REDUCTION AND CONTROLLING EMISSIONS OF DIESEL FUEL ENGINES

A Preliminary Study

By

KADDB & RSS

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EXECUTIVE SUMMARY

The world-wide trends indicate that the use of diesel engines will increase greatly for transportation, manufacturing or agriculture. Also studies indicate that diesel engines will remain one of the most attractive options in the visible future. However, in recent years, there have been major social problems relating to air pollution caused by hazardous materials, such as NOx and particulate matter (PM) contained in emissions from diesel engines. Therefore, there is a need for the urgent task of reducing these materials by proper engine maintenance and calibration, new combustion technology and improvements in fuel characteristics.

Diesel engines emit nearly 40 toxic substances which include sulphates, volatile organic compounds, hydrocarbons (HC), carbon monoxide (CO), nitrous oxides (NO), and particulate matter (PM). HC, CO and NOx are the major exhaust pollutants. Carbon monoxide can accumulate in the ambient atmosphere and cause headaches, dizziness and lethargy. Hydrocarbons and aldehydes cause eye irritation, choking sensations and they are major contributors to the characteristic of diesel smell. Hydrocarbons also have a negative environmental effect, being an important component of smog. CO is a direct poison to humans. Sulphur dioxide (SO2) is generated from the sulphur present in diesel fuel which has a profound impact on environment being the major cause of acid rains.

Out of tune and calibration vehicles with diesel engines tend to be uneconomical and inefficient because they don’t burn or consume all the diesel fuel and therefore, lots of unburned fuel is thrown out to the environment wasting energy & money and causing environmental hazards. On the other hand, vehicles which are properly tuned and adjusted tend to be cleaner, efficient and more economical than out of tune vehicles. Modern vehicles equipped with advanced pollution controls are even more dependent on properly functioning components to keep pollution levels low.

On national level, the total annual loses due to keeping poorly maintained and calibrated diesel vehicles is around JD 83.4 M a year besides the loses due to major social and environmental problems related to air pollution from badly maintained and calibrated diesel engines.

Therefore, joint efforts among the Ministry of Environment, Ministry of Interior; the King Abdullah II Design & Development Bureau (KADDB) and the Royal Scientific Society (RSS) are required to ***formulate a comprehensive national strategy to reduce diesel engine emissions. The key components of such national strategy are:***

A. ***Increasingly stringent emissions standards for new vehicles.***
B. ***Apply gradual higher specifications on diesel fuel and oil.***
C. ***Adopt strict regulations to ensure proper maintenance and calibration of vehicles with diesel engines.***
D. ***Promote transportation planning and demand management.***

Contents

1. Introduction

The world-wide trends indicate that the use of diesel engines will increase greatly for transportation, manufacturing or agriculture. Also studies indicate that diesel engines will remain one of the most attractive options in the visible future because of its reliability, fuel efficiency, easy to repair, and inexpensive to operate. At the same time the world climate change issues and Kyoto protocol agreement, call for creation of new standards and regulations to cut and control the emission levels of greenhouse gases. To apply these new regulations and standards both auto makers and oil refineries started thorough research and development to look for more efficient diesel engines with reduced emissions and to develop new standards for diesel fuel with less sulphur ingredients.

Diesel engines remain an attractive option for powering heavy-duty on road and non road vehicles. Vehicles are powered by diesel engines because: they are reliable, fuel efficient, easy to repair, and inexpensive to operate. Perhaps most impressive is the durability of the diesel engine. It is not uncommon for diesel engines to have a life of 1,000,000 miles in heavy-duty trucks, to power city buses for up to 15-20 years, and to power non road equipment for several thousand hours before requiring rebuild or replacement. Because of its inherently better fuel efficiency, the diesel engine compares favourably with engines powered by gasoline and alternative fuels.

Owing to their high economic feasibility, diesel engines have been used for many commercial vehicles as the major power source of transportation systems. However, in recent years, there have been major social problems relating to air pollution caused by hazardous materials, such as NOx and particulate matter (PM) contained in emissions from diesel engines. Therefore, there is a need for the urgent task of reducing these materials by proper diesel engine maintenance and calibration, new combustion technology and improvements in fuel characteristics. In terms of improvement in the fuel characteristics, an importance is placed on improving the quality of diesel fuel. One example of these efforts is the introduction of low-sulphur diesel fuel with 0.05% sulphur content into the market. Such fuel is considered low sulphur, lighter and has better combustion and emission characteristics.

The diesel emission has two side affects one is relating to the environment and climate changes, were it could pollute land, air, and water, and the second is relating to the public health effects. In some countries, a reduction of diesel engine emissions has traditionally been achieved through a combination of fuel system, combustion chamber, and engine control modifications. Because of the growing vehicle population and high emission rates from many of these vehicles, serious air pollution and health effect problems have become increasingly common phenomena in modern life. The adverse health effects and environmental damage can cause substantial economic impacts as well.

2. Objectives of Report.

The objective of this report is to provide an initial overview of the effect of diesel engines (i.e. fuel, engine oil and engine maintenance) on diesel emissions and to give some insight about the feasibility of several emission reduction strategies that could be implemented to reduce emissions in Jordan. The report will also look at the possibility of improving the quality and specifications of local diesel. This can be partially done based on examples from other countries such as USA, UK, EU, etc. recommendations will be presented to give practical solutions for decision-makers to use in order to effectively reduce diesel engine emissions.

This study will try to clarify the nature of diesel engine emission problems in Jordan including diesel health effects. It is important to state that transportation sector in Jordan is the biggest energy and diesel consumer and hence the focus in this study will be about automotive diesel engines. The problem is two fold: firstly the diesel quality and specifications, and secondly the maintenance and calibration of diesel engines.

This report is a joint *RSS/KADDB* effort which is designed to enhance the collective knowledge base about engines, diesel fuels, and emission control technologies in a systematic approach to guide industry in developing lower emitting applications of their products and provide part of the technical basis for government decisions on regulating the sulphur content in diesel fuel and enforcing proper engine maintenance and calibration.

3. Problem Statement.

Diesel emission is a serious pollution problem in Jordan and the on-road vehicles are the major contributor to this problem. Diesel emission has major impacts on the environment, health and economy of Jordanian hence solutions have to found and implemented.

4. Operation of Diesel Engines (Compression Ignition Engines- CIE).

Compared with gasoline engine, diesel engine is relatively easier to maintain. Unlike gasoline engines which depend on sparkplugs for ignition of the fuel, a diesel engine relies solely on the in-cylinder temperatures generated during the compression stroke for ignition of the injected fuel, hence, the term compression ignition (CI) engines is used. A requirement for proper combustion in a diesel engine is that it is operated lean, or with excess air in the combustion chamber, unlike the gasoline engine which is predominantly operated stoichiometrically, with the chemically precise amount of air in the combustion chamber to burn the injected fuel. In order to achieve the temperatures required to ignite diesel fuel in the combustion chamber, diesel engines are operated at high compression ratios, typically in the range of 12 - 24 depending on the size and application.

Combustion in a diesel engine is a complicated physical and chemical process, starting with the fuel injection into the combustion chamber to exhausting the burnt gases. The reason for the complication is that the combustion depends on many different parameters, such as mixing of air–fuel, injection pressure and time. Fuel vaporisation itself is also a complex process because, of the fuel contents, the self-ignition of the fuel vapour is directly related to the chemical process in the combustion chamber. The efficiency of a diesel engine depends upon the conversion rate of the chemical energy of the fuel into heat releases. This speed of heat release depends on the amount of fuel injected, ignition at an adequate time and the combustion process.

Diesel engine performance, combustion efficiency and emissions are simply related to the engine design, technical conditions and diesel fuel properties. These parameters are important for optimisation of the engine performance and for reducing emissions. The diesel fuel chemical contents and characteristics govern the emissions and power-torque characteristics. One of the reasons for forming exhaust pollutants is insufficient combustion in the engine cylinder. Fuels properties also play a significant role to increase or decrease exhaust pollutants.

5. Types of Diesel Engines

Both direct injection (DI) and indirect injection (IDI) diesel engines are in use today. In IDI engine, fuel is injected into a pre-combustion chamber where combustion is initiated. As combustion proceeds, increased pressures in the pre-combustion chamber causes the combustion process to propagate into the main combustion chamber under well-mixed conditions where the process is completed and the power stroke begins. In DI engines, atomized fuel is injected at high pressures directly into the cylinder as the piston approaches top dead centre (TDC) where it is combusted. IDI engines have been used in closed environments like underground mines because of the lower levels of pollutants associated with them. However, IDI engines are less fuel efficient than DI engines. With recent advances in lowering the emissions from DI engines, their use is becoming more prevalent. IDI systems have traditionally been more popular on smaller diesel engines.

Diesel engines can be naturally aspirated or they can be turbocharged for increased power and performance. The increased power is a direct result of the combustion of more fuel which can be introduced into the cylinder because of the increased mass of air delivered to the cylinder as a result of turbo-charging. Often air to air or liquid to air inter-cooling or after-cooling is provided on modern engines which helps reduce NO emissions.

