

Reduction of NO_x using Selective Catalytic Reduction in a Bio-Fuelled C.I Engine

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ABSTRACT:Waste vegetable oil is chosen as alternative fuel for diesel engines. It is renewable and offer potential reduction in CO; HC and smoke emissions due to higher O₂ contents in it compared to diesel fuel but higher nitrogen oxides (NO_x) emission. Nitrogen oxides (NO_x) in the atmosphere cause serious environmental problems, such as photochemical oxidant, acid rain, and global warming. The removal of nitrogen oxides (NO_x) from the exhaust of diesel engines is still a very challenging problem even though there have been many studies. Technologies available for NO_x reductions either enhance other polluting gas emissions or increase fuel consumption.

Injection of aqueous solutions of urea in the tail pipe of a diesel engine fuelled with waste vegetable oil for the reduction of oxides of nitrogen (NO_x) was carried out in a four stroke, single cylinder, water cooled, constant speed diesel engine. Four observations were made for various concentration of urea solution 0%, 10%, 20%, and 30% by weight with different flow rates of urea solution SCR catalyst which improves the chemical reactions. 30% NO_x reduction has been achieved with the urea flow rate 0.90 lit/hr, 30% concentration of urea solution.

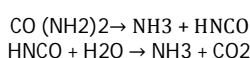
KEYWORDS:Vegetable oil, Urea, SCR, NO_x, Diesel Engine

I. INTRODUCTION

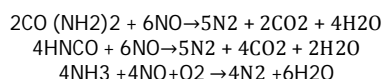
The minimisation of fuel consumption and the reduction of emissions have been two driving forces for engine development throughout the last decades. The first objective is in the financial interest of the vehicle owners. The second is imposed by legislation, sometimes also supported by excise reductions or customers' demands for clean engines.

Nitrogen oxides (NO_x) are the various compounds of nitrogen and Oxygen(O₂) formed during the combustion process. Both nitrogen and O₂ are present in the air used for combustion. Exposure to NO_x can cause respiratory problems, such as lung irritation, bronchitis, or pneumonia^[1]. Photochemical smog results when HC and NO_x are combined with sunlight. Smog can cause many health problems, including chest-pains, shortness of breath, coughing and wheezing, and eye irritation. When NO_x in the atmosphere mixes with rain (H₂O), nitric acid (HNO₃) or acid rain is created^[2].

SCR(Selective Catalytic Reduction) plays a important role in decreasing NO_x emission from the diesel engine using ammonia as the reducing agent in recent decades^[3]. But exposure of ammonia to larger level will lead to skin irritation, suffocation and other lung related diseases^[4].Urea appears to be the reductant of choice for most applications, stored on board in an aqueous solution. To overcome the difficulties connected with pure ammonia, urea can be hydrolysed and decomposed to generate ammonia^[5].



Urea is non-toxic and can be easily handled without any effects. It can be used as the source for ammonia for reduction of NO_x emission. Hence, ammonia can be produced by decomposing urea.



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Finally the NO_x from the diesel engine can be converted to nitrogen and water. Even though the water contains ammonia it can be disposed easily without any ill effects.

A) WASTE VEGETABLE OIL

It has been found that the vegetable oils are promising substitute, because of their properties are similar to those of diesel fuel and they are renewable and can be easily produced. Rudolph Diesel, the inventor of the diesel engine that bears his name, experimented with fuels ranging from powdered coal to peanut oil. Several researchers^[6-10] experimented the use of vegetable oils as fuel on diesel engine and reported that the performance was poor, citing the problems of high viscosity, low volatility and their polyunsaturated character.

The different fatty acids present^[6] in the vegetable oil are palmitic, steric, linoleic, oleic, linoleic and fatty acids. These fatty acids increase smoke emissions and also lead to incomplete combustion due to improper air-fuel mixing. Experiments were conducted^[7-10] on preheated vegetable^[9] temperature at which viscosity of the vegetable oils were matched to that of diesel fuel oils and it was reported that preheated vegetable oils improved the performance marginally and decreased pollution levels of smoke and NO_x emissions. The problems of crude vegetable oils can be solved, if these oils are chemically modified to bio-diesel.

Bio-diesels derived from vegetable oils present a very promising alternative to diesel fuel since biodiesels have numerous advantages compared to fossil fuels as they are renewable, biodegradable, provide energy security and foreign exchange savings besides addressing environmental concerns and socio-economic issues. Experiments were carried out^[11-15] with bio-diesel on direct injection diesel engine and it was reported that performance was compatible with pure diesel operation on conventional engine. However biodiesel operation increased NO_x levels.

