BACKGROUND ANALYSIS AND DEVELOPMENT OF A LUBRICATING OIL MANAGEMENT SYSTEM FOR BANGLADESH

A Project

Submitted to the Department of Petroleum & Mineral Resources Engineering in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING IN PETROLEUM ENGINEERING

by

Md. Rezaul Hoque

Student No. 1014132012F

DEPARTMENT OF PETROLEUM & MINERAL RESOURCES ENGINEERING

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET), DHAKA, BANGLADESH

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RECOMMENDATION OF THE BOARD OF EXAMINERS

The undersigned certify that they have read and recommend to the Department of Petroleum & Mineral Resources Engineering, for acceptance, a project entitled **BACKGROUND ANALYSIS AND DEVELOPMENT OF A LUBRICATING OIL MANAGEMENT SYSTEM FOR BANGLADESH** Submitted by MD. REZAUL HOQUE, ROLL NO. 1014132012, in partial fulfillment of the requirements for the degree of Masters of Engineering in Petroleum Engineering.

Chairman
(Supervisor)

.....

Dr. Mohammed Mahbubur Rahman
Associate Professor
Department of PMRE, BUET, DHAKA

Member

.....

Dr. Mohammad Tamim
Professor
Department of PMRE, BUET, DHAKA

Member

.....

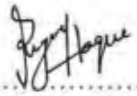
Md. Shahin Alom (M.Sc. Petroleum Engg.)
Deputy General Manager
MJL Bangladesh Limited

Date: 28 September, 2019

DECLARATION

This is to certify that this project entitled **BACKGROUND ANALYSIS AND DEVELOPMENT OF A LUBRICATING OIL MANAGEMENT SYSTEM FOR BANGLADESH** is carried out by the author Md. Rezaul Hoque under the supervision of Dr. Mohammed Mahbubur Rahman, Associate Professor, Department of PMRE, BUET.

It is hereby declared that this project or any part of it has not been submitted elsewhere for the award of any degree or diploma.



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Md. Rezaul Hoque

Roll no: 1014132012

ABSTRACT

Lubricating oil is called the 'Blood of an engine and machine'. The performance, desired service life, energy-economic efficiency of an engine and machine depends on quality of lubricants. However, adequate codes and standards, regulations, policies, guidelines and enforcement towards the effective quality control and application of lubricants are not up to date in Bangladesh. Proper implementation and monitoring of lubricating oil market are not sufficient to control proper management system. Adulteration of lubricating oil is common scenario in Bangladesh lubricating oil market, which causing damage to the durability of engines. Guidelines for law enforcement and punishments are needed to control adulterations. Used lubricants are harmful for environment and thus, the base oil can be used after re-refining for producing blended lubricants after mixing with additives in appropriate proportion.

Therefore, the current study was carried out to study the recent acts, notification, regulations, codes and standards of lubricants used for lubricating oil business. The study was carried out demand and supply trends of lubricants and environment impacts and proper disposal of used lubricants. The study also aimed to detect the opportunities of entering adulterated and sub-standard lubricating oils in the local market. For this purpose, three different categories of adulterated oil samples were collected and tested to conduct comparisons study. The study also reported the base oil recovery process from waste lubricants and its management system.

Based on literature survey it can be seen that globally the latest engine oil service category API (American Petroleum Institute) SN with resource conservation was established for gasoline engine. However, in Bangladesh API SJ, SG/CC category using as the latest lubricant standard for gasoline engine which is not compatible. On the other hand, API CF combined with ACEA 96 E2 and ACEA 96 E2 are the latest lubricant standards used for diesel engine in Bangladesh although those are obsolete according to API and ACEA standards for new model vehicles. Adulterated lubricating oil test results show that the difference between adulterated and original oil is difficult to tell. To find out adulterated lubricating oil, infrared spectrum test is more accurate than other tests. The engines of vehicles are getting damaged within a short service time for using the adulterated lubricants. The lack of regulatory control has led to unscientific disposal of hazardous waste throughout the country, posing serious risks to public health and the environment.

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NOMENCLATURE

Symbol	Description
ACEA	Association des Constructeurs Européens d'Automobiles or European Automobile Manufacturers Association
AN	Alkylated Naphthalene
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BERC	Bangladesh Energy Regulatory Commission
DEO	Diesel Engine Oils
DPF	Diesel Particulate Filter
EGR	Exhaust Gas Recirculation
FE	Fuel Efficiency
HTHSV	High Temperature High Shear Viscosity
ILSAC	International Lubricant Standardization and Approval Committee
ISO	International Organization for Standardization
JASO	Japanese Automotive Standards Organization
NOx	Oxides of Nitrogen
OEM	Original Equipment Manufacturers
PAG	Poly Alkylene Glycols
PCMO	Passenger Car Motor oils
PAO	Poly Alpha-Olefin
PTFE	Poly Tetra Fluoro Ethylene
SAE	Society of Automotive Engineers
VG	Viscosity Grade

Chapter-1 Introduction

1.1 Background of the study

The use of lubricants minimizes material wear and contributes to improved efficiency and life of equipment and energy savings. It consequently increases the power output and avoids seizure and serious damage of the components. Lubricants are extensively used in automotive applications and industrial applications [1]. The lubricant also acts as coolant, carrying heat away from the bearings, cylinders and pistons. The lubricating film on the cylinder wall in an IC engine acts as a seal to prevent the gases of combustion from blowing by the piston rings and entering the crankcase. Selection of the correct lubrication is a vital because nearly 40 percent of all premature bearing failures are caused by lubrication problem [2].

Lubricating oils not meeting required specifications can void engine warranty and result into costly repairs or replacements [3, 4]. Companies involved in production and marketing of lubricants must follow standard. There are a number of internationally acceptable standards such as SAE, API, ILSAC, and JASO to ensure product quality [5].

Adulteration of lubricating oil is the most common scenario in Bangladesh lube oil market. The current situation in this respect is alarming and requires urgent action.

Moreover, the used (waste) lubricating oils represent one of the most hazardous categories of environmental pollutants [6-9]. Whether direct or indirect, their short- and long-term impact on soil, waterways, plants, health of animals and humans is substantial if they are handled or disposed of in an uncontrolled manner. Therefore, procedures must be in place to maximize recycling and to minimize disposal [10].

However, BSTI set standards for IC engine crankcase oils and ministry of energy and mineral resources made notification named ‘Lube-Blending Plant establishment regulation, 2018’ and department of environment gives clearance but proper monitoring for lubricating oil system is not adequate.

Therefore, it is very important to critically assess the existing marketing and regulatory issues and develop a sound management system for the entire value chain of lubricants.

1.2 Objectives

The project covers both regulatory and technical matters. It will establish a foundation for proceeding to the development of regulations, policies, guidelines and standards required for ensuring the proper usage and management system of lubricants in Bangladesh.

The specific objectives are:

i. Identify opportunities through which non-standard or sub-standard products may get into the local market.
ii. Propose regulatory measures for quality control and to prevent uncontrolled handling and discharge of waste products.
iii. Develop a lubricant management system.

1.3 Outline of Methodology

The methodology applied during the work on this project task was based on the following approach:

i. Analysis of previous studies and reports of importance to the project.
ii. To collect and characterize adulterate lubricating oil from market and compare with standard products.
iii. Analysis and interpretation of collected information.
iv. Draw conclusions and make recommendations.

Chapter-2 Literature Review

2.1 Properties of Lubricants

A lubricant is a substance, usually organic, introduced to reduce friction between surfaces in mutual contact, which ultimately reduces the heat generated when the surfaces move. Lubricant may be considered as life blood of moving machinery. From sewing machine to giant crane from garden shears to locomotive and atomic power plants it is essential. Lubricating oil fractions extracted from crude oil are a widely varying mixture of straight and branched chain paraffinic, naphthenic aromatic hydrocarbons having boiling points ranging from about 302° C to 593°C [11].

The characteristics of Lubricant are:

- High boiling point
- Low freezing point
- High viscosity index
- Thermal stability
- Corrosion prevention and
- High resistance to oxidation.

General capabilities of lubricant are:

- Dispersivity or capacity to clean the cold parts of an engine
- Detergency or capacity to clean the hot parts of an engine
- Thermal strength or capacity to withstand temperature changes
- Anti-oxidant or capacity to resist the action of oxygen
- Anti-wear or capacity to prevent wear
- Anti-scuffing or capacity to preserve oil film even in the presence of high pressures
- Alkalinity reserve or capacity to neutralize acids formed during combustion or other sources thereby preventing corrosive wear
- Demulsibility or capacity to separate contaminants, Resistance to hydrolysis or capacity to withstand the action of water which can affect additives, Pump ability
- Centrifugibility and filterability or capacity to separate insoluble elements, Anti-rust.

The functions performed by lubricant are:

- Keep moving parts apart
- Reduce friction
- Transfer heat
- Carry away contaminants & debris
- Transmit power
- Protect against wear
- Prevent corrosion
- Seal for gases

2.2 Types of Lubricants

There are various types of lubricants namely:

1. Mineral oil;
2. Bio lubricant;
3. Synthetic lubricant and
4. Solid lubricant.

Lubricant is based on one or several types of base oil. Mixtures of the base oils may be blended to meet performance requirements.

A brief outline of these lubricants is given below:

2.2.1 Mineral oil

Mineral oil is any of various colorless, odorless, light mixtures of higher alkanes from a mineral source, particularly a distillate of petroleum, [12] as distinct from usually edible vegetable oils. Mineral oil term is used to encompass lubricating base oil derived from crude oil. The American Petroleum Institute (API) designates several types of lubricant base oil summarized in table 2.1. Each category is briefly described next.

a) Group I

Group I base oils are classified as Saturates less than 90%, Sulphur more than 0.03%, and Viscosity index (VI) of 80 to 120. It is manufactured from certain crude oil by distillation, solvent extraction, solvent or catalytic dewaxing, and hydro-finishing processes. Common Group I base oil are 150SN (solvent neutral), 500SN, and 150BS (bright stock) [13].

b) Group II

Group II base oils are defined as being more than 90 percent saturates, less than 0.03 percent sulfur and with a viscosity index of 80 to 120. They are often manufactured by hydrocracking, which is a more complex process than what is used for Group I base oils. Since all the hydrocarbon molecules of these oils are saturated. Group II base oils have better antioxidation properties. They also have a clearer color and cost more in comparison to Group I base oils. Still, Group II base oils are becoming very common on the market today and are priced very close to Group I oils.

c) Group III

Group III base oils are greater than 90 percent saturates, less than 0.03 percent sulfur and have a viscosity index above 120. These oils are refined even more than Group II base oils and generally are severely hydrocracked (higher pressure and heat). This longer process is designed to achieve a purer base oil.

Although made from crude oil, Group III base oils are sometimes described as synthesized hydrocarbons. Like Group II base oils, these oils are also becoming more prevalent.

d) Group IV

Group IV base oils are polyalphaolefins (PAOs). These synthetic base oils are made through a process called synthesizing. They have a much broader temperature range and are great for use in extreme cold conditions and high heat applications.

e) Group V

Group V base oils are classified as all other base oils, including silicone, phosphate ester, polyalkylene glycol (PAG), polyolester, biolubes, etc. These base oils are at times mixed with other base stocks to enhance the oil's properties. An example would be a PAO-based compressor oil that is mixed with a polyolester.

Esters are common Group V base oils used in different lubricant formulations to improve the properties of the existing base oil. Ester oils can take more abuse at higher temperatures and will provide superior detergency compared to a PAO synthetic base oil, which in turn increases the hours of use.

Table 2.1- Categories of API Base Oil

	API BASE OIL CATEGORIES				
	Base Oil Category	Sulfur (%)		Saturates (%)	Viscosity Index
Mineral	Group I (solvent refined)	>0.03	and/or	<90	80 to 120
Mineral	Group II (hydrotreated)	<0.03	and	>90	80 to 120
Mineral	Group III (hydrocracked)	<0.03	and	>90	>120
Synthetic	Group IV	PAO Synthetic Lubricants			
Synthetic	Group V	All other base oils not included in Groups I, II, III or IV			

2.2.2 Bio lubricants

Bio lubricants, also known as bio-based lubricants or bio-lubes, are made from a variety of vegetable oils, such as rapeseed, canola, sunflower, soybean, palm, and coconut oils. The best application for bio lubricants is in machinery that loses oil directly into the environment during use, total loss lubricants (TLLs), and in machinery used in any sensitive areas, such as in or near water [14]. Applications for TLLs include two-stroke engines, chain saw bars and chains, railroad flanges, cables, dust suppressants, and marine lubricants.

2.2.3 Synthetic lubricant

Synthetic oil is a lubricant consisting of chemical compounds that are artificially made. Synthetic lubricants can be manufactured using chemically modified petroleum components rather than whole crude oil, but can also be synthesized from other raw materials. The base material, however, is still overwhelmingly crude oil that is distilled and then modified physically and chemically. The actual synthesis process and composition of additives is generally a commercial trade secret and will vary among producers [15].

Synthetic lubricant oils are:

(a) Polyalpha-olefin (PAO);
(b) Synthetic esters;
(c) Polyalkyleneglycols (PAG);
(d) Phosphate esters;

(e) Alkylated naphthalene (AN);

(f) Silicate esters;

(g) Ionic fluids.

2.2.4 Solid lubricant

Dry lubricants or solid lubricants are materials that, despite being in the solid phase, are able to reduce friction between two surfaces sliding against each other without the need for a liquid oil medium [16]. Solid lubricants are:

(a) Teflon;

(b) Inorganic solids;

(c) Metal alloy.

Besides there are other relevant lubricant such as 'Glaze' formations (high temperature wears). But these are not covered here.

2.3 Codes and Standards: International practices

Lubricant can be classified based on their sector wise use such as automotive, industrial, marine and aviation. Usually, a lubricant contains three main components: base oil, polymers and performance additives. Based on the application of lubricants, the properties of base oil can radically be enhanced by adding polymers and performance additives. However, to ensure the performance of machineries, proper selection of lubricant is important to reduce the consumption of fuel and emissions of exhaust gases and particles.

2.3.1 Engine Oils

Engine oil lubricants have been classified in two categories: (1) based on viscosity (Society of Automotive Engineers-SAE) and (2) based on engine performance (API, ACEA, ILSAC, JASO and manufacturer's specifications). The industrial lubricants have been classified based on international standards organization (ISO) viscosity grades.

2.3.1.1 Viscosity Based SAE Classification

SAE standard specifies Engine Oil Viscosity which determine oil's fluidity at high and low temperatures. If the oil is too thin the oil pump cannot maintain enough pressure to circulate it and the oil will not withstand the forces that form between moving parts. The metal parts will rub

against each other and wear out or fail prematurely from lack of proper lubrication. Conversely, if the oil is too thick the oil pump will again have problems circulating the oil and it will be too thick to penetrate into the tiny openings between moving parts. The result is the same i.e. a premature wear and failure. It's important that the viscosity of a motor oil be a proper balance between too thin and too thick. Thus, a lubricant should remain fluid at low temperatures (to make cold starts easier) and viscous at high temperatures (in order to provide protection and sealing). The SAE has developed a means of classifying lubricants in order to specify their viscosity levels when hot and when cold/winter. The SAE currently has eight single active viscosity grades (8, 12, 16, 20, 30, 40, 50 and 60) for motor engine oil (Table 2.2). Multigrade oils such as SAE 5W-30 and 10W-30 (contain additives that oppose the tendency to thicken at low temperature) are widely used because, under all but extremely hot or cold conditions, they are thin enough to flow at low temperatures (winter) and thick enough to perform satisfactorily at high temperatures (summer). The word W stands for "winter". The winter performance was originally defined as at 0°F or (-) 11.8°C.

Table 2.2-SAE Engine Oil (SAE J300) Viscosity Classification Standard [17]

SAE Viscosity Grade	Low Temperature(°C) Cranking Viscosity[2], mPa.s Max	Low Temperature(°C) Pumping Viscosity[3], mPa.s Max. with Yield Stress	Kinematic Viscosity[4] (mm^2/s) at100°C Min	Kinematic Viscosity[4] (mm^2/s) at100°C Max	High Shear Viscosity[5] mPa.s at150°C min and $10^6 s^{-1}$
0W	6,200 @ -35^0 C	60,000 @ -40^0 C	3.8		
5W	6,600 @ -30^0 C	60,000 @ -35^0 C	3.8		
10W	7,000 @ -25^0 C	60,000 @ -30^0 C	4.1		
15W	7,000 @ -20^0 C	60,000 @ -25^0 C	5.6		
20W	9,500 @ -15^0 C	60,000 @ -20^0 C	5.6		
25W	13,000 @ -10^0 C	60,000 @ -15^0 C	9.3		
8	-	-	4.0	6.1	
12			5.0	7.1	
16			6.1	8.2	
20			6.9	9.3	2.6
30			9.3	12.5	2.9
40			12.5	16.3	2.9
40			12.5	16.3	3.7
50			16.3	21.9	3.7
60			21.9	26.1	3.7

[2]ASTMD5293.

[3]ASTMD4684.Note that the presence of any yield stress detectable by this method constitutes a failure regardless of viscosity.

[4]ASTMD445.

[5]ASTMD4683,

Figure 2.1 represents the SAE oil categories and their applicability range with temperature. The temperature represents the lowest possible temperature at which the engine can be started when lubricated with an oil of the corresponding SAE degree (e.g. a SAE 15W-40 mineral base lubricating oil makes it possible to start engine at up to -15^{0}C). The minimum pumping temperature is the minimum temperature at which oil, in addition to allowing start up, can flow freely and lubricate the critical parts of the engine [18].

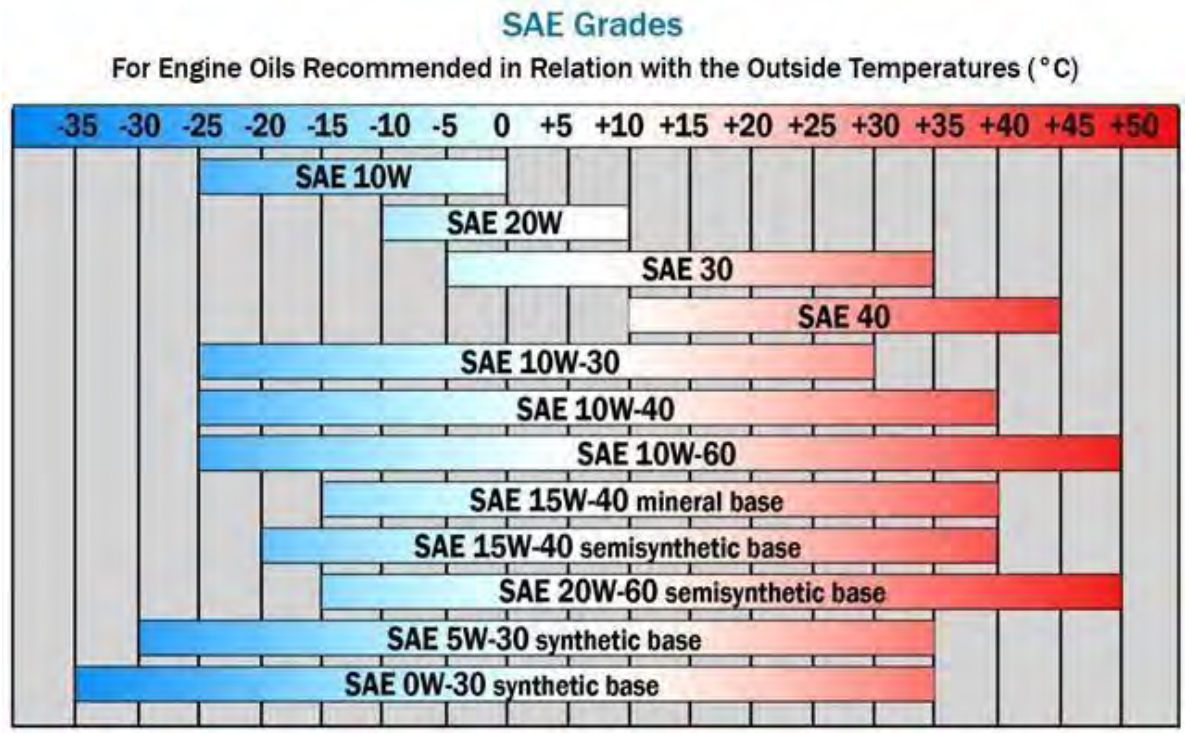

Fig. 2.1- Applicability of different SAE lubricants with temperature range.

2.3.1.2 Performance Based Classification

2.3.1.2-1 API engine oil classifications

The API Service Classifies the lubricant according to various criteria such as detergency, wear resistance anticorrosion etc. and according to their uses, and performance. When the oil is destined for a petrol (Spark Ignition) engine the letter “S” is used and for a diesel (Compression Ignition) engine the letter “C” is used. Oils designed for Gasoline Engines service fall under API’s “S” (service) Categories. Oils designed for diesel engines service fall under API’s ‘C’ (commercial) categories. Besides “GL” used for oils destined for Gear.

These classifications are presented:

i. Petrol
ii. Diesel Engine Oils
iii. Gear oil

(i) Petrol Engine (Gasoline engine)

For automotive petrol engine (Table 2.3), the latest engine oil service API SN plus and API SN categories cover the performance properties of each earlier category (SH, SJ, SL etc) with improved fuel economy API SN category introduced in October 2010 designed to provide improved protection at high temperature for pistons, more stringent sludge control, and seal compatibility. Recently, in 2017 API SN Plus (is a supplemental standard to the API SN specification) has been introduced to ensure gasoline direct engines protection against low-speed pre-ignition (LSPI) events [19].

Table 2.3- Standards for petrol engine

SA	Oil without additive.
SB	Some Antioxidant and anti-scuff properties, not suitable for engines built after 1951.
SC	Meets 1964-1967 requirements of Automotive manufacturers.
SD	Meets 1968-1971 requirements of Automotive manufacturers.
SE	Meets 1972-1979 requirements of Automotive manufacturers.
SF	Meets 1980-1988 requirements of Automotive manufacturers.
SG	Meets 1989-1993 requirements of Automotive manufacturers.
SH	Meets 1994-1997 requirements of Automotive manufacturers. It was introduced to provide improvement in deposit control, oil oxidation, wear, rust and corrosion.
SJ	Meets 1998-2000 requirements of Automotive manufacturers. It was introduced to provide improvement in oil volatility, filterability, gelation, deposits and catalyst compatibility.
SL	Meets 2001-2004 on requirements of Automotive manufacturers. It was introduced to provide improvement in high temperature deposit control and oil consumption.
SM	Meets 2004-2011 on requirements of automotive manufacturers. It was introduced to provide improvement in oxidation resistance, deposit control, anti-wear and low temperature performance.
SN	Meets 2011-on requirements of automotive manufacturers. Designed to provide high temperature deposit protection for piston more stringent to sludge control and seal compatibility. It matches ILSAC GF-5.

SN Plus	On November 9, 2017, the API Lubricants Standards Group approved the adoption of SN PLUS, a new classification that may be used in conjunction with API SN and API SN with Resource Conserving. Oils licensed by API as API SN with SN PLUS and Resource Conserving and ILSAC GF-5 are eligible to display the API Certification Mark Starburst. API service category SN engine oils that also carry the classification SN PLUS are formulated to provide API SN performance and additional protection against low-speed pre-ignition for turbocharged direct injection gasoline-powered vehicles.
SA to SH	Obsolete.

Detailed specifications of SJ to SN are given in appendices A1 to A5

(ii) Diesel Engine

For diesel engines (Table 2.4), the currently used categories of API codes are CJ-4, CI-4 and CH-4. CJ-4 oils are compounded for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm (0.05% by weight). However, use of these oils with greater than 15 ppm (0.0015% by weight) sulfur fuel may impact exhaust after treatment system durability and oil drain interval.