Both two-stroke and four-stroke diesel engines exist. The two-stroke engine is more popular on smaller diesel engines because of its simplicity since it has fewer mechanical parts. Two-stroke engines deliver more power relative to their weight as compared to four-stroke engines and they have been used extensively in the North American transit bus market, and can be found in underground mine vehicles. However, to a large extent, they are currently being replaced by four-stroke engines in both of these markets. The difference between two- and four-stroke engines lies in the number of times the piston travels between bottom dead centre (BDC) and top dead centre (TDC) to complete one combustion cycle.

Modern diesel engines have undergone a number of design changes in order to meet environmental regulations which have resulted in design changes to reduce both particulate matter (PM) and NO emissions.

6. Diesel Engine Emissions

Diesel engines convert the chemical energy contained in the fuel into mechanical power. The exhaust gases which are discharged from the engine contain several constituents that are harmful to human health and to the environment. Table 1 below lists typical output ranges of the basic toxic material in diesel fumes. The lower values can be found in new, clean diesel engines, while the higher values are characteristic for older equipment.

$$\textbf{Diesel} + O_2 \textit{ (in air)} \rightarrow CO_2 + H_2O + \textbf{heat}$$

Table 1: Emissions from Diesel Engine.

CO	**HC**	**PM**	**NOx**	**SO_2**
vppm	vppm	g/m^3	vppm	vppm
5 -1,500	20 - 400	0.1 - 0.25	50 - 2,500	10 -150

Diesel engines emit nearly 40 toxic substances which include sulphates, volatile organic compounds, hydrocarbons (HC), carbon monoxide (CO), nitrous oxides (NO), and particulate matter (PM). HC, CO and NOx are the major exhaust pollutants. Carbon monoxide (CO), hydrocarbons (HC), and aldehydes occur because the combustion efficiency is <100% due to incomplete mixing of the gases and the wall quenching effects of the colder cylinder walls. A significant portion of exhaust hydrocarbons is also derived from the engine lube oil. Carbon monoxide can accumulate in the ambient atmosphere and cause headaches, dizziness and lethargy. Hydrocarbons and aldehydes cause eye irritation, choking sensations and they are major contributors to the characteristic of diesel smell. Hydrocarbons also have a negative environmental effect, being an important component of smog. CO is a direct poison to humans.

The NOx is formed during the very high pressure and temperatures (>1500 ◦C) of the combustion process resulting in thermal fixation of the nitrogen in the air which forms NOx. NO_x consist mostly of nitric oxide (NO) and a small fraction of nitrogen dioxide (NO_2) which is very toxic. NO_x emissions are also a serious environmental concern because of their role in the smog formation.

The formation of ground level ozone occurs as a result of a chemical reaction between HC and NOx and sunlight. When stagnant air masses linger over urban areas, the pollutants are held in place for long periods of time. Sunlight interacts with these pollutants, transforming them into ground level ozone which is a major component of smog.

Sulphur dioxide (SO_2) is generated from the sulphur present in diesel fuel. The concentration of SO_2 in the exhaust gas depends on the sulphur content of the fuel. Low sulphur fuels of less than 0.05% sulphur are being used in many c countries for most diesel engine applications. Sulphur dioxide is a colourless toxic gas with a characteristic, irritating odour. Oxidation of sulphur dioxide produces sulphur trioxide which is the precursor of sulphuric acid which, in turn, is responsible for the sulphate particulate matter emissions. Sulphur oxides have a profound impact on environment being the major cause of acid rains.

Diesel particulate matter (PM) is a complex substance and is defined by the USA Environmental Protection Agency (EPA) regulations and sampling procedures as a complex aggregate of solid and liquid material. Its origin is carbonaceous particles generated in the engine cylinder during combustion. The primary carbon particles form larger agglomerates and combine with several other, both organic and inorganic, components of diesel exhaust. Generally, PM is divided into three basic fractions:

A. Solids: dry carbon particles, commonly known as soot.
B. Soluble Organic Fraction (SOF): heavy hydrocarbons adsorbed and condensed on the carbon particles.
C. SO4: sulphate fraction hydrated sulphuric acid.

The actual composition of PM will depend on the particular engine and its load and speed conditions. Wet particulates can contain up to 60% of the hydrocarbon fraction (SOF), while dry particulates are comprised mostly of dry carbon. The amount of sulphates is directly related to the sulphur contents of the diesel fuel.

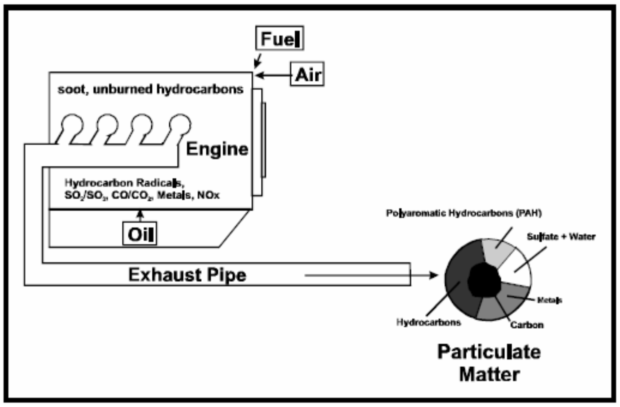


Figure 1: Diesel Particulate Matter Formation.

Polynuclear Aromatic Hydrocarbons (PAH) are hydrocarbons containing two or more benzene rings. Toxic compounds, like polyaromatic hydrocarbons (PAH), are also found in the exhaust of a diesel engine and can be associated with both the PM and HC emissions. Many compounds in this class are known human carcinogens. PAHs in the exhaust gas are split between gas and particulate phase. The most harmful compounds of four and five rings are present in the organic fraction of PM (SOF).

Table 2 below shows the diesel emission contents which either have been identified in diesel exhaust or are presumed to be in the exhaust, based on observed chemical reactions or presence in the fuel or oil.

Table 2: Toxic Air Contaminants and Hazardous Air Pollutants Found In Diesel Exhaust.

Acetaldehyde*	Chlorine	Methyl ethyl ketone
Acrolein	Chlorobenzene	Naphthalene*
Aluminium	Chromium compounds	Nickel*
Ammonia	Cobalt compounds*	4-nitrobiphenyl*
Aniline*	Copper	Phenol
Antimony compounds*	Cresol	Phosphorus
Arsenic*	Cyanide compounds	POM (including PAHs)
Barium	Dibenzofuran	Propionaldehyde
Benzene*	Dibutylphthalate	Silver
Beryllium compounds*	Ethyl benzene	Sulphuric acid
Biphenyl	Formaldehyde*	Toluene*
Bis [2-ethylhexyl]phthalate*	Hexane	Xylene isomers and mixtures
Bromine	Lead compounds*	Zinc
1,3-butadiene	Manganese compounds	
Cadmium*	Mercury compounds*	
Chlorinated dioxins*	Methanol	

*This class of compounds is known by the state of California to cause cancer or reproductive toxicity.

7. Causes of Diesel Engine Emissions

In addition to the vehicle, engine conditions and fuel type, there are other factors such as speed, load, ambient air temperature and relative humidity which affect diesel engine emission. For example ambient air temperature and the way in which diesel exhaust mixes in the atmosphere affect PM emission amounts and composition. Other factors that affect emissions include engine characteristics and the use of emission control devices such as a catalytic converter. Related to this is the maintenance of the engine and pollution control devices. Fuel type and its quality is a major factor which determines the level of emissions. In gasoline, the amount of lead used to be most important, but now that most Asian countries have banned the sale of leaded gasoline, attention has been shifted to sulphur, benzene and aromatics. For diesel, the sulphur levels are the most important parameter determining the emission levels. Emission levels are also influenced by the manner a vehicle is used. Cars in heavy traffic which have to stop repeatedly because of traffic congestion pollute considerably more than cars which operate in free flow conditions.

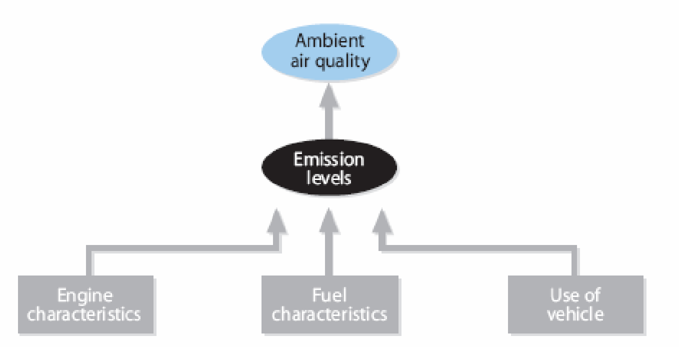


Figure 2: Factors Affecting Emissions.

However, a comprehensive strategy to achieve significant diesel engine emission reductions includes four key components as shown in fig. 3 below:

E. Increasingly stringent emissions standards for new vehicles.
F. Higher specifications for clean fuels and oil.
G. Programs to assure proper maintenance and calibration of vehicles.
H. Transportation planning and demand management.

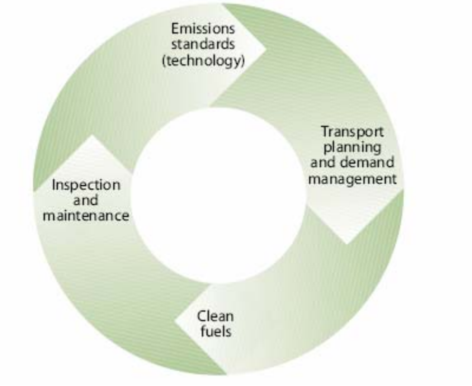


Figure 3: Emission reduction key components.

