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ECOLOGICAL AND TECHNICAL ASPECTS OF THE WASTE OILS INFLUENCE ON ENVIRONMENT

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ABSTRACT

In the last ten years, the world demand for lubricants is around 36 millions tons per year. More than 50 % of that amount is lost in exploitation, and the rest is potentially collectable waste oil. Waste oils are a serious threat to the human health and especially the environment. In order to prevent this threat, a proper waste oil management should be adopted. The solutions for the environmental protection comprise the following activities: the reduction of quantities of waste lubricating oil, the organized collection of the waste lubricating oil and recycling of waste lubricating oil.

Keywords: Waste oils, environment, prevention, collection, recycling

1. INTRODUCTORY REMARKS

Today, the lubricant industry is considered an important, complex and profitable business and the lubricants itself as high-tech products. Worldwide, in mid 90s', there were around 1,700 lubricant manufacturers, ranging from large to small and in Europe, there were around 300 [5, 7, 10]. Merging of the companies, there were 720 lubricant manufacturers worldwide in 2005 [5]. The differences in the size of the manufacturers are enormous – the top 10 finished lubricant's manufacturers hold more than 50% of the global volumes. Only 1% of the refined crude oil worldwide is used to manufacture lubricant products. In 2011, 35.1 million tons of lubricants were consumed worldwide, while in Europe, it was around 7 millions tons (Western Europe: 3.9 and Central and Eastern Europe: 3.1) [5]. As it can be seen in Fig. 1 that the world demand for lubricants has been broadly static over the past 10 years, with a slight downfall in 2009.

A distribution of the 2002 lubricant consumption for Central and Eastern Europe is presented in [4]. Now, the lubricant consumption in Serbia, is estimated at 45,000 to 50,000 tons per year. In addition, an amount of about 60% represents imported lubricants. There are about 25 lubricant producers in Serbia, mainly blenders.

The use of lubricants can be split according to two segments: automotive (more than 65%) and industry (less than 35%). Further classification is by families, with different shares in use of each family.

The lubricant families with the highest consumption are presented in Table 1. Among them, the lubricating oils represent over 95% and the lubricating oils derived from the mineral base oils are by far the most common type (Table 2). These data are very important in the analysis of the waste oil quantities and types.

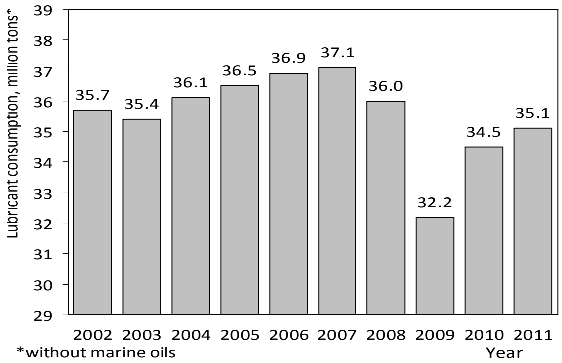

Fig. 1. World lubricant consumption (without marine oils) during last 10 years [5]

Table 1. Estimated lubricant's consumption by families [13]

Lubricant family	Consumption, %
Internal combustion engine oils	50
Gear oils	8
Hydraulic systems oils	15
Metalworking fluids	6
Total loss system lubricants	7
Greases	3
Others	11

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Table 2. Lubricating oil's consumption by base oil types

Base oil type	Consumption, %
Mineral oils	90
Synthetic oils	8
Vegetable oils	2

The lubricating oils, like other products that people use every day, have their own life cycle. During service use, it is normal for them to degrade, most often, by a combination of additive depletion and contaminant accumulation, so, their physical and chemical properties have changed in use such that it is not fit for its original purpose. As a result, we have a waste oil, which, in this case, is defined as used waste oil (Fig. 2). Along with used waste oils, there are unused waste oils. These waste oils are oils that have become contaminated during handling and storage, or that have failed to meet specifications.