API CK-4 is backward compatible with previous categories such as API CJ-4. In contrast, API FA-4 defines a new class of low high temperature high shear (HTHS) lower viscosity engine oils optimized for fuel economy. More importantly, this new category is positioned to address fuel economy, extended service and durability, i.e., 'total cost of ownership'. Both API CK-4 and FA-4 oils help to maintain engine durability while improving oxidation resistance, shear stability and aeration control compared to API CJ-4.

Table 2.4- Standards for Diesel Engine

CA	Light duty, high quality fuel, for MIL-L-2104A, 1954, not suitable for engines built after 1959.
CB	Moderate duty, lower quality (high sulphur) fuel, not suitable for engines built after 1961.
CC	Moderate to severe duty diesel and gasoline service, not suitable for engines built after 1959.
CD	Severe duty diesel, including turbo, Caterpillar Series 3, MIL-L-2104C, introduced in 1955.
CD-II	CD plus Detroit Diesel 6V53T approval for two stroke engines introduced in 1985.
CE	Turbo/Supercharged heavy-duty diesels from 1985.
CF	Off road indirect injection diesel engines and others using a broad range of fuel types including high sulphur, introduced in 1994. May be used to replace API CD oils
CF-2	Severe duty two stroke diesel engine service from 1994
CF-4	Severe Duty four stroke diesel engine service for lower emission diesel engines from 1990.
CG-4	Severe Duty four stroke engines meeting 1994 emission standards for engines using fuel with less than 0.5%w sulphur.
CH-4	High speed four stroke engines meeting 1998 emission standards for engines using fuel less than 0.5% w sulphur.
CI-4	Released from December 2001. High speed four stroke engines fitted with cooled Exhaust Gas Recirculation (EGR) and using fuel with up to 0.5% w Sulphur. It was introduced to meet 2004 engine exhaust standards.
CI-4 PLUS	As per CI-4 but with further restrictions on after shear viscosity and performance. (Released September 2004).

CJ-4	Released in 2006 for 15ppm maximum fuel sulphur. Enhanced wear, protection 1.0% ash maximum. CJ-4 Oils are especially effective at sustaining emission control system durability where particulate filters and other advanced after treatment system are used. Optimum protection is provided for control of catalyst poisoning, particulate filter blocking, engine wear, piston deposit, low and high temperature stability soot handling properties, oxidative thickening, foaming, and viscosity loss due to shear. Its performance exceeds the criteria of CI 4.
CK-4	API Service Category CK-4 describes oils for use in high-speed four- stroke cycle diesel engines designed to meet 2017 model year on- highway and Tier 4 non-road exhaust emission standards as well as for previous model year diesel engines. These oils are formulated for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm (0.05% by weight). However, the use of these oils with greater than 15 ppm (0.0015% by weight) sulfur fuel may impact exhaust aftertreatment system durability and/or oil drain interval. These oils are especially effective at sustaining emission control system durability where particulate filters and other advanced aftertreatment systems are used. API CK-4 oils are designed to provide enhanced protection against oil oxidation, viscosity loss due to shear, and oil aeration as well as protection against catalyst poisoning, particulate filter blocking, engine wear, piston deposits, degradation of low- and high-temperature properties, and soot-related viscosity increase. API CK-4 oils exceed the performance criteria of API CJ-4, CI-4 with CI-4 PLUS, CI-4, and CH-4 and can effectively lubricate engines calling for those API Service Categories. When using CK-4 oil with higher than 15 ppm sulfur fuel, consult the engine manufacturer for service interval recommendations.
CA to CF- 4	Obsolete

Detailed specifications of CH-4 to CJ-4 are given in appendices A6 to A7.

(iii) Gear Oil

Gear oils are classified by the American Petroleum Institute using GL ratings These are described below:

(A) **API GL-1** Lubricant denotes gear oil intended for manual transmissions operating under such mild conditions of low unit pressures and minimum sliding velocities, that untreated oil may be used satisfactorily. Oxidation and rust inhibitors, defoamers, and pour depressants may be used but friction modifiers and extreme pressure additives shall not be used.

(B) **API GL-2** Lubricant denotes gear oil intended for automotive worm-gear axles operating under such conditions of load, temperature, and sliding velocities that lubricant satisfactory for API GL-1 service will not suffice. Products suited for this type of service contain anti-wear or film-strength improvers specifically designed to protect worm gears.

(C) **API GL-3** Lubricant denotes gear oil intended for manual transmissions operating under moderate to severe conditions and spiral-bevel axles operating under mild to moderate conditions of speed and load. These service conditions require a lubricant having load-carrying capacities exceeding those satisfying API GL-1 service but below the requirements of lubricant satisfying API GL-4 service. API GL-3 service is not intended for axles with hypoid gears.

(D) **API GL-4** Lubricant denotes gear oil intended for axles with spiral bevel gears operating under moderate to severe conditions of speed and load or axles with hypoid gears operating under moderate speeds and loads.

(E) **API GL-5** denotes lubricant intended for gears, particularly hypoid gears, in axles operating under various combinations of high-speed/shock load and low-speed/high- torque conditions.

(F) **API GL-6** denotes lubricant intended for gears designed with a very high pinion offset. Such designs typically require protection from gear scoring in excess of that provided by API GL-5 gear oils.

(G) **API MT-1** denotes gear oil intended for non-synchronized manual transmissions used in buses and heavy-duty trucks. Lubricant meeting the requirements of API MT-1 service provides protection against the combination of thermal degradation, component wear, and oil-seal deterioration. Due to changes in manufacturers' recommended practices or due to the unavailability of testing hardware, API GL-1, GL-2, GL-3, and GL-6 are not in current use.

Detailed specifications of GL-4 & GL-5 are given in appendices A8 & A9**.**

Note: Automatic or semiautomatic transmission, fluid couplings, torque converters, and tractor hydraulic systems usually require special lubricant. Therefore, the manufacturer or lubricant supplier for the proper lubricant may be consulted.

2.3.1.2-2 ILSAC

The ILSAC has also standard for motor oil. ILSAC works with API to create newest gasoline oil specification. It introduced GF-4 in 2004. Standard for passenger car engine oils chart is currently known as GF-5. It was Introduced in October 2010 for 2011 and older vehicles, designed to provide improved high temperature deposit protection for pistons and turbochargers, more stringent sludge control, improved fuel economy, enhanced emission control system compatibility, seal compatibility, and protection of engines operating on ethanol-containing fuels [20].

Detailed specifications of GF-4 & GF-5 are given in appendices A10.

2.3.1.2-3 ACEA

ACEA is also known as European Automobile Manufacturers Association. It was established in 1991 and based in Brussels. ACEA has around 15 members [21] e.g. BMW Group, DAF Trucks, Daimler, Ford of Europe, General Motors Europe, Hyundai Motor Europe, IVECOS.p.A, Jaguar Land Rover, Porsche, PSA Peugeot Citroën, Renault Group, Scania, Toyota Motor Europe, Volks wagen Group.

The ACEA has developed a standard, in its name ACEA. 3 sets (classes) of sequences: one for Gasoline and Light-Duty Diesel engines; one specifically for Gasoline and Light-Duty Diesel engines with aftertreatment devices and one for Heavy-Duty Diesel engines. Within each of these sets there are categories which reflect different performance requirements-four (A1/B1, A3/B3, A3/B4 & A5/B5) for gasoline and light-duty diesel engines; four (C1, C2, C3, C4) specifically for engines with after treatment devices, and four (E4, E6, E7, E9) for heavy-duty diesel engines described in table 2.5 [22].

Table 2.5- Gasoline and Light-Duty Diesel Engines

Type	A/B: gasoline and diesel engine oils
A1/B1	Stable, stay-in-grade oil intended for use at extended drain intervals in gasoline engines and car & light van diesel engines specifically designed to be capable of using low friction low viscosity oils with a high temperature / high shear rate viscosity of 2.6 mPa.s for xW/20 and 2.9 to 3.5 mPa.s for all other viscosity grades. These oils are unsuitable for use in some engines.
A3/B3	Stable, stay-in-grade oil intended for use in high performance gasoline e and car & light van diesel engines and/or for extended drain intervals specified by the engine manufacturer, and/or for year-round use of low vis oils, and/or for severe operating conditions as defined by the engine manufacturer.
A3/B4	Stable, stay-in-grade oil intended for use in high performance gasoline and direct-injection diesel engines, but also suitable for applications described under A3/B3.
A5/B5	Stable, stay-in-grade oil intended for use at extended drain intervals in high performance gasoline engines and car & light van diesel engines designed to be capable of using low friction low viscosity oils with a High temperature / High shear rate (HTHS) viscosity of 2.9 to 3.5 mPa.s. These oils are unsuitable for use in some engines.

Detailed specifications of A1/B1 to A5/B5 are given in appendices A11

Table 2.6- Gasoline and Light-Duty Diesel Engines with after treatment devices.

Type	C: Catalyst compatibility oils
C1	Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines requiring low friction, low viscosity, and low SAPS oils with a minimum HTHS viscosity of 2.9 mPa.s. These oils will increase the DPF and TWC life and maintain the vehicles fuel economy.
C2	Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines designed to be capable of using low friction, low viscosity oils with a minimum HTHS viscosity of 2.9mPa.s. These oils will increase the DPF and TWC life and maintain the vehicles fuel economy.
C3	Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines, with a minimum HTHS viscosity of 3.5mPa.s. These oils will increase the DPF and TWC life.
C4	Stable, stay-in-grade oil intended for use as catalyst compatible oil in vehicles with DPF and TWC in high performance car and light van diesel and gasoline engines requiring low SAPS oil with a minimum HTHS viscosity of 3.5mPa.s. These oils will increase the DPF and TWC life.

Detailed specifications of C1 to C4 are given in appendices A12

Table 2.7- Heavy Duty Diesel Engines.

E: Heavy Duty-Diesel engine oils	
E4	Stable, stay-in-grade oil providing excellent control of piston cleanliness, wear, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under very severe conditions, e.g. significantly extended oil drain intervals according to the manufacturer's recommendations. It is suitable for engines without particulate filters, and for some EGR engines and some engines fitted with SCR NOx reduction systems.
E6	Stable, stay-in-grade oil providing excellent control of piston cleanliness, wear, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under very severe conditions, e.g. significantly extended oil drain intervals according to the manufacturer's recommendations. It is suitable for EGR engines, with or without particulate filters, and for engines fitted with SCR NOx reduction systems. E6 quality is strongly recommended for engines fitted with particulate filters and is designed for use in combination with low sulphur diesel fuel.
E7	Stable, stay-in-grade oil providing effective control with respect to piston cleanliness and bore polishing. It further provides excellent wear control, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under severe conditions, e.g. extended oil drain intervals according to the manufacturer's recommendations. It is suitable for engines without particulate filters, and for most EGR engines and most engines fitted with SCR NOx reduction systems.
E9	Stable, stay-in-grade oil providing effective control with respect to piston cleanliness and bore polishing. It further provides excellent wear control, soot handling and lubricant stability. It is recommended for highly rated diesel engines meeting Euro I, Euro II, Euro III, Euro IV and Euro V emission requirements and running under severe conditions, e.g. extended oil drain intervals according to the manufacturer's recommendations. It is suitable for engines with or without particulate filters, and for most EGR engines and for most engines fitted with

	SCR NOx reduction systems. E9 is strongly recommended for engines fitted with particulate filters and is designed for use in combination with low Sulphur diesel fuel.

Detailed specifications of E4to E9 are given in appendices A13

2.3.1.2-4 JASO

The (JASO) has created their own set of performance and quality standards for petrol engines of Japanese origin, analogous to the Society of Automotive Engineers (SAE) in the United States. JASO also sets standards for grades of oil; the highest grade for two-stroke engines being JASO FA, FB, FC and FD, and JASO MA for four-stroke engines (motorcycles) [23].

For four-stroke gasoline engines, the JASO T903 standard is used, and is particularly relevant to motorcycle engines. Subsequently it was merged to JASO T904. There 3 such standards, namely JASO T904-MA & MA2 and JASO T904-MB. The JASO T904-MA and MA2 standards are designed to distinguish oils that are approved for wet clutch use, and the JASO T904-MB standard is the lowest friction oils among the motor cycle 4 stroke engines oils.

Detailed specifications of JASO T904 is given in appendices A14

JASO M 355 has created standard for Automotive Diesel Engine Oils which are classified into DH-1, DH-2 and DL-1. DH-1 Oils have been developed for the diesel engines which are subjected to long-term exhaust emission. The DH-1 Oils are also applicable to engines which were predating the long-term exhaust emission regulations and where diesel fuel having more than 0.05% sulfur content is used. DH- 2 and DL-1 classifications have been developed for the engines which are equipped with after-treatment devices such as Diesel Particulate Filter (DPF) and catalyst in compliance with exhaust emission. DH-2 classification is adopted for heavy-duty use by trucks/buses and DL-1 classification is adopted for light-duty use by passenger car classes & used only in the environment where low-sulfur diesel fuel having not more than 0.005% sulfur content is used.

Detailed specifications of JASO M 355 is given in appendices A15

For two-stroke gasoline engines, the JASO M345 (FA, FB, FC) standard is used, and this refers particularly to low ash, kinematic viscosity, flash point lubricity, detergency, low smoke and exhaust blocking. Since it is for two-stroke engines, no further consideration is made.

These standards, especially JASO-MA and JASO-FC, are designed to address oil- requirement issues not addressed by the API service categories.

2.3.1.2-5 OEM

The OEM has also developed their own standards because they felt that API specification is not compatible to meet the need of the motor oils to be used in their engines. There are many OEM standards line VW50 MB 22&DQC etc. series. The required qualities of lubricating oil, according to DQC, for each engine type as well as according to engine output, operating conditions and exhaust gas after-treatment have been set out [24].

Brief description of oil Quality Classes according to DQC and the engines for which they are suitable is given below:

i. DQC I-02 Minimum oil quality, some shorter oil change intervals,
ii. DQC II-10 Standard quality, usually used in engines with open crankcase ventilation,
iii. DQC III-10 High performance diesel engine oils, application for engines with closed crankcase ventilation and/or with high thermal loads,
iv. DQC IV-10 Ultra high-performance diesel engine oil for engines with highest level of output with closed crankcase ventilation and/or with the highest thermal loads,
v. DQC II-10 LA Low-ash diesel engine oil, standard quality, usually used in engines with open crankcase ventilation,
vi. DQC III-10 LA Low-ash high performance diesel engine oil, application for engines with closed crankcase ventilation and/or with high thermal loads,
vii. DQC IV-10 LA Low-ash ultra-high-performance diesel engine oil for engines with highest level of output with closed crankcase ventilation and/or with the highest thermal loads.

Detailed specifications of DQCIII & DQC IV are given in appendices A16

2.3.1.3 Use and Labeling Requirements for API Marks [25]

2.3.1.3-1 API Engine Oil Quality Marks

API licenses three types of engine oil quality marks: the API Certification Mark "Starburst" (Figure 2.2), the API Certification Mark "Shield" beginning on May 1, 2020 (Figure 2.3), and the API Service Symbol "Donut" (Figures 2.4 and 2.5). The marketer may display an API Mark, as described in this section, only after obtaining a license to use the specific API Mark. Under the terms of the License Agreement, marketers may use the Marks in a number of ways: for example, on containers of licensed products [bottles, cans, jugs, kegs, drums, intermediate bulk containers (IBC), tanks, etc.]; in advertisements of licensed products; and in materials describing licensed products.

API will provide licensed marketers with "camera-ready" quality images or electronic versions (TIF, EPS, JPG, and BMP) of the API Marks, on request, for use in producing final artwork.

The API Certification Mark "Starburst" and API Certification Mark "Shield" may be used with the API Service Symbol "Donut" if the marketer meets all licensing requirements for the API Marks for that viscosity grade of engine oil. Note that a difference in viscosity grade, Service Category, or brand name denotes a separate engine oil. The API Marks shall be located and displayed as described in 2.3.1.2-2 through 2.3.1.2-4.

2.3.1.3-2 API Certification Mark "Starburst"

If the API Certification Mark "Starburst" is used, it shall be clearly displayed on the front of the container of those engine oils that have been properly licensed by API. Note that this does not prevent the licensed marketer from displaying the API Certification Mark again on the back of the container [24].

The outside diameter of the API Certification Mark "Starburst" (measured from the outside tips) shall be at least 2.1 centimeter and shall be 1.5 (±0.1) times the inside diameter. The background of the outer band (containing the words AMERICAN PETROLEUM INSTITUTE and CERTIFIED) shall be a color that contrasts with the label background. (For example, if the label background is white, the outside band could be black with the words in white.)

Fig. 2.2—API Certification Mark "Starburst"

The background of the inner circle shall be a color that contrasts with the outer band. The words AMERICAN PETROLEUM INSTITUTE and CERTIFIED in the outer band of the API Certification Mark and the words FOR GASOLINE ENGINES in the center shall be all capital letters. The relationship of the letter size to the allocated space within the API Certification Mark must be consistent for all users of the API Certification Mark. All lettering used for words in the API Certification Mark must be identical for all licensees.

API has registered the API Certification Mark only in the English language, and it can be displayed only as registered. However, the purpose of the API Certification Mark is to assist consumers, so API encourages licensed marketers to translate the words CERTIFIED and FOR GASOLINE ENGINES into any appropriate language outside of the API Certification Mark. The translation must be literal and provided to API as part of the licensing agreement. The location of the translations can be anywhere on the front of the label but not within a mark or symbol of any kind. AMERICAN PETROLEUM INSTITUTE is also a licensed mark and cannot be translated without permission of API.

2.3.1.3-3 API Certification Mark "Shield"

If the API Certification Mark "Shield" is used, it shall be clearly displayed on the front of the container of those engine oils that have been properly licensed by API. Note that this does not prevent the licensed marketer from displaying the API Certification Mark "Shield" again on the back of the container.

The length of the API Certification Mark "Shield" (measured from the top to the bottom of the shield) shall be at least 2.1 centimeters. The inner shield shape (containing the words AMERICAN PETROLEUM INSTITUTE and CERTIFIED FOR GASOLINE ENGINES) and the line denoting the outer shield shape shall be a matching color that contrasts with the label background. (For example, if the label background is a lighter color such as yellow, the inner and

outer shields should be a darker color with the lettering inside the inner shield displayed in a lighter color such as the background yellow or white.)

Fig. 2.3—API Certification Mark "Shield"

The words AMERICAN PETROLEUM INSTITUTE and CERTIFIED FOR GASOLINE ENGINES and the acronym SAE and letter "W" in the SAE viscosity shall be all capital letters. The relationship of the font size to the allocated space within the API Certification Mark "Shield" must be consistent with the design. A sans serif font must be used for all lettering.

API has registered the API Certification Mark "Shield" only in the English language, and it can be displayed only as registered. However, the purpose of the API Certification Mark "Shield" is to assist consumers, so API encourages licensed marketers to translate the words CERTIFIED FOR GASOLINE ENGINES into any appropriate language outside of the API Certification Mark "Shield." The location of the translation can be anywhere on the front of the label but not within a mark or symbol of any kind. AMERICAN PETROLEUM INSTITUTE is also a licensed mark and cannot be translated without permission of API.

2.3.1.3-4 API Service Symbol "Donut"

The API Service Symbol "Donut" may be located anywhere on the outside of the container. The outside diameter of the API Service Symbol shall be 1.9 times the inside diameter. The Service Category must be placed in the upper part of the Donut, the SAE viscosity grade in the center, and the optional Resource Conserving, CI-4 PLUS, and SN PLUS classifications in the lower part. The API Service Symbol shall be large enough for the lettering to be legible and shall strictly conform to the design (including the required information and its placement) shown in Figure 2.4.

Fig. 2.4—API Service Symbol "Donut"

Beginning December 1, 2016, when API Service FA-4 is claimed, the upper half of the Service Symbol must be divided by a single vertical line, and the API Service Categories and phrase "API Service" must appear as shown in Figure 2.5 (Service Categories left and "API Service" right of vertical line). Note that licensed FA-4 oils shall use a Service Symbol that conforms to the divided upper half designs in Figures 2.5 and 2.6.

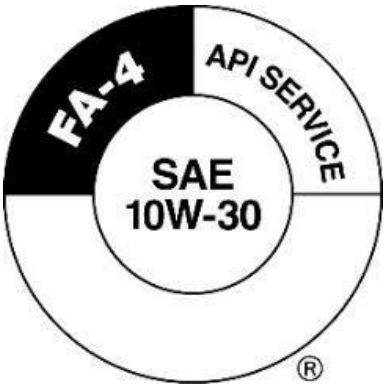

Fig. 2.5—API Service Symbol "Donut" with API FA-4

API Service Symbols may appear as black and white, reversed out, or in color. Examples of acceptable designs are provided in Figures 2.5 and 2.6. Any color is acceptable provided the design conforms to the designs shown in Figures 2.4 through 2.6.

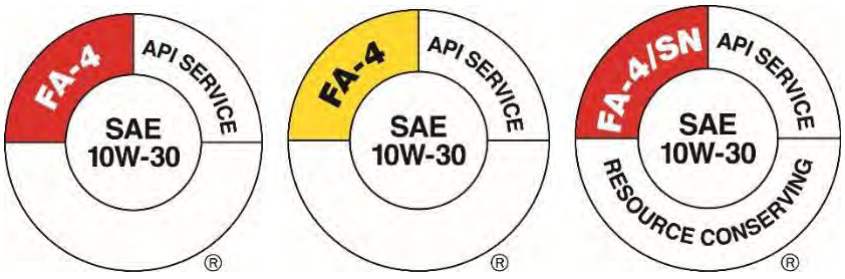

Fig. 2.6—Representative Examples of the API Service Symbol with FA-4

Use of more than one API S Service Category in the API Service Symbol is prohibited. SAE 0W-16 and 5W-16 oils may only be licensed as API SN, API SN with Resource Conserving, API SN with SN PLUS, and API SN with SN PLUS and Resource Conserving. Beginning on May 1, 2020, SAE 0W-16 and 5W-16 oils may be licensed as API SP, API SP with Resource Conserving, API SP with SN PLUS, and API SP with SN PLUS and Resource Conserving.

If API C Service Category oils are licensed for more than one current Service Category, these oils may display the Service Categories in the upper part of the API Service Symbol. Except as specified above, if the engine oil marketer chooses to include API C Service Categories with a current API S Category, a virgule (/) must be placed between the API S Service Category and the API C Service Categories, which are separated by commas. Licensees of Service Category C oils may use the C Categories first. Examples of acceptable notations are “API Service SN”; “API Service CK-4”; “API Service CJ- 4, CI-4/SM”; “API Service SJ”; “API Service CJ- 4/SM”; “API Service CI-4”; and “API Service CH-4.” Figure 2.7 shows examples of notations for various Service Categories used within the API Service Symbol.

For an oil that is formulated for diesel engine applications and meets both C and S Categories, the C Category should be put first so that the consumer can recognize that the oil is primarily a diesel engine oil but also meets S Category requirements. Conversely, for an oil that is formulated for passenger car motor oil applications and meets both S and C Categories the S Category should be put first so that the consumer can recognize that the oil is primarily a passenger car motor oil but also meets C Category requirements. Some automobile manufacturers are concerned that engine oils with greater than 800 parts per million (0.08% mass) phosphorus can adversely affect catalytic converters in gasoline-fueled engines.

