use of number 10 mineral oil in diesel engines is hazardous for human health.

High temperature resulting from the burning fuel in the engine leads to formation of nitrogen oxides with the combination of nitrogen in the air with oxygen. Besides, as burning period is lengthened in easily flammable fuels NO_X increase. In Figure 11, The NO_X values of fuels according to engine speed are given. According to the results, the NO_X values of waste vegetable oil are higher than number 10 mineral oil and diesel oil. This can be attributed to that fact that vegetable oils contain 11% oxygen. However, this problem can be dealt with by decreasing combustion temperature (by delaying burning 1-3° or by using catalytic convertor) (Zhang, 2002).

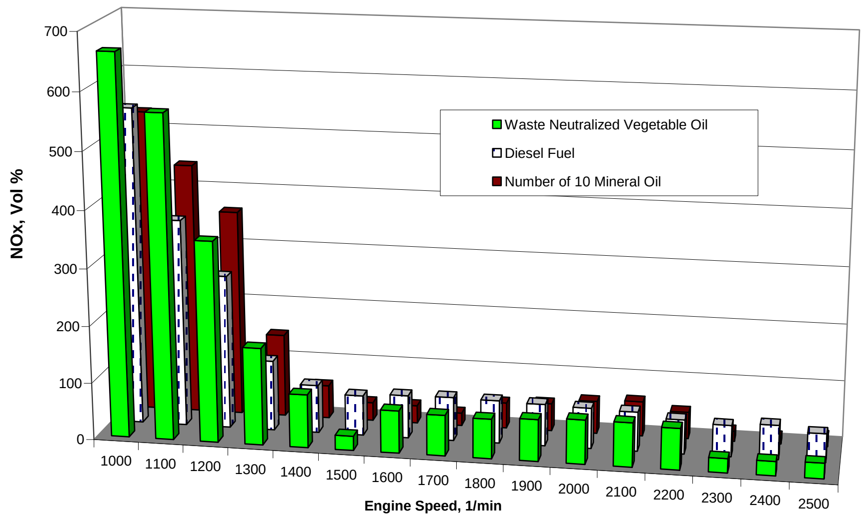

Figure 11. NO_X changes in fuels according to engine speed

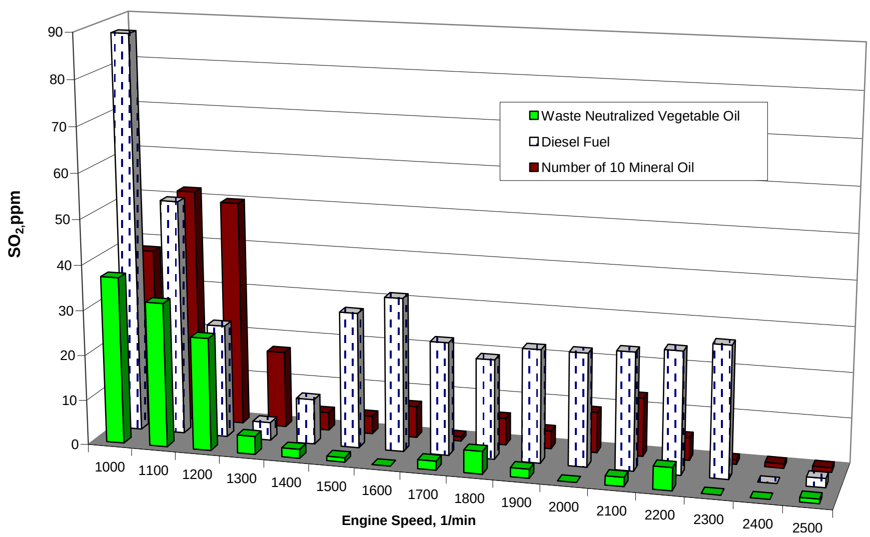

Figure 12. SO_2 changes in fuels according to engine speed

In Figure 12, the SO_2 values of fuels according to engine revolution are given. According to results, the SO_2 values of waste vegetable oil lower than number 10 mineral oil and diesel oil.

In conclusion, it is clear that non-standard fuels not only decrease engine performance but also lead to environmental problems because of exhaust emissions. Instead of using waste vegetable oils directly in diesel engines, which poses risk for the environment, they are to be directed to biodiesel production through licensed collectors as it is envisaged in the related regulation. The use of number 10 mineral oil as fuel which came about as a result of increase in diesel fuel prices, and thus in transportation and costs in agricultural production is highly hazardous for the environment It is necessary to encourage studies in the field of "Energy Agriculture" to prevent this unhealthy application which results from economic conditions. Considering the local and global effects of exhaust emissions and their effects on human beings and plants, besides sanctions, realistic and alternative methods are to be put into practice instead of "Diesel Fuel Incentive" model which is currently applied in agriculture to prevent the use of number 10 mineral oil and waste vegetable oil directly without turning into biodiesel.

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