8. Diesel Fuel Characteristics

Important Diesel Fuel variables are ignition behaviour (expressed in terms of Cetane number), density, viscosity, sulphur content and flash point. The flash point is the temperature at which the quantities of vapour that the diesel fuel emits into the adjoining atmosphere are sufficient to allow a spark to ignite the vapour-air mixture above the fuel. Most countries have transportation and storage safety considerations which dictate that diesel fuels have a flash point above 55EC.

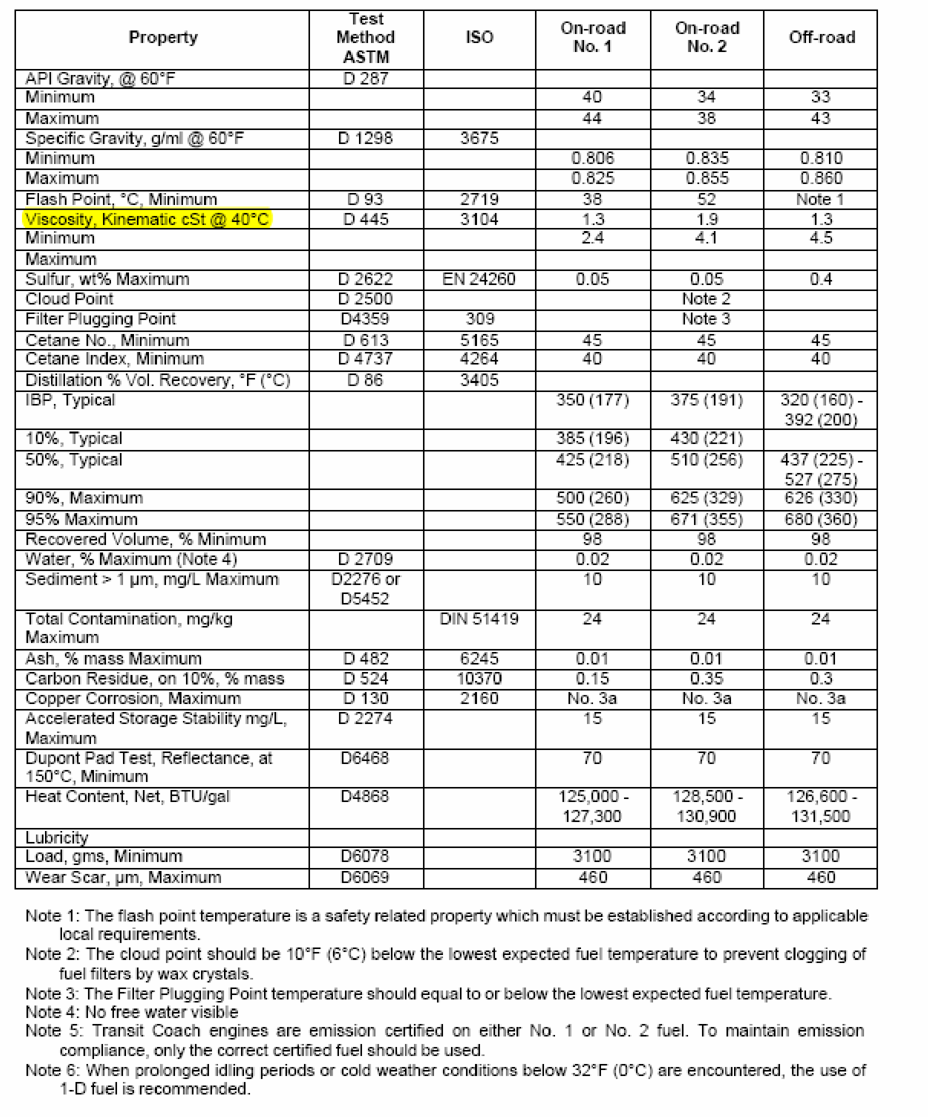
The sulphur content shows the maximum sulphur level by weight allowed in the fuel. Besides the major health concerns and adverse environmental effects caused by sulphur dioxide, sulphur also diminishes the effectiveness of catalytic converters installed on diesel engines. The sulphur content of diesel fuels depends on the source of crude oil and the refinery process. It is regulated by law in a number of countries and is usually between 0.05 and 0.5 weight percent. Low sulphur diesel is manufactured with substantially reduced sulphur levels. It is often produced in 30 ppm sulphur and 15 ppm (called ultra low sulphur diesel). Typical sulphur levels for standard diesel are 3,400 ppm for non-road diesel and 340 ppm for on-road diesel. Low sulphur diesel fuel results in lower SO2 and PM emissions, but most importantly, when this fuel is used in combination with some of the diesel emission control and retrofit technologies, it can offer significant NOx, PM and CO emission reductions. In fact, in order for many of these retrofit technologies to function properly, low sulphur diesel must be used. The emission reduction of low sulphur diesel used by itself is not substantial. For example, when formulated with higher Cetane and lower aromatics, low sulphur diesel may achieve a 5-10% NOx emission reduction, although, PM emission reductions with this same formulation may be much higher.

The higher the cetane number, the greater the fuel's tendency to support self-ignition. As a result of increasing the CN, the ignition delay period is reduced and causes the engine to run steadily. However, a high CN above the standard value causes the formation of excessive smoke and reduces the engine performance. In the case of lower CN, it may be difficult to start the engine, and it causes it to run with the engine knocking. NOx is reduced when the CN is increased. A cetane number of 50 or higher is desirable for optimal operation. Increasing the cetane index and lowering the aromatic content result in lower emissions of NOx, HC, CO, and PM. The CN also affects the combustion efficiency.

Additives are used to influence the flow, storage, and combustion of diesel fuel, to differentiate products, and to meet trademark specifications. At room temperature, diesel fuels are generally moderately volatile, slightly viscous, flammable, brown liquids with a kerosene-like odour. The boiling ranges are usually between 140 and 385°C (> 588°C for marine diesel fuel). At 20°C, the density is 0.87-1.0 g/cm^3 and the water solubility is 0.2-5 mg/litter. The specifications of commercial diesel fuel differ considerably in different countries. The physical properties of the fuel, such as viscosity, volatility and flash point, also affect the combustion process. The viscosity affects atomization and vaporisation of the fuel, and the volatility ensures good mixing of fuel to air.

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. In general, fuels meeting the properties listed in Table 1 are recommended for satisfactory performance.

Table 3: Diesel fuel specifications ASTM D974.



Property	Test Method ASTM	ISO	On-road No. 1	On-road No. 2	Off-road
API Gravity, @ 60°F	D 287				
Minimum			40	34	33
Maximum			44	38	43
Specific Gravity, g/ml @ 60°F	D 1298	3675			
Minimum			0.806	0.835	0.810
Maximum			0.825	0.855	0.860
Flash Point, °C, Minimum	D 93	2719	38	52	Note 1
Viscosity, Kinematic cSt @ 40°C	D 445	3104	1.3	1.9	1.3
Minimum			2.4	4.1	4.5
Maximum					
Sulfur, wt% Maximum	D 2622	EN 24260	0.05	0.05	0.4
Cloud Point	D 2500			Note 2	
Filter Plugging Point	D4359	309		Note 3	
Cetane No., Minimum	D 613	5165	45	45	45
Cetane Index, Minimum	D 4737	4264	40	40	40
Distillation % Vol. Recovery, °F (°C)	D 86	3405			
IBP, Typical			350 (177)	375 (191)	320 (160) - 392 (200)
10%, Typical			385 (196)	430 (221)	
50%, Typical			425 (218)	510 (256)	437 (225) - 527 (275)
90%, Maximum			500 (260)	625 (329)	626 (330)
95% Maximum			550 (288)	671 (355)	680 (360)
Recovered Volume, % Minimum			98	98	98
Water, % Maximum (Note 4)	D 2709		0.02	0.02	0.02
Sediment > 1 µm, mg/L Maximum	D2276 or D5452		10	10	10
Total Contamination, mg/kg Maximum		DIN 51419	24	24	24
Ash, % mass Maximum	D 482	6245	0.01	0.01	0.01
Carbon Residue, on 10%, % mass	D 524	10370	0.15	0.35	0.3
Copper Corrosion, Maximum	D 130	2160	No. 3a	No. 3a	No. 3a
Accelerated Storage Stability mg/L, Maximum	D 2274		15	15	15
Dupont Pad Test, Reflectance, at 150°C, Minimum	D6468		70	70	70
Heat Content, Net, BTU/gal	D4868		125,000 - 127,300	128,500 - 130,900	126,600 - 131,500
Lubricity					
Load, gms, Minimum	D6078		3100	3100	3100
Wear Scar, µm, Maximum	D6069		460	460	460

Note 1: The flash point temperature is a safety related property which must be established according to applicable local requirements.

Note 2: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

Note 3: The Filter Plugging Point temperature should equal to or below the lowest expected fuel temperature.

Note 4: No free water visible

Note 5: Transit Coach engines are emission certified on either No. 1 or No. 2 fuel. To maintain emission compliance, only the correct certified fuel should be used.

Note 6: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of 1-D fuel is recommended.