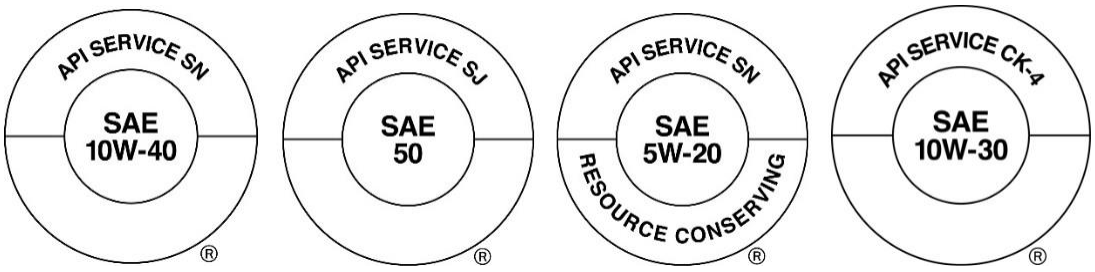

Fig. 2.7—Representative Examples of the API

2.3.2 Industrial Grade Lubricant

Industrial grade Lubricant include Hydraulic oils, Air compressor oils, Gas Compressor oils, Gear oils, Bearing and circulating system oils, Refrigerator compressor oils, Steam and gas turbine oils, Cutting Oil, Transformer Oils, Gas Engine Oil, Grease, and Heat Transfer Oil . These Lubricant are made from diester, polyalphaolefin or with ash less, rust or oxidation inhibitor or especially designed petroleum oils with anti-wear and extreme pressure additives for protection against corrosion, oxidation, rust and for extreme pressure performance.

Brief description of heat transfer oil and specification of Industrial Grade Oil (appendices A17) Turbine oil (appendices A18), Transformer oil (appendices A19), Heat transformer oil (appendices A20) and Grease (appendices A21) are given herein after.

Heat Transfer Oils are designed for heat transfer system where fuel oil, gas or electricity is used to heat a fluid in Textile, Pharmaceutical, Chemical and Processing Industries, equipped with indirect or secondary heating systems. They should possess excellent resistance to thermal cracking and chemical oxidation and are non-corrosive and non-toxic. They should also possess high specific heats and thermal conductivities that provide good heat transfer efficiency and their viscosities are such that they can be pumped readily at both start-up and operating temperatures. The Heat Transfer oils are formulated from very stable high viscosity index base oils, coupled with a low pour point and fortified with high temperature oxidation additives.

These are recommended for use in closed, forced circulation with indirect or secondary heating systems, equipped with expansion tanks. The temperature of the oil film surrounding the heating element should be about 15ºC to 30ºC above the bulk oil temperature. Higher than this may lead to deposit of sludge and coke which would interfere with the heat transfer rates and also shorten the service life of the oil. These oils are suitable for heat transfer up to bulk temperature of 310ºC and skin temperature of about 340^0C.

These oils are not recommended for use in open systems where hot oil is exposed directly to the air. If they spray or escape from leakage points, hot oils may spontaneously ignite.

The ISO viscosity classification uses mm^2/s (cSt) units and relates to viscosity at 40^0C. It consists of series of 18 viscosity bracts between 1.98 mm^2/s and 1650 mm^2/s. The numbers indicate to the nearest whole number, the mind point of their corresponding brackets. For example, ISO viscosity grade 32 relates to the viscosity bracket 28.8 to 35.2 mm^2/s, the midpoint of which is 32 mm^2/s. This is illustrated in the table 2.8, which shows the ISO viscosity grade number, the mid-point of each break and the viscosity limits.

Table 2.8- ISO VG codes for industrial lubricants.

Viscosity System Grade Identification	Mid-Point Viscosity cSt (mm^2/s) at 40.0°C	Kinematic Viscosity Limits, cSt (mm^2/s) at 40.0°C	
		minimum	maximum
ISO VG 2	2.2	1.98	2.4
ISO VG 3	3.2	2.88	3.52
ISO VG 5	4.6	4.14	5.06
ISO VG 7	6.8	6.12	7.48
ISO VG 10	10	9.00	11.00
ISO VG 15	15	13.50	16.5
ISO VG 22	22	19.8	24.2
ISO VG 32	32	28.8	35.2
ISO VG 46	46	41.4	50.6
ISO VG 68	68	61.2	74.8
ISO VG 100	100	90.0	110.0
ISO VG 150	150	135.0	165.0
ISO VG 220	220	198.0	242.0
ISO VG 320	320	288.0	352.0
ISO VG 460	460	414	506.0
I SO VG 680	612	680	748
ISO VG 1000	1000	900	1100
ISO VG 1500	1500	1350	1650
ISO VG 2200	2200	1980	2420
ISO VG 3200	3200	2880	3520

2.4 Bangladesh Standard (BSTI): Specification for Internal Combustion Engine Crankcase Oils (Diesel and Gasoline)

2.4.1 Significant feature of this specification

This specification covers the following two principal application-areas of lubricants:

a) Diesel Engine Lubricating Oils and

b) Passenger Car Motor Oils.

The standard currently provides for four types of crankcase lubricants for petrol engines designated from EPL1 to E-PL4; and six types of crankcase lubricants for diesel engines designated from E-DL1 to E-DL6. This specification does not cover the entire range of performance levels of lubricants currently in use in the country. Based on extensive interaction with OEM's in the country, it covers only those categories that are currently recommended by automotive OEM's for their engines [25].

2.4.2 Scope of this specification

This standard prescribes the requirements and methods of sampling and test for the various types of internal combustion engine lubricating oils for use in diesel engines and gasoline engines used in passenger and commercial vehicles including off highway equipment. This standard may also apply to lubricants used in internal combustion engines for stationary applications such as generators, compressors and pumps, wherever so recommended by the manufacturers or adopted by the users.

This standard permits the use of multi-labelled oils for lubrication of compression- ignition types of internal-combustion engines used in passenger and commercial vehicles, off-highway vehicles and industrial equipment. Lubricating oils, covered in this standard, are broadly classified into two types under the nomenclature as Diesel Engine Oils (DEO), Passenger Car Motor oils (PCMO).

2.4.3 Classification

2.4.3.1 Types of lubricants and Performance Level Categories

Internal Combustion Engine Lubricating Oils covered in this standard are of two types, that is, Diesel Engine Lubricating Oils and Passenger Car Motor Oils. They shall be qualified under the different performance-level categories, as per designations indicated in Table 2.9 and 2.10. Corresponding international equivalent performance levels and the prescribed engine tests are indicated, for the purpose of ready reference, against each of the designated categories.

Some of the prescribed test methods may no longer be available, and in such event the Engine Oil Qualification Approval Panel may consider alternate data provided as proof of performance level.

These oils may or may not contain friction modifiers. In certain cases, use of friction modifier containing oils in 4-stroke engines for 2 or 3-wheeled vehicles is not desirable. Users of 2 or 3 wheelers powered by 4-stroke engines are advised to refer to the oil recommendations by the original equipment manufacturers.

Table 2.9- Diesel Engine Lubricating Oils (DEO)

SL No.	BDS Category	International Equivalent	Engine Tests
1.	EDL 1	API CC	Not suitable for use in diesel-powered engines built after 1990.
2.	EDL 2	API CD/CF	CLRL-38, Cat 1G2 or MWM-B/CLR L-38 Cat. 1M-PC
3.	EDL 3	API CD/CF Plus, MACK T-7/T-8A	CLRL-38, Cat 1G2 or MWM-B/CLR L-38 Cat. 1M -PC plus Mack T-7 or Mack T-8A
4.	EDL 4	API CF-4	CLRL-38, Mack T-6, Mack T-7 or Mack T 8A, Cat 1K
5.	EDL 5	API CF-4 combined with ACEA E2- 96; (DB228.1)	CLRL-38, Mack T-6, Mack T-7 or Mack T-8A, Cat 1K, OM 364A, OM 602A, Mack T-8
6.	EDL 6	ACEA E3- 96; (DB 228.3)	OM 364A, OM602A, Mack T-8

Table 2.10- Passenger Car Motor Oils (PCMO)

SL No.	BDS Category	International Equivalent	Engine Tests
1.	EPL 1	API SC	CAUTION: Not suitable for use in gasoline-powered automotive engines built after 1967. Use in more modern engines may cause unsatisfactory performance or equipment harm.
2.	EPL 2	API SF	For 1988 and older engines.
3.	EPL 3	API SG	a) CLRL-38 b) Sequence IID c) Sequence IIIE d) Sequence VE e) Sequence VIA (optional) only for FE oils
4.	EPSL 4	API SJ	a) CLRL-38 b) Sequence IID c) Sequence IIIE d) Sequence VE e) Sequence VIA (optional) only for FE oils Mandatory catalytic converter compatibility

2.4.3.2 Viscosity Grades

The oils shall conform to one of the SAE mono-viscosity grades or SAE multi-grades, which are combinations of W-Grades and other mono grades, as for example: SAE 10W and SAE 30 for the SAE 10W- 30 grade.

2.4.4 Requirements

2.4.4.1 General

The oils shall be formulated by blending lube base stocks comprising of virgin oil or re-refined oil or synthetic fluid or a combination of any of these, and additives components as necessary, to meet the requirements of this standard.

2.4.4.2 Physico-Chemical Requirements

The oil shall be free from suspended matter, grit, water or any other foreign matter and impurities. The oil shall comply with the physico-chemical and other bench-test requirements as specified.

2.4.5 Stability and Compatibility of finished Lubricating Oils

The finished blended oils shall have the additive elements uniformly distributed throughout the oil and shall show no evidence of instability at temperature specified in the homogeneity and miscibility test described in this standard.

The oil shall be compatible with all other oils qualified as demonstrated by the homogeneity and miscibility test using standard reference oils approved by the qualifying authority.

2.4.6 Product Identification

To ensure acceptance of only qualified products and for the purposes of product identification, tests may be carried out by the purchaser or his agency on the characteristics of the oil mentioned in Table 2.11 and the test results shall be compared with the corresponding figures given in the product identification report. Permissible tolerances of the results are indicated against each of the characteristics in Table 2.11.

Table 2.11-Requirements for Finished product Identification and Permissible Variation for Product-Conformance

SN	Characteristics	Requirements	Method of Test Ref to BDS 1320/ASTM
(1)	(2)	(3)	(4)
i.	Density at 15°C, g/ml	To be reported	[P : 1]/ASTM D 4052
ii.	Flash point COC, °C,Min	As specified in appendices A22	[P : 28]/ ASTM D 92
iii.	Pour point °C, Max	As specified in appendices A22	[BDS ISO 3016]/ ASTM D 97
iv.	Kinematic viscosity, cSt at 40°C and cSt at100°C	± 10 of the reported and within viscosity range of the grade	[BDS ISO3104]/ ASTM D445
v.	Low temperature cranking viscosity, cP, Max	As specified in appendices A22	[BDS ISO 3104]/ ASTM D 4684
vi.	Viscosity-index, Min	As specified in appendices A22	[BDS ISO 3104]/ ASTM D2270
vii.	Foam tendency/stability Seq I, II &III	As specified in appendices A22	ASTM D 892
viii.	Total base number, mg KOH/g	9.5 + Open (Diesel, APICF) 7.0+ Open (Gasoline, API SG)	ASTM D2896
ix.	Total acid number, mg KOH/g	To be reported	ASTM D664
x.	Sulfur *	±20 per cent of the reported value	ASTM D4951
xi.	Sulphated ash *	±20 per cent of the reported value	ASTM D874
xii.	Calcium *	-10% to +20% of the reported value	ASTM D4951
xiii.	Barium*		
xiv.	Magnesium*		
xv.	Zinc *		
xvi.	Phosphorus *		[P: 47]/ASTMD4951]
xvii.	Nitrogen *		ASTM D4629 upto 1000ppm ASTM D5291 upto 1000ppm
xviii.	Sodium*		ASTM D4951

*This component is used in formulation by different brands to enhance the performance of the product. The per cent values are product specific.

2.4.7 Packing and Marking

2.4.7.1 Packing

The material shall be packed in metal containers or in any other suitable containers as agreed to between the purchaser and the supplier.

2.4.7.2 Marking

The container shall be securely closed and marked with the following:

a) Name of the material;

b) Manufacturer's name, address and its recognized trade mark, if any;

c) Net mass of the material;

d) Name of grades and percent of composition;

e) Batch number;

f) Date of manufacture;

g) Use best before/ date of expiry.

h) Maximum retail price

Each container may also be marked with the BSTI certification Mark.

2.5 Comparisons between Bangladesh and International Standards

Based on literature review, it is found that globally the latest lubricant grade is API SN PLUS for gasoline engine with the advantages of improved fuel economy, turbocharger protection, emission control system compatibility and protection of engines operating on ethanol containing fuels up to E85 lubricant. However, in Bangladesh API SJ brand is still using as the latest lubricant for gasoline engine. On the other hand, API CF combined with ACEA 96 E2 and ACEA 96 E2 are the latest lubricant standard for diesel engine in Bangladesh although those are obsolete according to API and ACEA standards. Recently, API CK-4 and FA-4 lube oils are introduced which have improved fuel economy, protection of environment by reducing NOx and CO_2 emission and unburnt carbon soot. Table 2.12 shows the comparisons of lube oil standards used according to API standards from the literature survey.

Table 2.12- Comparisons between Bangladesh Standards and Global Standards

Engine Type	BD Standards	Global Standards
Gasoline Engine	Latest API SJ	Latest API SN Plus Turbocharger protection from Low-speed pre-ignition (LSPI)
	Engine Test (Obsolete) Sequence IID Sequence IIIE Sequence VE Sequence VIA (optional) only for FE oils Mandatory catalytic converter compatibility	Sequence IIIG/IIIH, Sequence IIIGA/ROBO, Sequence IVA, Sequence VG, Sequence VIII, Sequence VID, Sequence IX LSPE test (turbocharger protection)
Diesel Engine	Latest API CF ACEA E3-96	Latest API CK-4 and FA-4 Reduced CO_2 emission, carbon soot and NOx emission.

At present old model vehicle's engines are being used in Bangladesh. For those old model cars and machines need old grade lubricating oil. On the other hand, for new models of cars and machines, new grades of lubricating oil are required. Because of using old cars and engines in Bangladesh, old grade or obsolete grades are still needed in the market.

Chapter 3 The Demand Supply Trend of Lubricating Oil Market

3.1 Global demand and value for lubricants

This statistic depicts the total global demand for lubricants from 2010 to 2018. Figure indicates the worldwide demand for lubricants reached a high in 2018, when demand reached nearly 37 million metric tons. In 2018, demand was 36.4 million metric tons [26].

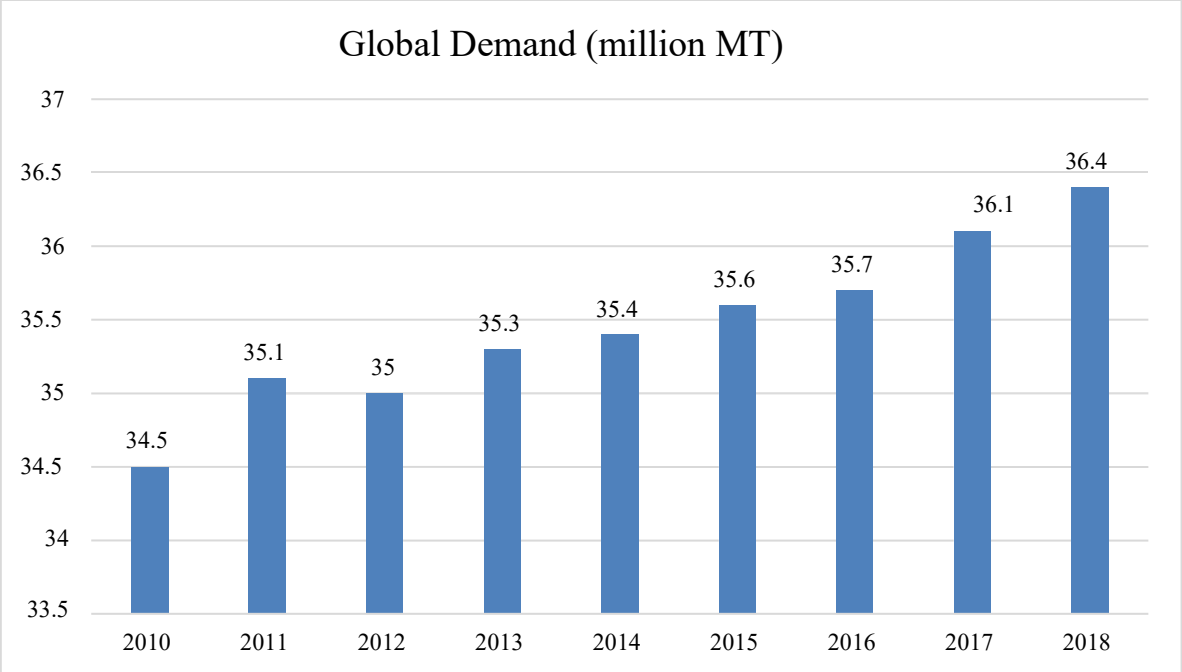

Fig. 3.1- Global Demand of Lubricants in million MT

Following figure show that Demand is expected to grow rapidly in this area, since many Asian countries (mainly China and India) are increasing their industrial production, as well as the fleet of their vehicles. Figure 3.2 also indicates that from 2012 to 2017 consumption increases by 20% in Asia Pacific area [27].

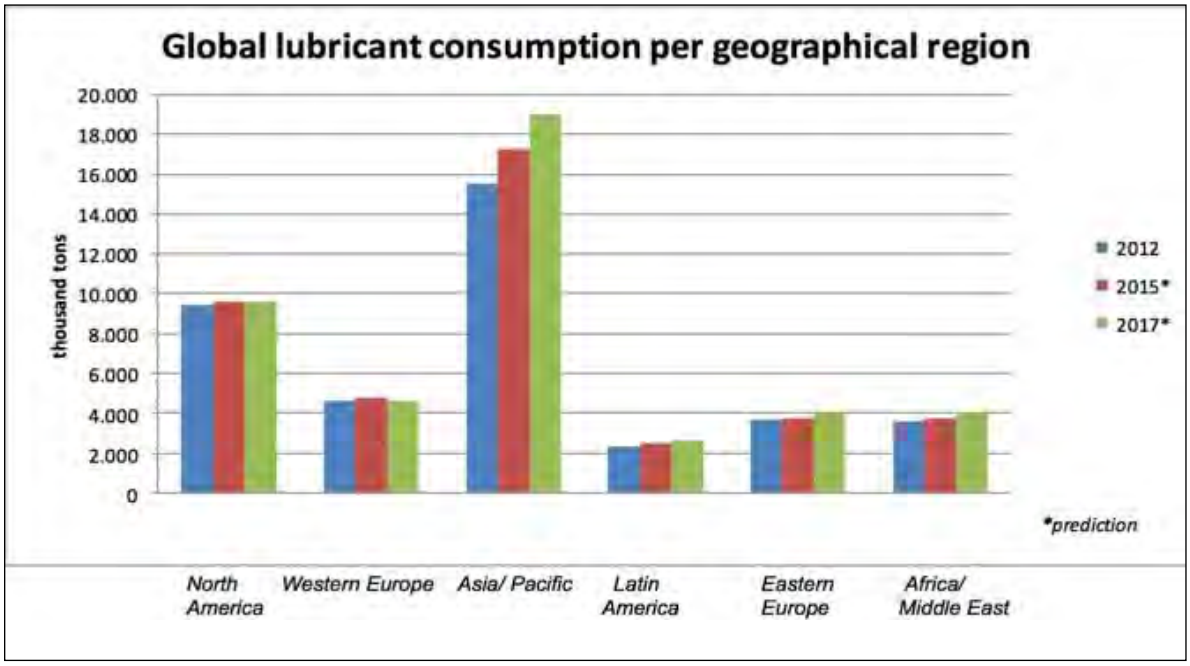

Fig. 3.2- Global Lubricant Consumption per geographical region [27].

Automotive Lubricants Market was valued at $68,716 million in 2017 and is expected to reach $89,585 million by 2022, registering a CAGR (compound annual growth rate) of 4.8% between 2016 and 2022 [28].

Key players include Royal Dutch Shell Plc., Exxon Mobil Corporation, Total S.A., BP Plc., Chevron Corporation, PetroChina Company Limited, Valvoline, BASF SE, Indian Oil Corporation Ltd., and FUCHS Lubricants. The other players in the value chain include Chevron Corporation, KMG Chemicals, Oryx Energies, Kenol Kobil, Oil Libya, Sinope, Pennzoil-Quaker State, Equilon, Burmah Castrol, Lukoil, and Idemitsu. Figure 3.3 Shows that lubricants market summary and key players companies in Asia Pacific area [30].

Fig. 3.3- Automotive Lubricants market growth and key players.

The automotive lubricants market is expected to register a CAGR of 2.45% during the forecast period of 2019–2024. Major factors driving the market studied are increasing automotive sales and the growing adoption of high-performance lubricants. On the other hand, extended drain intervals and the modest impact of electric vehicles (EVs) are expected to hinder the market's growth.

- Engine oil dominated the market in 2018 and is expected to continue the growth during the forecast period, owing to the increasing sales of automotive across the world.
- Growing automotive industry in Middle East & Africa is likely to act as the opportunity in the future.
- Asia-Pacific dominated the market, followed by North America and Europe across the world with the largest consumption from the countries, such as China, India, the United States, and Russia, among others.

The global **industrial lubricants market** is projected to witness a CAGR of 2.67% during the forecast period to the total market size of $71.413 billion by 2023, increasing from $60.964 billion in 2017. The global industrial lubricants market size was estimated at over 15 million tons in 2016.

Key companies operating in the global industrial lubricants market include Lubrizol, FUCHS Group, Amsoil Inc., Bel Ray Co., Kluber Lubrication, Total S.A., Valvoline International, Clariant, Quaker Chemical Corp., Royal Dutch Shell plc, Castrol, Lucas Oil, and Phillips 66.

Global demand for **marine lubes** was 2.35 million metric tons in 2017. Rising demand for durable products and increasing trade activities, especially in emerging economies of Asia Pacific, are among the key trends escalating market growth. The global marine lubricants market is estimated to be $ 5.98 billion in 2018 and is projected to reach $6.66 billion by 2023.

The leading marine lubricant suppliers are based elsewhere, Hout said., ExxonMobil accounts for 21 percent of global sales volumes, BP Castrol for 18 percent, Shell Lubricants for 16 percent, Total for 13 percent, Chevron for 7 percent and Lukoil for 3 percent.

3.2 Lubricating Oil Market in Bangladesh

The Bangladesh lubricants market is expected to register a CAGR of 3.01% over the forecast period, 2019-2024. The major factor which is driving the market studied is the increasing construction activities in the country. The high price of synthetic lubricants is expected to hinder the growth of the market.

- The automotive & other transportation dominated the market in 2018, and it is expected to grow during the forecast period.
- Growing demand for new motor vehicles is likely to act as an opportunity in the future.

Figure 3.4 indicates that Bangladesh lubricant market is projected to witness a CAGR of 3.01% increase during the forecast period from 2019 to 2014. Key players are MJL, BP, Total, Shell, Omera, Castrol and Caltex [31].

Fig. 3.4- Bangladesh Lubricants Market Summary and Key Brands.

3.2.1 Key Market Trends

In recent years, the construction activities in Bangladesh are increasing, owing to the growing per capita income and rising living standard of the consumers in the country. Major economies, like China, India, Japan, Korea, and the United States are keen to invest in the infrastructure sector of Bangladesh, owing to its good land to water connectivity, port operations, and other factors leading Bangladesh to be a strategic location to carry out business. As per the World Bank Business report, Bangladesh has improved its ranking in the terms of ease of doing business in the construction sector (starting a business, holding the minor investors and dealing with construction permits). According to the report, the whole process to start a new project in Bangladesh takes around 250 days including pre-planning. Bangladesh is the fourth fastest growing economy worldwide, with GDP of Bangladesh experiencing a continuous rise since the past 5 years. Bangladesh recorded a GDP growth rate of 7.86% in 2018 over the previous 7.28% in 2017 [32]. The construction activities accounted for a value of BDT 7,359.5 million in 2017- 2018 (~USD 86.93 million), witnessing an increase from BDT 6,659.1 million (~USD78.66 million) in 2016-2017.

In recent years, the contribution of the construction sector towards the country's GDP has been rising at a significant rate. Construction sector's contribution rose to 7.5% of total GDP in the 2017-2018 fiscal year from 7.36% in the 2016-2017 fiscal year.