The used waste oils are far more important than unused waste oils, from the standpoint of quantity and possible negative influence on the environment. They occur everywhere where lubricants are used: transport industry, ferrous and non-ferrous metallurgy, rolling mills, metal processing industry, chemical industry, as well as in fields of energetic, agriculture, forestry and mining. Such widespread use of lubricants also means a large dispersion of used waste oils and points to possible water, air and soil pollution of huge areas.

So, is the waste oil problem or opportunity? It can be a problem if handled improperly, or if they are discharged directly into drains, water-ways or soil. However, waste oil is very useful secondary raw material, which is particularly important for oil importing countries, and should be viewed as an opportunity for obtaining certain products and economic benefit [3, 12, 14].

2. THE IMPACT OF LUBRICATING OILS ON HUMAN HEALTH, ECONOMY AND ENVIRONMENT

Lubricating oils, in any form, are potentially harmful to the human health and the environment. To prevent potential undesired consequences to the human health relevant technical standards and procedures should be complied. First of all, appropriate lubricants should be used, but even then there is a threat of working environment contamination and consequently, risk to human health. Contamination of the working environment with lubricating oils origin, mostly due to: oil leakage, oil mist appearance, and spillage (deliberated or accidental) of oil due to improper storage and handling. These phenomena are potential causes of skin problems and/or respiratory organ's problems among humans who come into contact with oil.

In addition to the human health problems, leakage of oil means financial losses as well. These losses are not negligible, as it is shown by the data given in Table 3.

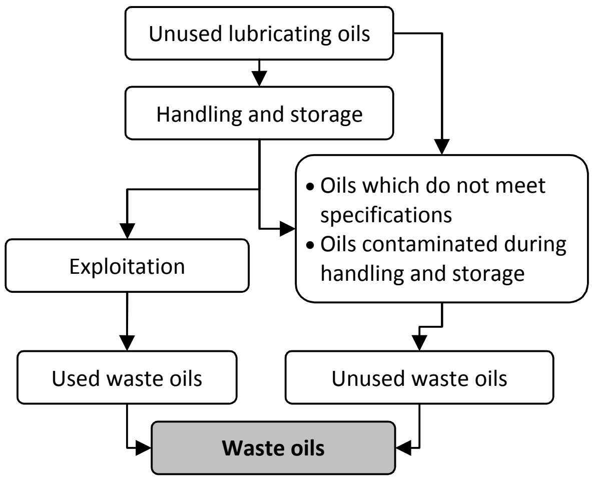

Fig. 2. Generation of waste lubricating oils [8]

Table 3. Approximately losses due to the lubricating oil's leakage*

Leakage frequency	Losses			
	Litres per month	**Litres per year**	**Euros per month**	**Euros per year** (for 10 leakage spots)
1 drop per second	131	1577	263	31,536
1 drop per 5 seconds	26	315	53	6307

**Approximation is made on the following basis: 1 drop ≈ 50 μl and 1 l ≈ 2 EUR*

Disposal of waste oils could also be a significant problem and environmental issue, especially when it is illegal or inappropriate. This is because the majority of waste oils originate from mineral base oils, and these oils posses poor biodegradability (Table 4). Waste oils interface with the environment resulting in pollution of the atmosphere, ground and water. Even though mineral oil products can be biodegraded by the micro organisms present in nature, these natural degrading systems are overwhelmed by the volume of the losses. In recent years, rapidly biodegradable total loss lubricants based on synthetic esters, polyglycols and vegetable oils have been introduced in order to reduce pollution.

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Table 4 Lubricating oil's biodegradability by base oil types [6]

Base oil type	Biodegradability, %	
	EPA method*	CEC method*
Mineral oils	42 – 48	20 – 40
Vegetable oils	72 – 80	90 – 98
Polyglycols	6 – 38	–
Synthetic esters	55 – 84	90 – 100

**EPA – Environmental Protection Agency; CEC – Coordinating European Council*

The most obvious effect of illegal or inappropriate disposals of waste oil are oil spills, and its effect is on aquatic environment, where it takes up to twenty years to return to a healthy condition. There, oil residue tends to settle on the bottom, covering the ground and whatever organisms live there. Oil film on water can reduce the penetration of light into the water and, consequently, reduce the rate of photosynthesis. When photosynthesis is reduced, oxygen production is also reduced. The oil film may furthermore inhibit the movement of oxygen from the air through the surface of the water. There are some side effects as well since waste oils contain common contaminants like: solids, additive degradation by-products, water, fuels, and process chemicals. In addition, many waste oils contain PCBs (polychlorinated biphenyl compounds), PAH (polyaromatic hydrocarbons), toxic metals and other human carcinogens and health threatened contaminants [2].