In Jordan, the Jordan Petroleum Refinery Company producing two types of diesel, regular diesel and special diesel with both a Cetane index < 45. While the special diesel contains less sulphur and is used by the army, the regular one is used for everything else: heating, industrial power generation and in vehicles. The following table shows the diesel specification in Jordan.

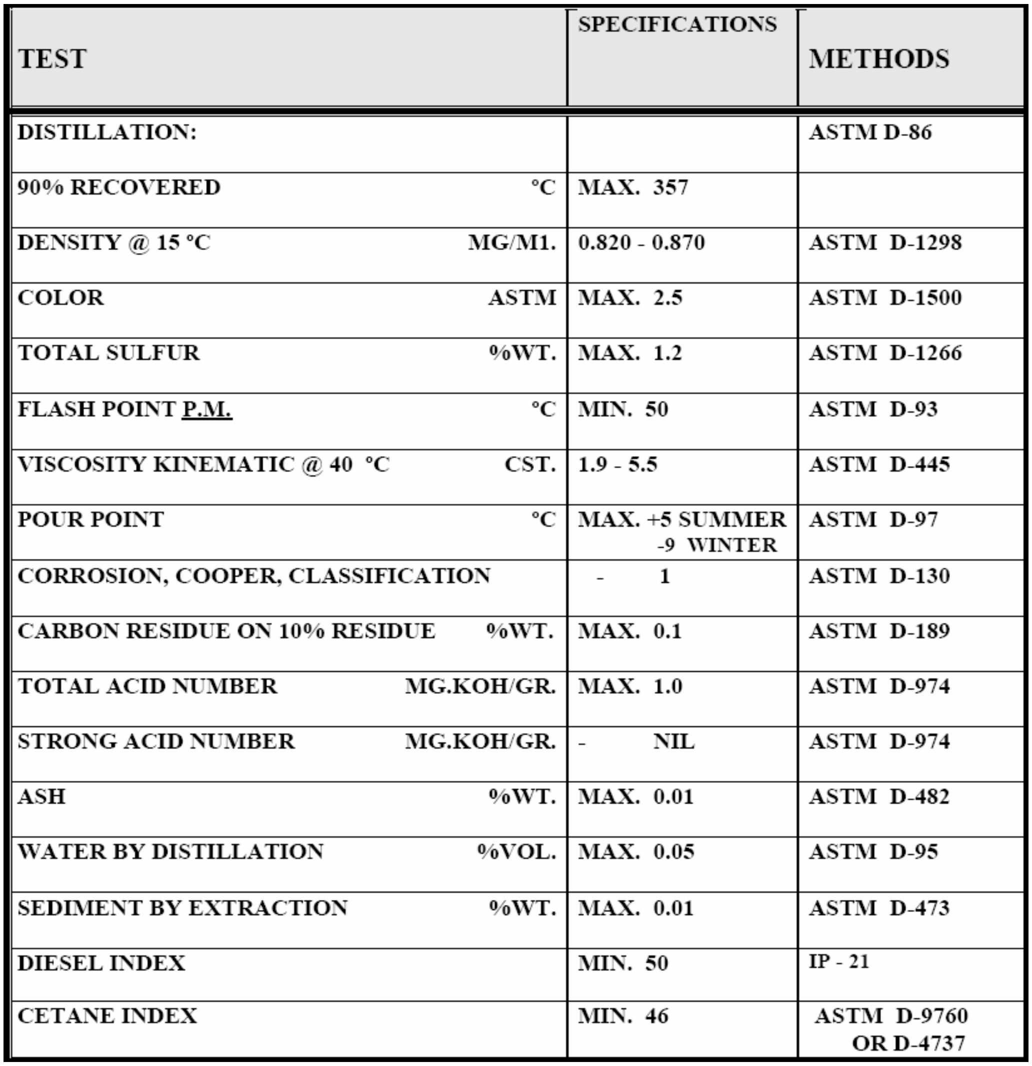
Table 4: Jordanian Diesel fuel specifications.

الخاصية	القيمة	طريقة الاختبار حسب ASTM
الوزن النوعي * عند ١٥° س	٠,٨٢ ٠,٨٧	D-1298
نقطة الوميض بجهاز بنسكي مارتن المغلق (حد أدنى)	٥٠° س	D-93
اللون بوحدات الجهاز (حد أعلى)	٢,٥	D-1500
اللزوجة الكيماتيكية عند ٤٠° س حد أعلى حد أدنى	٥,٥ مم^{٢}/ ث ١,٩ مم^{٢}/ ث	D-445
نقطة الانسكاب (س°) (حد أعلى) صيفا شتاء	٥+ - ٩	D-97
الرواسب% وزنا(حد أعلى)	٠,٠١	D-473
الماء % حجما (حد أعلى)	٠,٠٥	D-95
الرماد % وزنا (حد أعلى)	٠,٠١	D-482
الكربون % وزنا طريقة كونرادسن (حد أعلى)	٠,١	D-189
الكبريت الكلي % وزنا (حد أعلى) **	١,٢	D-1266
٩٠% حجما يتقطر عند درجة حرارة س° (حد أعلى)	٣٥٧	D-86
معامل السيتان (حد أدنى)	٤٦	D-976 أو D-4737
تأكل شريط النحاس عند ١٠٠° س لمدة ٣ ساعات (حد أدنى)	رقم (١)	D-130

* للاسترشاد فقط ولا يعتبر خاصية أساسية .

** يعاد النظر بهده القيمة عند الانتهاء من تنف شركة مصفاة البترول مشروع التوسعة الرابع .

Table 5: Jordanian Diesel fuel specifications.



TEST		SPECIFICATIONS	METHODS
DISTILLATION:			ASTM D-86
90% RECOVERED	°C	MAX. 357	
DENSITY @ 15 °C	MG/M1.	0.820 - 0.870	ASTM D-1298
COLOR	ASTM	MAX. 2.5	ASTM D-1500
TOTAL SULFUR	%WT.	MAX. 1.2	ASTM D-1266
FLASH POINT <u>P.M.</u>	°C	MIN. 50	ASTM D-93
VISCOSITY KINEMATIC @ 40 °C	CST.	1.9 - 5.5	ASTM D-445
POUR POINT	°C	MAX. +5 SUMMER -9 WINTER	ASTM D-97
CORROSION, COOPER, CLASSIFICATION		- 1	ASTM D-130
CARBON RESIDUE ON 10% RESIDUE	%WT.	MAX. 0.1	ASTM D-189
TOTAL ACID NUMBER	MG.KOH/GR.	MAX. 1.0	ASTM D-974
STRONG ACID NUMBER	MG.KOH/GR.	- NIL	ASTM D-974
ASH	%WT.	MAX. 0.01	ASTM D-482
WATER BY DISTILLATION	%VOL.	MAX. 0.05	ASTM D-95
SEDIMENT BY EXTRACTION	%WT.	MAX. 0.01	ASTM D-473
DIESEL INDEX		MIN. 50	IP - 21
CETANE INDEX		MIN. 46	ASTM D-9760 OR D-4737

9. Engine Oil Characteristics

Impure oil used to run vehicles could cause damage to the engine and indirectly pollute the air. With the increasing number of vehicles on the roads and far too few measures to introduce quality oil, the problems could be severe, and the fallout disastrous.

9.1 Impact of engine oil consumption on particulate emissions

Diesel lubricant is known to be consumed during the normal operation of the engine in small but not insignificant quantities. The engine design and the lubricant design impact oil consumption, which through the combustion impacts the engine emissions which ultimately causes the tailpipe emissions.

Sulphur from the lubricating oil can contribute to overall sulphur emissions. However, much of the sulphur content is associated with detergents and anti-wear additives in the additive packages of commercial CH-4 lubricating oils. Specifically, the anti-wear additives typically contain sulphur and phosphorus in the form of zinc dithiophosphates. Many detergent packages contain alkyl sulfonates as well. The net effect is that commercial diesel engine lubricating oils contain from 4,000 to 10,000 ppm sulphur. The use of synthetic oilcan is considered. Although synthetic oils do not use a petroleum derived base stock and will not have any sulphur from the base stock, they still use sulphur containing additives. Moreover, because petroleum-derived base stocks are highly refined and hydro treated, lowering the base stock contribution to the overall sulphur content through the use of synthetic oils would be expected to provide only a minor advantage.

9.2 Engine design impact on oil consumption

In order to understand the impact of engine oil on particulate emissions and to identify proactive actions that can be taken to significantly reduce oil consumption, it is important to generate data and characterize the contribution of different oil consumption sources. Figure 4 schematically illustrates the oil consumption sources in contemporary internal combustion engines, consisting of the piston ring-liner system, the turbocharger, the valve stem seals, and the crankcase ventilation system.

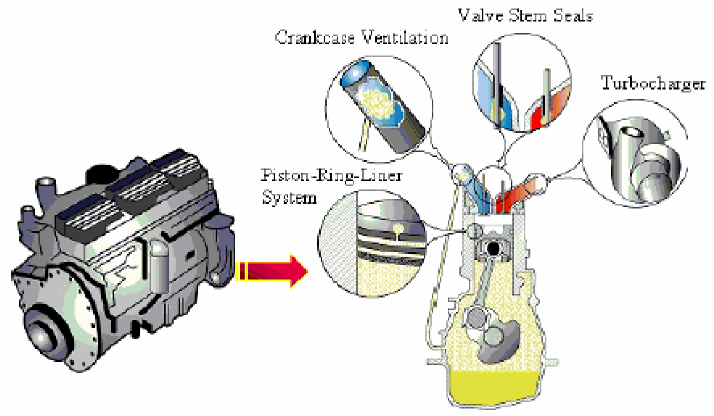


Figure 4: Oil Consumption Sources.