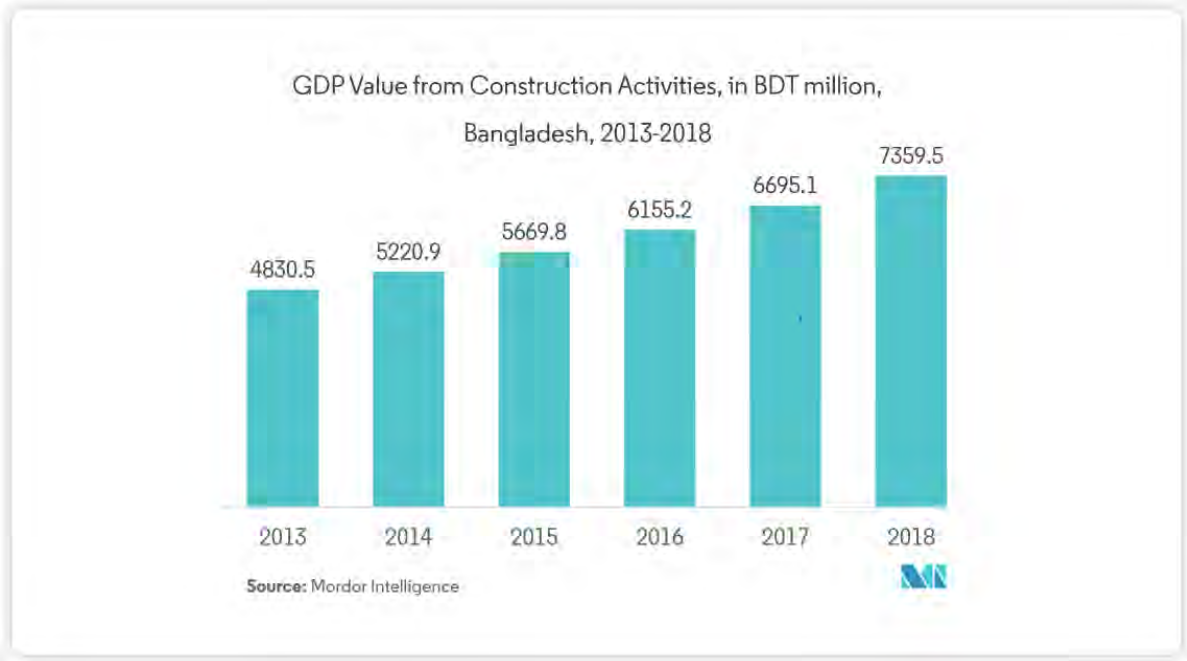

Fig. 3.5- GDP value from Construction Activities, in BDT million (2013- 2018).

Thus, the growing construction activities in the country are likely to drive the consumption of lubricants by increasing automobiles in new roads and engines in newly developed power plant through the forecast period.

3.2.2 Dominating Sectors

The automotive industry in Bangladesh is considered as the third largest in South Asia. Bangladesh is anticipating a rise in the demand for motorized vehicles. Until March 2018, 1,19,778 vehicles were registered against the 420,398 vehicles registered in 2017 and from Bangladesh Road Transport Authority issued total 34,19,884 vehicles [33]. Figure 3.6 show that number of automotive registered vehicles increases from 2014 to 2017 by 160% (1,60,639 to 4,20,398).

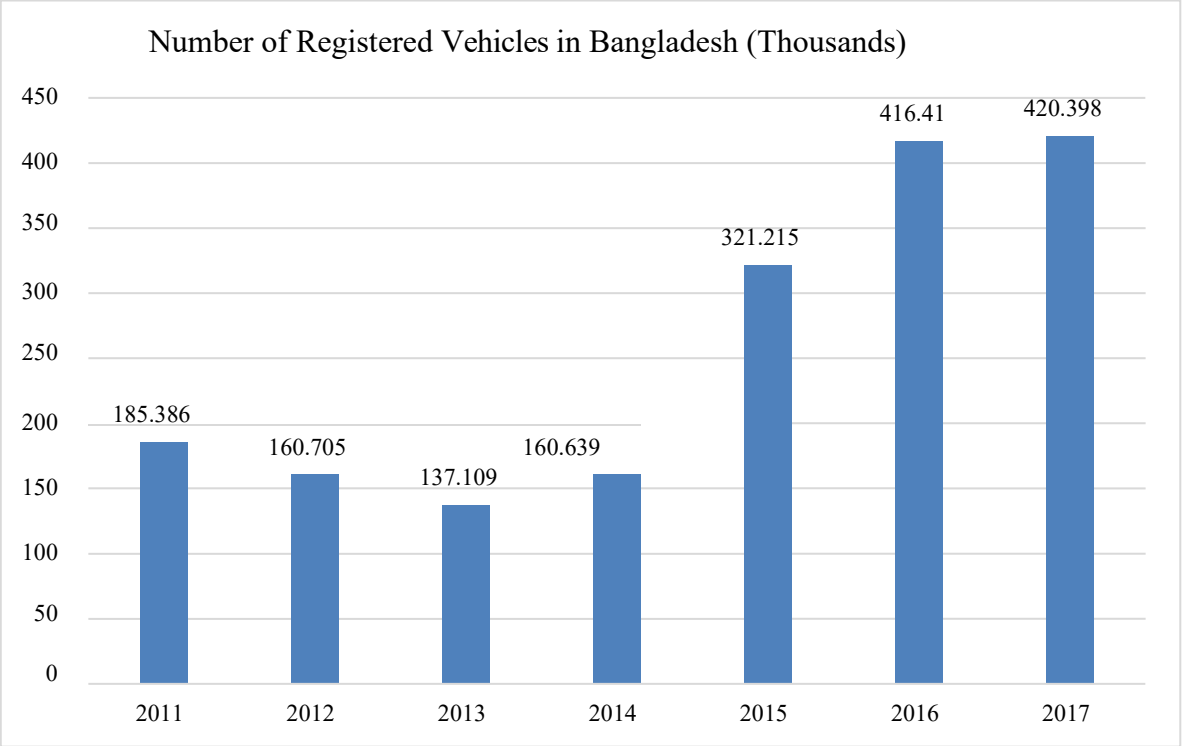

Fig. 3.6- Number of Registered Vehicles in Bangladesh.

Although the sales of new vehicles have been decreasing in the country for the past three years, the sales of used cars have increased significantly in the country, thereby driving the demand for automotive lubricants.

The automotive industry in Bangladesh is dominated by imports of new vehicles, mostly by Japan, China, and India on a large scale and a few from Europe and the United States.

Bangladesh is anticipating a growth in the aviation market, with the 170 million population increasing the use of the aerial route for traveling, owing to the growing middle-class income. Due to this, air travel is increasing in the country, which in turn is leading to the market growth for aviation lubricants.

The demand for engine oils will keep rising with the increasing automotive vehicles, which in turn will increase the market for lubricants in Bangladesh.

3.2.3 Supply and Consumption in Bangladesh

The current consumption of lubricating oil in Bangladesh is around 0.113 million MT per year (field survey report). The engine oil market has grown at nearly 20 percent during the last 03 (three) years (2015-2017) because of rising in the use of automobiles and introduction of new power plants.

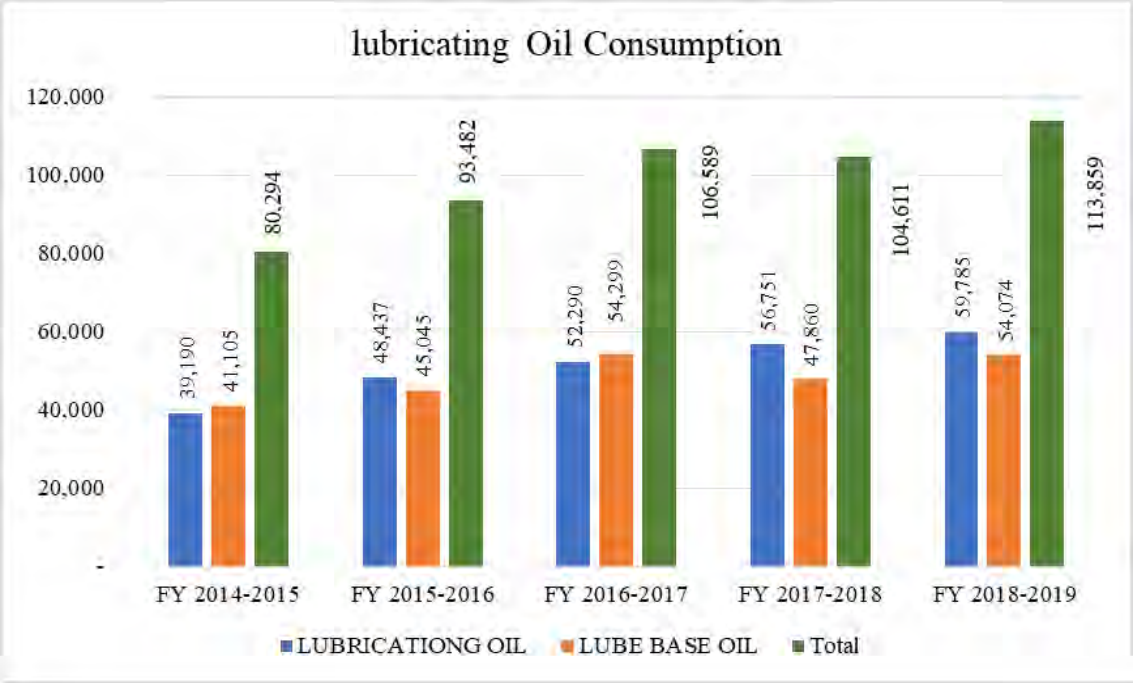

Fig. 3.7- Lubricating Oil consumption in Bangladesh (source: Field Survey Report)

The engine oil market has grown at nearly 20 percent during the last 03 (three) years (2015-2017) because of rising in the use of automobiles and introduction of new power plants. Figure 3.8 shows that the automotive sector will accounts for 70 percent of total lubricant consumption by 2014 in Bangladesh and the other industries remaining 30 percent [34].

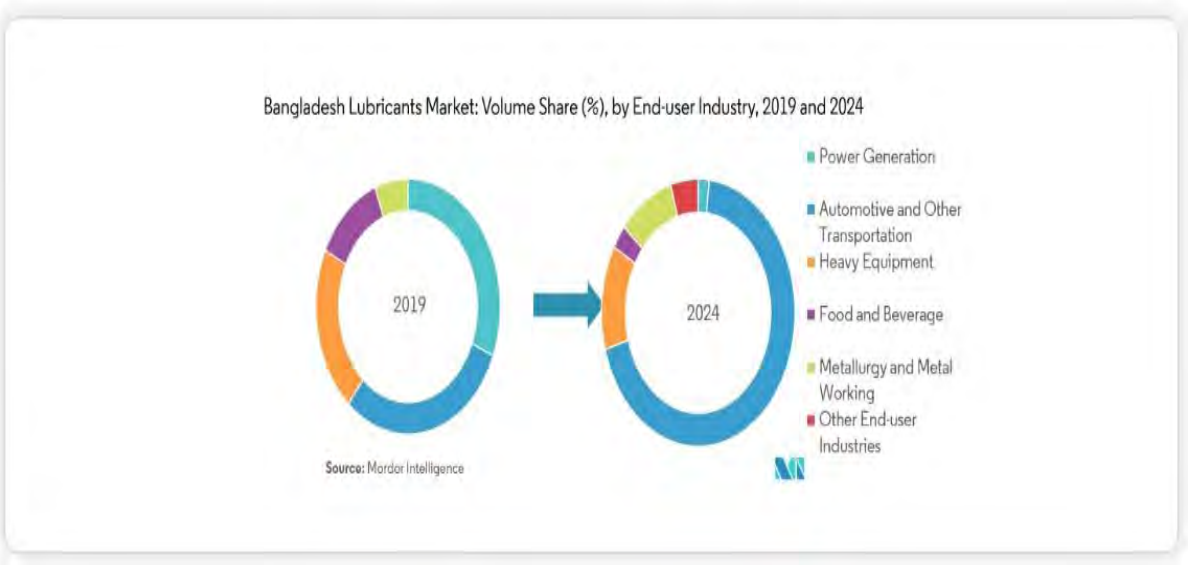

Fig. 3.8- Bangladesh Lubricants Market: Volume Share (%) by End-user Industry, 2019 and 2024. (Source: Mordor Intelligence)

Mobil is the leader with 30% market share, followed by British Petroleum (BP) 11%, French brand Total 5%, and Shell, Omera, Castrol and Caltex 2% each and the remaining is held by other brands [35].

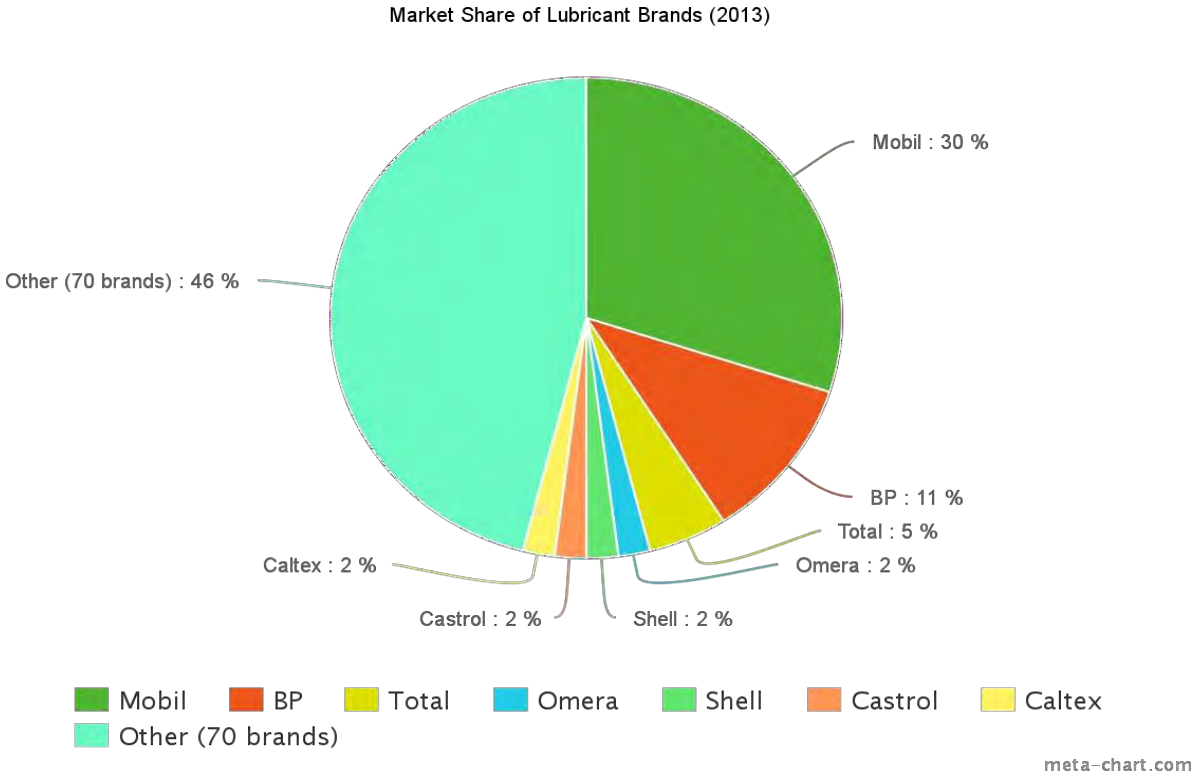

Fig. 3.9- Market share of lubricant brands in Bangladesh.

3.2.4 Lubricating oil Industry in Bangladesh

Lubricating oil industry in Bangladesh can be classified into four categories. These are:

I. Blenders and Manufacturers.
II. Importers, Marketing and Distributors.
III. For own Consumption.
IV. Recycling Plant

I. Blenders and Manufacturers

Various lubricating base oils are charged into blending vessel through flow indicator cum controller in fixed proportions depending on finished product desired. This is then dehydrated at atmospheric pressure followed by addition of various additives. Subsequently the blended product is filtered through centrifugal filter which retains any particle of size above 2 microns. This may then be filled in packs varying from ½ lit to 210 lit.

In Bangladesh around 15 blending companies have license to do business (field survey). Among them top key players are MJL Bangladesh Ltd., Lube House Industries Ltd., Mega Lubricants Bangladesh and Min oils Ltd. Etc. Table3.1 shows the top local blending plants and their brand names.

Table 3.1- Lubricating oil blenders and manufacturers in Bangladesh.

Serial Number	Company Name	Brand Name
1	MJL Bangladesh Ltd.	Mobil
2	Lube House Industries Ltd.	NATIONAL LUB
3	Lubricants Asia Ltd.	FUCHS
4	Eastern lubricants Blenders Ltd	Total
5	City Lube Oil Industries Ltd	Amirath Lube
6	Oriental Oil Co. Ltd.	HP lubricant
7	Mega Lubricants Bangladesh	MEGA
8	RYK Lube Oil Industries Ltd	King Lubricants
9	Global Oil Company Ltd.	Ap Oil
10	Sigma Oil Industries Ltd	SOIL
11	Standard Asiatic Oil Company Ltd	Lubzon, Repsol, Conoco, kendall, 76
12	Star Adhesives Ltd.	Star Bond
13	Min Oils Ltd. Unit-II	MOL-X

II. Importers, Marketing and Distributors

From Bangladesh Energy Regulatory Commission around 200 companies get license to import, marketing and distribution. They import international brand Engine oil, Industrial oil, Brake oil, ATF, Gear oil and Greases and distribute to industry, power plant and local.

III. For own Consumption

Power plant, manufacturing company and readymade garments industry use lubricants for their own production machine. They directly import lubricating oil from international market. For own consumption they import following types of lubricating oil.

1. Turbine Oil,
2. Hydraulic Oil,
3. Compressor Oil,
4. Flushing Oil,
5. Machine Oil,
6. Brake Oil,
7. Atf,
8. Gear Oil,
9. Punching Oil etc

From BERC total 47 number of power plant, manufacturing and textile mills company took license to import lubricating oil from international market. Some leading company have license to import lubricating oil for own consumption are shown in table 3.2.

Table 3.2- Leading companies of Bangladesh

Serial No.	Company Name
1	Karnaphuli Fertilizer Company Ltd
2	Bengal Glass Works Ltd.
3	Mak Steel Industries Ltd
4	Walton Hi-Tech Industries Ltd.
5	Apex Spinning &Knitting Mills Ltd.
6	Basundhara Industrial Complex Ltd.
7	KDS Textile Mills Ltd.
8	YKK Bangladesh Pte. Ltd.
9	The Aircons Ltd
10	ZakiaCottontex Ltd
11	Abdul Monem Ltd.
12	Bangla Trac Ltd

IV. Recycling Plant

For re-refining waste lubricating oil, only two companies have recycling license: Lube-rref Bangladesh Ltd. And Min oils Ltd.

3.2.5 Statistics of Lubricating Oil Business from BERC Annual Report

From 2008 to 2018, Petroleum division of Bangladesh Energy Regulatory Commission issued 632 licenses for different petroleum products [36]. In lubricating oil with base oil and additives petroleum product they issued 316 lubricating oil licenses.

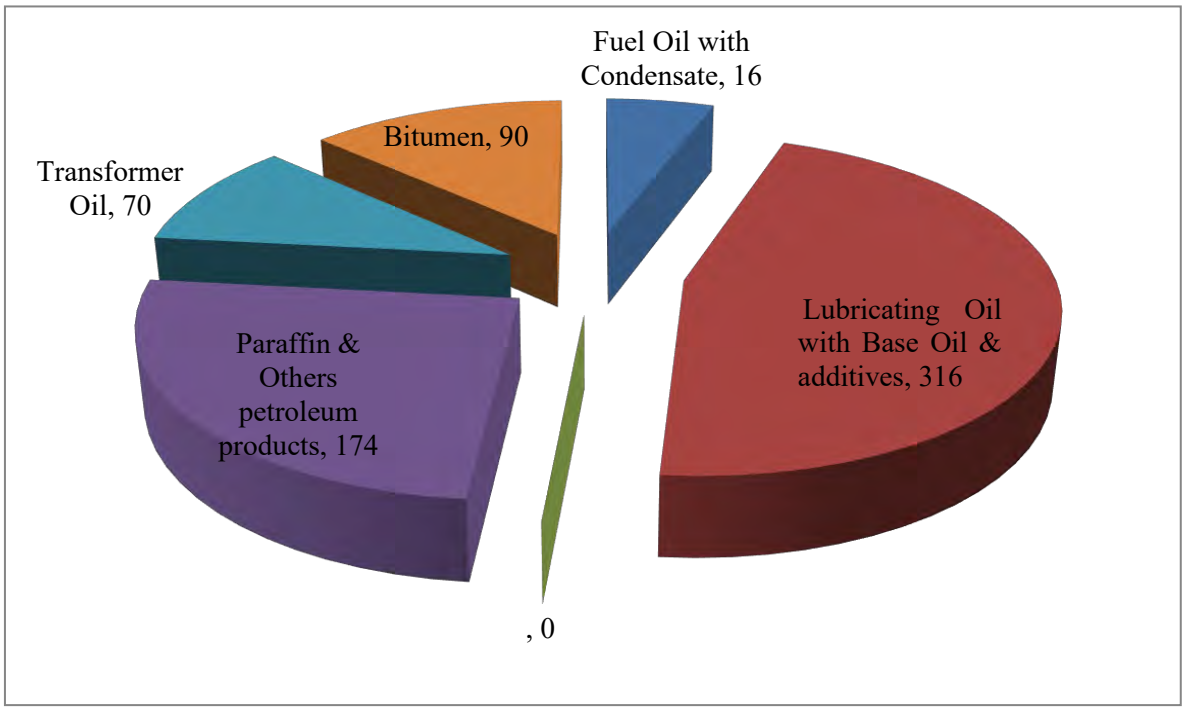

Fig. 3.10- Number of licenses by category of Petroleum Products.

From fiscal year 2013-14 to 2017-18 the quantity of petroleum storage for lubricating oil storage increased by 144% (Figure 3.11).

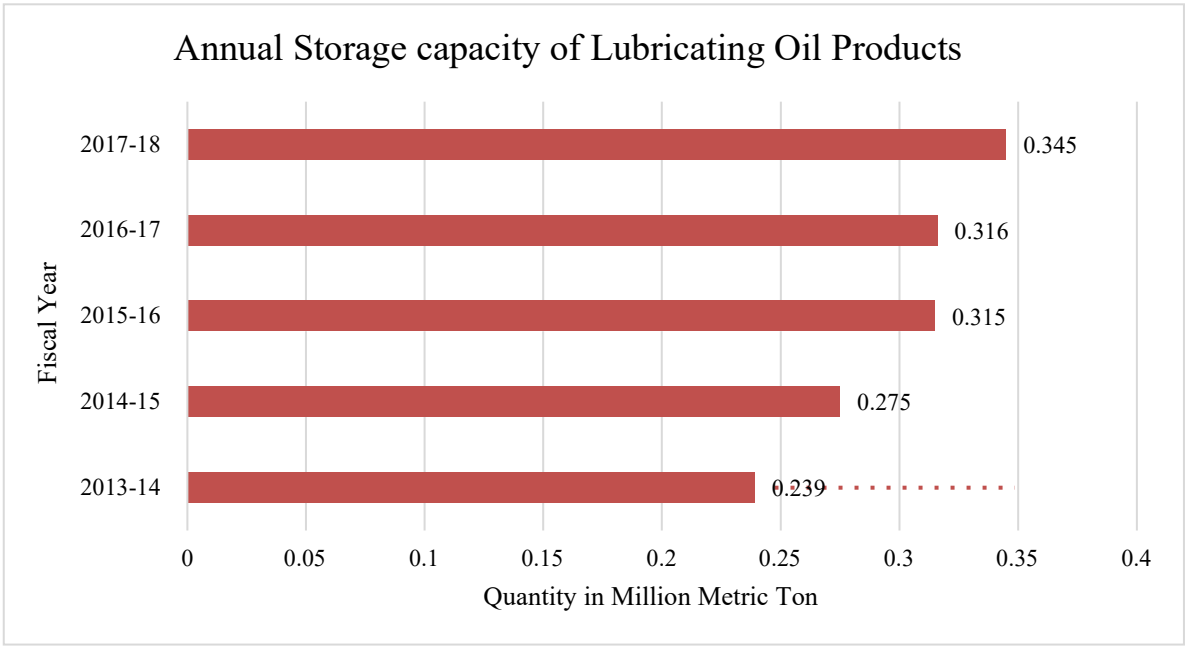

Fig. 3.11- Annual Approved Storage capacity of Lubricating oil, Base oil and additives.