How big is the impact of waste oils could be demonstrated with the following facts, occasionally found in the literature:

- one part of oil per million parts of water (1 ppm) can produce tastes and odours noticeable to humans and make water undrinkable. It is about equivalent to four drops of oil in a filled bathtub;
- the amount of 50 to 100 ppm oil in water are enough to foul water treatment plants and cause equipment damage;
- a 6.8 litre of oil can completely (1 mm thick layer) cover a lake the size of 0.7 hectare (about equivalent to a football field);

The fact is that the lubricating oils usually pollute the environment in small but, due to their widespread use, widely-spread amounts rather than in large, localized quantities. Having this in mind the phrase: *Think globally, act locally* is quite applicable.

3. POSSIBLE SOLUTIONS FOR THE ENVIRONMENT PROTECTION

Generation of waste lubricating oil is inevitable, so the question is: what can be done to protect the environment from waste oil pollution? In industrialized countries, people started to think about it and act some 40 years ago. The Council of the European Communities issued in 1975 the first Directive (75/439/EEC) relating to waste oil, which defined the collection, storage, recovery and disposal of waste oils [16]. The Directive aim was to protect the environment against the harmful effects of illegal dumping and treatment of these oils.

The latest Directive, which treats waste oils, is Directive 2008/98/EC, issued by the European Parliament and the Council of the European Union [18]. It repealed some previous Directives, but it still aims at protecting the environment and human health through the prevention of the harmful effects of waste generation and waste management. One of the things in this Directive is the establishment of a waste hierarchy, which is given in order of priority: prevention; preparing for re-use; recycling; other recovery, e.g. energy recovery; disposal.

Having this in mind, and applied it to the waste oils, the solutions for environmental protection comprise the following activities:

- reduction of quantities of waste lubricating oil (prevention),
- organized collection of waste lubricating oil, and
- recycling of waste lubricating oil (various recovering process).

3.1. Reduction of Quantities of Waste Lubricating Oils

In accordance with the established hierarchy in management of waste oils, ***prevention of waste lubricating oil generation has an absolute priority***. It could be done by:

- extending the life of the lubricating oil, and
- using the fast biodegradable lubricating oils.

Life extension of the lubricating oils can be achieved by using high-quality oils and by applying appropriate storage, handling and filtration of oils during exploitation. The current situation in Serbia and other developing countries is as follows: oils that are in usage are with the lowest price possible, control of the lubricating conditions is very low, lubricants are replaced based on its service life, and often incorrect usage of oils is present (contamination of

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unused oil, improper cleaning and maintenance of the lubrication system, etc.). A new approach in lubricant's management should comprise: use of premium oils for lubrication, replacement of the lubricants based on its condition (proactive maintenance), and continuous diagnostics (monitoring) of the oil and equipment that is lubricated. This new approach has positive environmental effects, as well as, economic effects.

Fast biodegradable lubricants (e.g. bio-based lubricants) usage is especially important in total loss systems and machines and equipment used in sensitive ecological areas (open gears, wire ropes, chain-saws, rail tracks and switches, etc.). The use of these oils is increasing in many countries, as a result of environmental policy implementation and adoption of the appropriate laws.

To combine the environmental behaviour and the technical properties of lubricants a lot of countries have developed environmental labelling schemes and special signs or labels. The aim of these signs is to draw the attention of lubricant users to environmentally acceptable lubricants. The first one was Blue Angel in Germany, developed in 1977. Today we have *Global Ecolabelling Network (GEN)*, which comprise 27 ecolabel organisations throughout the world. Some of the European programs and labels are: *EU Ecolabel*, *White Swan* (*Nordic Ecolabel*) in Nordic countries (Norway, Sweden, Finland, Iceland and Denmark), *UZ 14 Chain saw oils* in Austria, *NF Environnement mark* in France, *Vamil Regulation* in Netherlands, *Vitality leaf* in Russia, etc. [1, 9, 19].

