Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Oil Selection and Remaining Useful Determination for Internal Combustion Engines

Dorjsuren Ishdorj
Mongolian University of Life SciencesMechanical
Dulamsuren Batsuuri
Mongolian University of Life SciencesMechanical
Enkhbayar Gonchigdorj
enkhbayar@muls.edu.mn

Mongolian University of Life SciencesMechanical

Research Article

Keywords: Engine oil, metal element, smoke opacity, pollutants, engine stock

Posted Date: November 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11609979/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

OIL SELECTION AND REMAINING USEFUL DETERMINATION FOR INTERNAL COMBUSTION ENGINES

Dorjsuren Ishdorj, Dulamsuren Batsuuri, Enkhbayar Gonchigdorj
School of Engineering and Technology, Mongolian University of Life Sciences
E.mail; dorjsuren@muls.edu.mn, dulamsuren@muls.edu.mn, enkhbayar@muls.edu.mn

Keywords: Engine oil, metal element, smoke opacity, pollutants, engine stock

Abstract

This research focused on some tribological analysis of various types of engine oil, determination of depreciation products (metal elements) in used engine oil, measurement and analysis of diesel engine smoke opacity, carbon dioxide and nitrogen oxide emissions from gasoline engines. Mongolia's harsh climate and extremely cold weather, lasting for over five months together with the fact that most car owners do not have a warm garage are the main reasons for engine wear. We have studied some of the tribological parameters of 30 types of gasoline and diesel engine oils widely sold in the market of our country. The possibility of their use was determined by classifying them into two groups according to their advantages and benefits. Warning and limit values of metallic elements (fe, cr, cu, sn, al) were determined in oil samples taken periodically from diesel and gasoline engines of "land cruiser-200" cars used in our country. . "Toyota OEM, SAE 5W30" and "Elite Mannol, SAE 5W40" oils have a load withstand ability of 900N, a very low friction coefficient of 0.005, and an expected wear rate of 0.705 mm, which is superior to the other oils studied, became a condition. A nomogram was created to determine the possibility of the engine stock, which is used in the various climate conditions in mongolia, by a smoke opacity of ci engine and a content of metallic elements of si engine which is in used oils, such as carbon monoxide (co) and hydrocarbons (hc). In order to ensure that passenger cars imported from abroad are free of damage during their service life and fully utilize the engine stock, the period for engine oil changing, diagnosis and technical service has been determined based on research.

1. Introduction

Used oil is contaminated not only with heavy metals but also with polycyclic aromatic hydrocarbons (PAHs) that are insignificant in the unused oil [1].

Used crankcase oil contains contaminants that accumulate during use as an engine lubricant. Sources of contamination include additive breakdown products (e.g., barium and zinc); engine “blow-by” (i.e., material which leaks from the engine combustion chamber into the crankcase oil); burnt oil; and metal particles from engine wear, such as arsenic, lead, nickel and cadmium [2].

Numerous other metals are present in used oils such as aluminum, copper, iron, magnesium, silicon and tin; however, they are generally not given much attention due to their low concentrations and low toxicities [3].

If the engine oil is used for a long time without changing it for a specified period of time, the lubricating quality will deteriorate, and the small metal shavings from the friction of the moving parts will increase the wear and tear and reduce the durability reserve [4].

In gasoline vehicle engines the main emissions generated are nitrogen oxides (NOx), carbon monoxide (CO), and hydrocarbons (HC) and volatile organic compounds (VOC). CRRI conducted a study that petrol cars emit 49.61 kg of total pollutants/100 km,

followed by buses and trucks (38.05 kg), 3-wheelers (35.79 kg), 2-wheelers (27.29 kg) and diesel cars (3.21 kg). Yet, the proportion of CO in the total emission is highest in patrol cars at 80.62 %, followed by 3-wheelers, (71.32 %), 2-wheelers (62.29 %), diesel cars (34.26 %), and buses and trucks (33.37 %) [5].