From fiscal year 2013-14 to 2017-18 the quantity of petroleum marketing and distribution for lubricating oil increased by 135% (Figure 3.12).

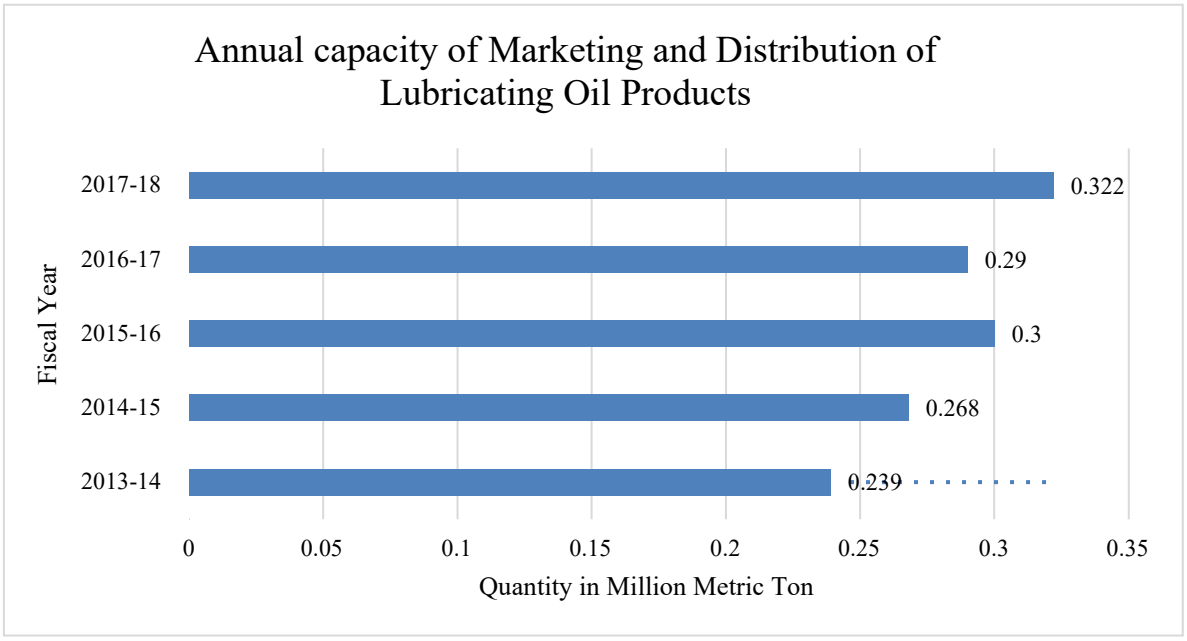

Fig. 3.12-Annual Approved capacity of Marketing and Distribution of Lubricating Oil Products (in M.T.)

So, we can see globally lubricating oil demand reached nearly 37 million metric tons and automotive lubricants market expected to reach $89,585 million by 2022. The automotive industry in Bangladesh is considered as the third largest in South Asia. According to BRTA report, registered vehicles increase from 2014 to 2017 by 160% there by driving the demand for automotive lubricant.

In Bangladesh around 15 blending company has license to do business and over 200 companies get license to import, marketing and distribution. On the other hand, around 47 numbers of power plant, manufacturing and readymade garment industries took license to import lubricating oil from international market. Only two companies have recycling license to recycle and blending used lubricating oil. Generally, lube base oil and lubricating oils are in 27 H.S Chapter defined in Bangladesh Custom Tariff 2019-20. From field survey report, the current consumption of lubricating oil in Bangladesh is around 1.6 lac MT per year. The engine oil market has grown at nearly 20% during last 03 (three) years because of automobiles and introduction of new power plants.

From annual report of Bangladesh Energy Regulatory Commission (BERC) 3,45,911 MT Lubricating oil, base oil and additives was approved for storage and 3,22,563 MT was approved for marketing and distribution to import. So, there is a huge difference between demand and approved quantity to do business and there will be a change to do illegal activities in local market.

Chapter 4 Review of Legal and Institutional Framework in Bangladesh

For doing lubricating oil business in Bangladesh, Bangladesh Energy Regulatory Commission gives final license to do business. Before that company needs to have certificate/NOC from different organization depends on their business activities such as: Fire Service and Civil Defense Department, Department of Environment, NOC from District Administration, Permission from Energy and Mineral Resource Ministry (EMRD) etc. To establish lube-blending plant, a primary and final permission from EMRD needed to setup plant by owner. EMRD technical team evaluate project proposal consisting of plants basic documents details are mentioned in this chapter. Finally, before doing business they must have to get BERC license. Basically, in this chapter we are going to discuss about related documents and certificates needed to establish/import lubricating oil company and certification organizations rule over this business.

4.1 Bangladesh Energy Regulatory Commission (BERC)

According to Section 27 of the Bangladesh Energy Regulatory Commission Act, 2003, a person has to obtain a license from the commission if he is engaged in power generation, energy transmission, energy marketing and distribution, energy supply and energy storage. Where according to section 2 (b), "energy" means the electricity, gas and petroleum product; and according to section 2 (q), *"petroleum products" means processed or unprocessed liquid or mixture of solid hydrocarbon and petroleum byproducts such as lubricant and petroleum solvent but shall not include natural gas;* [37]

Petroleum wing is issuing licenses to the private and public business entities engaged in the storage, marketing, distribution, transmission, processing and production of petroleum products.

4.1.1 Procedure to get license from BERC

In order to obtain a license, a prescribed application form (can be downloaded from www.berc.org.bd) is to be filled up and submitted to the commission with necessary documents. After receiving the application, petroleum wing evaluates the documents and inspects the operational facilities, safety aspects and environmental compliances of the applicant. If all these evaluation reports are found in proper order, the petroleum wing places the application to the commission meeting for a temporary license which afterward is confirmed by an open meeting and ultimately a formal license is issued. There is arrangement for license renewal and amendment also. Recently, Commission arranged E-licensing system software for online application system. In this software, an applicant easily applies for new

license, renew and amend license. License is being issued by BERC for the lubricating oil petroleum products shown in Table 4.1.

Table 4.1- Issued license for lubricating oil products by BERC.

SN	Lubricating Oil Products
1	Gear oil
2	Hydraulic oil
3	Compressor oil
4	Engine oil
5	Spindle oil
6	Knitting oil
7	Turbine oil
8	Crankcase oil
9	Therm oil
10	Chain oil
11	Flash oil
12	Transmission oil
13	Rubber oil
14	Imaging oil
15	Recycling oil
16	Refrigeration oil
17	Lube base oil
18	Stamping oil

4.1.2 Documents and certification needed to get BERC license

BERC is the authorized body to issue licenses for the following business categories:

a) Blending and Recycling Plant License

Blending and recycling plant must have following permission and licenses [38]:

i. Permission from Energy and Mineral Resource Ministry.
ii. NOC from Fire Service and Civil Defense Department.
iii. Certificate from Department of Environment.
iv. NOC from the Department of Explosives.
v. NOC from the District Administration.
vi. Laboratory and Testing Method Documents.

vii. PFD and PID of the plant.
viii. Layout Diagram of the plant.
ix. Documents of ETP and Disposal Method of the plant.
x. Current Income Tax Certificate.
xi. Current Trade license.
xii. VAT Registration Certificate.
xiii. For limited Company:
- Memorandum & Articles of Association
- Certificate of Incorporation

b) Import, Marketing and Distribution license

A company must have following permission and license:

i. NOC from Fire Service and Civil Defense Department.
ii. NOC from the District Administration.
iii. Layout Diagram of the plant.
iv. Current Income Tax Certificate.
v. Current Trade license.
vi. VAT Registration Certificate.
vii. For limited Company:
- Memorandum & Articles of Association
- Certificate of Incorporation

c) Own consumption license

For own use of lubricating oil by importing from abroad, a company must have following documents:

i. NOC from Fire Service and Civil Defense Department.
ii. NOC from the District Administration.
iii. Certificate from Department of Environment.
iv. Layout Diagram of the plant.
v. Current Income Tax Certificate.
vi. Current Trade license.
vii. VAT Registration Certificate.
viii. For limited Company:
- Memorandum & Articles of Association
- Certificate of Incorporation

4.2 Notification from Ministry of Energy and Mineral Resources

To set up lube-blending plant, a notification was published on 15 April, 2018 as Bangladesh gazette named 'Establishment of Lube-blending Plant Regulation, 2018' from the Energy and Mineral Resources Department [39].

4.2.1 Process steps to get final permission

Step 1	Submit application with supporting documents.
Step 2	Verification of application and supporting documents by Technical Team
Step 3	Based on evaluation report Team convener and Chairman, BPC recommend and send recommendation report to EMRD
Step 4	EMR consider for Initial Permission
Step 5	Set up plant by Owner
Step 6	Apply for Final Permission
Step 7	Inspection by the authorized officer after verification of all report and documents and conduct Performance Test Run.
Step 8	Base on inspection report, Chairman BPC send letter to EMRD
Step 9	EMRD consider for Final Permission
Step 10	Contact sign between Owner and BPC
Step 11	Start Production

4.2.2 Initial Permission

In this notification section 2 describe the application procedure for initial permission. For initial permission to set up lube-blending plant, applicant apply in the energy and mineral resources department along with the following documents:

1. **Project Proposal or Project Proforma** consisting below subjects:
    i. Plant layout approved by explosive department.
    ii. Objective and justification of establishing plant.
    iii. Land lease agreement/deed.
    iv. Source and specification of base oil & additives.
    v. Base oil, finished products name or group and specification.
    vi. Process description and Flow-diagram.
    vii. Health safety security and environment (HSSE).
    viii. List of equipment: Storage Tanks, Process equipment and Utilities.

2. Feasibility Study Report.
3. Clearance of Environment Department.
4. Fire Service and Civil Defense Clearance.
5. Explosive Clearance.
6. Local authority clearance certificate.
7. Income tax certificate.
8. Trade license and certified documents.
9. License agreement with international brand company which have 10 years' experience at this business.

4.2.3 Laboratory test apparatus and methods

According to Section 4, a lube-blending company must have laboratory instrument to do following test:

Table 4.2- Laboratory test apparatus and test methods.

S.N.	Test Name	Description of the Apparatus	Test Method
1	Aniline Point	Automatic Aniline Point Analyzer	ASTM D 611
2	Appearance	Standard Bar Chart Plate	ASTM D 4176
3	Cloud Point, Pour Point	Automatic No-flow Analyzer	ASTM D 2500 ASTM D 97
4	Color	Automatic Colorimeter	ASTM D 1500
5	Copper Strip Corrosion	Copper Strip Corrosion Pressure Vessel & Digital Oil Bath	ASTM D 130
6	Density	Digital Density Meter	ASTM D 4052
7	Flash Point (Open cup)	Semi-Automated Cleveland Open Cup Flash Point Tester	ASTM D 92
8	Evaporation Loss	Automatic Evaporation Loss Apparatus	ASTM D 5800
9	Foaming Tendency	Foaming Characteristic Tester	ASTM D 892
10	Kinematic Viscosity	Automatic Viscometer	ASTM D 445
11	Low Temperature Cranking Viscosity	Cold Cranking Simulator	ASTM D 5293

12	Low Temperature Pumping Viscosity	Mini Rotary Viscometer	ASTM D 3829/4684
13	Metal Content	ICP-OES	ASTM D 4951/5185
14	Pentane Insoluble	Centrifuge Apparatus & Precision Balance	ASTM D 893
15	Sulphated Ash	Sulphated Ash Apparatus & Precision Balance	ASTM D 874
16	Sulphur Content		ASTM D 2622/4294
17	Total Acid Number	Potentiometer	ASTM D 664
18	Total Base Number	Potentiometer	ASTM D 2896
19	Water Content	Karl Fasher Titration Apparatus	ASTM D 1533
20	Water Separability	Demulsibility Bath	ASTM D 1401
21	Oxidation Stability	Oxidation Stability Test Apparatus for Lubricants as Per ASTM D 7098-8	ASTM D 7098-8
22	Crackle Test	Burner/Test Tube & Accessories	
23	Demulsibility	Demulsibility Test Apparatus for Lubricants as Per Astm D 2711	ASTM D 2711
24	Air Release		ASTM D 3427

4.2.4 Other Conditions

According to section 6, lube-blending plant must be followed below conditions:

i. Within 03(three) running years, company must get ISO 9001:2008/2015 certification.
ii. For production and marketing of lubricating oil, company have to follow government or BSTI standards.
iii. For finished lubricating oil products, plant must use virgin base oil and under any circumstances, no one can use imported recycle lube oil or recycle base oil.
iv. Government approved (time to time) updated standards will be followed.

4.3 Environmental Laws of Bangladesh Regulating Water Pollution

The National Water Policy adopted by the Ministry of Environment and Forest (MoEF) describes principles and directions for water planning and utilization towards fulfilling the national goals of the entire population, as well as the protection of the natural environment. In line with international legal developments, Bangladesh has promulgated policies and enacted legislations as a framework for the protection of inland water resources from pollution. The Constitution of Bangladesh does not explicitly provide for the right to a healthy environment, but Article 31 and 32 set out the fundamental 'right to life' and the Supreme Court, the interpreter of the Constitution, has liberally interpreted the constitutional 'right to life' as extending to the right to a safe and healthy environment and including anything that affects life, public health and safety.

Legislation for the control, prevention and abatement of water pollution in Bangladesh dates back to the Water Pollution Control Ordinance 1970, which was replaced by the Environmental Pollution Control Ordinance 1977 and is considered the first regulatory legislation of this kind of the country. The government revised the old laws by enacting the Bangladesh Environment Conservation Act 1995. Although various legislations have been enacted to deal with inland water pollution, the question remains as to their implementation due to inadequate legal provision and institutional weaknesses.

The Ministry of Environment and Forest (MoEF) was established in 1989 to address the emerging environment-related issues, and the government of Bangladesh started to enact environmental laws in response to the national conservation strategy. The Department of Environment (DoE) of the MoEF in Bangladesh has a mandate to regulate and enforce environmental regulations, including regulations for the control of inland water resources. However, in most cases the service of DoE remains limited to issuing toothless cautionary notices.

The Ministry of Water Resources (MoWR) is the apex body of the government of the People's Republic of Bangladesh for the development and management of the water resources of the country. The Ministry also has an implementing arm called the Bangladesh Water Development Board (BWDB). According to Water Act 2013, Water Resources Planning Organization (WARPO) is the main institution involved in water resource management. This institution is responsible for national water planning, monitoring, formulation of water legislation and regulations, inter-sectoral coordination of water plans and for maintaining the central data system.

The National Environment Policy (NEP) was formed in 1992 and emphasizes the need for the ratification of relevant international documents.

Legislation directly or indirectly related to protection of inland water pollution is present in Bangladesh.

4.3.1 Bangladesh Environment Conservation Act, 1995 (Amended 2010)

Environment Conservation Act 1995 is currently the main act governing environmental protection in Bangladesh, which replaced the earlier environment pollution control ordinance of 1992 and provides the legal basis for Environment Conservation Rules, 1997(ECR'97). The main objectives of ECA'95 is: conservation of the natural environment and improvement of environmental standards, and control and mitigation of environmental pollution. According to Article-12 of Environment Conservation Act 1995, "No industrial unit or project shall be established or undertaken without obtaining, in the manner prescribed by rules, an Environmental Clearance Certificate from the Director General" [40]. Penalty for non-compliance with such direction is imprisonment not exceeding 10 years or fine not exceeding 10 lakh taka or both (Section 15).

4.3.2 Environment Conservation Rules, 1997 (Amended 2002)

Environmental Conservation Rules, 1997 consists of a set of the relevant rules to implement the Environment Conservation Act, 1995 which specify: Categorized list (Green, Orange-A, Orange-Band Red) of the projects; Procedure to take environmental clearance; Ambient standards in relation to water pollution, air pollution and noise, as well as permitted discharge/emission levels of water and air pollutants and noise by projects Environmental Categories. Procedure for issuing Environmental Clearance Certificate has been stated in the Rule-7 of the Environmental Conservation Rules, 1997. The validity period is also stated in the Rule-8.

4.3.3 Environmental Clearance Procedure [41]

It is mandatory to obtain Environmental Clearance for each and every type of industry and project as per Bangladesh Environment Conservation Act, 1995(Amended 2010). For the purpose of issuance of Environmental Clearance Certificate, the industrial units and projects shall, in consideration of their site and impact on the environment, be classified into the following four categories:

- Green
- Orange-A
- Orange-B
- Red

Lubricating oil industries are in Red Category.

4.3.4 Application Procedure for Red Category

1. Application through prescribed form-3 under Environment Conservation Rules 1997;
2. Prescribed fees under schedule-13 under Environment Conservation Rules1997 (Amended 2002);
3. Report on the feasibility of the industrial unit or project (applicable only for proposed industrial unit or project);
4. Report on the Initial Environmental Examination (IEE) relating to the industrial unit or project, and also the term so reference(ToR) for the Environmental Impact Assessment (EIA) of the unit or the project and its Process Flow Diagram; or Environmental Impact Assessment(EIA) report prepared on the basis of term so reference previously approved by the Department of Environment, along with the Layout Plan (showing location of Effluent Treatment Plant), Process Flow Diagram, design and time schedule of the Effluent Treatment Plant of the unit or project, (these are applicable only for a proposed industrial unit or project);
5. Report on the Environmental Management Plan (EMP) for the industrial unit or project, and also the Process Flow Diagram, Layout Plan (showing location of Effluent Treatment Plant), design and information about the effectiveness of the Effluent Treatment Plant of the unit or project (these are applicable only for an existing industrial unit or project);
6. No objection certificate (Prescribed Form) of the local authority;
7. Emergency plan relating adverse environmental impact and plan for mitigation of the effect of pollution;
8. Outline of relocation, rehabilitation plan (where applicable);
9. Other necessary information (where applicable);

4.3.5 General Process Steps for Environmental Clearance

A guide to Environment Clearance Procedure prepared by Department of Environment says following process steps must be followed for get a clearance certificate from this department:

Step 1	Submit application with supporting documents.
Step 2	Verification of application and supporting documents by DOE
Step 3	Inspection by the authorized officer after verification of all report and documents. [Then make decision about the clearance (Only Green and Orange-A)]
Step 4	Meeting of Environmental Clearance Committee (for Orange-B and Red Category)
Step 5	Decision

Chapter 5 Adulteration & Introduction of Substandard Lubricating oil in Bangladesh

5.1 Adulterated Lubricating oil in Local Market

Adulterated lubricants are sold at motorcycle garages, auto-rickshaw workshops and hardware shops in the city. Low-quality lubricants and used engine oil mixed with certain chemical substance are being sold in shops and automobile workshops. Addition of the chemical gives the color of the product such that it becomes difficult to tell the difference between the genuine and the tampered products.

The demand for engine lubricants is on the rise as the number of vehicles, especially motorbikes and private cars, is increasing in the capital [42]. Some car drivers are also aiding the unscrupulous oil traders to deceive the vehicle owners by refilling adulterated engine oil in cars. Adulterated engine oil is in high demand in the market, because the drivers are taking money from the owners for buying original lubricants.

Counterfeit products are sold in plastic containers of popular engine oil brands. Dishonest traders purchase burnt black engine oil at Tk 20 to Tk 25 per liter. Customers are buying the low-priced lubricants unknowingly. Low quality and used lubricant oil are sold using the names of international oil brands like Visco, Long run, Pe+, Climax, Super-V, Castrol and so on. The engines of vehicles are getting damaged within a short time for use of the adulterated lubricants and it is also causing accidents and loss of lives and properties.

5.2 Study of Adulterated lubricants and Standard lubricants

Investigation in the different areas were conducted. Investigation reveals that several syndicates in the city's Bangla Motor, Chankharpul, Khaje Dewan, Nimtali, Chawkbazar, Lalbagh, Islampur, Tantibazar, Dholaikhal, Gendaria, Demra and Karwan Bazar are involved in the production and marketing of adulterated engine lubricants.

Samples are collected from Bangla Motor, Dhaka. Normally it is very difficult to find adulterated lubricating oil, because to avoid legal issues they sale adulterated lubricants to drivers and want to confirm buyers purchase for own use. Three samples of adulterate lubricating oil were collected for three different categories. These are sold in popular engine oil plastic container for same prices.

5.2.1 Sample Collection and Test Methods

Three samples of lubricating oil were collected for three different categories which were suspected as adulterate. These are sold in popular engine oil plastic container with same prices.

Samples were collected as following categories:

1. Motor Cycle Oil (Grade SAE 20W50)
2. Engine Oil (Grade SAE 20W50)
3. Engine Oil (Local Grade)

Following Tests were conducted for comparisons between original and adulterate lubricating oil:

SL No	Name of the Test	Methods
1	Viscosity @40^0C, cSt	ASTM D 445
2	Viscosity @100^0C, cSt	ASTM D 445
3	Viscosity Index	ASTM D 2270
4	Infrared Spectrum	ASTM E2412

5.2.2 Test results of Adulterate Lubricating oil

For doing comparison study with original lubricating oil and adulterate oil, four tests were done for three sample. Table 5.1 shows values of these test results.

Table 5.1- Test results of Adulterate Oil

SL No.	Oil Name	Viscosity @40^{0}C, cSt	Viscosity @100^{0}C, cSt	Viscosity Index	Infrared Spectrum
1	Sample 1 (Motor cycle oil grade SAE 20W50)	127.9	13.34	99	Not Match
2	Sample 2 (Engine Oil grade SAE 20W50)	129.3	13.54	100	Not Match
3	Sample 3 (Engine Oil Unknown grade)	95.53	13.13	136	Not Match

5.2.3 Comparison with Original Lubricating Oil

Original oil properties were collected from website of this renowned brand and following table 5.2 shows the differences between original and adulterated oil properties.