B) SCR(Selective Catalytic Reduction)

SCR device is used for after treatment process in a engine. It decreases the amount of NO_x emitted in to the atmosphere and converts it in to nitrogen and water. NO_x reduction by SCR process takes place without a fuel penalty. For vehicles the most common option is a solution of urea in water carefully metered from a separate tank and injected into the exhaust system where it hydrolyses into ammonia ahead of the SCR catalyst. Urea solution is a stable, colorless, non-flammable fluid containing 32.5% urea which is not considered as hazardous to health and does not require any special safety measures according to the MSDS of urea.

II.RELATED WORK

The emission from the vehicles causes various ill effects to the environment and people. Reducing the emissions is the important factor for saving our planet. Our work aims to reduce the emissions from the C.I engine considerably using bio-diesel extracted from waste vegetable oil. The preparation of bio-diesel is done by transesterification process which is shown in fig.1

The various steps which have followed are summarized as follows

1. The Used vegetable oil was collected from the kitchen (1.5 litres) and used cooking oil had a darker colour to it and more chunks of fried foods floating around.
2. The cooking oil was completely run through the filter. Window screen adequately removed the particles that are large enough to affect the biodiesel reaction. The small particles are allowed to get settled for a day.
3. The oil was heated up to 55° C, and was put on a stir, the KOH was dissolved in the Methanol and slowly the methanol-KOH was allowed into the oil in drops and the oil was left for 2 days.
4. The bio-diesel was separated from glycerin very carefully and filtered.
5. Blends are prepared by mixing bio-diesel prepared from vegetable oil with diesel in various proportions. B10, B20, B30 Samples have been prepared initially to find out the perfect well suited blend which gives better performance and emission characteristics.
6. Finally B20 is found to be best blend as its shows better performance and emission characteristics than B10 and B30 blends.

The Carbon monoxide and Hydrocarbons have been decreased with use of B20 blend but NO_x emission is found to be more. This work focus on decreasing the NO_x emission to the atmosphere from C.I Engine.

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III. MATERIALS AND SETUP

This section deals with fabrication of SCR device, Bio-diesel preparation, Bio-diesel tank setup, experimental setup, specification of testing engine, specifications of gas analyser.

The testing were conducted in a diesel engine with specification shown in table.1. A separate tank is fabricated for using bio-diesel in the testing engine and linkages to the diesel filter was given using tubes. Initially the engine has to be started with diesel, hence valves were provided to inject and cut- off flow of bio-diesel in to the engine. The tank also provided with levelling device for measuring fuel consumption. Bio-diesel were prepared from waste fried vegetable oil and raw vegetable oil (Unused vegetable oil). It is prepared by trans- esterification process which is found to be more effective for preparing bio-diesel[5].

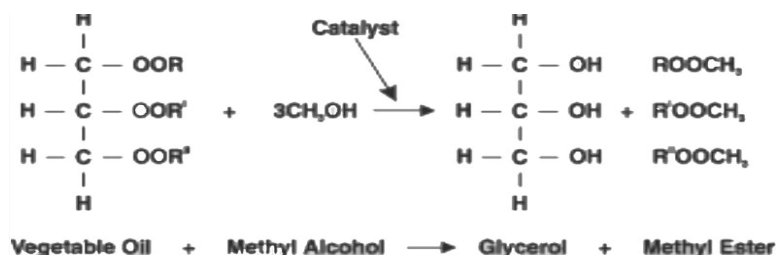


Fig. 1 Transesterification Process

Vegetable oil contains up to 72.9 % (wt.) free fatty acids ^[11]. The methyl ester was produced by chemically reacting the linseed oil with an alcohol (methyl), in the presence of a catalyst (KOH). A two-stage process was used for the esterification ^[11-15] of the waste fried vegetable oil. The first stage (acid-catalyzed) of the process is to reduce the free fatty acids (FFA) content in linseed oil by esterification with methanol (99% pure) and acid catalyst (sulfuric acid-98% pure) in one hour time of reaction at 55°C. In the second stage (alkali-catalyzed), the triglyceride portion of the linseed oil reacts with methanol and base catalyst (sodium hydroxide- 99% pure), in one hour time of reaction at 65°C, to form methyl ester and glycerol. The methyl ester produced is the Bio-diesel and the glycerol is separated and safely disposed. The impurities were removed from methyl ester by filtering through a fine cloth and leaving it for a day. The larger impurities will get filtered on the cloth while small particles will settled down due to gravity. Bio-diesel blend B20 is prepared by mixing 80% diesel with 20% methyl ester.



