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PROFESSIONAL PAPER

Recycling of waste motor oils

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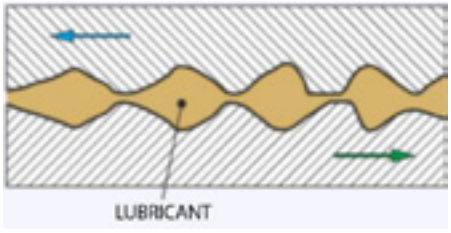
Abstract: During the use of motor oils, they lose their physical and chemical characteristics, their aging occurs and over time the oil becomes unusable and becomes waste motor oil.
After use, in addition to being harmful to the environment, waste oils pose a serious threat to human health.
In order to avoid the harmful effects of waste oils on humans and the environment, used oils must be disposed of appropriately.
The problem of waste motor oil can be solved in several ways: using waste motor oil as an energy source - incineration, recycling and disposal/disposal.
From an economic point of view and from the point of view of protecting the living environment, the recycling of waste motor oils has advantages over burning and disposal.
Recycling of waste motor oils is any procedure by which a new product is obtained through certain processing procedures, which enables the reuse of waste motor oils.

Keywords: lubricants, waste motor oil, disposal, recycling.

LUBRICANTS AND LUBRICATION

Lubricants are substances with specific physical and chemical characteristics that are used for lubrication.

Lubrication is the process of creating a protective layer of certain characteristics between the contact surfaces that are in mutual relative motion, in this way friction and wear of the contact surfaces is reduced.



Picture 1. lubrication

MOTOR OILS

Engine oil has the function of lubricant/lubrication in internal combustion engines. In addition to reducing friction and wear when operating an internal combustion engine, engine oil helps dissipate heat from heated engine parts and keeps engine assemblies clean.

In order for motor oil to be able to perform all the functions required of it, it must have appropriate characteristics, the most important of which are: stability at high operating temperatures, resistance to oxidation, be able to neutralize acidic compounds that are formed in motor oil as a result of fuel combustion, and have good anti-foaming and anti-corrosion properties. Engine oil acquires all the required characteristics in the production process when appropriate additives are added to it in certain quantities.

The base of motor oils is a base oil to which appropriate additives are added to improve the physicochemical and operational characteristics. According to the type of base oil used in production, motor oils are divided into: mineral, synthetic and semi-synthetic.

Mineral motor oils are produced from mineral base oils, which are obtained by distillation of crude oil. Mineral motor oils are primarily suitable for older vehicles or engines with less demanding technology. The main disadvantage of mineral motor oils is less protection at extreme temperatures and shorter replacement intervals compared to synthetic motor oils. They are the most represented on the market, and the reason for this is their favorable production price and availability.

Synthetic motor oils are obtained by adding additives to synthetic base oils. Synthetic base oils are produced by complex chemical-technological processes and have significantly better physical and chemical characteristics compared to mineral base oils. Synthetic motor oils have better characteristics at high and low temperatures, provide better engine protection and extend oil change intervals. They are suitable for modern, high-efficiency

Table 1. SAE J 300 classification of motor oils

SAE viscosity grade	Maximum viscosity (mPas) at low temperatures		Maximum pumpability temperature for viscosity 60,000 mPas	Kinematic viscosity (mm2/s) at 100 °C		HTHS viscosity (mPa.s) at 150 °C and shear rates of 106s-1
	max.	°C	°C	min.	max.	min.
0W	6200	-35	-40	3.8	-	-
5W	6600	-30	-35	3.8	-	-
10W	7000	-25	-30	4.1	-	-
15W	7000	-20	-25	5.6	-	-
20W	9500	-15	-20	5.6	<9.3	2.6
25W	13000	-10	-15	9.3	<12.5	2.9
20	-	-	-	12.5	<16.3	2.9 (0W-40, 5W-40, 10W-40)
30	-	-	-	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40)
40	-	-	-	-	-	-
40	-	-	-	-	-	-
50	-	-	-	-	-	-
60	-	-	-	-	-	-

vehicles and engines operating in extreme operating conditions. Synthetic oils reduce engine wear in the long term and improve fuel efficiency.

Semi-synthetic motor oils, also known as partially synthetic oils, are a mixture of mineral and synthetic oils. Semi-synthetic motor oils provide better protection than mineral oils and are suitable for most modern vehicles. They have better resistance to oxidation, ensure better lubrication at higher temperatures and extend the life of the engine. They are a good choice for drivers looking for a compromise between price and quality.