Table 5.2- Comparison values between Original and adulterate oil

SL No.	Oil Name	Original	Adulterate	Original	Adulterate	Original	Adulterate
		Viscosity @40^{0}C, cSt		Viscosity@100^{0}C, cSt		Viscosity Index	
1	Sample 1 (Motor cycle oil grade SAE 20W50)	178.4	127.9	20.5	13.34	130	99
2	Sample 2 (Engine Oil grade SAE 20W50)	154.3	129.3	19	13.54	141	100
3	Sample 3 (Engine Oil Unknown grade)	154.3	95.53	19	13.13	141	136

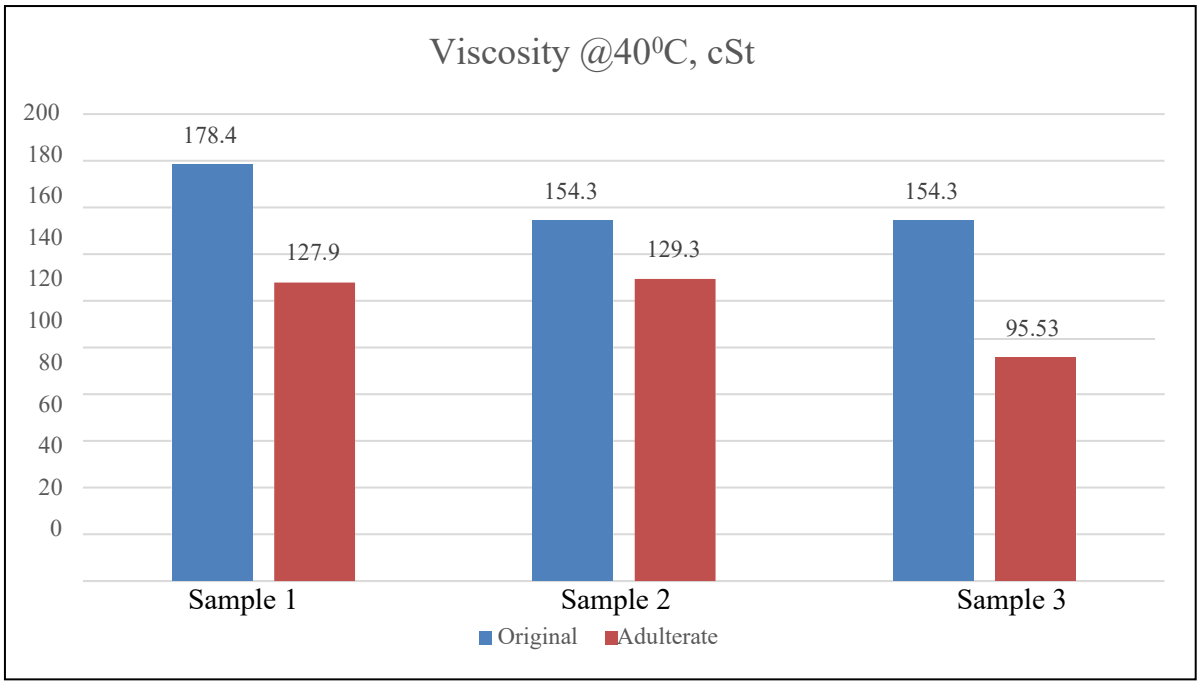

Fig. 5.1- Comparison between Original and Adulterated Oil (Viscosity@40⁰C, cSt).

Test results show that difference between the value of viscosity @40⁰C of original and adulterate oil is quite significant (Fig. 5.1). From original to adulterate oil, values were differed by 28.3% for Motor oil (SAE 20W50), 16.2% for Engine oil (SAE 20W50) and 38.08% for Engine oil (Local). From these tests it is clear that local grade engine oil viscosity is quite low from original oil viscosity.

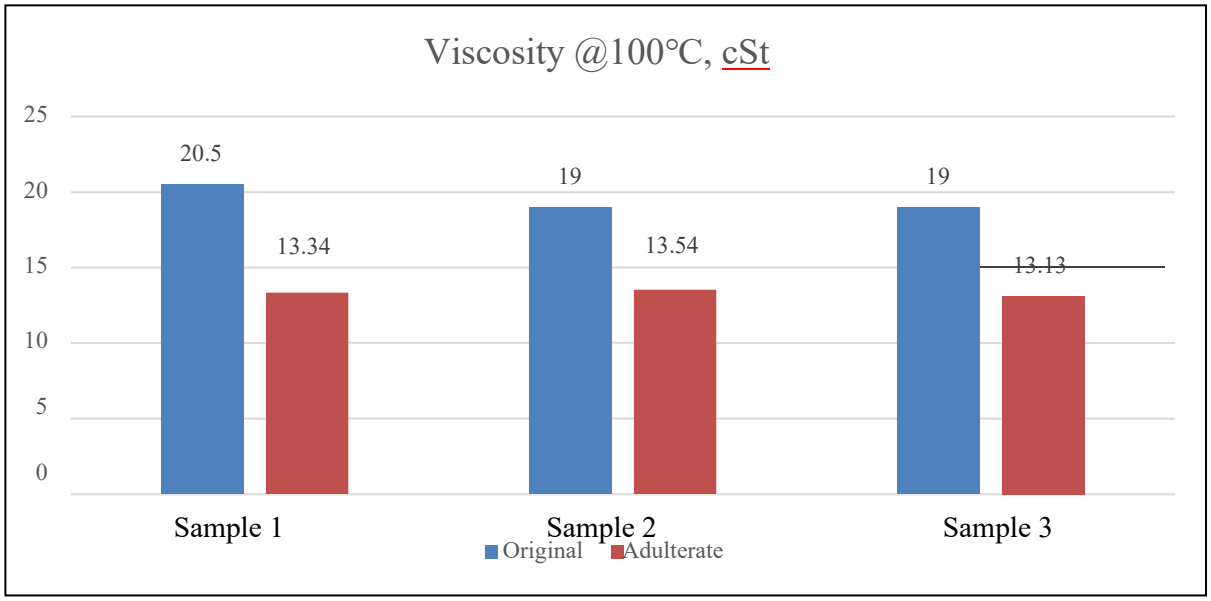

Fig. 5.2- Comparison between Original and Adulterated Oil (Viscosity@100⁰C, cSt).

From original to adulterate oil, viscosity@100^{0}C were differed by 34.9% for Motor oil (SAE 20W50), 28.7% for Engine oil (SAE 20W50) and 30.89% for Engine oil (Local).

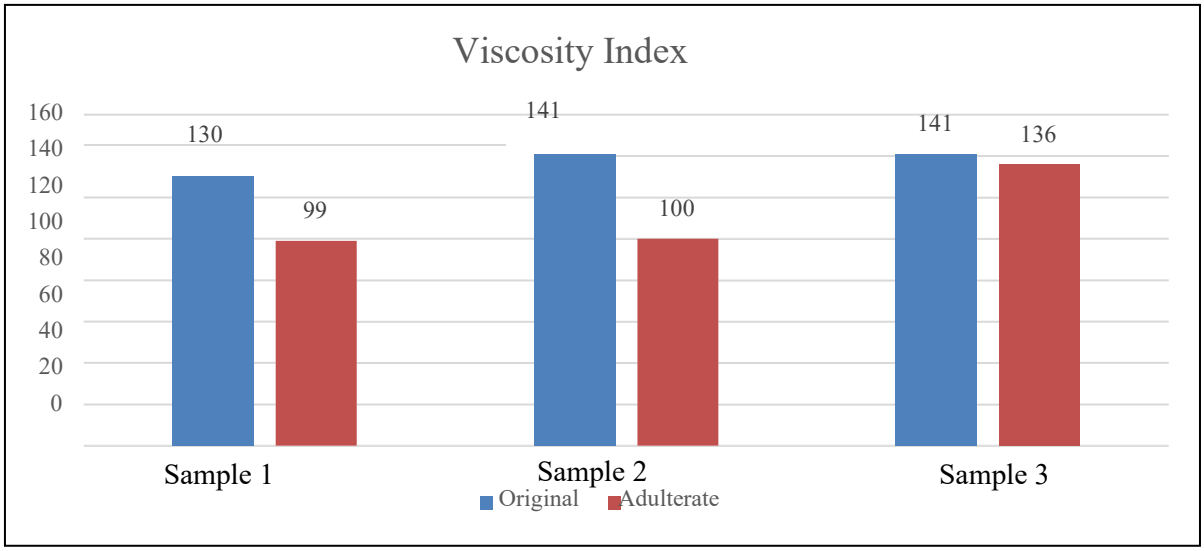

Fig. 5.3- Comparisons between Original and Adulterated Lubricating Oil(Viscosity Index).

From original to adulterate oil, viscosity index was differed by 23.84% for Motor oil (SAE 20W50), 29.07% for Engine oil (SAE 20W50) and 3.54% for Engine oil (Local). From these tests it is clear that local grade engine oil viscosity is about similar value from original oil viscosity. So, it is difficult to find out adulterate oil from this test values.

5.2.4 Infrared Spectrum

Infrared spectroscopy (IR spectroscopy or vibrational spectroscopy) involves the interaction of infrared radiation with matter. It covers a range of techniques, mostly based on absorption spectroscopy. As with all spectroscopic techniques, it can be used to identify and study chemical substances. Samples may be solid, liquid, or gas. The method or technique of infrared spectroscopy is conducted with an instrument called an infrared spectrometer (or spectrophotometer) to produce an infrared spectrum.

Because of difficulties to identify fake lubricating oil by testing viscosity or viscosity index measurement, because different kind of techniques are followed to meet standard value such as Viscosity Modifier. For this reason, infrared spectrum test was conducted for ensure the adulteration of lubricating oil and result was not match. This means collected samples are adulterate and sold in the local market every day.

5.2.5 Finding from Tests

To find out adulterate oil, infrared spectrum test is more accurate than other tests. Finding out sub-standard or adulterate oil, there is no facility of doing test in customs own area. For this reason, it is so difficult to check adulterate lubricating oil in entry point. There must be regulations or monitoring cell to find out adulterate lubricating oil both in local market or import from international market.

Chapter 6 Environmental and Disposal Management of Waste Lubricating Oils

6.1 Used/waste lube oil

Every time an engine runs, by-products from combustion contaminate the engine oil. If the contaminants build up in the oil, they can settle and create sludge and the color becomes blackish. This contaminant oil is called used oil which contains numerous toxic substances including polycyclic aromatic hydrocarbons, which are known to cause cancer. In addition, tiny pieces of metal from engine wear and tear, such as lead, zinc and arsenic, make their way into lubricants, further contributing to the polluting potential of used engine oil. Engine oil is exposed to heat and oxygen during combustion, which changes its chemical composition. Because spent engine oil is heavy and sticky, and contains an extensive concentrated mixture of toxic compounds, it can build up and persist in the environment for years [43].

6.1.1 Environmental impact of used oil

After certain running hour's most used engine oil eventually makes its way into waterways in the form of runoff. The oil and greases have been known to cause extensive damage to environment, creates risks of contaminating air, water and soil with substances that pose substantial hazards to animal and plant life, deaths to migrating birds, marine life, as much harmful to human life and a great threat to environment. Very small concentrations of waste oils (50 to 100 ppm) in the wastewater can foul sewage treatment plants, resulting in increased maintenance costs and reduced treatment efficiency (US. EPA, 1994).

As per US EPA 1994, just one gallon of used oils can make a million gallons of fresh water undrinkable. Most waste oils contain small amounts of materials that can cause cancer and other health problems if these materials are inhaled and ingested. Other environmental impacts are given below:

- Used/waste oils can be ingested if they get into drinking water sources and are not detected and removed.
- Oils have considerable potential to cause environmental damage by virtue of their ability to spread over large areas of land and water. A film of used/waste oils on a water surface prevents oxygen from entering the water and blocks sunlight. This makes it difficult for plants to photosynthesize and reduces plant and animal life in water body.
- Used oils applied to land can render the soil unproductive. Oil placed in landfill may seep through the bottom of such landfill and subsequently contaminate groundwater supplies.

- Waste oil pollution can affect a high fish mortality rate and affect the reproductive cycle. These considerations are important in relation to the food chain and ultimate consumption of these fish and fish products.
- In the environment, used oils degrade very slowly 20% to 80% of petroleum products in soil are degraded after one year.
- For waterways, only 20% get degraded. Spillage of waste oils into soil can bring changes in the biological cycles in the soil. The presence of used motor oils in the soil inhibits plant development since oil fills the pores between the soil particles and hampers oxygen access.
- Also, the metal content of surviving plants is increased. These metals inhibit carbon mineralization, nitrogen transformations and mineralization of Sulphur and phosphorous.
- Unrestrained burning of waste oils may result in significant levels of hazardous emissions to the environment. This may expose humans, wildlife and vegetation to harmful substances.

6.2 Typical Compositions of waste oil

The demand of finished lube oil in different sectors in the world is about 36.1 mMT per year; of which 52% is used for automotive lube oil, 43% is used as industrial oil and the rest is used as marine engine oil. When used, blended lubricating oil goes through normal degradation and about 50% of it is consumed in the process. The rest of the oil picks up number of contaminants from the working environment, such as, residual components of engine fuels, solids from wear processes along with corrosion products and dirt, soot, combustion products etc. The typical composition of waste lube oil is shown by figure 6.1.

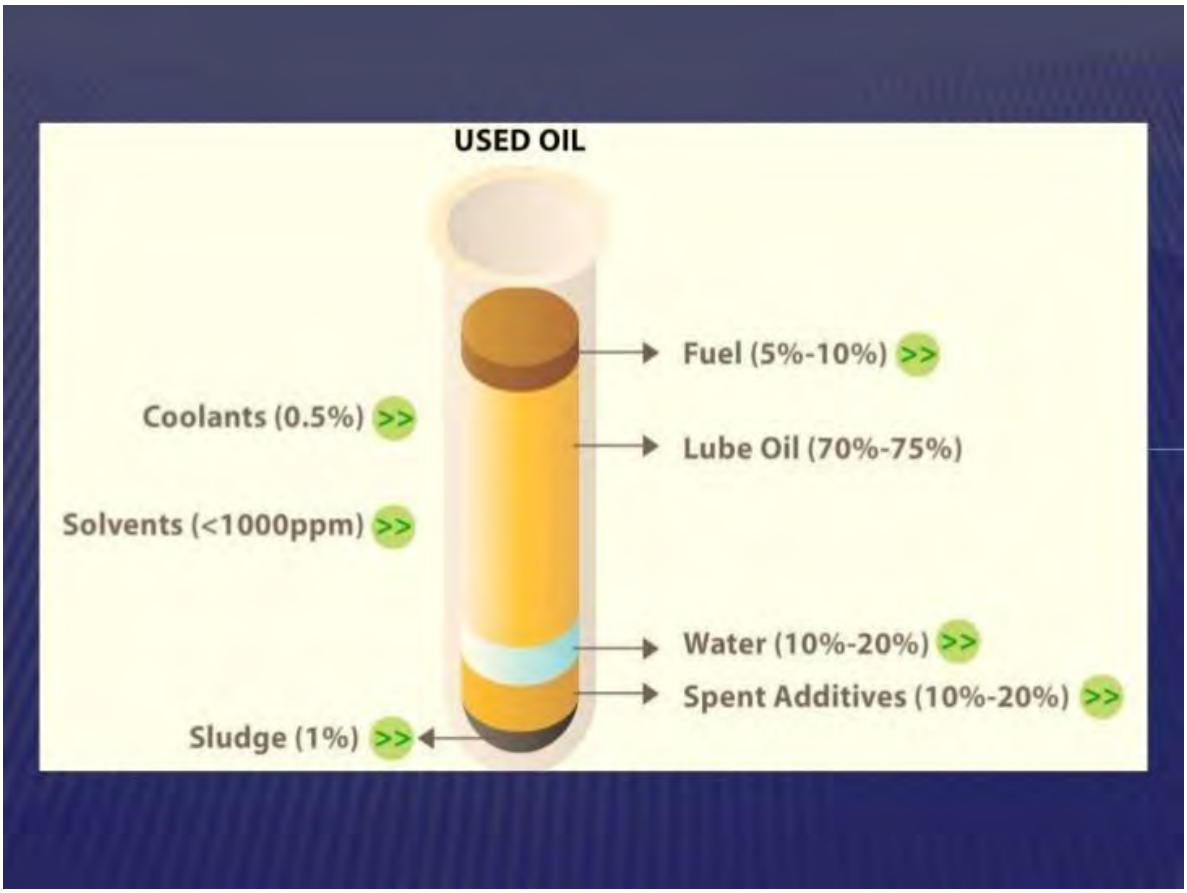

Fig. 6.1- Typical composition of waste lube oil (Re-refining used oil by Sequoia).

There are basically three options to deal with the regarding waste oil in the world:

a) dumping the waste oil on land, garbage heap and sewerage system

b) regeneration of base oil from waste oil and

c) extracting of heat value of waste oil through combustion process.

a) Dumping of lube oil:

Waste oil creates enormous problems if it is improperly disposed in the environment (land, garbage heap, surface water, sewerage systems). Simply one gallon of waste oil can ruin the taste of a million gallons of drinking water. Films of oils on the surface of water prevent the replenishment of dissolved oxygen thereby hamper aquatic life, impair photosynthesis processes and block sunlight. Studies showed that, significant long-term effects have been observed freshwater fishes with concentration of oil of 310 ppm and in marine life forms at concentration of oil of only 1 ppm [44]. Therefore, this is a bad option and should be presented by all means.

b) Combustion of waste oil:

Waste oil is also used as fuel for industrial furnaces. Combustion of waste oil destroys valuable resources and also represents a significant threat to the environment. All the toxic components present in the waste oil reach the environment with the flue gas. In extreme cases, these contaminants damage the furnace, leading to increased environmental pollution. Emission of Zn can be as high as 600 times and Cu can be 2100 times if waste oil is burnt instead of re-refining [45].

c) Re-refining of waste oil:

The used oil needs proper management to make it a valuable product. Average crude oils have 3-8% base oil whereas waste lube contains 65-75% recoverable base-oil content in used automotive oils, which if burnt or dumped would mean the loss of a valuable natural resource. Re-refining of waste oil is energy efficient; less energy (about one third) is used to produce a gallon of base stock from waste oil than to produce the same gallon from crude oil. It is also environment friendly. In case of regeneration of base oil from waste oil is that the noxious compounds as well as heavy metals are solidified and stabilized due to their disposition as a solid and pose minimal environmental risks.

6.3 Conventional Re-refining Process

Used oil can be re-refined using techniques such as chemical (acid/clay) treatment, physical treatment by distillation and thin film evaporation and solvent extraction. Figure 6.2 shows the major steps involved in typical re-refining process [46]. Pre-treatment involve with the removal of solid particles and water from the waste oil by gravity settling. Two separate layers of waste oil and water are formed in the gravity settler, wherefrom upper layer of waste oil is collected and sent to the next step for further treatment. Catalytic cracking of waste oil took place at the atmospheric pressure and the typical duration time is about 3.5 hr with zeolite as the catalyst. After catalytic cracking the oil is washed with water to remove carbon particles from the oil. Then the oil is heated at 140^0C and atmospheric pressure for 1 hr to remove carbon particles from the oil. Then the oil is heated at 140^0C and atmospheric pressure for 1 hr to remove residual free and emulsified water. Dehydrated oil is then cooled to about 30^0C and treated with commercial grade sulfuric acid (about 92%) and kept undisturbed for 24 hrs for de- asphalting and settling of acid sludge from acid treated oil [47]. The oil is then mixed with fuller's earth and then is fed to a vacuum distillation unit. Light fraction is collected from the top of the column. Bottom product of the column is filtered, to separate spent clay, and the filtrate is collected as re-refined base oil.

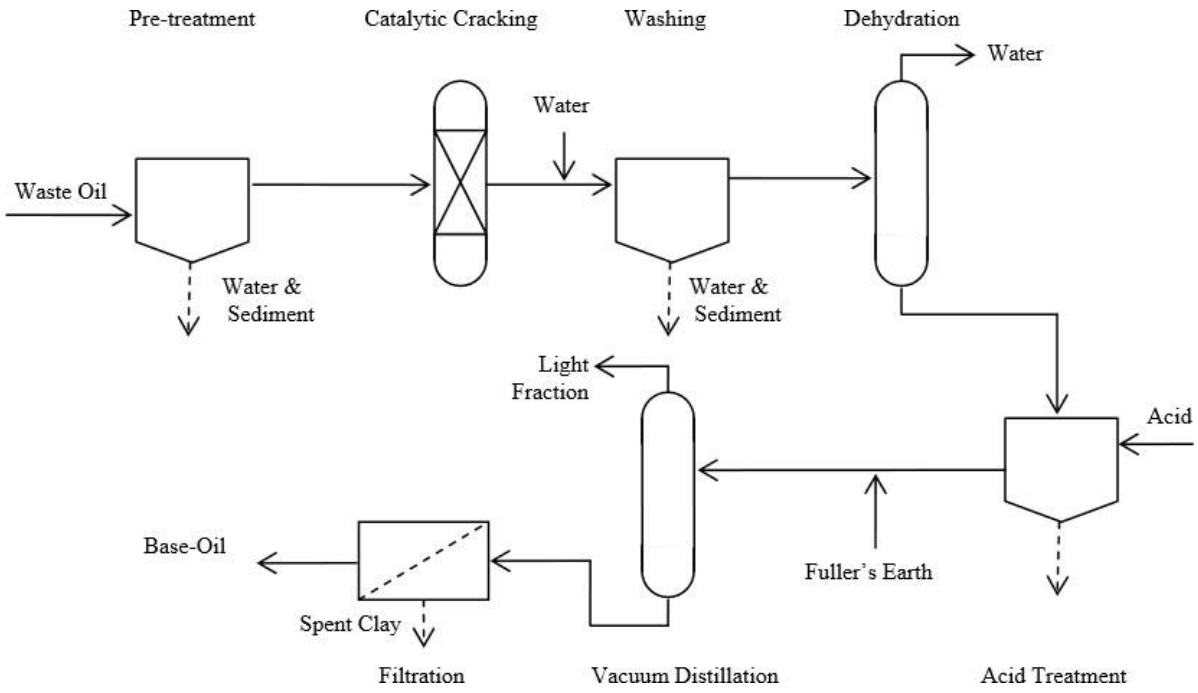

Fig. 6.2- Base-Oil Regeneration Process

6.4 Re-refining in Context of Bangladesh

The demand of finished lube oil in different sectors in Bangladesh is about 0.16 million MT per year; of which 70% is used for automotive lube oil and rest 30% is used as industrial oil and marine engine oil. When used, lubricating oil goes through normal degradation and about 50% of it is consumed in the process. Around 60-65% of the waste lubricant can be recovered by re-refining process [48].

In Bangladesh, there are around 15 licensed lube oil blending companies with a total production of around 60,000 MT per year. The rest of finished lubricants are imported by different importers under different brand names. This recovered amount of lube oil would produce about 35,000 MT of waste oil per year.

The best way to manage this waste oil is to regenerate the base-oil from waste oil. Currently, there are two approved waste lube recycling plant in Bangladesh: Lubereff Bangladesh Ltd. and Min oils Ltd. Jointly they produce about 4,000 MT recycled base-oil per year. Both plants follow conventional acid-clay method to reclaim waste oil. Thus, setting up more re-refining process plant can save huge foreign currency as well as reduce the environmental pollution in Bangladesh.

6.5 Waste Oil Management Program

Various countries have designed their own systems for management of waste oils. The salient features and action points of such efforts in selected countries are depicted in Table 6.1.

Table 6.1: Features of waste oil management programs in different countries.

Country	Features of the waste oil management program
France	78% collection of used oils; government-funded programs and fees are imposed on virgin lubes producers; 42% of used oil is re-refined by government directed re-refining associations.
Germany	94% recovered; high level of consumer interest in recycling, all used oils treated as hazardous waste; all oil marketers must provide collection facility near the retail establishment; retailers pay for used oil pick up; 41% of used motor oils are re-refined, 35% burned in cement kilns, and 24% processed and burned in other applications; recovering 48% of total lube oils sold.
Japan	No national level recycling program; no subsidies/funding; essentially no DIY market in Japan; high percentage of used motor oil is recovered, treated, and burned for heating value; re-refining is very limited.
Italy	Mandated use of re-refined oils in motor oils; six operating re-refining plants; funded by lube oil sales taxes; collectors and re-refiners both subsidized; only 10% of used oil can be directed to cement kilns. The collection efficiency of used oil has increased from 42.6% in 2008 to 48.7% in 2009. An incentive for recycling comes in the form of reduced excise duty. In Italy, re-refined product pays 50% of the excise duty applied to virgin lubricant. This tax advantage is granted only if the used oils for re-refining are collected in Italy. The EC has requested Italy to cease application of the ruling concerning used oil from outside of Italy. Also, it was estimated that the quantity of used oil collected by the COOU consortium is steadily over 95% of the collectible oil.
Australia	High subsidies for re-refining, low subsidies for low grade burning oils; none for reclaimed industrial oils; collecting 81% of available oil; $10M Australian funded by government to subsidize recycling; revising re-refining incentive downward; collecting 38% of total lube sold.
Canada (Alberta)	Focus on increasing collections; little emphasis on avoiding contamination; little emphasis on re-refining; funded by sales tax; recovering 51% of total lube oil sold.