Engine oil consumption can contribute significantly to particulate emissions. However, little is known about the relative importance of each source. It is speculated that the oil passing the valve guides and turbocharger are major contributors, since large portions of the oil from these sources may not enter the cylinder and escape the combustion event through the exhaust manifold. In particular, oil leaking through the turbocharger seal is expected to exhibit the highest unburned oil fraction, since it is located, downstream of the exhaust valve.

The major contributor to total oil consumption is the piston-ring-liner system. The unburned oil fraction of this source depends on the timing within the cycle when the oil is transported into the cylinder. Oil transport into the combustion chamber during late expansion and exhaust strokes is exposed to lower temperatures. This oil may therefore escape the combustion event, and may contribute to unburned oil consumption and the particulate emissions. Therefore, it is critical to understand and model oil consumption mechanisms to minimize particulates.

Generally, oil viscosity and volatility are believed to be the significant physical oil properties that affect oil consumption and particulate emissions. While the viscosity affects complicated oil transport mechanisms on the liner and piston, the volatility directly governs the oil evaporation rate from hot surfaces during the engine cycle. However, other oil properties and parameters such as additive composition can have an impact on oil consumption as well. There is a lack of studies that investigate the effects of these oil properties and parameters on oil consumption and particulates. Two oils with different volatility (Noack volatilities of 13.5% and 16.8%) and similar viscosity characteristics were used to analyze oil evaporation at different steady state speed and load conditions. These oils operate in the piston-ring-liner system over a broad range of temperatures. Analysis results showed a similar low shear-rate viscosity-temperature relation for both oils at temperatures above 100 °C. The major conclusions are:

- Higher oil viscosity reduces most likely the oil consumption and the oil-derived particulate emissions.
- Lower oil volatility reduces the oil consumption and the oil-derived particulate emissions.
- Oil evaporation increases strongly with engine load.
- Viscosity and volatility are connected properties through a trade-off curve for a given base stock.
- Constraints on either the viscosity or the volatility may necessitate a substitution to a more refined base stock.
- The impact of auxiliary lubricant additives on oil consumption is poorly documented in the literature.
- Oil friction characteristics have shown a strong effect on nitrogen oxide emissions.

10. Engine Maintenance and Calibration

Combustion-powered vehicles naturally tend to deteriorate with age and usage, and as a result, emission levels can rise significantly. Good maintenance is required to keep emission levels at or near design levels. The service industry must have sufficient equipment to properly repair vehicles. In addition, adequate training must be made available so that the mechanics and technicians are sufficiently skilled, and careful attention must be paid to assuring that the service industry has sufficient lead time to properly equip itself.

Vehicles that are properly tuned and adjusted tend to be cleaner than out of tune vehicles. Modern vehicles equipped with advanced pollution controls are even more dependent on properly functioning components to keep pollution levels low. Minor malfunctions in the air/fuel or ignition management systems can increase emissions significantly. A relatively small number of vehicles with serious malfunctions frequently cause the majority of vehicle related pollution problems. Unfortunately, it is rarely obvious which vehicles fall into this category as the emissions themselves may be unnoticeable and emission control malfunctions do not necessarily affect vehicle drivability. Effective vehicle inspection programs based on periodic short tests can identify these problem cars and, by requiring a re-test after necessary maintenance, assure their repair.

Proper maintenance, engine calibration, and emissions testing are critical to reduce the diesel emission level; even that emission control technologies and cleaner diesel are being used. This includes replacing damaged parts, cleaning, tuning and general maintenance of the engine, through regular maintenance and periodic inspections to ensure complete fuel combustion and as a result PM exhaust is minimized. Proper maintenance can also improve fuel economy and extend engine life.

In Jordan the existing regulation regarding this issue need to be amended and implemented. Furthermore, engine testing carried out by police also is not effective where most of the time it is reduced to visually inspecting the engine and looking for heavy dark smoke from the exhaust. For that a new rules and regulations need to be issued and implemented.

11. Environmental and Health Impacts of Diesel

The growth in mobility in Jordan helps Jordanians in their economic development. At the same time the increased air pollution that is associated with the growth in mobility also has a negative impact on development. More people die prematurely or get sick more often because of increased pollution. This results in considerable financial and economic costs for households and the national economy at large.

Diesel emission is considered one of the greenhouse gazes that contribute to the world climate changes that cause increase in earth temperature. Also diesel emission causes acid rain. All that will affect humans, animals and plants. It damages building and threatens the historical architecture through smog output.

Emissions from diesel engines contribute to serious public health problems. These problems include premature mortality, aggravation of respiratory and cardiovascular disease, rokes, heart attacks, aggravation of existing asthma, acute respiratory symptoms, chronic bronchitis, and decreased lung function. Numerous studies also link diesel exhaust to increased incidence of lung cancer. On-road diesel-fuelled vehicles contribute approximately 27 percent of the NOx emission inventory and 62.5 percent of the PM emissions. An older, dirtier diesel vehicle can emit almost 8 tons of pollution per year. This amounts to 160 to 240 tons of pollution over the life of the engine. A heavy-duty truck can create the same amount of air pollution as 150 passenger cars.

The health effects of diesel emissions have received attention worldwide. Several organizations have been concerned about the health effects on road diesel engines present for the general population. Various reports cited the significant health risk attributable to exposure to diesel emission including fine particulate material. Combustion-generated particles have carcinogenic, mutagenic, and irritant properties. These particles play a major role in the deterioration of ambient air quality and have also been linked with various atmospheric conditions. For example, the National Institute for Occupational Health and Safety categorized whole diesel exhaust as a probable carcinogen. Several other organizations, including the World Health Organization (WHO), the Health Effects Institute (HEI), and the International Agency for Research on Cancer (IARC), have published information on the potential adverse health effects of diesel emissions.

One of the components in diesel engine emissions is carbon monoxide. The Occupational Safety and Health Administration (OSHA) standard for carbon monoxide (CO) is 50 parts per million of air. The adverse health effects of exposure to carbon monoxide are asphyxiation, and anoxia. The symptoms of acute CO poisoning are headache, dizziness, drowsiness, nausea, vomiting, collapse, coma, and death.

Diesel engines emit a very large number of particulates that are extremely small (less than 10 microns) consisting of a carbon core that are coated with several compounds (figure 5) which are formed during the engine combustion process and the subsequent travel of these particulates down the exhaust stream. These particulates are possible cancer-causing substances that can be carried directly into the lungs where a large fraction remains. These particulates are also of concern because they are typically emitted directly into the breathing zone where the urban population works and recreates.

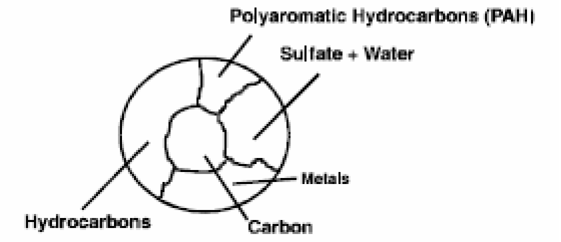


Figure 5: Diesel engines particulates.

Diesel emissions also contain sulphur dioxide (SO_2). OSHA's permissible exposure limit for SO_2 is 5 parts per 1 million parts air. Exposure to SO_2 may result in broncho-constriction, fatigue, altered sense of smell, and the symptoms of chronic bronchitis.

12. The Economical Impact of Badly Tuned and Maintained Vehicles with Diesel Engines.

Proper engine maintenance, tuning and calibration will essentially have an impact on short and long running cost. It will increase fuel efficiency, reduce maintenance cost and increase engine life. In this section these three aspects will be discussed and supported by some estimated figures.

12.1 Fuel Efficiency.

The reduction in diesel engine efficiency can drop in principle up to 40% if engines are not properly maintained and calibrated. The cost impact of efficiency reduction can be calculated either by considering number of vehicles using diesel engines or by considering the annual national consumption of diesel fuel. The two approaches will be considered as follows:

12.2 Points to consider.

a. Jordan consumption of diesel fuel during year 2004 was 543105 ton imported and 1187460 ton for local sources. The total is 1730565 ton.
b. Calculations can be done based on the total diesel consumption or for transportation purposes only.
c. The energy consumption by transportation sector in Jordan is about 37%.
d. Number of diesel vehicles in Jordan according to 2004 statistics from Public Security is 193972 (32%) and petrol engine vehicles are 411236 (68%).
e. Each 1 metric ton of diesel fuel is equivalent to 1159 litres.
f. The price of diesel is about 3.8 JD/20 Lt (219.05 JD/m ton).