The complete combustion of diesel fuel would only generate CO_2 and H_2O in combustion chambers of the engine (Prasad and Bella 2010). The most significant harmful products are CO, HC, NOx, and PM. Among these pollutant emissions , CO and HC are emitted because of incomplete combustion and unburned fuel while NOx emissions are caused because of high combustion temperatures above $1{,}600^0$C (Burtscher 2005) [6].

The main beneficial effects in smoke opacity were found during the cold start when the load increased at low engine speed [7].

The main factors to ensure longevity and reliable operation of any machinery, their aggregates, nodes, and parts, and to improve the efficiency of use are the reduction of friction wear and the appropriate selection of oil-lubricating materials [8].

In recent years, enterprises and citizens of Mongolia have been buying more than 2,000 Land Cruiser-200 cars, which are imported at a high cost. These vehicles are being used widely in every corner of the country.

Mongolia buys 100% imported cars, machinery, technical equipment, oil and lubricants and supplies them to the market. Seventeen-point-three percent of it is retail trade or individual sales, which indicates that the risk of serving products that do not meet quality standards and are not guaranteed may increase.

Car owners are not always familiar with the oils and alternatives suggested by manufacturers. them, so they artificially reduce the durability of their valuable assets and suffer economic losses. Car owners do not always know the dedication oils specified by the manufacturers and the alternatives to use them, so they artificially reduce the durability of their valuable assets and suffer economic losses. Therefore, it is necessary to get used to the correct selection and use of engine oil when using the engine to the full reserve and mileage specified by the manufacturer. This is the same paragraph as the previous one.I would delete it.

2. Materials and Method

The laboratory experiments were carried out with the support of "Tribology" L aboratory of The School of Engineering and Technology of Mongolian University of Life Sciences, "Fuel and Lubricants" of "Technomics Mongolia" LLC, and oil and lubricants laboratories of "NCS" company in Beijing, China.

Some tribological parameters were determined by laboratory tests according to ASTM D:4172B standard by selecting 30 types of engine oil commonly sold in the Mongolian market.

Practical experiments to determine pollutants of gasoline engine exhaust gases and smoke opacity of diesel engine were conducted according to Mongolian MNS5013-2009 and MNS5014-2009 standard methods, and the results were compared with the maximum acceptable level of the standard. Microsoft Excel, Matlab, and Statstica-10 programs were used to analyze and summarize the research results and process the test results.

3. Results and Discussions

3.1 Laboratory experiment (Oil Group)

The load withstands ability of engine oil, which is widely used in passenger cars with gasoline and diesel engines imported from foreign countries, the detected amount of wear on the surface of the test bearing under load, and the coefficients of friction by laboratory tests.
These oils are divided into two groups according to the superiority of their parameters determined by laboratory tests and as shown in Table 1. Oils of the first group are recommended to be used first, and oils of the second group can be used as a substitute in the absence of oils from the previous group.

Table 1. Grouping of engine oils according to their tribological parameters.

Properties	*Load withstand ability, N*		*Wear rates, mm*		*Friction coefficients*	
	800-900	600-700	0.5-0.8	0.9-1.3	0.001-0.005	0.006-0.009
Groups	I	II	I	II	I	II
	-Mitasu -Addeca -Micking -Kendall GT -Toyota OEM -Abro -Mannol Elite -Motor Gold -Luqui moly -Enoes	-Magnatec -Havoline -76 motor oil -Zic -Deluxe -Brilltex -Lucas -Shell -Mobile -Dragon -Kixx -Gastrol	-Shell -Gastrol -Mannol Elite -Abro -Maxxpower -Toyota OEM -Ardeca -Mitasu -Xteer	-GTX -Motor Gold -Magnatec -Havoline -Mobile super-1000 -Kixx	-Mitasu -Addeca -Micking, -Kendall GT -Toyota OEM -Abro -Mannol Elite -Motor Gold -Eneos	-Gastrol -GTX -Kixx -Motor Gold -Mobile super-1000 -Brilltex -Micking -Guadol

3.2 Laboratory experiment (Diesel Engine)

Metallic Elements of Diesel used Oil

Cars which were manufactured between 2007 and 2019 were included in the test. Engine used oil samples were taken at each specific miles of the researched vehicles, starting at 1000, 5000, and 10000 km, and increasing by 5000 km. Samples of engine oil were taken for laboratory analysis and the amount of metal elements (Fe, Cr, Cu, Sn, Al) contained in the used oil was determined.