Motor oils can be divided or classified according to several criteria, the most important classification of motor oils is by viscosity. The so-called SAE viscosity grades were introduced by the Society of Automotive Engineers. The viscosity gradation of motor oils is defined by the SAE J 300 standard. Two series of viscosity gradations of motor oils are defined, the gradation with the "W" mark and without the "W" mark. Oils marked "W" represent monograde oils for winter operating conditions (winter oils). Oils without the "W" mark are monograde oils for summer operating conditions (summer oils). By combining two viscosity gradations of oil, with and without the "W" mark, multigrade motor oils are obtained that satisfy both summer and winter operating conditions.

According to the type of engine in which they are used, engine oils are divided into oils for four-stroke engines, oils for two-stroke engines and oils for other engines.

During the use of motor oils, they lose their physical and chemical characteristics, their aging occurs and over time the oil becomes unusable and needs to be replaced with a new one.

Waste motor oil is any motor oil whose physical and chemical characteristics have changed during exploitation to such an extent that it is no longer suitable for the use for which it was originally intended.

After use, in addition to being harmful to the environment, waste oils pose a serious threat to human health, as they contain many toxic and carcinogenic substances such as heavy metals and polycyclic aromatic hydrocarbons.

Collection of waste motor oils

The first stage in solving the problem of waste motor oil is its collection. In order to evaluate the efficiency of waste motor oil collection, it is important to know what amount of waste motor oil is available for collection. The amount of waste motor oil available for collection is estimated based on the amount of fresh motor oil that is put on the market and it amounts to about 50% of its amount.

Solving the problem of waste motor oil

In order to avoid the harmful effects of waste oils on humans and the environment, used oils must be disposed of appropriately.

The problem of waste motor oil can be solved in several ways:

- using waste motor oil as an energy source - incineration,
- by recycling and
- disposal/disposal.

Recycling of waste motor oils

Recycling of waste motor oil in relation to incineration and disposal has a number of advantages, the most significant of which are:

- preservation of the environment,
- creation of new jobs,
- conservation of natural resources,
- energy conservation,
- reduction of health risks,
- contribution to technological progress i
- - economic benefit.

Preservation of the environment

One of the most significant advantages of recycling waste motor oil is its positive impact on the environment. The release of waste oils into the environment and their improper disposal leads to environmental contamination. Recycling waste oil contributes to the *preservation of the environment.*

Opening of new jobs

One of the advantages of recycling waste oil is the *creation of new jobs*. Recycling of waste motor oil is a process that requires the use of special equipment used for collection, processing and recycling. The recycling of waste motor oil will employ workers who will work on its packaging and manipulation, as well as in companies that recycle waste motor oil.

Conservation of natural resources

By reusing waste motor oils or by extending their life (extended replacement intervals), less raw material is used for their production. Today, the largest share of raw materials used for the production of lubricating oil comes from crude oil, which is extracted from oil fields and oil platforms. Crude oil is a non-renewable resource whose reserves are limited. The exploitation and refining of crude oil has a significant negative impact on the environment. By reusing waste oils, the amount of crude oil used for their production is reduced, which directly affects the *preservation of natural resources*.

Conservation of energy

The process of recycling waste motor oil involves filtering out impurities and contaminants, which can then be used as fuel in power plants, industrial boilers and other energy-intensive applications. By using this kind of energy, we can reduce our dependence on fossil fuels and contribute to a sustainable energy future and *energy conservation*. In addition, with appropriate preparation and control of the combustion process and processing of the resulting combustion products, waste motor oil can be used as an energy source for households and industrial needs.

Reduction of health risks

Improper disposal of waste motor oil can pose significant health risks to humans and animals. When waste motor oil enters the ground or water sources, it can release harmful toxins and chemicals. These toxins can enter the food chain, leading to health problems. Proper disposal and recycling of waste motor oil *reduces health risks* and ensures a safer environment for everyone.

Contributes to technological progress

Research and development of new engines or equipment that can use recycled motor oil must be used effectively and efficiently. As a result, it is a *contribution to the advancement of technology* that enables the reuse of waste motor oil.