United States	The United States has implemented a broad range of recycling programs; some states impose sales taxes to subsidize collections; some states classify used oil as hazardous waste to discourage illegal dumping; some local municipalities fund collection activities; signs of quick lube facilities growth which has produced positive results by reducing oil improperly disposed of by DIY oil changers; small re-refining industry; disposition of used oil as a fuel encouraged. The United States has no central coordinating body that focuses on used oil management similar to Europe, therefore industry statistics are not readily available. The U.S. does have a mandatory federal policy requiring the preferential purchase of re-refined oil and does promote the source reduction and recycling of materials over their treatment (including burning as a fuel)
	and disposal under the Resource Conservation and Recovery Act and the Pollution Prevention Act.
India	The Ministry of Environment and Forests (MoEF), GOI has licensed about 170 smalls to medium recyclers (352 MT per annum to 26,460 MT per annum) with a total licensed capacity of about 0.69 MMT of used and waste oil recycling capacity.

6.6 Waste Management in Bangladesh

The lack of regulatory control has led to unscientific disposal of hazardous waste (HW) throughout the country, posing serious risks to public health and the environment. Rapid industrialization and development mean HW from industrial process, medical waste, e- wastes and Bangladesh's thriving scrap recycling industry are polluting the air, soils and water ways. However, there is some established policy and legislation that can provide support for HW and to meet the requirements of the Basel Convention. The main instruments are summarized in Table 6.2. It was recognized that the Environment Protection Act 1995 could potentially be used to enact HW rules and these draft rules and draft policy have subsequently been developed.

Table 6.2: Summary of Some Relevant Legislation in Bangladesh

Policy/Laws	Date	Content	Implication
National Environmental Policy, 1992 (NEP) (MOEF, 1994)	1992	Protection and sustainable management of the environment. Objectives: Maintaining the ecological balance and overall development through protection and improvement of the environment; Identifying and regulate polluting and environmentally degrading activities; Ensuring environmentally sound development; Ensuring sustainable and environmentally sound use of all-natural resources	MOEF to remain actively remain associated with all international environmental initiatives (e.g., Basel Convention).
National Environmental Management Plan, 1995	1995	Framework of programs and interventions to manage resources, reduce environmental degradation, improve the natural and manmade environment, conserving habitats and biodiversity, promote sustainable development and improve quality of human life.	MOEF to implement NEP. Actions and interventions also for government, NGOs and wider civil society.
Environmental Conservation Act (ECA)	1995	Important legislative control on industrial water pollution. Dedicated to the "conservation, improvement of quality standards, and control through mitigation of pollution of the environment".	

Environmental Conservation Rules	1997	Rules under ECA 1995 provide additional guidance for specific components of the Act that is to be enforced by the DoE, which has responsibility for: 1. Coordinating with other authorities or agencies. 2. Adopting safety and abatement measures to prevent environmental degradation. 3. Advising persons on environmentally sound use, storage, transportation, import and export of hazardous material or its components. 4. Conducting research and assisting in conservation and improvement of the environment. 5. Investigating locations, equipment, processes, materials, to ensure improvement of the environment, and control and mitigate pollution. 6. Collect, publish and disseminate environmental information on pollution. 7. Advising Government on processes and materials that cause pollution. 8. Ensuring potable water quality	Standards set for liquid effluents and gaseous emissions with some legal authority and powers given to DOE. IEE/EIA studies have been made mandatory for new industries. Penalties for failure to comply with ECA rules and regulations. Essential powers for HW in line with international requirements are in place
The Environmental Court Act 2000	2000	Supports ECA & ECR by establishment of environmental courts for offences relating to environmental pollution. Protocols for the establishment of court, defines the court's jurisdiction, penalties, powers of search and entry, and procedures for investigation, trial and appeal.	Confirms powers for HWM and lines of enforcement in line with international requirements

The EIA Guidelines for Industry		Despite title, EIA Guidelines for Industries cover water sector interventions, including flood control embankments, polder and dykes and roads and bridges. All these water sector interventions for under the 'Red' category of industrial units. These are required for project construction, reconstruction & extension.	
Other related legislations		a. The Dhaka Municipal Corporation Ordinance, 1983 b. Pesticide Ordinance, 1983 c. Pourashava Ordinance, 1977 d. Factory Act, 1965 e. The Explosive Substance Act, 1908 f. The Explosive Act, 1884 g. Lead Acid Battery Recycling and Management Rules, 2006 h. Draft National Solid Waste Management Handling Rules, 2005 i. Environment Policy, 1992	

NEP = National Environmental Policy, ECA = Environmental Conservation Act Source: National consultant for Bangladesh's report on policy and guidelines, Aug 2009

The lack of management of HW has recently gained significant attention particularly with regard to ship breaking and subsequently the Supreme Court instructed DOE to frame rules for HW.

6.7 Proposed Management Programs for Bangladesh

In this chapter information about used oil composition, recycling, recovery, laws and relative regulations governing them were given. The best way to manage waste oil to regenerate base oil in recycling plant from waste oil. For collecting used lubricating oil from generator and sending to recycling plant, we can be categorized in two ways from generation point of view.

i) Bulk Generators

These are points where large quantities of waste oils are generated. The entities that fall under this category may be identified as the centralized and company operated or authorized service stations, defense establishment entities, state owned transport corporations, electricity utilities (especially the power distribution companies), sea and airports, railways maintenance workshops etc. In so far most of the periodic maintenance of the vehicles and equipment is carried out at a central local, a large portion of vehicles and equipment comes to such central places, enabling the accumulation of waste oils at these points. At such points it is much easier to collect and segregate at source types of waste oils.

ii) Small Generators

These are points where smaller quantities of waste oils are generated on a daily basis. The generated oils at such points are generally mixed up, forming multi-grade waste oils. The generated quantities are small and may not offer any explicit economic advantage incentive for collection or safe handling. It is this sector that needs the utmost care and concerted government supported efforts to collect and consolidate waste oil in a central place. Well designed incentive schemes must be put in place to ensure that such oils find their rightful place in recycling businesses. One way could be to adopt a multi-layered collection system in which micro level generators are incentivized to store their waste oils in proper storage containers, with these then collected periodically by vendors of the recyclers. Depending upon the geographical distribution, such oils can be transferred to a central processing facility.

However, as a generator one needs to be aware of the regulations applicable to them in details and also the possible options to manage used oil. For waste oil management, generator should be following the below steps:

a) Properly storing waste lubricating oil for collection and recycling

The first step in proper oil disposal is to properly handle waste oil in the right container. The most reliable approach is to transport the oil in its original tanks. The storage container should also be tightly sealed to avoid leakage that might endanger the environment. The used oil should be properly moved into the storage container to avoid spillage. Once the storage unit has been tightly sealed, it should be clearly labeled.

b) Do not pour it into the drain, sink, or into the river nearby

It should be properly stored and labeled as stated above with the objective of later disposing of it correctly, sending it for recycling, or using the services of a professional. Waste lubricating/hydraulic oils are classified as hazardous waste, for this reason protecting our environment one should not pour it into the drain, sink or into the river nearby.

c) Waste oil should be packed properly and stored in a proper storage

If generator will be unable to dispose of the waste oil on the very day he should replace it from his machine, do ensure that it is kept in a safe place so no one without the right information will be able to access it, particularly if children and pets are present. To avoid confusion, waste oil should not be stored in the same place as unused oil, particularly if it is stored in regular fuel storage.

d) Call the collectors to manage your waste oil properly

There are two recycle companies in Bangladesh and they collect used oil from local collector. Generator should contact with a local waste oil collection company. The majority of waste oil recycle company have the required equipment and facilities to ensure safe and effective waste oil disposal.

e) Transport the waste oil to the recovery facilities

Authorized company will buy waste lubricating oil from generator with sealed container and transport the waste oil to the recycling or recovery facilities. Transporters must be aware of local regulations governing the management of used oil.

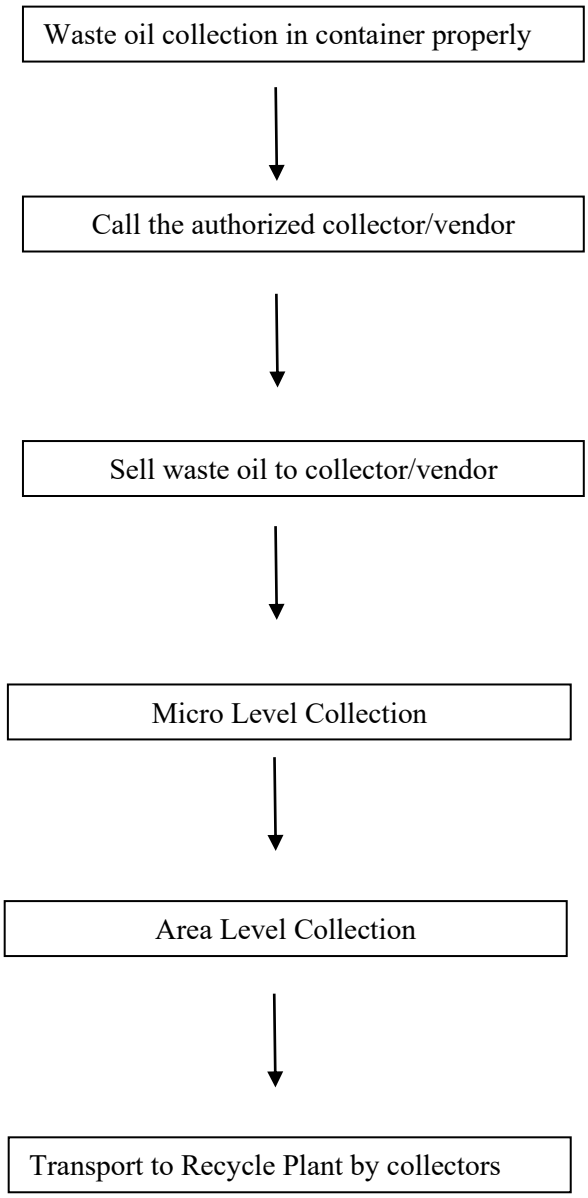

Fig. 6.3: Waste collection from generator to recycle plant.

Chapter 7 Conclusions and Recommendations

From the literature survey of legal and institutional frameworks, it is found that monitoring authority for check quality and standards is not specific in any regulations and proper instruction/regulations for waste oil management is not sufficient to control used lubricating oil and their illegal uses. Guidelines for law enforcement and punishments are also needed to control adulterations. Otherwise, non-standard or sub-standard products may get into local market.

Globally the latest lubricant brand is API SN plus with resource conservation has been established for gasoline engine operating. However, in Bangladesh API SJ brand is still using as the latest lubricant for gasoline engine which is not compatible for protection of turbocharger. On the other hand, API CF combined with ACEA 96 E2 and ACEA 96 E2 are the latest lubricant standards used for diesel engine in Bangladesh although those are obsolete according to API and ACEA standards. Recently, API CK-4 and FA-4 lube oil standards are introduced which have improved fuel economy, protection of environment by reducing NOx and CO_2 emission and deposition of unburnt carbon soot.

The current consumption of lubricating oil in Bangladesh is around 0.113 million MT per year, on the other hand total approved storage capacity of lubricating oil with base oil and additives are 0.35 million MT. There is an opportunity to do adulterate oil business with approved capacity of different company in lubricating oil market.

From the test report of adulterate lubricating oil, it is difficult to find out fake lubricating oil by testing only viscosity values and viscosity index. Because of practicing different kind of techniques to improve viscosity of adulterate oil such as viscosity modifier. For finding difference, infrared spectrum test is required.

Thus, from the study, the following recommendations can be drawn:

- Lubricating standards for Bangladesh are not up to date. It is urgently required to establish new updated standards for latest model engines.
- Formation of proper monitoring cell to control adulteration and quality of lubricants is required.

- Authority should assist to build up waste oil re-refining plant to recover base oil. This will reduce hazards to the environment as well as save foreign currency. Used oil is a pollutant and by re-refining this, the pollution can be reduced. Hence, it should get the status of eco-friendly technology and get grants and incentives from the government and funding organizations involved in eco-friendly activities. Besides, re-refining leads to oil conservation, the concept of re-refining should be promoted and strongly supported by the authority.
- The proposed lubricant management scheme may be considered by the authorities to draft and implement, on an institutional and legal basis, a proper lub oil management system for the country. It should be enforced strongly.

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APPENDICES

A1. API SH Category Petrol Engine Oil

Parameter	ASTM Test Method	Performance Criteria
Average engine rust rating , min	D5844 (sequence IID),	8.5
Ball Rust Test Average gray value, min	D6557	100
Hours to 375% kinematic viscosity increase at 40 ^{0} C , min.	D5533 (sequence IIIE)	64
Average engine sludge rating min	D 5302 (sequence VE)	9.0
Rocker arm cover sludge rating , min		7.0
Average piston skirt varnish rating, min		6.5
Average engine varnish rating , min		5.0
Oil ring clogging, %w, min.		report
Oil screen clogging, %,w max		20.0
Compression ring sticking (hot stuck)		none
Cam wear, µm		
Average, max		127
Maximum, max		380
Average engine sludge rating, min	D 6593 (sequence VG)	7.8
Rocker arm cover sludge rating, min		8.0
Average piston skirt varnish rating, min		7.5
Average engine varnish rating, min		8.0
Oil screen clogging, %, max		20
Hot stuck compression rings		none
Bearing weight loss, mg, max	D 5119 (L-38)	40
Bearing weight loss, mg, max.	D6709	26.4

Parameter	Test Method	SAE 5W-30	SAE 10W-30	SAE 15W-40
Volatility Loss. Max.	D 5800	25	20	18
Volatility Loss at 371^{0}C, max.	D2887	20	17	15
EOFT,% Flow reduction max.	D 6795	50	50	nr
Phosphorus. % w, max	D4951/ D5185	0.12	0.12	nr

Flash Point, ^{0} C, min	D 92	200	205	215
Flash Point, ^{0} C, min	D 93	185	190	200
Foaming tendency Sequence I, max, foaming/settling Sequence II, max, foaming/settling Sequence III, max, foaming/settling	D 892 (Option A)	10/00 50/00 10/00	10/00 50/00 10/00	10/00 50/00 10/00
High temperature foaming characteristic	D 6082	report	report	report
Homogeneity and miscibility	D 6922	Homogenous with SAE reference oils		

A2. API SJ Category Petrol Engine Oil

Parameter	ASTM Test Method	Performance Criteria
Ball Rust Test Average gray value, min	D 6557	100
Average engine sludge rating min Rocker arm cover sludge rating , min Average piston skirt varnish rating, min Average engine varnish rating , min Oil ring clogging, % Oil screen clogging, %, max Compression ring sticking (hot stuck) Cam wear, μm Average, max Maximum, max	D 5302	9 7 6.5 5 report 20.0 none 127 380
Average engine sludge rating, min Rocker arm cover sludge rating, min Average piston skirt varnish rating, min Average engine varnish rating, min Oil screen clogging, %, max Hot stuck compression rings	D6593	7.8 8.0 7.5 8.9 20 none
Bearing weight loss, mg, max Shear stability	D 6709	26.4 p
Volatility loss, % max	D 5800	Viscosity Grades SAW 0W-20, SAE 5W-20, SAE 5W-30, SAE 10W-30 / All others

		22	20
Volatility loss at 371°C (700 °F), % max	D 6417	17	15
% Flow reduction, max	D 6795 (EOFT)	50	50
% Flow reduction, max with 0.6 % H_20	D 6794 (EOWTT)	 report	 report
with 1.0 % H_20 with 2.0 % H_20 with 3.0 % H_20		report report report	report report report
Phosphorus % mass, max	D 4951 or D 5185	0.10	NR
Flash point, °C, min	D 92	200	NR
Flash point, °C, min	D 93	185	NR
Viscosity Index, min	D 2270	120	100
TBN, mg KOH/g	D2896 / D4739	10	10
Foaming tendency Sequence I, max, foaming/settling Sequence II, max, foaming/settling Sequence III, max, foaming/settling	D 892	 10/0 50/0 10/0	 10/0 50/0 10/0
Static foam max, tendency/stability. Max	D 6082	200/50	200/50
Homogeneity and miscibility	D 6922	Homogeneous with SAE reference oils.	
High Temperature Deposits, wt. mg, max	D 6335 (TEOST 33)	60	60
Gelation Index), max	D 5133	12	Not Required

P: Ten-hour stripped kinematic viscosity (oil shall remain in original viscosity grade)

A3. API SL Category Petrol Engine Oil

Parameter	ASTM Test Method	Performance Criteria
Kinematic viscosity, % increase at 40^0 C, max,	D 5302	275
Average piston skirt varnish rating, min		9.0
Weighted piston ring deposit rating, min.		4.0
Screened average cam-plus filter wear µm max.		20
Hot Stuck Rings		none
Low temperature viscosity performance		report
Compression ring sticking (hot stuck)		none
Cam wear, Average, max		127
Maximum, max		380

Average engine sludge rating, min Rocker arm cover sludge rating, min Average piston skirt varnish rating min Average engine varnish rating, min Oil screen clogging, %, max Hot stuck Compression rings Cold stuck rings Oil screen debris, % Oil ring clogging,%	D6593	7.8 8.0 7.5 8.9 20 none report report report
Bearing weight loss, mg, max Shear stability	D 6709	26.4 : p
Homogeneity and miscibility	D 6922	Homogeneous with SAE reference oils.

p= Ten-hour stripped kinematic viscosity (oil shall remain in original viscosity grade).

		Viscosity Grades	
Parameter	ASTM Test Method	SAW 0W-20,SAE 5W-20 SAE 0 W-30, SAE 5W-30 SAE 10W-30	All others
Ball Rust Test Average gray value, min	D 6557	100	
Volatility loss, % max	D 5800	15	
Volatility loss at 371°C (700 °F), % max	D 6417	10	
% Flow reduction, max	D 6795(EOFT)	50	
Flash point, °C, min	D 93	185	
% Flow reduction, max with 0.6 % H_20 with 1.0 % H_20 with 2.0 % H_20 with 3.0 % H_20	D 6794 (EOWTT)	 50 50 50 50	 50 50 50 50
Phosphorus % mass, ma	D 4951 or D 5185	0.1	Not Required
High Temperature Deposits, mg, max	D7097 (TEOST MHT)	45	45

A4. API SM Category Petrol Engine Oil

Parameter	ASTM Test Method	Performance Criteria	
		SAW 0W-20,SAE 5W-20 SAE 0 W-30, SAE 5W-30 SAE 10W-30	All others
Engine oils ability to protect against oil thickening and engine wear during moderately high-speed, high-temperature service.	D 7320 (Sequence IIIG)	Pass	Pass
Determination of Yield Stress and apparent viscosity at low temperature service.	D 4684 (Sequence IIIGA)	Pass	Pass
Average engine sludge rating, min	D 6891 (Sequence IVA)	Pass	Pass
Average engine sludge rating, min	D 6593 (Sequence VG)	Pass	Pass
Bearing weight loss, mg, max	D 6709 (Sequence VIII	Pass	Pass
Bearing weight loss, mg, max Shear stability	D 6709	26.4	
Homogeneity and miscibility	D 6922	Homogeneous with SAE reference oils.	
		Viscosity Grades	
		SAW 0W-20,SAE 5W-20 SAE 0 W-30, SAE 5W-30 SAE 10W-30	All other
Ball Rust Test average Gray Value, Min	D6557	100	100
Volatility loss, % max	D 5800	15	15
Volatility loss at 371°C (700 °F), % max	D 6417	10	10
% Flow reduction, max	D 6795 (EOFT)	50	50
% Flow reduction, max with 0.6 % H_20 with 1.0 % H_20	D 6794 (EOWTT	50 50	50 50

with 2.0 % H_20 with 3.0 % H_20	)	50 50	50 50
Phosphorus % w, max Phosphorus % w, min	D 4951 or D 5185	0.08 0.06	Not Required 0.06
Flash point, °C, min	D 92	200	200
Flash point, °C, min	D 93	185	185
Foaming tendency Sequence I, max, foaming/settling Sequence II, max, foaming/settling	D 892	10/0 50/0	10/0 50/0
Sequence III, max, foaming/settling		10/0	10/0
Static foam max, tendency/stability. max	D 6082	100/0	100/0
High Temperature Deposits, mg, max	D7097 (TE OST MH T)	45	45
Gelation Index), max.	D 5133	12	Not Required

A5. API SN Category Petrol Engine Oil

Parameter	ASTM Test Method	Performance Criteria	
		SAW 0W-20,SAE 5W-20 SAE 0 W-30, SAE 5W-30 SAE 10W-30	All other
Engine oils ability to protect against oil thickening and engine wear during moderately high-speed, high-temperature service.	D 7320 (Sequence IIIG)	Pass	Pass
Determination of Yield Stress and apparent viscosity at low temperature service.	D 4684 (Sequence IIIGA)	Pass	Pass

Average engine sludge rating, min	D 6891 (Sequence IVA)	Pass	Pass
Average engine sludge rating, min	D 6593 (Sequence VG)	Pass	Pass
Bearing weight loss, mg, max	D 6709 (Sequence VIII	Pass	Pass
Homogeneity and miscibility	D 6922	Shall remain homogeneous and when mixed with ASTM reference oils, shall remain miscible.	