A mathematical model of how each metal element detected in a diesel engine uses oil is calculated by the mileage of the car and developed using the MATLAB program. For example, the dependence of iron emerging is shown in Fig. 1, and the dependence of aluminum emerging in Fig. 2, respectively.

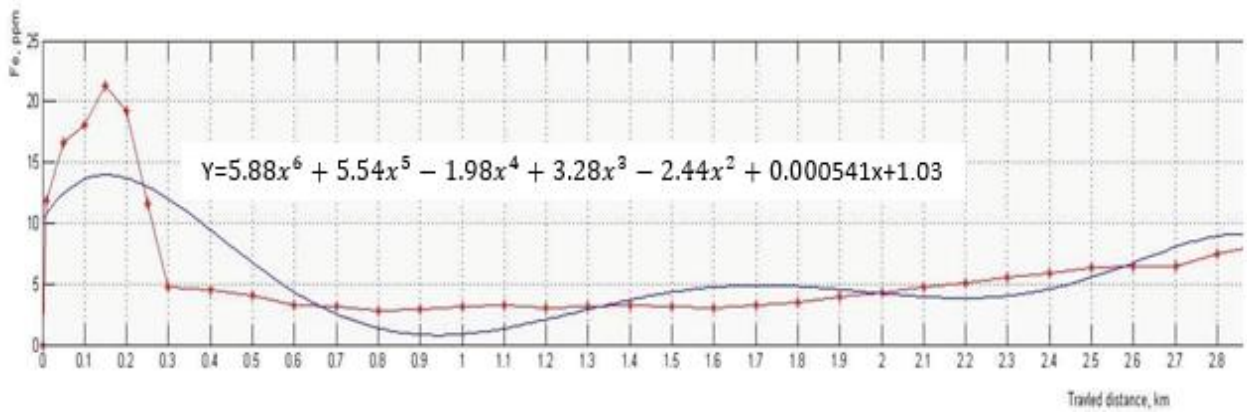

Fig1. The amount of iron formed in diesel engine oil.

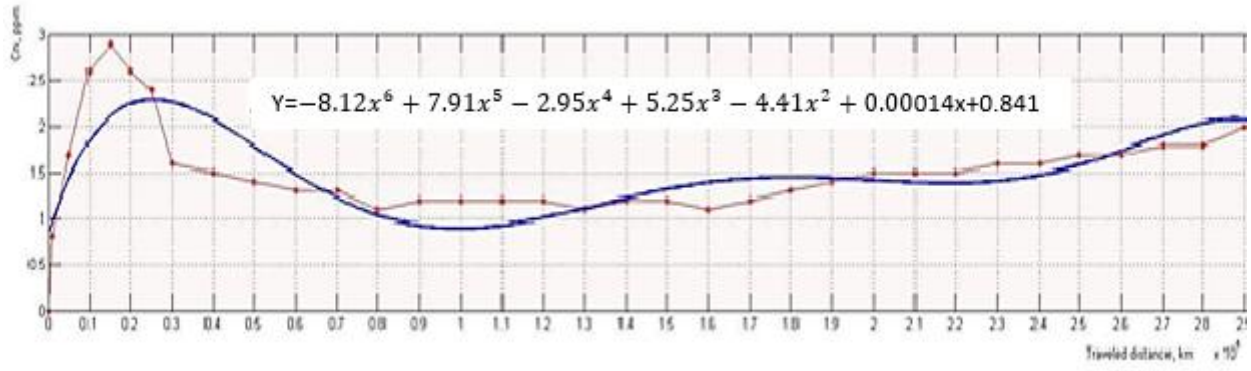

Fig. 2 The amount of formed aluminum in diesel engine oil

If we look at the graph, the amount of iron detected in the used oil when the engine runs up to 30,000 km is 21.9 ppm or very high, while as the mileage increases, this element decreases when reaching to 2.9 ppm or very low at around 90,000 km (Fig.1).