Economic benefits

One of the advantages of recycling waste motor oil is the *economic benefit* it offers. The recycling industry creates jobs and contributes to the local and national economy. The recycling of waste motor oil creates opportunities for the installation and commissioning of facilities for recycling, processing and related industries.

Recycling of waste motor oils

Recycling of waste motor oils is any procedure by which a new product is obtained through certain processing procedures, which enables the reuse of waste motor oils.

The recycling process refers to the removal of impurities, partially and additives from waste motor oils, resulting in a base oil, which can be used as a raw material for the production of new lubricants and lubricating oils. The main problem of recycling waste motor oil, which has gone through the process of degradation during use, is its composition. Waste motor oil contains fractions of diesel and gasoline fuel that have entered the motor oil during the combustion process from the fuel combustion chamber, light hydrocarbons that result from the degradation of base oils, moisture/water that enters the motor oil from the atmosphere, sediments that form as a product of motor oil degradation (resin and asphalt) and additive residues.

The primary processing processes of waste motor oils are:

- deposition,
- filtration and
- dehydration and separation of the vapor phase.

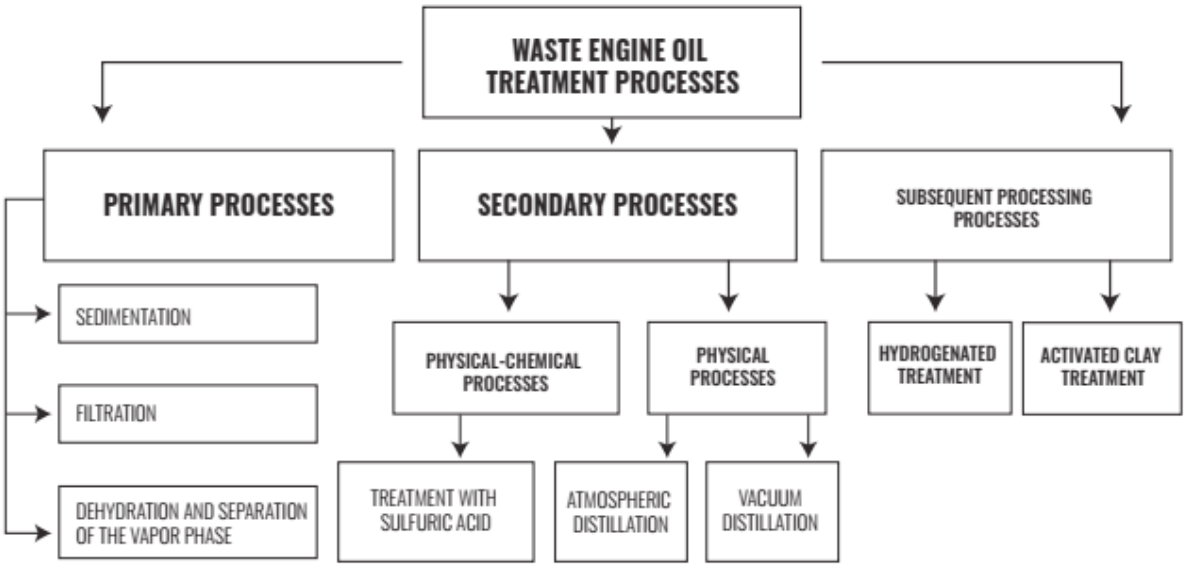
The processes of secondary processing of waste motor oils are:

- physical-chemical processes - treatment with sulfuric acid,
- physical processes:
  - ◊ atmospheric distillations to separate light diesel and gasoline fuel fractions and
  - ◊ vacuum distillation for the separation of fractions of base oils with the possibility of deasphalting the vacuum residue.

The processes of post-treatment of waste motor oils are:

- hydrogen treatment procedures i
- processing procedures with active clays for whitening.

Image 2. Schematic representation of the recycling of waste motor oils



Processes of primary treatment of waste motor oils

Sedimentation is an operation aimed at extracting water and sediment from waste motor oil. A certain amount of sediment and water is retained in the motor oil during exploitation due to the presence of dispersant additives in the oil. Deposits in engine oil are mainly a product of engine oil degradation during exploitation. The sedimentation process can be carried out in gravity separators that work on the principle of gravity and centrifugal separators that are more efficient and faster and that work on the principle of centrifugal force.