		Viscosity Grades	
		SAW 0W-20,SAE 5W-20 SAE 0 W-30, SAE 5W-30 SAE 10W-30	All other
Ball Rust Test Average gray value, min	D 6557	100	100
Volatility loss, % max	D 5800	15	15
Volatility loss at 371°C (700 °F), % max	D 6417	10	10
% Flow reduction, max	D 6795(EOFT)	50	50
% Flow reduction, max with 0.6 % H_20 with 1.0 % H_20 with 2.0 % H_20 with 3.0 % H_20	D 6794(EOWTT)	 50 50 50 50	 50 50 50 50
Phosphorus % w, max Phosphorus % w, min	D 4951 or D 5185	0.08 0.06	Not Required 0.06
Sulphur % w, max	D 4951 or D 2622	0.50	Not Require

			d
Flash point, °C, min	D 93	185	185
Foaming tendency Sequence I, max, foaming/settling Sequence II, max, foaming/settling Sequence III, max, foaming/settling	D 892	 10/0 50/0 10/0	 10/0 50/0 10/0
Static foam max, tendency/stability. max	D 6082	100/0	100/0
High Temperature Deposits, mg, max	D7097 (TEOST MHT)	45	45
Gelation Index), max.	D 5133	12	Not Required

A6. API CH-4 Category Diesel Engine Oil

Parameter	ASTM Test Method	Performance Criteria		
Copper strip rating,	D 130 / D5968	3		
		One-test	Two-test	Three-test
Weighted demerits (WDP), max	D 6681	350	378	390
Top groove carbon (TGC), demerits, max		36	39	41
Top land carbon (TLC), demerits, max		40	46	49
Average Oil Consumption, g/h (0-360 h), max		12.4	12.4	12.4
Final Oil Consumption, g/h (312-360 h), max		14.6	14.6	14.6
Piston, ring, and liner scuffing		none	none	None

Weighted demerits (WDK), %, max Top groove fill (TGF), %, max Top land heavy carbon (TLHC), %, max Average fuel consumption g/kWh (0 250h) max. Piston ring liner scuffing	D 6750	332 24 4 0.5 none	347 27 5 0.5 none	353 29 5 0.5 none
Average Liner Wear, normalized to 1.75 % soot, µm max Average Top Ring Weight Loss, mg max. EOT Used Oil Lead Content less New Oil Lead Content, mg/kg (ppm), max	D 6483	25.4 120 25	26.6 136 32	27.1 14 4 36
Average Pin Wear, mils, max, (µm, max)	D 5966	0.3 (7.6)	0.33 (8.4)	0.36 (9.1)
Average Wt. Loss, normalized to 4.5 % soot, mg max Oil Filter Differential Pressure, kPa max Average Engine Sludge, CRC Merits, min	D 6838 at EOT	6.5 79 8.7	7.5 93 8.6	8.0 100 8.5
Relative Viscosity at 4.8 % Soot by TGA, max Kinematic Viscosity increase at 3.8% Soot by TGA, cSt max Sequence IIIF 60 h Viscosity at 40°C, increase from 10 min sample, % max	D 5967	2.1 11.5 295	2.2 12.5 295 (MTAC)	2.3 13.0 295 (MTAC)
Aeration, volume, % max	D 6894	8.0	8.0(MTAC)	8.0(MTAC)

Used Oil Elemental Concentration Copper, mg/kg (ppm) increase, max Lead, mg/kg (ppm) increase, max Tin, mg/kg (ppm) increase Copper strip rating, max	D 6594	20 120 repo rt 3	
Foaming/Settling, mL, max. Sequence I Sequence II Sequence III	D 892 (Option A not allowed)	10/0 20/0 10/0	
% volatility loss at 250°C, max	D 5800	SAE 10W-30	SAE 15W-40
		20	18
% volatility loss at 371°C, max	D 6417	17	15
Kinematic Viscosity after shearing, cSt. min	D 6278	9.3	12.5
Viscosity Index, min	D 2270	120	100
TBN, mg KOH/g	D2896 / D4739	report	report

A7. API CI-4 Category Diesel Engine Oil

Parameter	ASTM Test Method	Performance Criteria		
		One-test	Two-test	Three-test
Weighted demerits, (WDR) max	D 6923	382	396	402
Top groove carbon, demerits, max		52	57	402
Top land carbon, demerits, max		31	35	3
Initial oil consumption, (0-252 h), g/h, average				6
Final oil consumption, (432-504 h), g/h, average, max		13.1	13.1	
Piston, ring, and liner distress Ring sticking				13.1
Ring sticking		IOC + 1.8	IOC + 1.8	IOC + 1.8
Merit rating [v] min				
Average crosshead wt. loss, mg, max		none	none	none
Average top ring weight loss, mg		none	none	
Oil filter differential pressure at 250 h, kPa, max		1000	1000	none
Average engine sludge, CRC merits at EOT, min				

		20.0 report 275 7.8	21.8 report 320 7.6	1000 22.6 report 341 7.5
Relative Viscosity at 4.8 % Soot max, Kinematic viscosity (at 40°C), % increase, max	D 5967 (Sequence IIIF)	1.8 275	1.9 275 MTAC)	2.0 275 (MTAC)
Weighted demerits (WDK), %, max Top groove fill (TGF), %, max Top land heavy carbon (TLHC), %, max Average fuel consumption g/kWh (0 250h) max. Piston ring liner scuffing	D 6750	332 24 4 0.5 none	347 27 5 0.5 none	353 29 5 0.5 none
Average Pin Wear, mils, max, (μm), max)	D 5966	0.30 (7.6)	0.33 (8.4)	0.36 (9.1)
Viscosity of 75 h used oil sample fromT-10 test (or T-10AAE test) tested at-20°C, mPa-s, max yield stress, Pa min	D 4684	2 5 0 0 0 3 5		
Evaporative loss at 250°C, %, max	D 5800	1 5		
Average Wt. Loss, normalized to 4.5 % soot, mg max Oil Filter Differential Pressure at EOT, kPa max Average Engine Sludge, CRC Merits at EOT, min	D 6838	6.5 79 8.7	7.5 93 8.6	8.0 100 8.5
Aeration, volume, % max	D 6894	8.0	8.0 (MTAC)	8.0 MTAC)
Copper, mg/kg (ppm) increase, max Lead, mg/kg (ppm) increase, max Tin, mg/kg (ppm) increase	D 6594	20 120 report		

Copper strip rating, max		3	
Foaming/Settling, mL, max Sequence I Sequence II Sequence III	D 892 (Option A not allowed)	10/0 20/0 10/0	
Kinematic Viscosity after shearing, cSt min	D 6278	SAE XW-309.3	SAE XW-40
		9.3	12.5
Viscosity Index, min	D 2270	120	100
TBN, mg KOH/g	D2896 /4739	10	10

API Category Gear oil

A8. API GL-4

Properties.	unit	ASTM Test Method	Limits		
Viscosity Grade			SAE 80W-90	SAE-90	SAE 140
Kinematic Viscosity at 100^0C	cSt	D445	13-15	16-18	28-30
Viscosity Index		D 2270	90	90	80
Flash Point, min.	^{0}C	D 92	165	180	190

A9. API GL-5

Properties.	unit	ASTM Test Method	Limits	
Viscosity Grade			SAE 80W-90	SAE 140
Kinematic Viscosity at 100^0C	cSt	445	13-15	28-30
Viscosity Index		D 2270	90	85
Flash Point, min.	^{0}C	D 92	210	218

A10. ILSAC GF-4 & GF -5 Category Oil

Parameter	ASTM Test Method	Performance Criteria	
		GF-4	GF-5
Engine oils ability to protect against oil thickening and engine wear during moderately high-speed, high-temperature service. Kinematic viscosity increase at 40^0C,max Av. Piston deposit , merit, min Hot stuck rings Av.cam plus filter wear m , max	D 7320(Sequence IIIG)	 150 3.5 none 60	 150 3.5 none 60
Average engine sludge rating, max	D 6891 (Sequence IVA)	90	90
Average engine sludge rating, min Average Rocker arm cover sludge rating, min Average piston skirt varnish rating min Average engine varnish rating, min Oil screen clogging, %, max Hot stuck Compression rings Cold stuck rings, rate Oil screen debris, % Oil ring clogging,%	D 6593 (Sequence VG)	7.8 8.0 7.5 8.9 20 none report report report	8.0 8.3 8.9 7.5 15 none report report report
Bearing weight loss, mg, max	D 6709 (Sequence VIII	26	26
Homogeneity and miscibility	D 6922	Shall remain homogeneous and when mixed with ASTM/TMC / SAE reference oils shall remain miscible.	
Ball Rust Test Average gray value, min	D 6557	100	100
Volatility loss, % max 250^0C	D 5800	15	15
Volatility loss at 371°C (700 °F), % max	D 6417	10	10
% Flow reduction, max	D 6795 (EOFT)	50	50
% Flow reduction, max	D 6794		
with 0.6 % H_20 with 1.0 % H_20 with 2.0 % H_20 with 3.0 % H_20	(EOWTT)	50 50 50 50	50 50 50 50
Phosphorus % w, max Phosphorus % w, min	D 4951 or	0.08	0.08

	D 5185	0.06	0.06
Sulphur % w, max 0W-XX, 5W-XX 10W-30	D 4951 or D 2622	 0.50 0.70	 0.50 0.70
Flash point,9 °C, min	D 93	185	185
High Temperature Deposits, wt. mg, max	D 6335(TEOST 33)	30	30
Static foam max, tendency/stability. max	D 6082(Option A)	100/0	100/0
High Temperature Deposits, mg, max	D7097 (TEOST MHT)	35	35
Gelation Index), max.	D 5133		12

A11. ACEA Category A1 /B1, A3/B3, A3/B4 &A5/B5 Grade

Properties	ASTM Test Method	Limits			
		A1 / B1	**A3 / B3**	**A3 / B4**	**A5 / B5**
Shear stability at 100°C Viscosity after 30 cycles, mm^2/s , max.	D 6278	xW-30 : 9.3 xW-40: 12	All grades to be stay in grades		
Evaporative loss after 1 h at 250°C (Noack), % max.	D 5800	15	1 3		
TBN, min, mg KOH/g	D 2896	8.0	8.0	10.0	8.0
Sulphated ash, % w max.	D874	1.3	1.5	1.6	1.6
Sulphur, % w	D5185	report			
Phosphorus, % w		report			
Chlorine, % w	D6443	report			
Foaming tendency – stability, ml, max	D892 (without option A)				
Sequence I (24°C)		10 - nil			
Sequence II (94°C)		50 - nil			
Sequence III (24°C)		10 - nil			
High temperature foaming Tendency Sequence IV (150°C),	D6082	100 – nil			

High temperature deposits Ring sticking (each part), Merit min	CEC L-088-02 72 Hour test	9.0
Ring sticking Piston varnish (6 elements, average of 4 pistons), Merit min		RL 216
Oil thickening Absolute viscosity increase at 40oC between min and max values during test, mm^2/s, max.		0.8 x RL216
Low temperature sludge merit		
	D6593	7.8
Rocker arm cover sludge rating, merit min		8.0
Average piston skirt varnish rating , merit min		7.5
Average engine varnish rating, merit, min		8.9
Oil screen clogging, %, max		20
Hot stuck Compression rings		none

A12. ACEA C1, C2, C3 &C4 Category

Properties	**ASTM Test Method**	Limits			
		C1	**C2**	**C3**	**C4**
Shear stability at 100ºC Viscosity after 30 cycles	D 6278	All grades to be stay in grade			
Evaporative loss after 1 h at 250ºC (Noack), %	D 5800	13			11
max					
TBN. min.	D 2896	6.0			
Sulphated ash, %w max.	D874	0.5	0.8		0.5
Sulphur, % w max.	D5185	0.2	0.3	0.2	

Phosphorus %w. max.		0.05	0.09	0.07	0.09
Chlorine ppm	D6443	Report			
Foaming tendency – stability ml	D892 (without option A)				
Sequence I (24°C)		10 - nil			
Sequence II (94°C)		50 - nil			
Sequence III (24°C)		10 - nil			
High temperature foaming Tendency - stability Sequence IV (150°C)	D6082	100 - nil			
High temperature deposits Ring sticking (each part), , merit min	CEC L-088-T 02 72 Hour test	9.0			
Ring sticking Piston varnish (6 elements, average of 4 pistons), merit, min		RL216			
Oil thickening Absolute viscosity increase at 40°C between min and max values during test, mm^2/s max.		0.8xRL216			
Oil consumption, kg/test		Report			
Low temperature sludge					
Average engine sludge rating, merit min	D6593	7.8			
Rocker arm cover sludge rating, merit min		8.0			
Average piston skirt varnish rating merit min		7.5			
Average engine varnish rating, min		8.9			
Oil screen clogging, %, max		20			
Hot stuck Compression rings		none			

A13. ACEA E4, E6, E7 & E9 Category

PROPERTIES	**ASTM Test Method**	Limits			
		E4	**E62**	**E7**	**E9**
Shear stability at 100°C Viscosity after 30 & 90 cycles, mm^2/s	D 6278	All grades to be stay in grade			
Evaporative loss after 1 h at 250oC (Noack),%, max	D 5800	13			

TBN. mg KOH/g, min.	D 2896	12	7	9	7
Sulphated ash, max.	D874	2.0	1.0	2.0	1.0
Sulphur, max.	D5185	0.2	0.3		0.4
Phosphorus			0.08		0.12
Chlorine	D6443	Report	Report	Report	Report
Chlorine		Report			
Foaming tendency - stability	D892 (without option A)				
Sequence I (24°C)		10 - nil			
Sequence II (94°C)		50 - nil			20-nil
Sequence III (24°C)		10 - nil			
High temperature foaming Tendency - stability Sequence IV (150°C)	D6082	200 - 50			
Corrosion: Copper increase, ppm Lead increase, ppm Copper Strip	**D6594**	Report Report Report	Report 100 Report		Report 100 3
High temperature deposits Ring sticking (each part) min	CEC L-088-T 02 72 Hour test	9.0			
Ring sticking Piston varnish (6 elements, average of 4 pistons), merit, min		RL 216			
Oil thickening Absolute viscosity increase at 40°C between min and max values during test, max.		0.8 x RL216			
Oil consumption, kg/test		Report	Report	Report	Report
Low temperature sludge					
Average engine sludge rating, min		7.8			
Rocker arm cover sludge rating, min		8.0			
Average piston skirt varnish rating min		7.7			

Average engine varnish rating, min	D6593	8. 9
Oil screen clogging, %, max		20
Hot stuck Compression rings		no ne

A14. JASO T904 category engine oils

Properties	**ASTM Test Method**	LIMITS
Density, Kg/lit	D 1298 / D4052	report
Flash Point, ^{0}C	D92 or D93	report
Kinematic viscosity at 40^{0}C, mm^2/s	D 445	report
Kinematic viscosity at 100^{0}C, mm^2/s		report
Viscosity Index	D 2270	report
Low-temp viscosity, mPa.s	D 5293	report
High-temp. High share rate at 100^{0}C viscosity, mPa.s, %w, min.	D 4683	2.9
Sulphated ash, max.	D874	1.2
Acid Number mgKOH/g	D 664	report
TBN, mg KOH/g	D 2896	report
Evaporation loss% w, max	D5800	20
Foaming tendency - stability	D892 (without option A)	
Sequence I (24ºC)		10/0
Sequence II (94ºC)		50/0
Sequence III (24ºC)		10/0
Shear stability at 100ºC Viscosity after 30 cycles mm^2/s, min	D 6278	xW-30:9.0
		xW-40: 12.0
		xW-50: 15.0
Phosphorous, %w,	D4951	min,0.08
		Max. 0.12

Other (Ca, Ba, Mg, Zn, Br,)		report

A15. JASO M 355 Category

Properties	ASTM Test Method	Limits		
		Category		
		DH-1	**DH-2**	**DL-1**
Soot Dispersancy, Viscosity increase, max.	D 5967	0.2	0.2	0.2
High Temperature Oxidation Stability, viscosity increase mm^2/s, max.	D 5533	200	200	..
High Temperature Oxidation (60H) Stability, viscosity increase ,max.	D6984	295	295	..
High Temperature Oxidation (80H) Stability, viscosity increase ,max.	D6984	..	..	275
Foaming tendency - stability	D 892			
Sequence I (24ºC) ,max		10/0	10/0	10/0
Sequence II (94ºC)		50/0	50/0	50/0
Sequence III (24ºC)		10/0	10/0	10/0
Evaporative loss after 1 h at 250oC (Noack),max	D 5800	1 8	18	15
Anti Corrosion, Copper, max	D 6594	20	20	20
Anti Corrosion, Lead, max		120	100	120
Anti Corrosion, Tin, max		50	50	50
Copper strip Corrosion, max	D 130	3	3	3
Shear stability at 100ºC Viscosity after 30 cycles	D 6278	min , 9.3		
		max. 12		

Sulphated ash, max.	D874	..	1	0.6
Total Base Number (TBN)m min,	D 2896/ D4739	1 0	5.5	..
Sulphur ,max.	D5185	..	0.5	0.5
Phosphorus. Max.		Report	0.12	0.1
Chlorine, max.	D6443	Report	150	150

A16. OEM: DQCIII-05 and DQC IV-05 Grade Engine oil

Laboratory Tests			
Properties	Test Method	Limit	
		DQC III-05	DQC IV-05
Density , g/ml	ASTM D 4052	TDM	TDM
Viscosity Class	SAE J 300	xW30 & xW40 (x=0,5,10,15)	xW30 & xW40 (x=0,5,10)
Viscosity at 40 ^{0}C, cSt	ASTM D 445	TDM	TDM
Viscosity at 100 ^{0}C, cSt		TDM	TDM
Viscosity Index	ASTM D 2270	TDM	TDM
TBN	ASTM D 2896/ASTM D 4739	TDM	TDM
Sulphated Ash, max.% w/w	ASTM D 874	2	2
Calcium, %w		TDM	TDM
Magnesium, % w/w		TDM	TDM
Zink, % w/w		TDM	TDM
Molybdenium, % w/w		TDM	TDM
Boron, % w/w		TDM	TDM

Natrium, % w/w	ASTM D4951	TDM	TDM
Phosphorus, % w/w		TDM	TDM
Silicon,mg/kg		TDM	TDM
Sulfur, % w/w	ASTM D 2622	TDM	TDM
Flash Point, ^{0}C, min	ASTM D 92	215	220
Pour Point,^{0}C	ASTM D 97	TDM	TDM
Oxidation Induction Time, minute, min		90	70
Corrosion (Lead increase, at 135^{0}C), ppm, max.	ASTM D6594	90	70
Foaming Tendency, ml	ASTM D 892 Option A	As ACEA	As ACEA
High Temperature Foaming Tendency ml,	ASTM D 6082	As ACEA	As ACEA
Turbocharger deposit forming Tendency, mg max.	DIN 51535	110	80

TDM=To be declared by the Manufacturer.

A17. Industrial Grade Lubricant (ISO Grades)

Industrial Grade Lubricants

Test	Method ASTM D		Grade											
			ISO											
			Normal					EP						
			15	32	46	68	100	68	150	220	320	460	680	1200
Density	1298		0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.91	0.92	0.92	0.94	0.95
Pour Point ^{0}C, max.	97		(-) 6	(-) 6	(-) 6	(-) 6	(-) 6	(-) 6	(-) 6	(-) 6	(-) 6	(-) 6	(-) 6	(-) 6
Flash Point ^{0}C, min	93		150	220	214	220	228	190	190	190	200	200	200	220
Total Base No. mg KOH/g, min	2896		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total Acid No. mg KOH/g, max,	664		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Kinematic Viscosity, cSt.	445	at 40^{0}C	16	30	45	65	100	65	143	210	306	440	660	1150
		at 100^{0}C	4	5	8	11	15	8.6	14.6	18.8	23.8	30	40	53
Vicosity Index	2270		155	102	150	150	150	103	101	100	98	97	99	92
Metal Content	4951		report	report	report	report	report	report	report	report	report	report	report	report
Rust Protection	1748		No rust				No rust	No rust	No rust	No rust	No rust	No rust	No rust	No rust
Copper Strip corrosion, max.	130		1	1	1	1	1	1	1	1	1	1	1	1
Gear scuffing Wear Test, min	5182		12	12	12	12	12	12	12	12	12	12	12	12
Foam Test at 95 or 135^{0}C			No foam	No foam	No foam	No foam	No foam	No foam	No foam	No foam	No foam	No foam	No foam	No foam

A18. Turbine Oils

Parameter	ASTM Test method	Limits				
ISO viscosity grade	D 2422	32	46	68	100	150
Flash point, °C, min	D 92	180	180	180	180	210
Pour point, °C, max	D 97	(-) 5	(-) 5	(-) 5	(-) 5	(-) 5
Viscosity, cSt, 40°C (mm^2/s)	D 445	28.8–35.2	41.4–50.6	61.2–74.8	90–110	135–165
Visual examination at 20°C	clear and bright					
Total Acid Number, mg KOH/g, max	D 974	report	report	report	report	report
Emulsion characteristics:	D 1401					
at 54°C, minutes to 3 mL emulsion, max		30	30	30		
at 82°C, minutes to 3 mL emulsion, max					60	60
Foaming characteristics:	D 892					
Sequence I, tendency/stability, mL, max		50/0	50/0	50/0	50/0	50/0
Air release, 50°C minutes max	D 3427	5	10	10	17	25
Rust preventing characteristics	D 665	pass	pass	pass	pass	pass
Copper corrosion, 3 h at 100°C, max	D 130	1	1	1	1	1
Oxidation stability: Hours to neut. No. 2.0, min	D 943	2000	2000	1500	1000	1000
Minutes to 175 kPa drop, min	D 2272	350	350	175	150	150
Load carrying capacity: fail stage, min	D 5182	8	8	8	8	8

Specifications denote a minimum acceptable performance level. Thus, many equipment manufacturers add on their own particular requirements or tighten the tolerance on a general specification to meet their particular needs. Therefore, recommendations of the engine manufacturers should be consulted and submitted to the Commission for the endorsement/approval if in doubt.

A19. Transformer/Insulating Oil.

Parameter	ASTM Test Method	Requirement
Kinematic Viscosity, Centistokes, cSt max @ 0 °C, @ 100 °C, @ 40 °C	D455	 76 3.0 12
Pour Point °C, max.	D97	(-) 6
Colour, max.	D1500	0.5
Interfacial Tension, min., dynes/cm	D971	39.99
Aniline Point °C. max.	D611	76
Visual Exam	D 1524	clear and bright
Flash Point, minimum, °C	D92	150
Density @15°C/15°C, max.	D1298	0.91
Total acid number, mg KOH/g max.	D974	0.0 3
Water Content, ppm, max.	D 1533	8
Dielectric Strength, KVA, min	D877	29.9
VDE Electrodes , KVA, min	D1816	34.9
Impulse Strength, KVA, min	D3300	145

Dissipation (Power) Factor, % max @ 25 °C @ 100 °C	D924	 0.05 0.3
Oxidation stability, 72h % w sludge.max TAN, max mg KOH/g Oxidation stability, 164h % w sludge, max TAN, max mg KOH/g	D2440	 0.1 0.3 0.2 0.4
Oxidation inhibitor content, max	D2668	0.3 %

A20. Heat Transfer Oils

Sr. No.	Properties	ASTM Test Method	Limits
1.	Kinematic Viscosity, cSt @40ºC	D 455	28-35
2.	Viscosity Index, min.	D 2270	95
3.	Flash Point, COC,ºC, min.	D 93	210
4.	Pour Point, ºC, min.	D 97	-3
5.	Copper Strip Corrosion, 3 hrs. @100ºC, (ASTM), max.	D 1301	1
6.	Neut. Number, mg KOH/gm., max.	D 664	0.15
7	Density, kg/lit.	D1298	0.86
8	Specific heat, Cal/gm/^{0}C	D 3947	0.49
9	Thermal conductivity, cal/s.cm.^{0}C	D 2717	0.0000021

A21. Grease

Characteristics	ASTM Test Method	Type in use/ Base		
		Calcium (for Chassis)	Sodium (for Bearing)	Lithium (for multipurpose)
Penetration at 250C(60second)	D 217	210-250	220-250	220-295
Drop Point	D217	150	150	180

Grease should be capable to withstand extreme pressure. Vibration, shock, water resistant and high temperature. It should have oxidation stability and thermal stability

A22 Requirement for Physico-Chemical (Other than Viscosity)

Sl No.	Characteristics	Requirement for Grade												
(1)	(2)	SAE 0W (3)	SAE 5W (4)	SAE 10W (5)	SAE 15W (6)	SAE 20W (7)	SAE 25W (8)	SAE 20 (9)	SAE 30 (10)	SAE 40 (11)	SAE 50 (12)	SAE 60 (13)	Multi-Grade (14)	Method of Test, Ref to BDS ISO (15)
i)	Appearance	When examined transmitted light in a colourless glass test tube of 25 mm internal, diameter, oil shall be clear, bright and free from turbidity and sediment.												
ii)	Viscosity index, Min	100	100	100	95	95	95	95	95	90	90	90	-	BDS ISO 3104
iii)	Pour point, °C, Max	-33	-33	-27	-24	-21	-15	-9	-6	-6	-6	6	-	BDS ISO 3016
iv)	Flash point COC °C, Min	160	160	190	190	200	200	200	215	215	220	220	220or 185	BDS1320:28
v)	Evaporative loss, per cent, Max	20	20	20	15	15	15	15	10	10	10	10	22or 20	
vi)	Foaming tendency/stability quantity of foam ml/ml, Max a) at 24°C, Max b) at 93.5°C, Max c) at 24°C, after the test at 93.5°C	25/Nil 150/Nil 25/Nil												-

NOTES

1 For defence requirement pour point for SAE 30 and SAE 40 shall be -18°C, Max and for SAE 50 shall be -9°C Max.

2 Flash point for multigrade is valid only for 0W-20, 5W-20, 5W-30, 10W-30 and for other multigrade it is not required

3 Evaporation loss for SAE 0W-20, 5W-20, 5W-30, 10W-30 is 22 and for SAE 15W-40 it is 20

4 For SJ category the foaming tendency requirement shall be 10/0, 50/0, 10/0 (P-67) and 200/50 for high temperature foaming tendency ASTM D 6082. High temperature foaming tendency /stability quantity of foam ml/ml, Max.