3.3 Laboratory experiment (Gasoline Engine)

Metallic Elements of Gasoline used Oil

Laboratory tests were performed in the same manner as for diesel engines. A mathematical model of how each metal element detected in a gasoline engine used oil depends on the mileage of the car was also developed using the MATLAB program. This time the dependence of copper emerging is shown in Fig.3, and the dependence of chrome emerging in Fig.4, respectively.

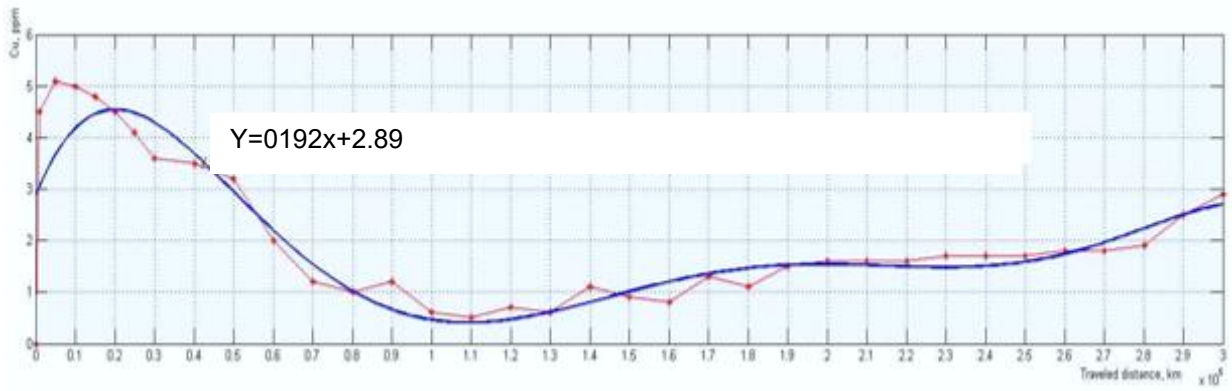

Fig.3 The amount of copper formed in diesel engine oil.

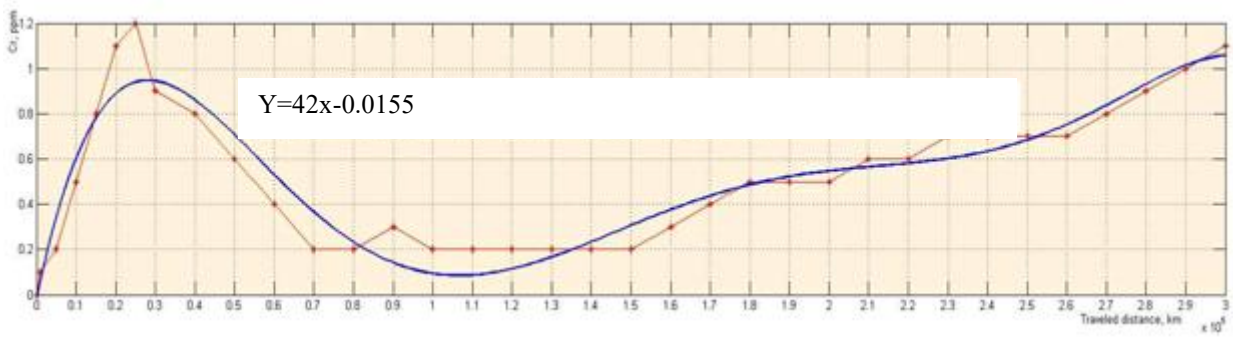

Fig.4 The amount of chrome formed in diesel engine oil.