12.3 Calculations.

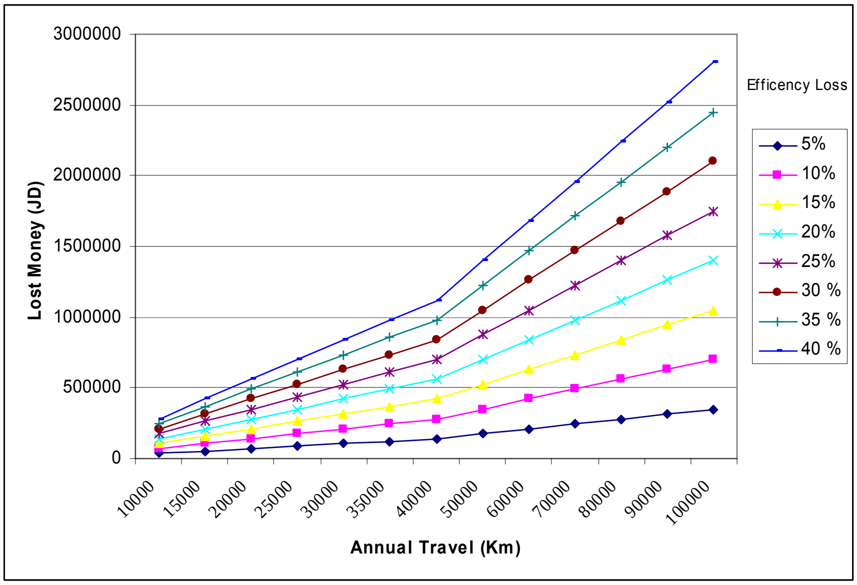
a. The annual national consumption of diesel can be calculated by considering international figures for diesel fuel efficiency which is about 11 liter/100km and an annual average travel of 50000 km. Then the annual national consumption of diesel for transportation is:

Number of diesel vehicles x fuel efficiency x average travel
193972 x 11/100 x 50000 = 1066846000 Lt = 920488 metric. ton

b. The amount of lost money can be calculated by assuming a percentage of lost efficiency. For example, assuming an average of 20% efficiency loss, then the lost money is:

Efficiency loss x annual national consumption of diesel for transportation x diesel price /m ton
20% x 920488 m ton x219.05 JD/m ton = 8547309 JD

c. However, average travel could vary from one country to another and from one vehicle to another. Furthermore, reduction of diesel engine efficiency can vary per vehicle. Therefore, ranges of average travel and efficiency loss can be considered to obtain the following graph based on similar calculations as done in step 1 & 2 above:



12.4 Maintenance Cost.

Based on study done for diesel tractors maintenance saving, the following analogy was done for diesel vehicles in Jordan (shttp://www.ext.vt.edu/pubs/bse/442-451/442-451.html).

Diesel vehicles maintenance cost can be reduced up to 25 percent by routine maintenance calibration & tuning improvement. As an example, 15000 JD diesel vehicles will typically require about JD 900 in repair costs during 40,000 km when badly maintained and calibrated and will require JD 700 when receiving average maintenance and calibration. This cost can be dropped down to approximately 500 JD with excellent maintenance and proper calibration. Timely preventative maintenance and inspection will not only help reduce major problems and downtime, it will also help identify problems when they can be corrected with relatively minor repairs. Considering the number of diesel vehicle in Jordan and an average annual travel of about 40000 km then:

- Cost of loses due to below average maintenance and calibration:
  Number of diesel vehicles x (“900-700” JD saving /40000 km) x 40000 km/year =
  193972 x (200 / 40000) x 40000 =38794400 JD/year.
- Cost of loses due to below bellow excellent maintenance and calibration:
  Number of diesel vehicles x (“900-500” JD saving /40000 km) x 40000 km/year =
  193972 x (400 / 40000) x 40000 =77588800 JD/ year.

12.5 Engine Life.

National maintenance and testing programs must be based on technical specifications as determined by an accurate service record for each piece of equipment as recommended by the manufacturers and adjusted to individual conditions. If extending economic machinery life is the objective, timing of proper maintenance, as recommended by the manufacturer, is the best way. However, no statistics are available for this part, but savings are guaranteed and not less than 10 % of the original price per 10 years life. Considering the price of the average diesel engine 3000 JD, then the saving is:

Number of vehicles x engine cost x % savings = 193972 x 3000 x 0.1/10 = 5819160 JD /year

12.6 Total Annual Savings or Loses.

The total annual savings (or annual loses) considering an average annual travel of 40000 km and a reduction of 20% of fuel efficiency is:

- Total annual loses from keeping vehicles with diesel engines bellow average from maintenance and calibration point of view is: 38794400 + 5819160 = 44613560 JD/Year.
- Total annual loses from keeping vehicles with diesel engines bellow excellent from maintenance and calibration point of view is: 77588800 + 5819160 = 83407960 JD/Year.

13. Methods to Reduce Diesel Emission

The benefits of catalytic controls have been documented and up to year 2000, over 800 million tons of combined pollutants of HC, CO and NOx had been abated using auto exhaust catalyst and prevented from entering the atmosphere. There are many different options for reducing the pollution coming from diesel engines. These options can be divided into: first improving engine operation, maintenance and calibration, second controlling engine exhaust by using certain devices, and third by improving diesel fuel standards and characteristics.

Diesel emissions are controlled either at their very source, through engine design and modifications, or by exhaust gas after-treatment. The two approaches are in fact complementary and should be followed simultaneously in real life.

There are two groups of diesel exhaust after-treatment devices: diesel traps and diesel catalysts. Diesel traps, which are primarily diesel filters, control diesel particulate matter emissions by physically trapping the particulates. The major challenge in the design of diesel filter system is to regenerate the trap from collected particulate matter in a reliable and cost-effective manner. So far diesel filters are used commercially only in a few specialized diesel engine applications.

Diesel catalysts control emissions by promoting chemical changes in the exhaust gas. They are most effective towards the gaseous emissions, i.e., hydrocarbons and carbon monoxide. Modern diesel catalysts are also becoming more and more effective in controlling diesel particulate matter. Diesel catalysts have been commercially used for many road and off-road applications. Diesel exhaust emission controls were first used in work environments when diesel oxidation catalysts were used in trucks over 30 years ago, primarily for CO and HC control. More recently because of the U.S. EPA’s urban bus rebuild/retrofit requirements for the reduction of diesel PM emissions, diesel oxidation catalyst technology has become recognized as an effective means of reducing PM emissions from diesel engines by greater than 25 percent. In the late 1970s, considerable attention was given to the development of diesel particulate filter (DPF) technology, which was capable of reducing over 90 percent of diesel PM emissions.
A number of diesel emission control technologies have been developed, falling generally into one of the four categories discussed below. These categories are:

A. Diesel oxidation catalysts.
B. Diesel particulate filters.
C. Selective catalytic reduction.
D. Emerging emission control technologies.

It should be noted that diesel emission control technologies may be adversely affected by sulphur in the fuel. As such, it is often necessary to utilize a low sulphur diesel fuel in conjunction with a retrofit technology.

13.1 Diesel Oxidation Catalysts

The concept behind an oxidation catalyst is that it causes chemical reactions without being changed or consumed. An oxidation catalytic converter consists of a stainless steel canister that typically contains a honeycomb-like structure called a substrate or catalyst support. There are no moving parts, just acres of interior surfaces on the substrate coated with catalytic precious metals, such as platinum or palladium. It is called an oxidizing catalyst because it transforms pollutants into harmless gases by means of oxidation. In the case of diesel exhaust, the catalyst oxidizes carbon monoxide (CO), gaseous hydrocarbons (HCs), and the liquid hydrocarbons adsorbed on the carbon particles. The liquid hydrocarbons are referred to as the soluble organic fraction (SOF) and make up part of the total particulate matter. The operating principle of a diesel oxidation catalyst is shown in figure 6 below.

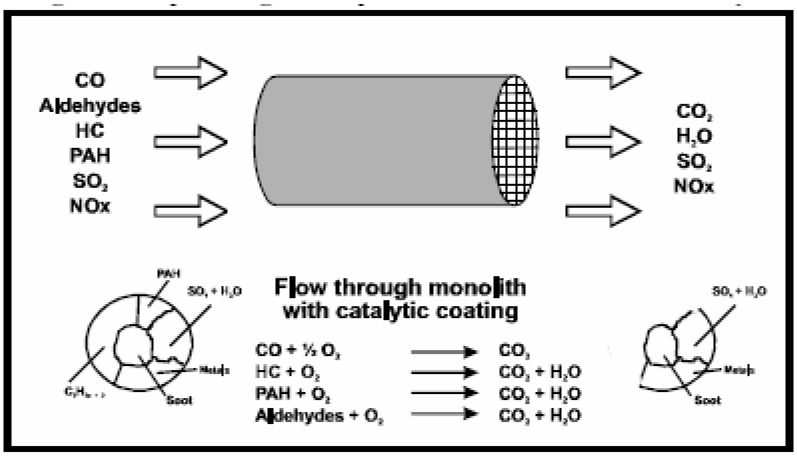


Figure 6: Operating Principle of a Diesel Oxidation Catalyst.

The level of total particulate reduction is influenced in part by the percentage of SOF in the particulate. For example, a Society of Automotive Engineers (SAE) Technical Paper reported that oxidation catalysts could reduce the SOF of the particulate by 90 percent under certain operating conditions and could reduce total particulate emissions by 40 to 50 percent. Destruction of the SOF is important because this portion of the particulate emissions contains numerous chemical pollutants that are of particular concern to health experts. Oxidation catalysts are also effective in reducing particulate and smoke emissions on older vehicles. Under the U.S. EPA’s urban bus rebuild/retrofit program, five manufacturers have certified diesel oxidation catalysts as providing at least a 25 percent reduction in PM emissions.