Fig.2 Diesel Engine Setup

Injection of aqueous solutions of urea from a separate urea tank in the tail pipe of test the diesel engine fuelled with Waste vegetable oil and diesel for the reduction of oxides of nitrogen (NOx) was carried out in a four stroke, single cylinder, water cooled, constant speed diesel engine. Four observations were made for the exhaust gas analysis of various concentration of urea solution 0%, 10%, 20%, and 30% by weight with different flow rates of urea solution.

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The table.1 shows the technical specifications of the testing engine. AVL gas analyser was used for the measurement of amounts of exhaust emissions. A control valve is used to maintain the urea flow rate. Urea solution for different concentration is made before the experiment. The measurements were taken after steady state of the engine for each set of readings.

Table 1. Testing Engine Specification

Make	Kirloskar TV-1
Max. Speed	1500RPM
Compression Ratio	17.5:1
Power	7bhp
Bore/Stroke	87.5mm/110mm

The SCR device consists of inlet and outlet pipe with urea injection tube at top of the mixer. To perform proper liquid vaporisation and enhancing the mixing process larger surface area and smaller flow channel is needed. The small flow channel increases the turbulence inside the mixer and increasing the surface area makes the better mixing enhancement in the SCR unit. Steel wire mesh of 2mm thickness is used to create turbulence in the mixer. The Fig.3 shows the Schematic diagram of SCR unit.

The L-shaped urea injection tube makes swirl action which helps in creating turbulence inside the mixer and performs better mixing process inside the mixer. At tail pipe the NO_x and ammonia is partially converted in to nitrogen and water. Urea injection has been carried out for three different flow rates 0.3lit/hr,0/6lit/hr,0.9lit/hr for various urea solution proportions.

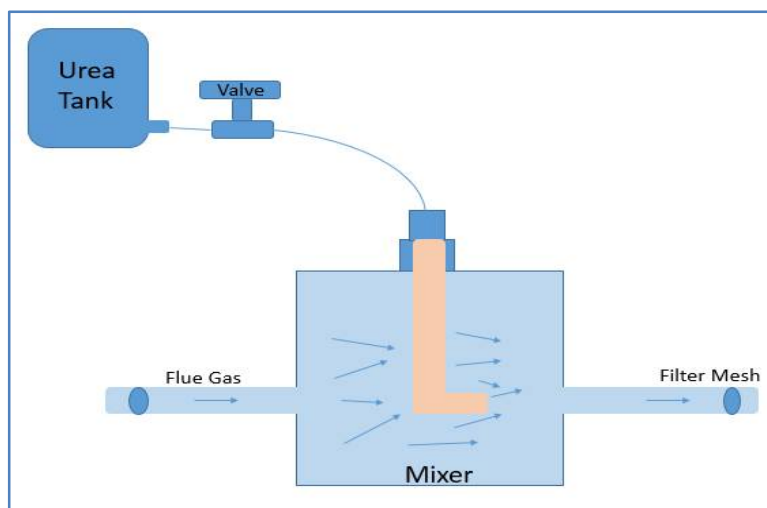


Fig. 3 SCR mixer design

The SCR device has been placed at the end of the tail pipe and urea injection has been carried out to the emission gases to decreasing the NO_x emission in to the atmosphere. The valve is used for flow rate and also for cut-off the urea injection. The mixer has been sealed completely to avoid gas leakage without proper mixing with the aqueous solution.

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IV. EXPERIMENTAL SETUP

The experiment has been carried in a diesel engine fuelled with waste fried vegetable oil Bio-diesel. The power output was measured in the dynamometer and emission gas is measured using AVL gas analyser. The schematic of the experimental setup is shown in Fig. 4