If we look at Fig.3, the amount of copper detected in the used oil when the engine runs up to 5.000 km is 5.1 ppm or very high. Although, as the mileage increases, this element decreases when reaching 1.7 ppm, which is lowest, when the engine runs to 70.000 km. However, wear stabilizes beyond this run. It has been observed that the amount of copper increases, starting from the run of 190.000 km.

As can be seen from the 4th picture above, the amount of chromium found in the used oil when the engine runs up to 25.000 km is 1.2 ppm, which is very high. But as the mileage increases, the amount of wear decreases to 0.2 ppm when the engine runs up to 70.000 km. As the mileage increases wear is stabilizing, but starting from the run of 190.000 km, it is observed that the amount of chromium rapidly increases.

3.4 Practical tests (Pollutant emissions of Gasoline Engine)

Carbon monoxide (CO) and hydrocarbons (HC) were determined from pollutants of gasoline exhaust gases of the cars included in the study and the results shown in Table 3. According to the results summarized in the table, it can be seen that the amount of CO and HC emissions of the car with gasoline engine that used the oil that was superior in terms of tribological parameters was lower (in blue).

Table 3. Pollutants of exhaust gases for Passenger Cars with gasoline engines .

Vehicle ages	Produced in	CO, %	CH, ppm
2	2018-2017	0.11	13
4	2016-2015	0.13	19
4	2016-2015	**0.12**	**13.5**
6	2014-2013	0.23	24
8	2012-2011	0.32	31
10	2010-2009	0.76	28
12	2008-2007	1.81	33

3.5 Practical tests (Smoke opacity of Diesel Engine)

The results of determining the percentage of smoke opacity of passenger cars with diesel engines depending on their age which are listed in Table 4. As can be seen from the table below , the percentage of smoke opacity is increasing with the used year of the car. According to the results summarized in the table, it can be seen that the percent of smoke opacity of the car with diesel engine that used the oil that was superior in terms of tribological parameters was lower (in blue). The following brands of oils were superior in some tribological parameters according to laboratory tests: Toyota-OEM, SAE5W30

or Mannol Elite, SAE5W40. It was also determined that the amount of smoke opacity of passenger cars is polynomially dependent on age.

Table 4. Smoke opacity for passenger cars with diesel engine

Produced in	Car numbers	Smoke opacity, %
2018-2017	20	12.32
2016-2015	24	14.11
2016-2015	**28**	**12.56**
2014-2013	24	14.66
2012-2011	23	17.54
2010-2009	24	26.6
2008-2007	30	36.11

3.6 Nomogram (for Diesel Engine)

A nomogram was developed to determine the residual stock of a Diesel engine based on the increas e of metal elements detected in the engine oil and the percent of smoke opacity either are depending on the mileage of the car (Fig.5). The horizontal axis of the nomogram was shown used years of the car, and the vertical axis were shown the smoke opacity and metal content in parallel. For easy use of the nomogram, the experimentally determined smoke opacity curves were included with each metal element to create 5 separate graphs.

In this plot the written 35 value is the maximum acceptable value of Mongolian National Standard (MNS5014-2009). But the numbers 8.1, 1.3, 2.5, 1.8 and 5 represent the content of metal elements detected in used engine oil.