13.2 Diesel Particulate Filters

The trap oxidizer system consists of a filter positioned in the exhaust stream designed to collect a significant fraction of the particulate emissions while allowing the exhaust gases to pass through the system. Since the volume of particulate matter generated by a diesel engine is sufficient to fill up and plug a reasonably sized filter over time, some means of trapped particulate disposal must be provided. The most promising means of disposal is to burn, or oxidize, the particulate in the trap, thus regenerating, or cleansing, the filter. However, in non-road applications there has also been use of a disposable filter system.

A number of filter materials have been tested, including ceramic and silica monoliths and fibber wound cartridges, knitted silica fibber coils, ceramic foam, wire mesh, sintered metal substrates, and temperature resistant paper in the case of disposable filters. Collection efficiencies of these filters range from 50 percent to over 90 percent. Currently, the ceramic monoliths, fibber wound cartridges, and paper filters have been used most extensively commercially. Silicon carbide is also beginning to be used commercially. All of the filter technologies function in a similar manner; that is, forcing particulate-laden exhaust gases through a porous media and trapping the particulate matter on the intake side. Excellent filter efficiency has rarely been a problem with the various filter materials. Figure 7 shows an example of one type of filtration mechanism.

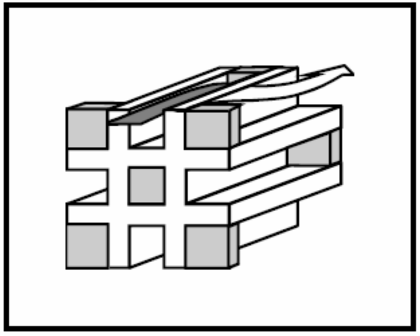


Figure 7: Diesel Particulate Filter.

13.3 Selective Catalytic Reduction (SCR)

Like an oxidation catalyst, SCR causes chemical reactions without being changed or consumed. However, unlike oxidation catalysts, a reluctant is added to the exhaust stream in order to convert NOx to nitrogen and oxygen in what would otherwise be an oxidizing environment. The reductant can be ammonia, but in mobile source applications, urea is normally preferred.

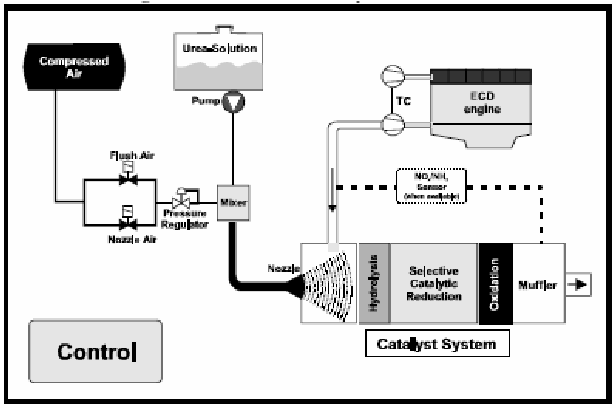


Figure 8: Selective Catalytic Reduction.

13.4 Emerging Emission Control Technologies

Lean-NO*x* Catalysts helps in reducing NO*x* emissions from diesel engines with a catalyst stems from the fact that the engines run lean, and hence, there is excess O_2 in the exhaust stream. However, the key to catalytically reducing NOx emissions is a reducing, not an oxidizing reaction. The first type of lean-NOx catalysts developed employs base metals and/or precious metals contained on zeolitic structures. The zeolitic "cage" acts to provide a local reducing environment, essentially creating a micro rich environment where the catalyst promotes the reaction of NOx, HC, and CO to form N_2, O_2, and water.

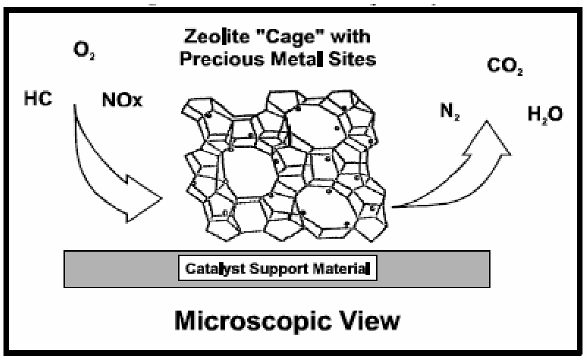
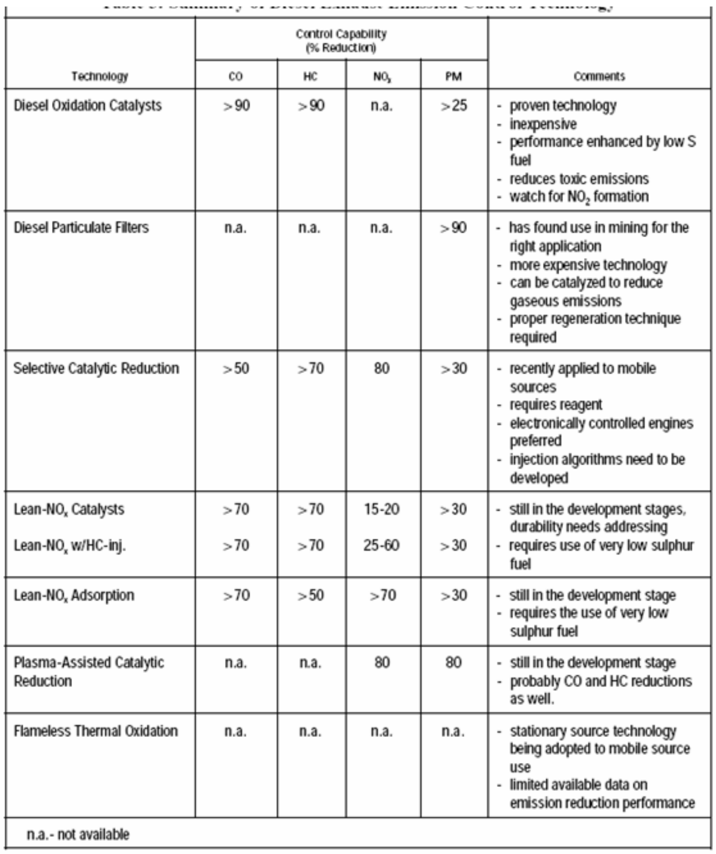


Figure 8: Zeolite Lean-NO Catalyst

Other technologies exist for diesel engine emission reduction such as Lean-NO Absorber Technology used for NOx reduction using absorber technology.

Table below summarizes the current state of the art of diesel exhaust emission control technologies.

Table 6: Summary of Diesel Exhaust emission control technology.



Technology	Control Capability (% Reduction)				Comments
	CO	HC	NO_x	PM	
Diesel Oxidation Catalysts	>90	>90	n.a.	>25	- proven technology - inexpensive - performance enhanced by low S fuel - reduces toxic emissions - watch for NO_2 formation
Diesel Particulate Filters	n.a.	n.a.	n.a.	>90	- has found use in mining for the right application - more expensive technology - can be catalyzed to reduce gaseous emissions - proper regeneration technique required
Selective Catalytic Reduction	>50	>70	80	>30	- recently applied to mobile sources - requires reagent - electronically controlled engines preferred - injection algorithms need to be developed
Lean-NO_x Catalysts	>70	>70	15-20	>30	- still in the development stages, durability needs addressing - requires use of very low sulphur fuel
Lean-NO_x w/HC-inj.	>70	>70	25-60	>30	
Lean-NO_x Adsorption	>70	>50	>70	>30	- still in the development stage - requires the use of very low sulphur fuel
Plasma-Assisted Catalytic Reduction	n.a.	n.a.	80	80	- still in the development stage - probably CO and HC reductions as well.
Flameless Thermal Oxidation	n.a.	n.a.	n.a.	n.a.	- stationary source technology being adopted to mobile source use - limited available data on emission reduction performance

n.a.- not available

14. Improving Operation of Diesel Engine

Several engine improvements or ways can be conducted in order to control or reduce diesel emissions, these options are:

A. Fuel Injector Design: Significant research and development has taken place on fuel injector design and placement to help manufacturers meet the new emission standards. Injector inclination, the number of holes and their diameters, sac volumes, and spray patterns have all been optimized for low emissions. Also in some instances, valve covered orifices (VCO) have been incorporated into injector designs to minimize residual fuel from entering the combustion chamber. Hydraulically-actuated electronic unit injectors have allowed manufacturers to control the rate of fuel injection which also has resulted in lower emissions of PM and NO for those engines which use them.

B. Fuel Injection Pressure: Increased fuel injection pressure has been used to increase atomization of the fuel in the combustion chamber, which in turn has resulted in lower PM emissions. Injection pressures in excess of 20,000 psi can be found on some diesel engines today. These engines are characterized by decreased swirl in order to minimize the NO formation.

Manufacturers have had to make more robust fuel system components because of the increased pressures which have in turn increased the cost of the engines.

C. Turbo-charging and Air Cooling: A turbocharger is used to extract energy from a diesel engine's exhaust flow by using of an air compressor attached to an exhaust gas turbine located in the exhaust stream. The turbine is used to compress air to be fed to the intake air manifold. The increased mass of air to the combustion chamber allows for more fuel delivery and hence, increases engine power. Better combustion also results from turbo-charging which in turn decreases PM emissions. Cooling the compressed air supplied to the intake air manifold reduces the NO emissions which otherwise would result from increased combustion temperatures.