3.2. Collection of Waste Lubricating Oils

Collection of waste lubricating oil is also an important part of the waste oil's management. Already indicated widespread use of lubricating oils gives the spatial dispersion of waste oils, which creates problems with its collection, both technical and financial. In addition, very often a separate collection of waste oils by lubricant families is required. Nevertheless, collecting as many waste oils as possible is crucial, both to avoiding contamination of the environment and to realising a profit from the very high recovery potential of this waste stream.

The amount of waste oils is associated with the consumption of lubricants. However, not all used oils are collectable (Fig. 3). Many oils are either consumed during processing (e.g. rolling oils, quench oils, and other process oils) or are lost during use (e.g. chain saw and two-stroke engine oils). In addition, some waste oils are generated, which have not been used. This includes waste oils remained as residues in tanks, containers, packages and oil filters, spillages during topping-up, and so on. Experience shows that up to 50 % of lubricants are lost during exploitation, and that it is possible to collect 50 to 60 % of the used lubricants.

The average waste oil collection rate in the EU-15 in 2000 was around 72 %, and individual member countries collection rates are shown in Fig. 4. According to more recent reports [21], average waste oil collection rate in the EU-15 in 2003 was 83 %. The 44 % of this amount was regenerated or re-refined, while the 46 % were treated by direct burning. It is obvious that the remaining 10 % of collected waste oil and 17 % of potentially collected waste oils are probably burned illegally or dumped in sewage or elsewhere.

3.3. Recycling/Recovering of Waste Lubricating Oils

Recycling of waste lubricating oil is not a new idea. As early as World War I, there was recognition that waste oils represented a resource that could be accumulated and utilized instead of thrown away. Interest for waste oil recycling is the past was connected mainly with base oil price. For example, the last peak of studies that have been done on waste oil characteristics, recycling technologies and related topics was in the 1970s and 1980s, during the period of oil embargoes [2].

More recently, environmental problems with waste oils renewed interest in finding ways to increase collected used oil volumes and improve the quality of recycled products.

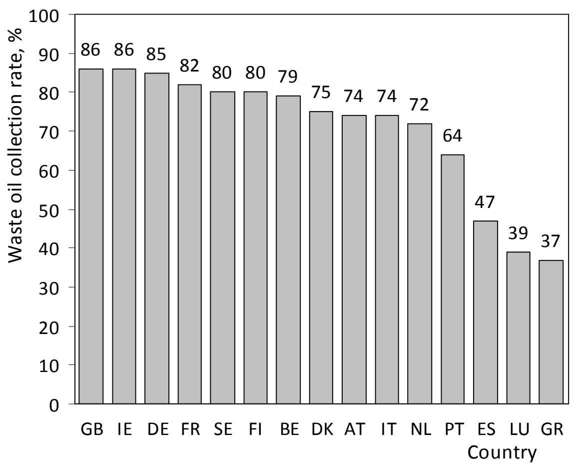

Fig. 4. Waste oil collection rate by countries in the EU-15 in 2000 [17]