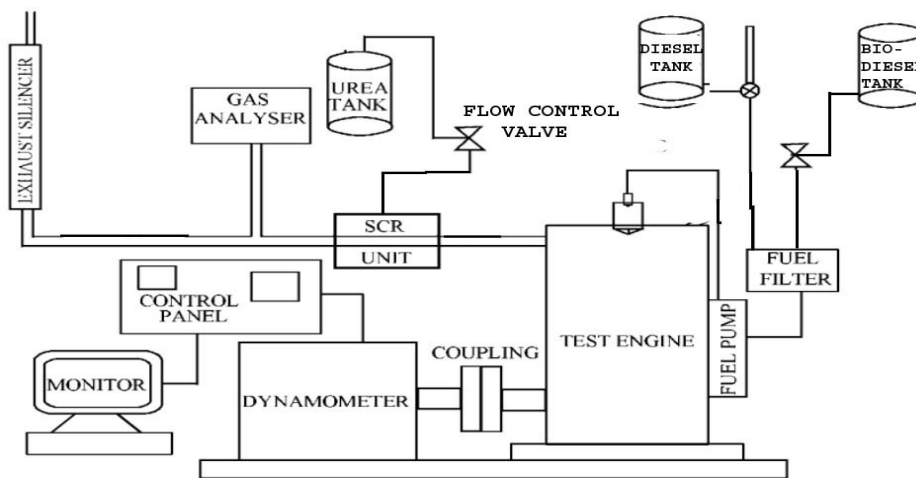


Fig.4 Schematic of Experimental Setup

V. RESULTS AND DISCUSSIONS

The emission from the engine is plotted to determine the effect of urea injection in the SCR unit for various flow rates.

1. CO Emission Vs Engine Load Without SCR

Fig.5 shows the variation of Carbon monoxide with engine load using both waste fried vegetable oil and diesel.

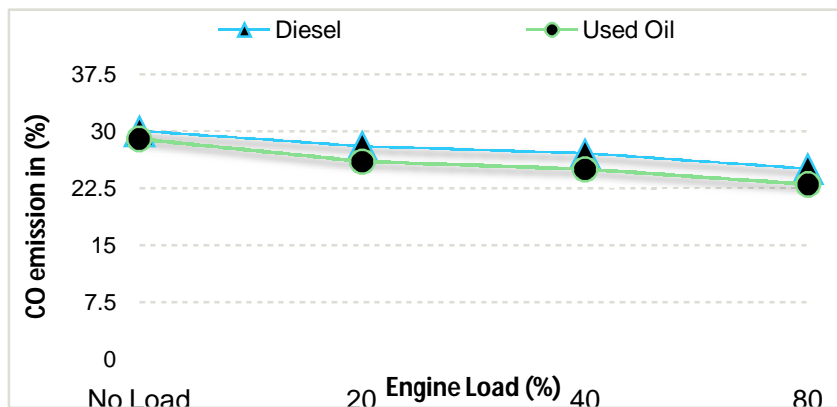


Fig.5 CO emission vs Engine load

From the graph it is observed that the CO emission decreases with the use of waste vegetable oil as fuel due to less carbon atoms in bio-diesel compared to conventional diesel. The formation of CO emission depends upon mixture

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strength and the availability of oxygen quantity and the fuel viscosity which in turn atomisation. The CO emission decreases with increase in load for all the test fuels. It is observed that waste vegetable oil biodiesel exhibits lower carbon monoxide emission as compared to diesel.

2. HC emission Vs Engine Load without SCR

Fig.6 shows the variation of Hydrocarbons with engine load using both waste fried vegetable oil and diesel.

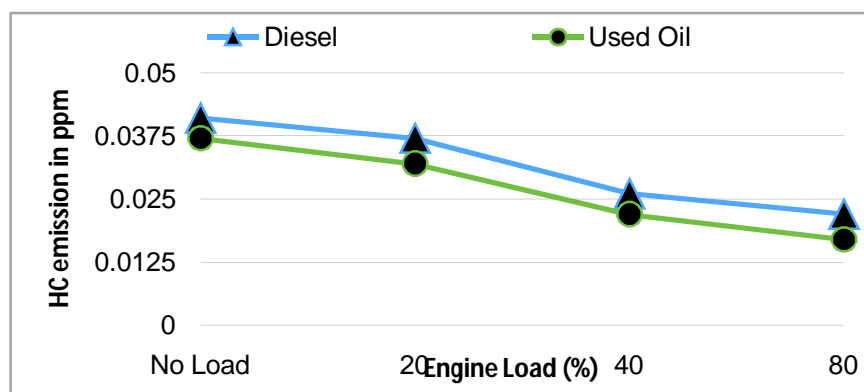


Fig.6 HC emission vs Engine load

From the graph it is observed that the HC emission decreases with the use of waste vegetable oil as fuel due to less Hydrogen atoms and better combustion than diesel. Hence HC emission decreases considerably with the use of waste vegetable oil.