D. Intake Manifold and Port Design: Intake manifolds and port configurations have been designed for better in-cylinder air distribution, eliminating fuel-rich spots. Rich areas during combustion result in incomplete combustion of some of the injected fuel and increase HC and PM emissions. The designs also ensure proper fuel penetration into the cylinder and minimize cylinder wall wetting which both serve to decrease HC and PM emissions.

E. Combustion Chamber Design: Medium-duty diesel engines generally use re-entrant piston bowl designs. The re-entrant bowl causes in-cylinder turbulence and better fuel/air mixing. The better mixing improves combustion and decreases both PM and HC emissions.

F. Oil control: Oil control on 1991 and newer on-road diesel engines have improved significantly compared to pre-1991 engines where as much as 30 percent of the PM emitted could be attributed to the combustion of lubricating oil. This improvement has decreased PM emissions by 10 %.

15. Diesel Fuel

Other techniques to reduce diesel emissions are using mixed or hybrid diesel fuel. Number of choices exists as discussed below.

15.1 Emulsified Diesel Fuel

Emulsified diesel fuel is diesel fuel (low sulphur LSD or ultra low sulphur ULSD) blended with up to 20% water and a proprietary additive. The water emulsion has to be stirred regularly when kept in a stationary tank to ensure that the water molecules are completely enclosed by fuel molecules. This is important to avoid separation, which could cause engine corrosion and decreased lubricity.

Emulsified diesel fuels generally do not require engine modifications. However, fleet operators should check with manufacturers before using a fill-and-go system like emulsified diesel and they should confirm warranty compatibility with the equipment/engine manufacturer before using emulsified fuels. Emulsified fuels have been tested for many on-road and non-road diesel engines. The USA Environment Protection Agency (EPA) has verified PuriNOx use and has confirmed a 16.8-23.3% reduction in PM and a 17-20.2% reduction in NOx for non-road applications. Using an emulsified fuel with diesel particulate filters (DPF) produces PM emission reductions of 95%, HC reductions of 85%, CO reductions of 75% and NOx reductions of 25%. Use of emulsified diesel fuel in conjunction with a Diesel Oxidation Catalysts (DOC) as follows: PM 65%, HC 60%, CO 70% and NOx 25.

15.2 Bio-Diesel.

Bio-diesel is a renewable, biodegradable, low-sulphur fuel that is produced from many types of feed-stocks including vegetable oils (soybeans, rapeseeds, and canola oil) or animal fat. Bio- diesel is high in oxygen content which leads to lower PM emissions. Typically, bio-diesel is blended with conventional diesel in a 20 % bio-diesel to 80 % conventional diesel solution (“B20”). At B20, most of the potential PM benefits have been achieved while minimizing potential NOx emission increases. Bio-diesel can also be blended with ULSD fuel, and in fact makes up for ULSD's low lubricity. For example, using a 1 % bio- diesel and 99 % ULSD blend increases lubricity 65 % over pure ULSD, which is essentially equivalent to regular diesel fuel.

16. Emission Standards in the United States.

In the United States, emissions standards are managed by the Environmental Protection Agency (EPA) as well as some state governments. Some of the strictest standards in the world are enforced in California by the California Air Resources Board (CARB). Currently, vehicles sold in the United States must meet "Tier 1" standards that went into effect in 1994. Additional "Tier 2" standards have been optional from 2001 to 2003, and are currently being phased in—a process that should be complete by 2009. The current Tier 1 standards are different between automobiles and light trucks (SUVs, pickup trucks, and minivans), but Tier 2 standards will be the same for both types. A common measurement system for American standards is the somewhat confusing mixed-standard unit of gram per mile.

There are several ratings that can be given to vehicles. A certain percentage of the cars produced by major manufacturers must meet these different levels in order for the company to sell their products in affected regions. Tier 1 has been the baseline used. Beyond Tier 1, in increasing stringency, there are

- TLEV – Transitional Low Emission Vehicle
- LEV – Low Emission Vehicle
- ULEV – Ultra-Low Emission Vehicle
- SULEV – Super-Ultra Low Emission Vehicle
- ZEV – Zero Emission Vehicle

The last category is largely restricted to electric vehicles and hydrogen cars, although such vehicles are usually not entirely non-polluting. In those cases, the other emissions are transferred to another site, such as a power plant or hydrogen reforming center, unless such sites run on renewable energy. However, a battery-powered electric vehicle charged from the California power grid will still be up to ten times cleaner than even the cleanest gasoline vehicles over their respective lifetimes.

The above standards are being made even more stringent. Tier 2 variations are appended with "II", such as LEV II or SULEV II. There are other categories that have also been created.

- ILEV – Inherently Low-Emission Vehicle
- PZEV – Partial Zero Emission Vehicle
- AT-PZEV – Advanced Technology Partial Zero Emission Vehicle
- NLEV – National Low Emission Vehicle

PZEVs meet SULEV emission standards, but in addition have zero evaporative emissions and an extended (15-year/150,000 mile) warranty on their emission-control equipment. Several ordinary gasoline vehicles from the 2001 and later model years qualify as PZEVs; in addition, if a PZEV has technology that can also be used in Zeds like an electric motor or high-pressure gaseous fuel tanks for compressed natural gas (CNG) or liquefied petroleum gas (LPG), it qualifies as an AT-PZEV. Hybrid electric vehicles like the Toyota Prius can qualify, as can internal combustion engine vehicles that run on natural gas like the Honda Civic GX. These vehicles are called "partial" Zeds because they receive partial credit in place of Zeds that automakers would otherwise be required to sell in California.

17. Emission Standards in Europe.

The European Union has its own set of standards that vehicles must meet. The tiers are:

- Euro 0 (1988-1992) limits car emissions to 12.3 g CO/kWh, 2.6 g HC/kWh, 15.8 g NOx/kWh
- Euro I (1992-1995) limits car emissions to 4.9 g CO/kWh, 1.23 g HC/kWh, 9.0 g NOx/kWh, 0.4 g particles/kWh
- Euro II (1995-1999) limits car emissions to 4.0 g CO/kWh, 1.1 g HC/kWh, 7.0 g NOx/kWh, 0.15 g particles/kWh
- Euro III (1999-2005) limits car emissions to 2.1 g CO/kWh, 0.66 g HC/kWh, 5.0 g NOx/kWh, 0.1 g particles/kWh
- Euro IV (2005-2008) limits car emissions to 1.5 g CO/kWh, 0.46 g HC/kWh, 3.5 g NOx/kWh, 0.02 g particles/kWh
- Euro V (2008-2012) limits car emissions to 1.5 g CO/kWh, 0.46 g HC/kWh, 2.0 g NOx/kWh, 0.02 g particles/kWh

In addition, all car advertisements in the EU mandate the display of car's value of CO2 emissions in gram/kilometer format (usually 120-160 g/km for a small compact).

Although most cars in Europe are significantly smaller and lighter than US vehicles, with compact cars predominant, in recent years there has been a market trend of increasing engine power made available in the same sized chassis. Most EU-made cars that used to sell with some 75 hp (56 kW) six years ago are now frequently sporting 100 hp (75 kW) or more. Thus CO2 emission sums are rising and a fine print at the bottom of car ads is apparently not enough to stop this trend. The EU must act on vehicular CO2 emissions if it intends to maintain an international lead role in the fight against Global Warming

18. Recommendations

Solutions adopted to address pollution from transport vehicles need to be integrated solutions which address the most common contributing factors (1) improvements in emissions standards and technology; (2) improved inspection and maintenance; (3) cleaner fuels; and (4) improved transport planning and traffic demand management. Although, the strategies adopted will differ from place to place, due to the specific nature of the problem to be addressed, it is important to realize that some of the measures can only be taken together with other measures. This is especially true for the imposition of tighter emissions standards, both for new and in-use vehicles, which cannot be done without the imposition of stricter standards for cleaner fuels.

In order to reduce the pollution problem caused by diesel fuel engine the following are recommended:

A. Setting new standards relating to local or imported diesel, by focusing on new fuel with balanced sulphur content rate and based on international standards.
B. Setting new standards for importing new diesel vehicles to ensure that new vehicles entering the market meet the emissions standards. These approval tests should be tight & comprehensive.
C. Setting and applying strict laws and adherence programme ensure reduction of emission and fuel saving.
D. Setting new licensing and testing regulation.
E. Establishing test centres for yearly licensing or upon traffic police requests to ensure adherence to emission standards. This can be done based on examples from other countries such as UK, USA, etc.
F. Cooperative work between government and private institution to provide professional and skilled workers for engine maintenance and calibration.
G. Setting tax incentives to promote the use of efficient diesel vehicles.
H. Replacing the traditional old diesel engine with new advanced engines and promote this strategy by tax free replacement policy and tax reduction incentives.
I. Tax free for the diesel emission control technologies products.
J. Start a national promotional campaign explaining the problem of diesel emission and its effects on health and environment.
K. Launching incentive scheme by the government to cut the diesel emission level.
L. Launching a campaign for public awareness in driving management skills which will reduce emission and save fuel.