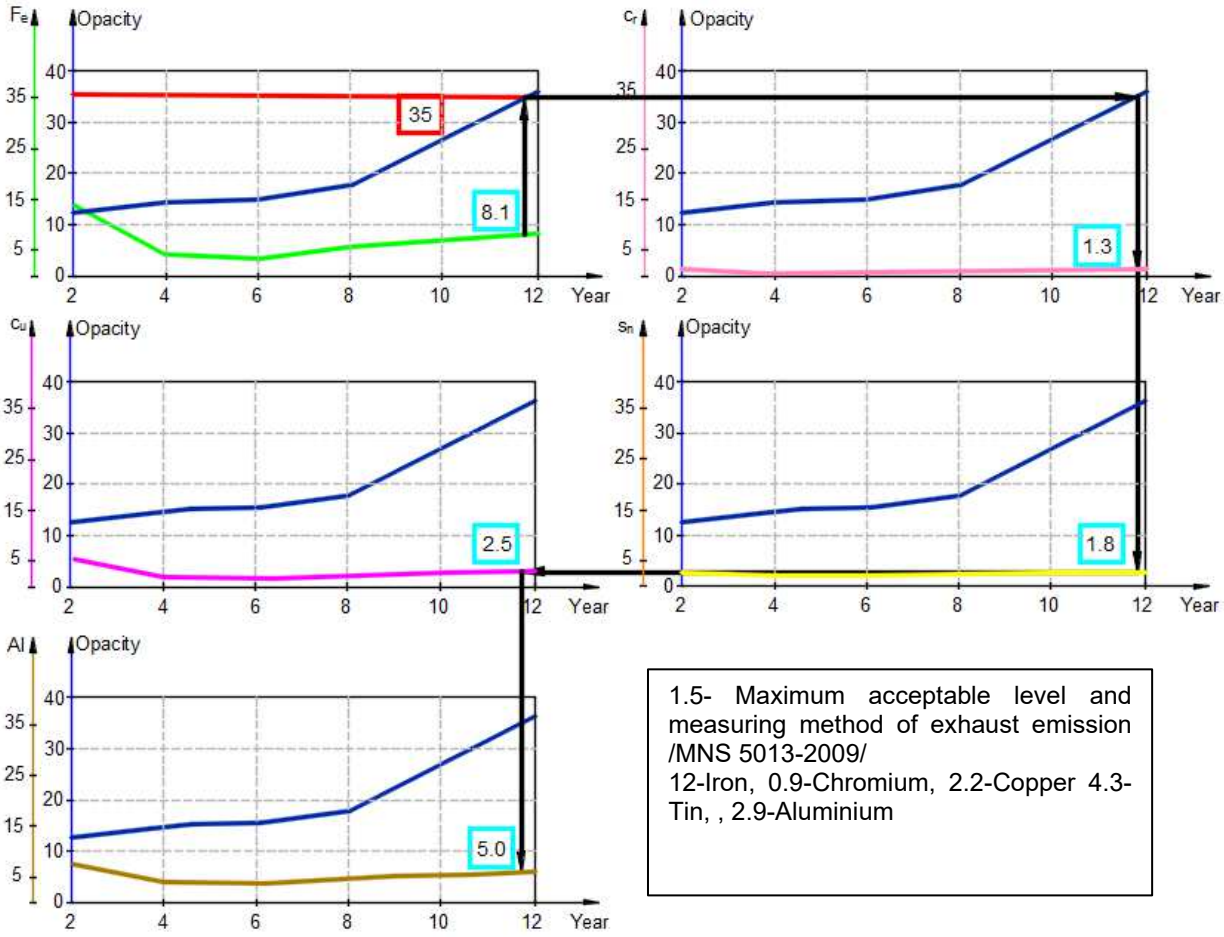

Figure 5. Nomogram for determination of engine residual stock by a metal content of used oil and smoke opacity of Diesel Engine.

3.7 Nomogram (for Gasoline Engine)

A nomogram was developed to determine the residual stock of a Gasoline engine based on the increasing Carbon monoxide (CO) detected in the pollutant gases and the using years of a car either are depending on the mileage of the car (Fig.6). The horizontal axis of the nomogram was shown used years of the car, and the vertical axis were shown the smoke opacity and Carbon monoxide (CO) in parallel. For easy use of the nomogram, the experimentally determined smoke opacity curves were included with each metal element to create 5 separate graphs.