Mechanical impurities (metal filings, hardened degradation products of motor oils) are removed from waste motor oil by *filtration* using different types of filters. Filters can be ordinary mesh filters that remove larger-sized impurities from the oil, and fine filters with 150-250 μm pores of the filtration medium, which are used to remove micro and fine particles from waste motor oil.

In most cases, *vapor phase separation processes* take place at atmospheric pressure and at temperatures up to 180°C, which remove compounds with boiling points lower than the boiling point of diesel fuel from waste motor oil in addition to water.

Processes of secondary processing of waste motor oils

Sulfuric acid treatment procedure

Waste motor oil contains polar oxides, acidic compounds, residual additives, by-products of oil degradation, suspended particles and other substances that pollute it. The process of treating waste motor oil with sulfuric acid is based on mixing waste motor oil with sulfuric acid with the aim of removing harmful substances. As a result of the treatment of waste engine oil with sulfuric acid, acid tar is formed, while the hydrocarbon chains in the base oil in the engine oil do not degrade. In order to avoid reactions and processes of sulfonization and oxidation of the hydrocarbon chains of the base oil, the process must be conducted at a controlled temperature of 40 to 50°C. After the treatment of waste motor oil with sulfuric acid, the oil that remains after separating the acid tar is subjected to treatment with active clays. The role of active clay in the process is to absorb tiny drops of sulfuric acid that remain in the oil after treatment. After treatment with sulfuric acid and treatment with active clay, the obtained residue is subjected to vacuum distillation in order to divide the obtained residue into several fractions.

Processes for treating waste motor oil with sulfuric acid are economically more profitable (lower cost of the process) compared to other processes and are suitable for countries where a relatively small amount of waste motor oil is collected annually, up to several thousand tons. The negative side of this process is the formation of acid tar as a by-product of the treatment of waste engine oil with sulfuric acid, which is extremely dangerous and harmful to the environment.

If the motor oil in an internal combustion engine is replaced prematurely with a new, fresh motor oil, a significant amount of active additives remain in the oil that becomes waste motor oil, including dispersant additives that have not been used. If such an oil is to be refined with sulfuric acid and a good separation of the acid tar is to be achieved, a significantly larger amount of sulfuric acid is needed than when the dispersants in the oil have been used up. The solution to this problem is to destroy the active dispersant additives in the oil without changing the viscosity of the oil, which is achieved by thermal treatment of waste motor oil or flocculation with chemical means before treatment with sulfuric acid. The process of heat treatment is used more in practice, where care must be taken to ensure that the processes are conducted in as mild conditions as possible in order not to change the viscosity of the oil. The flocculation process is based on the contact of waste oil with the aqueous and organic phase with the aim of removing most of the dispersant and detergent additives from the oil. The

aqueous phase contains chemical agents that destabilize the dispersed particles and react with the metals to form salts that are then deposited. The organic phase consists of a mixture of polar solvents for oil extraction that cause the precipitation of polar compounds, suspended particles and various oxidized substances.

Physical separation procedures
Distillation

In most waste motor oil recycling technologies, the first step is atmospheric distillation, which removes residual water, light hydrocarbons and other volatile compounds from the oil. The conditions for the separation of the vapor phase are mild, temperatures from 160 to 180°C and a pressure of about one bar or lower.

After separating the vapor phase by atmospheric distillation, vacuum distillation takes place in vacuum columns. In order to be able to separate the residual fraction of diesel fuel at the top of the column, it is necessary to construct the vacuum column properly, so that the passage time through the columns is as short as possible due to the very high temperature of the process.

In practice, vacuum distillation is often used in combination with TFE (Thin Film Evaporator). In these processes, the dehydrated oil is added at the top of the cylindrical column so that it flows down its walls, which are heated from the outside. In order for the oil to flow down the walls evenly and create a film of equal thickness in all places, rotating vanes are installed in the column, which enable regulation of the film thickness.

After distillation, it is necessary to remove the asphalt material from the vacuum residue by the process of deasphalting. The procedure is carried out by extraction with propane, butane or pentane. As a result, an oil phase with a large proportion of solvent is obtained, with which the extraction procedure is carried out and asphalt phases with a small proportion of solvent.

Final processing

Whitening clays

Treatment with adsorbents (bauxite, natural clay, charcoal) is still widely used, in some countries it is even growing due to the prohibition of oil refining with sulfuric acid. Adsorbents on their boundary surface bind molecules of dissolved substances from the solution, in this case particles of impurities in waste motor oil. The size of the adsorbent particles used is 0.25 - 0.50 mm.