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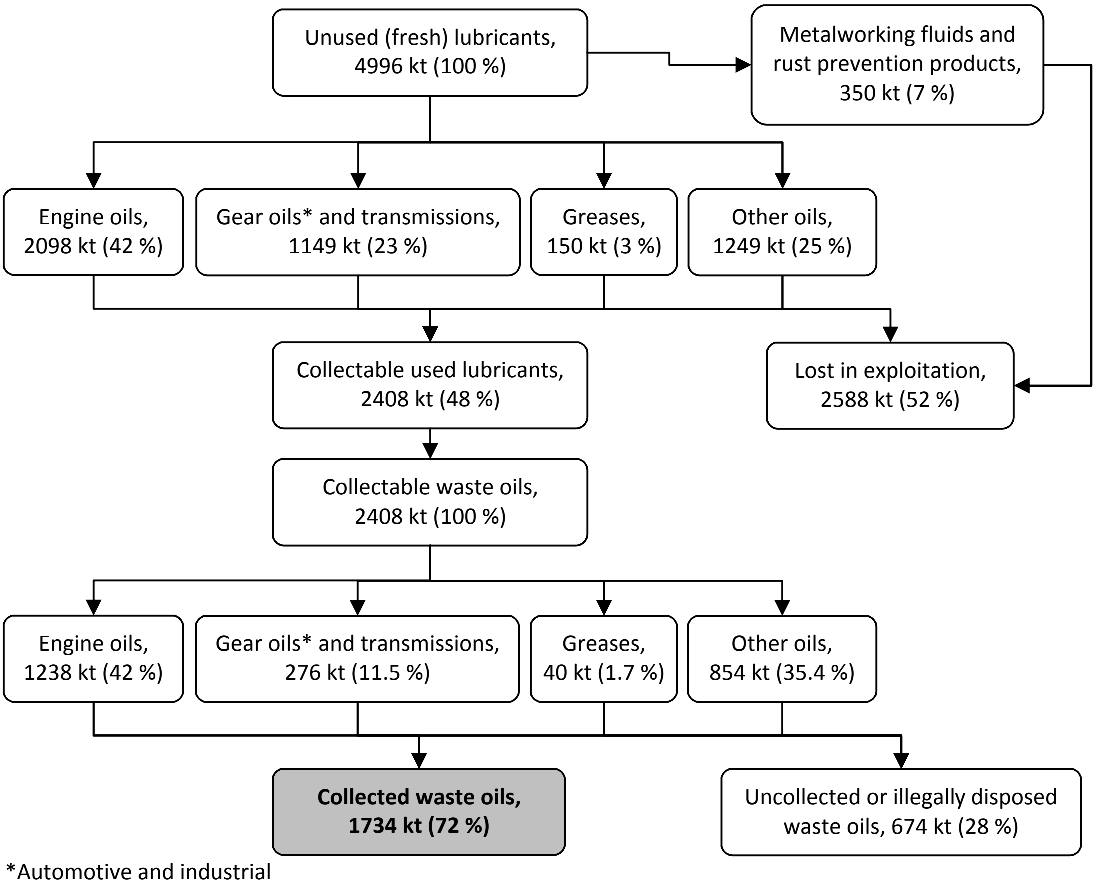

Fig. 3. Lubricants and waste oils by categories in the EU-15 in 2000 [17]

The term recycling usually covers various recovering process. Although there are quite a lot of them, they can be divided into three main categories, depends on the type of product they result:

- regeneration (the primary objective is rejuvenating a lubricant, so it can be used in its original application or as lower grade lubricant);
- re-refining (the primary objective is a clean base oil for reuse in blending lubricating oil);
- re-processing (the primary objective is to improve its quality as a fuel, whether for burning in small space heaters or large industrial boilers).

These main methods are constantly improving, and together with that some new processes are introducing. The most notable, but not widely applied, are gasification and thermal cracking, which produce high-quality fuels. The recovering processes themselves vary in terms of the treatment operations. Additionally, because of the wide variety of lubricant types involved, each category is considered separately from the recovering viewpoint. The most significant recovering processes and possible products are listed in Table 5.

Regeneration process is based on the fact that the mineral base lubricating oils never degrade completely. Therefore, waste oils, which are not heavy contaminated and degraded, can be re-used after simple purification and if necessary replenishment of depleted additives. This recovering process is recommended wherever there is a technical and economic justification. Regeneration is especially useful for hydraulic fluids and other industrial lubricants that have relatively simple compositions and less demanding applications. Depending on the contamination level, mechanical or adsorptive purification is applied. The purification methods most commonly used are settling, size filtration, centrifuging (mechanical purification), and clay or depth filtration (adsorptive purification) [11, 20].

Re-refining process is often viewed, from the environmental standing point, as the optimum pathway for waste oil recovery. By making a product that can be used over and over, re-refining saves a valuable natural resource while diverting a potentially hazardous waste from loss into the environment.