In this plot the written 1.5 value of Carbon monoxide (CO) is the maximum acceptable value of Mongolian National Standard (MNS 5013-2009). However, the amount of metal elements detected in used oil was 12 for iron, 0.9 for chromium, 4.3 for tin, 2.2 for copper, and 2.9 for aluminum.

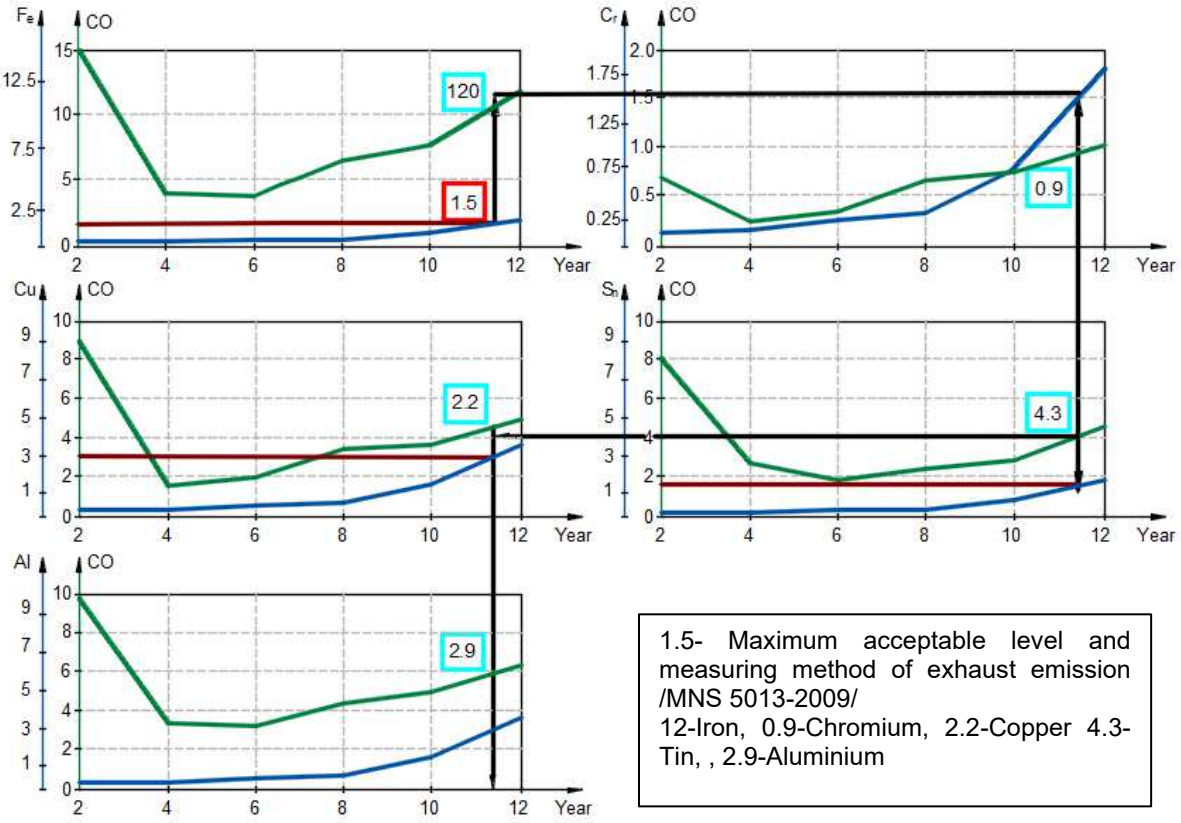

Figure 6. Nomogram for determination of engine residual stock by the using years of a car and a carbon monoxide of Gasoline Engine.

Conclusion

1. Many types of engine oils sold in the Mongolian market are divided into 2 groups according to the results of laboratory analysis and tribological parameters. "Toyota OEM, SAE 5W30" and "Elite Mannol, SAE 5W40" oils have a load withstand ability of 900N, a very low friction coefficient of 0.005, and an expected wear rate of 0.705 mm, which is superior to the other oils studied, became a condition.