3. NOx emission Vs Engine Load Without SCR

Fig.7 shows the variation of NOx with engine load using both waste fried vegetable oil and diesel.

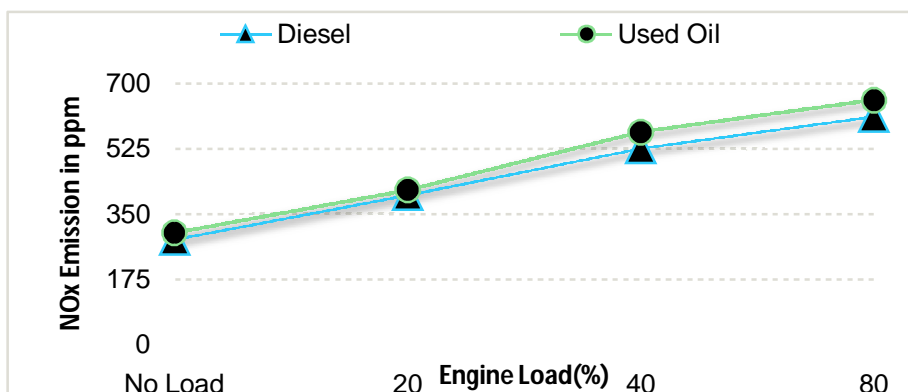


Fig.7 NOx emission vs Engine load

From the graph it is observed that the NOx emission increases with the use of waste vegetable oil as fuel. The NO emissions are formed by oxidation of the atmospheric nitrogen at sufficiently high temperatures [15]. The NO_x emission increases while the load is increased for all the test fuels. It is also observed that the NO_x emissions are increased at full load due to more oxygen molecules present in the biodiesel as compared to diesel.

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4. NOx emission Vs Engine load with Urea Injection at flow rate of 0.3lit/hr

Fig.8 shows the variation of NOx emission with the engine load using the bio-fuel with urea injection of various concentrations at flow rate of 0.3lit/hr.

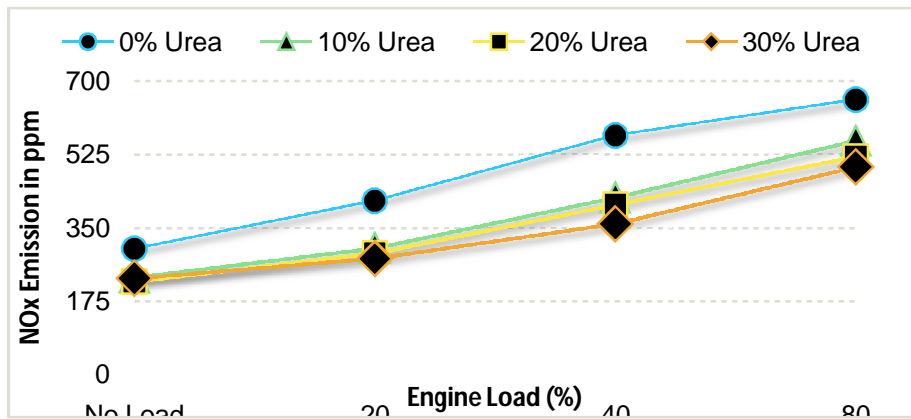


Fig.8 NOx emission vs Engine load

From the graph it is observed that the NOx emission decreases with increasing the concentration of urea with 0.3lit/hr of flow rate.

5. NOx emission Vs Engine load with Urea Injection at flow rate of 0.6lit/hr

Fig.9 shows the variation of NOx emission with the engine load using the bio-fuel with urea injection of various concentrations at flow rate of 0.6lit/hr.