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Table 5. Waste lubricating oil's recovering process and its products [17]

Type of waste oil	Recovering process	Product
Industrial waste oils low contaminated	Regeneration	• Hydraulic oil • Gear reducer oil • Neat metalworking oil • Mould oil • Total loss lubricant
Engine and other waste oils	Re-refining	• Base oil
All types of waste oils	Thermal cracking	• Gas oil (also called heating oil, diesel oil, furnace oil...)
Mixed wastes	Gasification	• Synthetic gas
All types of waste oils, especially heavy contaminated and degraded	Severe re-processing	• Marine diesel oil • Fuel for heating plants
	Mild re-processing	• Replacement fuel oil (cement kilns, large marine engines, pulverised power stations)
	Direct burning (waste incinerators, cement kilns)	

On the other hand, re-refining process is the most demanding recovery process. It requires a relatively complex technology in order to obtain high-quality base oils. The consequence is a relatively high process costs and therefore, high selling prices of re-refined base oil compared to conventional base (virgin) oil prices. This is the reason why re-refining is hardly economical without legislative provisions or subsidies. The waste oils most suitable to re-refining are those not too heavily polluted and with a high viscosity index. Re-refining is especially stimulated in engine waste oil recovering, since these waste oils dominate by quantity and are unsuitable for regeneration process. Modern re-refining technologies produce high-quality base oils: at least Group I according to the API base oil's classification and, when resorting to a severe hydro or solvent finishing, Group II base oils.

Re-processing normally involves chemical or physical treatment of the waste oil to produce a fuel oil. The primary use of waste oils worldwide is still as a fuel. It was estimated [17] that about 50 % of all collected waste oil in EU-15 in 1999 was burned for energy recovery either directly in space heaters and industrial boilers, as blended fuels used in commercial applications or from re-processing facilities, which produce fuels for various applications. Waste oils containing carcinogenic and toxic components is burned is in special facilities intend for that purpose, or disposed under strictly controlled conditions.

There are a number of options of using waste oil as fuel, like [15]:

- direct burning (no pre-treatment of the waste oil, with several methods of energy recovery);
- mild re-processing (simple cleaning process, mainly separation from water and solids, before further use, e.g. burning after blending into fuel oil);
- severe re-processing (waste oil is transformed into fuels, which can be burned with similar emissions to those from burning other fuel oils, e.g. marine diesel oil and fuel for heating plants).

Gasification consists in converting the waste oils (and other carbon containing materials), in gasification plants, to synthesis gas (H_2 and CO). It presents the advantage of accepting mixed wastes, e.g. waste oil and plastic. Because large-scale plants are necessary to reach the break-even point only existing plants, built for other purposes, could be used to treat these waste oils [15].

Thermal cracking process is one of the newer technologies to produce fuel from waste oil [17]. The strategy of thermal cracking is to produce high-quality products ranging from heavy fuel oil to re-refined light industrial lube oil, including gas oil products. Thermal cracking can accept all types of waste oils. Various technologies exist for cracking waste oils. The main drawback is that it is an energy-intensive process requiring sophisticated, and thus costly, equipment. The process can not compete directly with the direct use of waste oil as a fuel. On the other hand, the thermal cracking products posses a relative high value compared to other fuels (heavy distillate fuel oils, residual replacement fuels) derived from waste oils by re-processing technologies.

4. CONCLUSIONS

Various aspects of the waste oil's management are now in focus of research and occupy significant part in industries of many countries. This is especially true for the highly industrialized countries, with high lubricating oil's consumption, for two reasons: ecological and financial.

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This means that two problems must be solved simultaneously: the environmental problems, which may be caused by lubricant's inappropriate handling, storage and operating procedures, and at the same time to optimise the operating costs to an economically payable level.

In order to achieve this, appropriate actions are necessary. There are three main factors that need to be obtained:

Stimulation – **O**pen eyes (education) – **S**anctions

Indeed, an SOS signal is needed if we want to have not only the sustainable development, but the Earth as we know.

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