2. Warning and limit values of metallic elements (Fe, Cr, Cu, Sn, Al) were determined in oil samples taken periodically from diesel and gasoline engines of "Land Cruiser-200" cars used in our country. According to the results of the study, it was determined that in the conditions of Mongolia, the period of orientation should be 15,000.0 km, the period of reliable operation should not exceed 300,000 km, and the period of first maintenance should not exceed 350,000 km.

3. Using the nomogram created as a result of the research work, it became possible to directly determine the amount of metals found in the mileage and oil of the "Land Cruiser-200" car, and the amount of pollutants in the exhaust gases.

4. According to the results of the research, limits were set for the oil used in the engine of the "Land Cruiser-200" used in Mongolia and classified into two groups. Users recommended the list of oils of the first group "/Toyota OEM/ SAE 5W30" and "/Elite Mannol/ SAE 5W40" brands to be used as a priority, and if it is not possible to use them as a substitute.

References

[1] Some Adverse Effects of Used Engine Oil (Common Waste Pollutant) On Reproduction of male Sprague Dwley Rats, *Open Access Macedonian Journal of Medical Science Volume 3(1)*; (2015 Mar 15).

[2] U.S. EPA. National Recommended Water Quality Criteria. Office of Water. *Office of Science and Technology. United States Environmental Protection Agency*.Posted (2004) at: www.epa.gov/waterscience/criteria/nrwqc.

[3] ATSDR, *Toxicological Profile for Used Mineral-based Crankcase Oil. Agency for Toxic Substances and Disease Registry*. Atlanta, Georgia: (1997). Posted at: www.atsdr.cdc.gov/toxprofiles/tp102.html . [Google Scholar].

[4] G.Enkhbayar, T.Nigamet, *Fuel and Lubricating, Ulaanbaatar, Textbook* (2016).

[5] Saini.B, Verma.R, Himanshu.S. K and Gupta.S, *Analysis of Exhaust Emissions from Gasoline Powered Vehicles in a Sub-urban Indian Town, International Research Journal of Environment Sciences,* ISSN 2319–1414 Vol. 2(1), 37-42, January (2013).

[6] Ibrahim Aslan Res¸itog˘lu, Kemal Altinis¸ik, Ali Keskin, *The pollutant emissions from diesel-engine vehicles and exhaust after treatment systems*, Clean Techn Environ Policy (2015)17:15–27.

[7] Octavio Armas, Carmen Mata *"Montes Smoke Opacity and NOx Emissions from a Bioethanol-Diesel Blend during Engine Transient Operation",* September (2007) DOI:10.4271/2007-24-0131 Conference: 8th International Conference on Engines for Automobiles.
[8] G. Davaasuren's "*Study of tribological parameters of Internal Combustion Engine Oil*" Dissertation (2015).
[9] MNS 5013:2003, Petrol engine vehicle – *Maximum acceptable level and measuring method of exhaust emission.*
[10] MNS 5013:2003, Diesel engine vehicles – *Maximum acceptable level and measuring methods of opacity*

Declarations

Data availability. The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Consent to publish. “Not applicable.”

Ethical Approval and accordance. “Not applicable.”

Consent to participate. “Not applicable.”

Author contributions. *[AUTHOR ACTION REQUIRED: Specify each author's contribution and obtain approval from all listed authors.]*

Funding. *[AUTHOR ACTION REQUIRED: State whether the research received funding. If funded, name the funder and grant number; otherwise state that no specific funding was received.]*

Competing interests. *[AUTHOR ACTION REQUIRED: Declare any financial or non-financial competing interests, or state that none exist.]*

Ethics statement. *[AUTHOR ACTION REQUIRED: Confirm whether the work involved human participants, animals, identifiable personal data, or biological materials; add an ethics declaration if applicable.]*