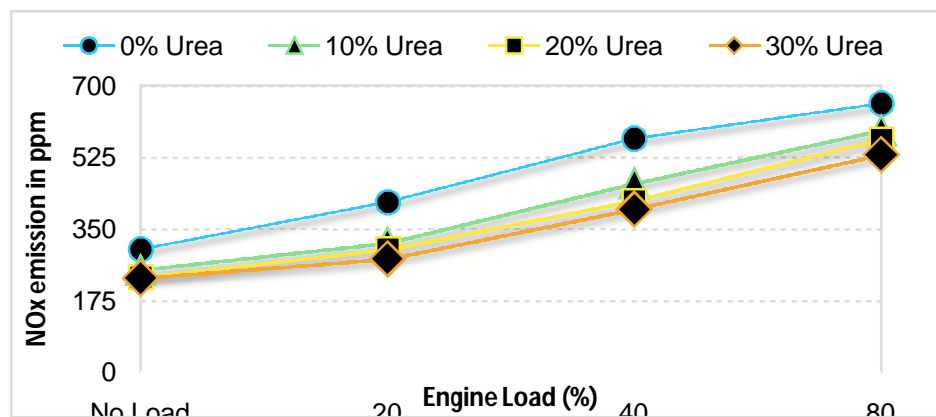


Fig.9 NOx emission vs Engine load

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From the graph it is observed that the NOx emission decreases with increasing the concentration of urea with 0.6lit/hr of flow rate. At 30% of urea concentration it shows better emission performance by decreasing NOx emission.

6.NOx emission Vs Engine load with Urea Injection at flow rate of 0.9lit/hr

Fig.10 shows the variation of NOx emission with the engine load using the bio-fuel with urea injection of various concentrations at flow rate of 0.9lit/hr.

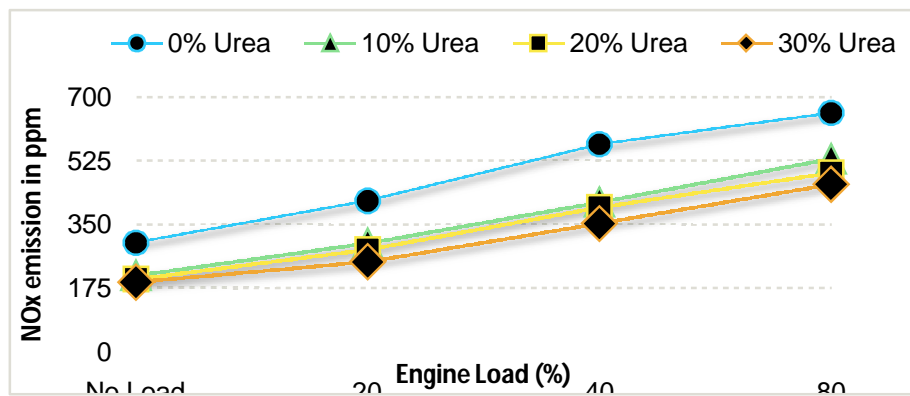


Fig.10 NOx emission vs Engine load

From the graph it is observed that the NOx emission decreases with increasing the concentration of urea with 0.9lit/hr of flow rate.

At 30% of urea concentration it shows better emission performance by decreasing NOx emission. Further increasing urea concentration is not recommended as over exposing to urea causes human hazards according to MSDS of urea.

The Fig.10 shows the average NOx difference between with and without urea injection for various flow rate and it also shows that more amount of NOx around 171.5 ppm has been decreased using urea injection of concentration of 30% at flow rate of 0.9lit/hr.

Table.2 Average NOx difference between with and without urea injection for various concentration with different flow rates.

FLOW RATE	AVERAGE NOx DIFFERENCE BETWEEN WITH AND WITHOUT 10% UREA INJECTION	AVERAGE NOx DIFFERENCE BETWEEN WITH AND WITHOUT 20% UREA INJECTION	AVERAGE NOx DIFFERENCE BETWEEN WITH AND WITHOUT 30% UREA INJECTION
0.30 lit/hr	81.5ppm	105.75ppm	126.5ppm
0.60 lit/hr	106.5ppm	125.75ppm	144.5ppm
0.90 lit/hr	122.5ppm	142.25ppm	171.5ppm

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V. CONCLUSION

In this study, the experiment was conducted to study the mission characteristics of a diesel engine with waste vegetable oil biodiesel equipped with SCR unit and the results were compared with the conventional diesel. From this experimental study the following conclusions were drawn.

1. The CO emission is decreased for the biodieseland also the HC emission is decreased compared to conventional diesel due to less carbon content and better combustion in the diesel engine.
2. The NOx emission found to be high while using Bio-diesel compared to diesel and it has been decreased using urea injection.
3. The engine exhaust temperature has been increased while using bio-diesel thus promoting formation of NOx in the combustion chamber.
4. Considerable amount of NOx emission has been decreased with 30% concentration of urea at 0.9lit/hr flow rate. From the detailed study, it is observed that NOx emission is decreased up to 171.5ppm using urea injection of 30% concentration at flow rate of 0.9lit/hr in the bio-fuelled C.I engine.

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