The role of the adsorbent is to neutralize acids in acid-refined oils, unstable oxide and sulfur compounds and sulfuric acid residues. Adsorbents can also increase the oil's resistance to oxidation at high temperatures and color stability during storage.

Two methods of treatment with adsorbents are used, the first is filtering through filters containing the previously used adsorbent, and the current method is contact with clay.

When filtering through the filters, the waste motor oil passes through a medium on which an adsorbent has been applied. The main characteristics of this method are: long contact time (up to several hours), low temperature of the process, but high enough for the oil to be liquid. Adsorption efficiency is not constant, during the process it is difficult to ensure constant production quality, and the flow of oil through the adsorbent decreases over time.

When the oil comes into contact with the clay, the oil and the clay are continuously mixed and heated in a container for a certain time, and then separated by filtration. The characteristics of this method are: high temperature (150 - 330 °C) which enhances the catalytic effect of active clay, contact time of 15 - 30 minutes and uniform production quality.

Catalytic hydrogenation

For many years, catalytic hydrogenation has been considered an efficient refining process from the point of view of yield and quality of final products. The process consists of bringing oil fractions into contact with hydrogen at high pressure and temperature in the presence of a catalyst located on a suitable support. Catalytic hydrogenation, with the correct choice of catalyst and conditions in which the process takes place, can be applied to a wide range of products, from the lightest to the most difficult compounds. There are two basic reactions that take place:

- hydrorefining - which aims to remove sulfur, nitrogen and metals and hydrogenate olefinic and aromatic hydrocarbons and
- hydroconversion - with the aim of changing the structure of hydrocarbons by cracking and isomerization.

Saturated hydrocarbons are formed by these processes/reactions, and sulfur, oxygen and nitrogen are removed from waste motor oil.

There are a number of commercial processes that combine the above procedures and unite them in the process of recycling waste motor oils.

Thermal treatment of waste motor oil - incineration

Thermal treatment of waste motor oils means a procedure in which waste motor oils are used as energy sources. Thermal treatment of waste motor oils can be carried out in two ways:

- waste motor oil is only used as fuel or
- waste motor oil is mixed with some conventional fuel and the mixture is used as fuel

Waste motor oil consists of hydrocarbons, which makes it suitable for use as an energy source. Unlike heavy fuel oils, waste motor oil has a lower viscosity, so it can be injected into the combustion chamber at a

temperature almost twice as low as the temperature at which fuel oils are injected into the combustion chamber, around 70 °C. In addition, waste motor oil is sufficiently fluid that it can be pumped and stored at a temperature of up to 10 °C, while heavy fuel oils must be heated to temperatures of 50 to 70 °C before pumping. Waste motor oil has a low sulfur content, which makes it competitive with other low-sulfur fuels.

The main disadvantage of the thermal treatment of waste motor oil is that it is necessary to reduce the emission of harmful substances in the flue gases produced by its combustion. In addition, before starting the combustion process, it is necessary to remove almost all metal particles from the waste engine oil, because otherwise there will be increased wear of injectors and pumps for manipulation and combustion. In addition, metal particles present in motor oil are also responsible for the formation of floating ash in flue gases.

Processes of thermal treatment of waste motor oils have found application in the cement industry, brickyards and asphalt production plants.

Harmful emissions from flue gases resulting from the burning of waste motor oil can be reduced by dedusting the flue gases, and dedusting can be carried out:

- mechanical methods - the principle of operation is based on gravitational, inertial or centrifugal forces,
- electrical methods - which ionize dust particles that are later collected on surfaces whose polarity is opposite to that of the dust particles,
- porous dust removers and
- hydraulic dust removers - which can work on three principles: washing with bubbles, sprinklers and in a venturi tube.

CONCLUSION

Due to their characteristics, waste motor oils are categorized as hazardous waste, which is why it is necessary to establish a system for their collection in order to minimize the amount of waste motor oils that ends up in the environment.

The problem of waste motor oil can be solved in several ways: using waste motor oil as an energy source - incineration, recycling and disposal/disposal.

Recycling of waste motor oils is any procedure by which a new product is obtained through certain processing procedures, which enables the reuse of waste motor oils.

From an economic point of view and from the point of view of protecting the living environment, the recycling of waste motor oils has advantages over burning and disposal.

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